European Union 2020

Energy Policy Review

International Energy Agency

INTERNATIONAL ENERGY AGENCY

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Foreword

The International Energy Agency (IEA) has conducted in-depth peer reviews of its member countries' energy policies since 1976. This process not only supports energy policy development, but also encourages the exchange of and learning from international best practices and experiences. By seeing what has worked – or not – in the "real world," these reviews help identify policies that achieve their objectives and bring concrete results. Since 2017, the IEA has moved to modernise the reviews by focusing on the key energy challenges in today's rapidly changing energy markets.

This in-depth review of the energy policies of the European Union (EU) comes at a particularly challenging time as governments around the world are dealing with the health emergency and the economic crisis brought about by the Covid-19 pandemic. It is commendable that the European Commission under the leadership of President Ursula von der Leyen has responded to these challenges while also keeping a strong focus on the major priority of accelerating clean energy transitions.

President von der Leyen and her team took office in December 2019, setting out an ambitious programme for the EU – the European Green Deal, which aims to prepare the EU for climate neutrality by 2050. I applaud the Commission for its global leadership at this critical time for clean energy transitions. Europe made the Green Deal its top priority in 2019 and is now promising a green recovery from the Covid-19 crisis. I would like to thank Frans Timmermans, the Commission's Executive Vice-President for the Green Deal, and Kadri Simson, the Commissioner for Energy, for their strong engagement and co-operation with the IEA on energy and climate issues during this extraordinary period.

In May 2020, the European Commission presented a massive recovery plan and budget proposals to counter the economic damage from the pandemic. The plan aims to achieve a resilient, inclusive and green recovery in Europe while laying the foundations for a low-carbon future. The investments envisaged by the plan will help Europe move closer to meeting its international climate and environmental goals while making its economy more resilient to future shocks. Policies will play an essential role in ensuring the effective use of the recovery funds, and the recommendations of this IEA report will support the EU and its member states in achieving a secure and sustainable recovery.

On 18 June 2020, the IEA released its *World Energy Outlook Special Report on Sustainable Recovery*, which offers governments around the world a policy roadmap enabling them to boost economic growth, create jobs and put greenhouse gas emissions into structural decline. In line with our findings, the EU recovery efforts should support projects that bring both immediate and long-term gains, such as retrofitting buildings to improve their energy efficiency, expanding clean energy infrastructure and accelerating the shift low-carbon transport. To bolster the energy transition of Europe's transport and industry, two promising technologies – hydrogen electrolysers and lithium-ion batteries – will be vital. They have the breakthrough potential to become key parts of Europe's new integrated energy system and play a major role in the continent's industrial and technology leadership.

This IEA review supports the design of the EU's future energy and climate policies with a range of recommendations. The review shows the important role the energy sector plays in the transformation of the European economy by contributing to the decarbonisation of end-uses (transport, industry, and buildings), while enhancing resilience and security. It also underscores that electricity security needs to be at the heart of the EU's efforts, as the speed of clean energy transitions, extreme weather events and cyber security threats add potential strains on the power system.

The IEA is working with the European Commission and EU member states to draw lessons from previous stimulus programmes that included clean energy components and to analyse the potential of new measures to create jobs. This work is intended to provide policy makers with the best possible advice to inform the critical decisions they will have to make. It is my hope that this in-depth review will support the EU in its admirable efforts to accelerate its energy transitions. The IEA is committed to helping European governments and the Commission achieve their goals of providing affordable, secure and clean energy to their populations as they adapt to a fast-changing global energy landscape.

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1. Executive summary

Over the past five years, the European Union (EU) has made significant progress in completing the internal market for electricity and gas, promoting energy efficiency action, renewable energy deployment, greenhouse gas (GHG) emissions reductions and a stronger carbon price signal. In 2019, the EU proposed the European Green Deal (EGD), a set of 50 actions for the coming five years across all sectors to prepare the EU economy for climate neutrality by 2050.

This in-depth review of the EU energy and climate policies by the International Energy Agency (IEA) assesses progress made over the past five years and reviews opportunities for boosting energy-sector action in the context of the EU economic recovery and the climate neutrality.

Together with the European recovery plan and the EU budget, the EGD is an excellent framework for the the EU to leverage short- and long-term actions for a clean, resilient and just recovery of the EU economy. The EGD has the potential to fast-forward investments and technology progress needed for the longer term decarbonisation during the coming five years to smoothen the mitigation efforts over time. Last but not least, the EGD is an opportunity for greater consistency of EU policies, to enable cost-effective, secure and guided transitions across the EU and across sectors beyond 2030 towards 2040 and 2050, within a common framework to promote industrial transformation, technology, and innovation leadership and a "just transition".

Covid-19 tests the EU's resilience and clean energy transitions

In 2020, the EU is facing a 7-10% economic downturn as a result of the Covid-19 health crisis. The longer the crisis lasts, the higher the impacts will be felt in the economy, including in the energy sector. Maintaining energy security is critical, as the energy sector is vital for the health of the citizens and the economy and needs to continue functioning. The physical resilience of the EU energy sector has been strong however, its financial resilience is under severe stress.

The EU energy sector witnessed a fall in energy demand and supply, and lower levels of CO_2 emissions and air pollution, amid the sharp reduction of air and road transport and industrial activity. During the first quarter of 2020, EU coal demand declined by 20% and the share of renewables reached an all-time high, with lower generation from coal, gas and nuclear. For the year 2020 as a whole, EU energy demand is expected to be 10% below the 2019 levels, which would be twice the decline experienced during the 2008-09 financial crisis. Energy-related CO_2 emissions in the EU declined by 8% during the first quarter of 2020 compared with the same period in 2019.

While these trends could enable the EU to meet its 2020 targets for renewable and energy efficiency, it should not lead to complacency. Investment in renewable energy is set to decline by one-third in 2020, compared to 2019, which would be a historic decline for the

EU, notably the 50% decline in solar PV. The rebound in emissions and energy use is expected to be high, supported by very low global commodity prices. As the energy sector – production and use – accounts for 75% of the EU's greenhouse gas emissions, efforts are required to mitigate such a rebound across the economy, including in buildings/heat, industry and transport.

Europe's energy transitions progressed fast in electricity

In 2018, total EU GHG emissions have fallen by 17% since 2005 and by 23% since 1990. Energy efficiency, renewables and fuel switching were essential drivers of the GHG reductions in the power sector.

In electricity, wind power is becoming the largest renewable source. In 2018, the EU share of renewables reached 32% in electricity. The EU has seen substantial investments in renewable electricity thanks to robust renewable energy policies, such as the Renewable Energy Directives (RED I and II), ambitious targets and relevant national policies and incentives, including recent auctions and long-term power purchase contracts. Thanks to low natural gas prices, significant coal-to-gas switching took place in the power sector, which also relied on nuclear for 25% of its generation in 2018.

Other policy drivers are the plans of 16 member states to phase out coal use in the next decades (coal still accounted for 20% of the EU electricity mix in 2018) and the successful reform of the EU Emissions Trading System (EU ETS) with a market stability reserve (MSR), which adapts to the economic development. In 2019, the EU saw a price for allowances of EUR 28, up from only EUR 8 in 2014. In 2020, the EU ETS withstood the oversupply from the Covid-19 crisis thanks to the MSR.

By international comparison, the EU has a significantly lower emissions intensity of power generation than other large economies. The carbon intensity was 270 grammes of CO_2 per kilowatt-hour (gCO_2/kWh) in 2018, compared with over 400 gCO_2/kWh in the United States, over 500 gCO_2/kWh in Japan, around 600 gCO_2/kWh in the People's Republic of China and over 700 gCO_2/kWh in India and Australia. In 2019, the EU power generation carbon intensity reached 235 gCO_2/kWh.

Progress was slower in buildings and transport by end of 2019

Outside the electricity sector, energy transitions have only just begun with varied results for energy efficiency and renewable deployment in sectors such as transport, buildings and industry.

Renewables reached 18% in the EU's gross final consumption in 2018; results in transport and heating and cooling are, however, below expectations. Energy efficiency has enabled the decoupling of the EU's GHG emissions and energy use. Emissions and energy use would have been higher without EU-wide energy efficiency improvements during 2010-19. However, the rate of energy efficiency improvements has slowed down, and the EU as a whole is not on track towards its energy efficiency target for 2020. Growing energy consumption in road and air transport had been the most important drivers for the shortfall in the EU's energy efficiency target for 2020. Covid-19 has changed some of these dynamics and will impact on the 2020 trends.

The transport (notably aviation) and buildings sectors had seen a rebound in emissions until the end of 2019. Emissions from intra-EU aviation (not from third countries) and electricity used in rail and road transport are covered under the EU ETS. Road transport and buildings are subject to national emissions reductions targets stipulated under the EU Effort Sharing rules, and are subject to national energy taxation, regulations and incentives. Efforts in these sectors will result in the EU being able to meet the 2020 target of 10% below 2005, but seem not to be on track for a 30% cut in emissions by 2030 (from the 2005 baseline).

The transport sector has been a key focus and the EC will address the shortfall in emission reductions in the forthcoming EU Sustainable Transport and Smart Mobility Strategy. The European Green Deal seeks a 90% reduction of greenhouse gas (GHG) emissions from transport by 2050. To support the transition in transport, a substantial part of the 75% of inland freight carried today by road should shift onto rail and inland waterways. By 2025, the Commission expects 1 million public recharging and refuelling stations (and 3 million by 2030) will be needed for the 13 million zero- and low-emission vehicles on the road.

Fuel switching is also promoted by the Directive on the deployment of alternative fuels infrastructure, which requires that member states provide a minimum infrastructure for alternative fuels such as electricity, hydrogen and natural gas. A revision of the Directive is planned for 2021 to achieve greater harmonisation of efforts and a level playing field across fuels.

Transport sector demand and emissions have seen major trend changes in 2020 in the context of the Covid-19 pandemic. Faced with lockdowns around the world, global aviation activity almost fully collapsed and EU aviation activity, too. Covid-19 and the related lockdown measures across the EU and the globe may have medium-term impacts on public, air and road transport, as behavioural changes and stimulus measures from governments for electric vehicles might show longer-lasting impacts on the sector and fast-forward the transition. Europe's sales of electric vehicles have been very robust. It will be critical for the Commission to assess these trends when preparing the strategy.

Renewables play a minor role in gross final consumption in transport (8%). The share of renewables in heating and cooling was 20% in 2018. Despite the doubling of bioenergy use in the heat sector, the sector remains a large consumer of fossil fuels – natural gas was the largest fuel in district heating with 37% of total heat production in 2017, followed by coal with 25%. Buildings account for 40% of the total final consumption in the EU and offer large opportunities for renewables penetration.

Enhanced efficiency gains have been most apparent in the buildings and industry sectors, where several policies have driven efficiency gains. These include minimum energy performance standards for electrical equipment and appliances and the building envelope, more stringent building codes, and other policies (i.e. Energy Performance Certificates and financial measures to support renovations), utility obligations and energy audits. Energy consumption has started to increase in transport and buildings, after a period of decrease in energy use from 2007 to 2014, which was partly due to the global financial crisis.

Fuel switching is promoted through renewable targets under RED II. With the RED II, the EU introduced a target of 14% renewable energy in transport by 2030 (with a 3.5% target for advanced biofuels), an ambitious increase from 8% in 2018. Overall, the transport target for renewables will be increasingly met through the promotion of electric vehicles (EVs). Rail is providing the highest contribution to the target in terms of renewable electricity. Advanced biofuels and biomethane are expected to play a significant role in a number of transport sectors, notably aviation and maritime.

The EU has the world's most stringent CO_2 emissions standards for light- and heavy-duty vehicles. To reach the EU fleet-wide target of 95 grammes of CO_2 per kilometre (gCO_2 per km) in 2020-21 for newly registered cars, companies can deploy a number of different technologies. This includes technologies for the electrification of the fleet. While electrification increases energy efficiency, the increase in sales of SUVs resulted in a slow-down in energy efficiency improvements. Today, the EU fleet is made up of conventional cars, and they will dominate new sales at least for the coming years. If new car sales will be largely composed of SUVs, the EU could see a further slowdown in energy efficiency improvements, if no fuel economy standards are adopted. It is therefore welcome that the European Green Deal announced a revision of the CO_2 standards to ensure a clear pathway from 2025 onwards towards zero-emission mobility.

The industry sector is covered under the EU ETS with free allowances for those industries that are at risk of carbon leakage. Industry does not have any specific target for energy efficiency or renewables, and its inclusion under the EU ETS has not yielded substantial reductions in emissions. From 2013 to 2018, CO_2 emissions from industrial installations decreased by only 0.3%. The EU should assess the allocation of allowances, investigate life-cycle approaches and review carbon leakage implications. The amount of carbon leakage may be lower than expected, including in electricity imports from third countries (which are very low in volume). The new Industrial Strategy for Europe, along with the Circular Economy Action Plan and the SME Strategy set a clear direction for a globally competitive, climate-neutral and digital industry. It has the potential of promoting the transformation of Europe's industrial sector and small and medium-sized enterprises (SMEs).

Energy sector action is central to the European Green Deal

Under the European Green Deal (EGD), the European Commission announced a review of its energy and climate legislation to scale up emissions reductions, boost the deployment of renewables and energy efficiency, and review the Energy Taxation Directive. In the field of state aid, the European Commission started the review of its 2014 Environmental Protection and Energy Aid Guidelines.

The EU is not yet on track towards the targeted increase of the renewables share to 32% (which was at 18% in 2018), nor energy efficiency savings of 32.5% by 2030. Today's 2030 targets will require a significant system transformation, even more so with the announced enhanced targets under the EGD. The EU should therefore accelerate the implementation of the current policies and regulations (Clean Energy Package [CEP] adopted in 2018-19) while considering the need for new EU policies, notably in energy system integration, to decarbonise the heat and transport sectors, and in innovation and technology deployment, in areas of underperformance.

Progress will require both EU actions and higher efforts from national measures under the National Energy and Climate Plans (NECPs). The NECPs are at the heart of today's energy sector governance: each member state had to submit its plan to the European Commission (deadline was 31 December 2019; almost all countries have submitted the final NECPs by end of May 2020). Taken together, the NECPs should ensure the EU meets its energy and climate targets set under the landmark CEP. The implementation of the NECPs and the CEP has just started in 2020. While member states are in the driver's seat to meet collective EU-wide targets for 2030, the EU can also adjust policies in the medium term. The European Commission will assess all final NECPs in the course of 2020 and discuss the possible medium-term reviews of energy sector legislation during 2020-21. This will provide a sense of direction and progress, and opportunities for strengthening policies and/or initiating new action under the EGD.

The EU's competition and internal market rules should continue to focus on preserving the integrity of the EU single market in energy, i.e. avoid undue fragmentation of energy markets (along national lines), leading to cost inflation and undue distortions to competition and trade. Covid-19 crisis measures and public economic rescue spending may exacerbate this challenge.

Whether the EU will increase its 2030 targets for emission reductions will be subject to a major impact assessment and political debate conducted in 2020. Analysis by the European Environment Agency outlined that national measures implemented by 2019 will not be enough to meet the 2030 targets of a reduction by 40% from 1990 levels, let alone enhanced targets. The European Commission therefore considers that the implementation of the final NECPs will be critical to deliver on the 40% target.

This IEA review has assessed EU polices and identified opportunities to strengthen policies. There are a number of opportunities to scale up ambitions and improve policies on the way to 2030, having in mind the long-term decarbonisation towards 2050.

Boosting EU economic recovery under the Green Deal

For Europe's recovery, the EGD presents a real opportunity to boost investments in clean energy transitions. The EC presented on 27 May 2020 proposals for an increased long-term EU budget of EUR 1.1 trillion (2021-27) and the creation of a new short-term recovery instrument of EUR 750 billion (2021-24), with financing raised on the financial markets. The EU should swiftly agree on an economic recovery programme that can leverage private investments by both designing adequate public sector funding instruments and by implementing the right policies to lift barriers to investments.

First, stimulus investments in efficiency should be a prime target, as they can boost job creation in critical manufacturing, construction, and small and medium-sized businesses, save consumers money, and reduce GHGs. The European Commission is developing a new Renovation Wave initiative announced by the EGD in order to stimulate the renovation of the existing building stock at a faster and deeper pace, by addressing the main barriers to building renovation and reinforcing the pull factors for faster and deeper renovation focusing on areas such as social housing, public buildings, schools and hospitals and their related energy distribution, lighting and heating infrastructure (upgrade to solar rooftop photovoltaic [PV], renewable heat).

Equally, national fiscal stimulus programmes for home owners and builders can create a market for higher-efficiency products and services. State aid or EU funding (including EIB loans) should support high energy efficiency and/or CO_2 emissions requirements and be conditional upon scaling up existing standards, codes or ratings. Campaigns to replace old, inefficient technologies and products with new, efficient ones (to fast-forward implementation of the EU eco-design requirements), also referred to as "cash for clunkers" programmes can target cars, refrigerators, or other appliances and motors in industry, and need to include recycling and end-of-life aspects.

Second, the period of low fuel prices represents an opportunity to undertake a number of measures that will be difficult to do as prices rise again, including phasing out fossil fuel subsidies, reforming energy prices and taxation to favour low-carbon energy, abolishing high taxation of electricity, and reforming fixed network charges.

Third, investment in energy sector resilience, notably infrastructure and smart energy systems, has multiple cross-sector spillovers for the digital industrial revolution. Smart energy systems also enable an efficient and secure decarbonisation of the entire energy system.

Fourth, the EU should act to avoid the scaling back of private investment in the clean energy industry. EU funding instruments are available across the entire innovation value chain, with programmes for energy research, development and demonstration (RD&D). Horizon Europe, the Innovation Fund, the Modernisation Fund, InvestEU and others take research to development and demonstration. The EIB is expected to play a major role in stimulating private-sector investment. The greater involvement of the EIB in earlier-stage and riskier energy projects compared with five years ago is a very positive sign. This will also be critical for the economic recovery – the EIB has a critical role in supporting energy efficiency investment and more risky innovative projects, including by equity funding. The EU needs to better evaluate the impact of EU energy RD&D funding, notably in the context of the EU economic recovery, ensure the alignment of EU and national priorities (under the Strategic Energy Technology Plan) in the NECPs, and boost private capital and innovation.

Besides, EU rules for state aid and sustainable finance will be critical. The new EU taxonomy for sustainable finance is going to guide public and private finance flows in energy transitions. Its implementation will need to cater for a wide range of technologies, including technologies that are critical enablers of energy transitions and the EU recovery. The EU should ensure a level playing field for investors and technologies, including natural gas and nuclear, for those countries and sectors that rely on it. When reviewing the state aid guidelines for environment and energy for the period after 2020, the European Commission will also need to account for the EU recovery and opportunities for EU industrial leadership and large-scale investment opportunities in technology and innovation, including in offshore wind, in electrolysers for hydrogen, and lithium-ion batteries and related infrastructure. EU rules need to facilitate state aid for public and private renovation (for instance by energy service companies), large-scale infrastructure and technology replacement.

Scaling up long-term actions on the road to net-zero

There are many different national policy approaches on energy transitions for the period 2030 to 2050. Several EU member states have already adopted 2050 objectives for climate neutrality (or earlier) and very ambitious targets in non-ETS sectors (transport, buildings) alongside policies to phase out fossil fuels. At their EU Council meeting of December 2019, EU member states agreed to the climate neutrality goal by 2050. This allowed the European Council as a whole to endorse the 2050 climate neutrality goal. In

March 2020, the EU formally submitted its long-term strategy to the United National Framework Convention on Climate Change (UNFCCC), based on several scenarios for a 2050 vision.

Under the Paris Agreement, the EU is invited to submit an updated nationally determined contribution (NDC) that reflects increased ambitions for 2030 by the 26th Conference of the Parties (COP26). This would require EU leaders to agree on an increased 2030 target by COP26, which has been postponed to 2021. As the EU accounts for 8% of the global GHG emissions, global action is a critical part of the EGD.

The European Commission presented a proposal for a first EU Climate Law in March 2020, which aims at creating a new governance framework for emissions reductions during 2030-50 based on five-year reviews of progress and the NECPs.

The road to net-zero will require further action. First, the EU needs to fully implement its "energy efficiency first" principle for the achievement of its 2030 targets and the long-term pathways towards net-zero emissions by 2050. The EU should unlock the potential for energy efficiency in transport, industry and buildings and operationalise the principle at various levels and sectors. Measures to scale up energy efficiency include raising standards, strengthening market-based instruments, and boosting opportunities from digitalisation and electrification. For instance, a more efficient organisation of the entire mobility system based on EU wide digitalisation, data sharing and interoperable standards could help make mobility cleaner. Such an efficient organisation should include smart traffic management and increasingly automated mobility in all modes and result in reducing congestion and increasing occupancy rates. All this requires the better tracking of progress through measurement, reporting and monitoring of impacts of national measures, as well as the strengthening of EU-wide standards for buildings, appliances and vehicles.

Efficiency gains across all sectors will continue to be vital for EU member states seeking to meet their 2030 renewable energy targets (as less energy consumption automatically increases the share of existing renewable energy consumption), especially as renewable energy deployment in several EU countries has not been sufficient to meet their renewable goals.

Second, the EU power system is going to be characterised by higher shares of variable renewables. Wind is expected to become the largest power source in the coming years, mostly driven by investment in offshore parks, where the EU has taken global leadership. The need for power system flexibility will rise fast in the coming decade, but the development of flexibility sources, such as interconnections and grids, demand response, and energy storage is slower than renewable development. The growing deployment of digital technologies will unlock new opportunities in this area.

The implementation of the CEP will upgrade the EU electricity market design to more active demand participation and enhance system operation for higher shares of variable renewables. The CEP rules should enable efficient cross-border capacity utilisation, and trading across shorter time frames in day-ahead, intra-day and balancing markets. However, the scale of investment needed and the transformation of the system required is significant. This is not just an issue of infrastructure assets but enhanced market and regulatory frameworks will also be needed.

The EU identified critical transmission interconnections, marked as projects of common interest as part of the ten-year network development plans by the European Network of

Transmission System Operators for Electricity (ENTSO-E). However, progress is slow in building such new large-scale power transmission, as public acceptance in most member states remains the limiting factor. The CEP focuses on increasing the utilisation of existing power lines and requires that 70% of cross-border electricity capacity is allocated to the market. Transmission and distribution system operators and energy markets will also need to facilitate the operation of system flexibility by unlocking demand response, smart grids and smart meters, with help of increased digitalisation.

The EU should assess the techno-economic potential of storage – in all its forms – as another important source of system flexibility, and work on policies and incentives needed to unlock such potential. This includes pumped hydro, batteries, both at large scale and distributed level and thermal (heat and cold) storage. Several projects exist across the EU for the development of electrolysers to convert and store wind power and other renewable electricity into hydrogen, to be transported by the gas grid, which can boost the flexibility of the EU power system.

Third, system integration will become the EU's regulatory priority. As the electrification of end-use sectors increases, opportunities for energy system integration will multiply efforts from renewables and energy efficiency. This IEA review finds the EU can reap the full benefits of flexibility, reliability and decarbonisation by adopting an energy system-wide approach. This includes reducing barriers from separate sector policies, improving system operation, use and planning for a range of low carbon fuels, while prioritising efficient end use, fuel switching and the development of innovation and technologies and digitalisation. The planned EU energy system integration strategy should support the alignment of policies and reduction of barriers. One example is the elimination of EU-wide barriers for the production, transportation and use of clean hydrogen (produced either from fossil fuels with carbon capture, utilisation and storage or from renewable electricity) which is being developed by France, Germany, the Netherlands, Portugal and others. These barriers include the cost of low-carbon hydrogen, the availability of transportation infrastructure and regulatory stability. The EU should facilitate regional industrial clusters by lifting regulatory barriers, supporting the enabling infrastructure and industrial alliances.

The EU ETS system has been and can be a strong enabler of fuel switching. The European Commission should examine the opportunity of strengthening the carbon price signal under the non-ETS and the EU ETS to incentivise innovation in low-carbon industrial development. As part of the EGD, the European Commission is exploring options of including transport and buildings in the ETS. The European Commission should assess the costs and benefits of different policy options, and prioritise their alignment across sectors. The review of the EU Energy Taxation Directive is important in this context. National taxation should be more reflective of climate objectives. The European Commission should work with the member states to improve green budgeting and fiscal reforms, as revenues from fuel taxation have come under pressure, while aligning EU-wide energy taxation rules to carbon content and air quality standards.

The EGD is expected to bolster the EU ETS price, creating concerns that industrial production could relocate to countries with lower environmental standards. Industry concerns regarding carbon leakage risks will need to continue to be addressed. The elctectricity sector has seen some carbon leakage related to electricity imports into countries at the border of the EU, which have doubled with the rising EU ETS price. However, the amount of total electricity imports to the EU and the related leakage risk is very small today.

The European Commission is contemplating the adoption of a border adjustment mechanism for certain sectors by 2021, should differences in levels of climate ambition persist among EU trade partners worldwide, to reduce the risk of carbon leakage to countries with lower-cost and more carbon-intensive products. Taking a life-cycle approach in accounting for emissions is an important policy enabler to avoid leakage across end-use sectors. This would also reflect upstream and downstream emissions and end-of-use, including addressing waste management in a circular economy. However, today, global emission accounting and reduction strategies are country-based and reflect the national determined contributions made under the Paris Agreement.

Strengthening the EU's energy security and resilience

Maintaining and further reducing the carbon intensity of power generation is central to the EU's decarbonisation strategy, given that many EU member states envisage boosting the electrification of end-uses, notably in transport and buildings. This includes the phasing out of coal use in power generation, switching to natural gas and further to low-carbon and renewable gases (biomethane, hydrogen), and boosting all other low-carbon sources in power generation, such as wind and solar, sustainable biomass and new nuclear plants and extending the lifetime of existing ones that can operate in a safe manner. Electrification entails a range of security aspects that need to be addressed.

The EU cannot take energy security during the transition for granted, notably as members states' energy transitions are national in scope and do not regularly account for cross-border impacts. Electricity security is a key priority, as countries phase out coal and retire nuclear baseload and see domestic gas production falling in the coming years, while increasing generation from variable renewables like wind and solar PV. Several EU countries rely on their neighbours for baseload capacity. As a next step, the EU needs to fully implement and guarantee the envisaged regional approach by building on regional security co-ordination of system operators and regional and European adequacy assessments. This can critically help electricity systems to have appropriate operating flexibility and ramping ability in the context of a rapid shift from dispatchable to variable renewable generation.

Gas security is increasingly linked to electricity security, as the reliance on flexible natural gas-fired power generation is set to increase across the EU with the coal-phase-out and some countries' decision to end the use of nuclear energy. Natural gas can boost coal to gas switching (in particular in Central and Eastern European countries) and support the transition to cleaner fuels, including for hydrogen. As domestic gas production is declining, imports will increase even further. The EU is well placed to benefit from the rapid expanding global market for liquefied natural gas (LNG). In 2019, LNG imports to the EU hit the 100 billion cubic metre (bcm) mark, accounting for 115 bcm and 25% of total imports. Lead by the TTF, EU gas hubs have seen record low prices. But not all countries are yet able to access LNG supplies at competitive terms. The completion of gas market integration in Eastern Europe has been the focus of EU efforts in recent years to ensure the free flow of gas at competitive prices to improve security of supply.

At the same time, the use of gas in the EU is changing. The EU needs to study further the role of gas in its pathway to decarbonisation and the contribution of gas infrastructure. For instance, the natural gas infrastructure creates prospects to accommodate the uptake of low-carbon gases in the EU. The upcoming EU hydrogen strategy and system integration strategy are an opportunity to reduce barriers and promote a European hydrogen market.

The European Commission's long-term vision expects nuclear to contribute to 15% of electricity production in 2050. Europe's nuclear reactor fleet is ageing, with many nuclear plants being taken out of service and only a few reactors under construction and several planned. IEA analysis finds that without new policy action at the national level, nuclear power capacity in the EU could fall to 5% by 2040. This may have implications not only for the cost of electricity but also the security of supply at a regional level, if not properly studied and addressed. To keep the nuclear energy option open for 2030 and beyond, the EU needs to maintain a level playing field for the financing of nuclear, to support lifetime extensions and new plants in countries where nuclear is accepted, and foster safety and waste disposal for the decommissioning of existing plants.

The EU has strengthened oil and gas emergency preparedness and security, notably by increasing the co-ordination among member states (in dedicated co-ordination groups) and by implementing a regional approach under the Energy Union. The EU has maintained a robust oil security system, and managed well the largest oil disruptions in the EU during this century, the Druzhuba oil contamination in 2019 and the Covid-19 crisis. However, the refinery outlook for the EU is bleak, as refining margins have turned negative in North West Europe in April 2020. Equally, robust gas security measures have been put in place and critical gas interconnections and reverse flows have been implemented. The EU is also bolstering measures to address cybersecurity, including in the energy sector, with a dedicated network code. This marks strong progress in terms of preparedness, but much of the implementation work lies ahead.

Across the EU energy infrastructure, impacts of extreme weather have been on the rise, be it the impacts of lower water levels of the Rhine or an increased number of storms, droughts or heat waves. Steady temperature increase can put stress on energy infrastructure, wether through higher demand for cooling in buildings or reduced ability to use water from rivers to cool thermal power plants or transport energy commodities. The EU is promoting adaptation and has a framework in place for critical infrastructure, but has yet to evaluate measures that can boost the resilience of its energy infrastructure against climate change impacts. Integrating resilience into the NECPs and energy security policies will allow governments to improve prevention and preparedness.

Key Recommendations

The European Union should[1]:

- ☐ Boost energy sector action for Europe's short-term recovery with large-scale programmes for renovation, and by lifting barriers for investment in energy projects and promoting the clean energy industries and infrastructure of the future.

[1] Please note that recommendations are addressed to the European Union, taking the institutional and decision-making structure of the EU as given. This IEA report does not reflect the impact of the withdrawal of the United Kingdom from the EU as it covers policy analysis and data until 2018-19.

- Implement the 2030 framework based on the NECPs in a cost-effective manner and review policies to scale up energy action towards climate neutrality while ensuring competitiveness, security of supply, sustainability and affordability.
- Fully operationalise the energy efficiency first principle and strengthen standards across end uses. Foster the integration of policies across end-use sectors, including for energy efficiency, renewables, the internal energy market, and carbon pricing by reducing regulatory and pricing barriers and enabling digitalisation and electrification.
- Strengthen carbon price signals in the EU ETS/non-ETS sectors and EU energy taxation in line with climate and air pollution objectives.
- Ensure the functioning of the internal energy market and the level playing field for energy technology development, investment and sustainable financing in the EU to keep all technology options open for achieving net-zero emissions.
- Keep under regular review the EU's energy security position based on foresight and long-term energy modelling at regional and EU levels, in line with European energy system adequacy assessments.

2. General energy policy

Key data

(2017)

TPES: 1 619.0 Mtoe (oil 32.8%, natural gas 24.6%, coal/oil shale 14.3%, nuclear 13.4%, bioenergy and waste 9.8%, wind 1.9%, hydro 1.6%, solar 0.9%, geothermal 0.4%, peat 0.1%, electricity imports 0.1%, heat imports 0.1%), -8.6% since 2007

TPES per capita: 3.2 toe/capita (IEA average: 4.1 toe)

TPES per unit of GDP: 87 toe/USD million PPP (IEA average: 105 toe)

Energy production: 754.4 Mtoe (nuclear 28.7%, biofuels and waste 20.1%, coal/oil shale 17.1%, natural gas 13.7%, oil 9.8%, hydro 3.4%, wind 4.1%, solar 1.9%, geothermal 0.9%, peat 0.2%, heat 0.1%), -12.9% since 2007

TFC: 1 154.0 Mtoe (oil 41.5%, natural gas 22.0%, electricity 20.8%, bioenergy and waste 8.0%, district heat 4.2%, coal 3.0%, solar 0.2%, geothermal 0.05%, peat 0.04%), -5.2% since 2007.

TFC by sector: industry (including non-energy use) 31.7%, transport 28.3%, residential 24.6%, commercial and public services (including agriculture, forestry and fishing) 15.4%

Overview

The European Union (EU)[1] is the second-largest economy in the world in nominal terms (after the United States [US]) and according to purchasing power parity (PPP) (after the People's Republic of China ["China"]). The EU's gross domestic product (GDP) amounted to EUR 16.4 trillion in 2019 (Eurostat, 2020a), representing almost one-quarter of the global economy. On 1 January 2019, the EU had a population of 513.5 million people, according to Eurostat.

Over 64% of EU's total trade is done within the bloc. EU external trade accounts for some 16% of global imports and exports. Accounting for 6.9% of the world's population and 12% of global energy consumption, the EU is responsible for 9% of the global CO_2 emissions.

[1] The present publication is based on analysis of policies and data through 2019 and includes time series which end before the United Kingdom's (UK) withdrawal from the European Union on 1 February 2020. The EU aggregates presented in the in-depth review therefore refer to the European Union including the United Kingdom, which is EU-28. In future International Energy Agency (IEA) publications, once the time series presented extend to periods beyond the UK withdrawal, the EU aggregate will change to reflect the new EU country composition.

The EU has a strong monetary zone, with the euro as the second-largest reserve currency and second-most-traded currency in the world (after the US dollar). The eurozone is a monetary union of 19 EU member states; the other EU member states continue to use their own national currencies. The European Central Bank (ECB) sets the monetary policy of the zone.

The EU recovered rather slowly from the financial and economic crisis in 2008-09 and the subsequent recession. In 2020, the near-term outlook for the European economy is overshadowed by the Covid-19 crisis and related external factors, including the breakdown in export markets and global trade tensions. The GDP in 2020 is expected to decline by 7.5%, according to the European Commission spring forecast 2020.

In 2019, the EU entered a new institutional cycle, with the start of a new European Parliament and five-year term of the new European Commission following the appointment of Ursula von der Leyen as president of the European Commission on 1 December 2019, and Charles Michel as president of the European Council. Among the prominent key priorities of the EU agenda for the next five years are the European Green Deal (EGD), which aims to makes the EU climate-neutral by 2050, and the recovery plan for Europe and the multiannual financial framework 2021-27, which shall help repair the economic and social damage brought by the Covid-19 pandemic, kick-start European recovery, and protect and create jobs.

The energy sector in the EU directly employs about 1.6 million people in extraction, production and distribution of energy and generates an added value of EUR 250 billion to the economy, corresponding to 4% of the non-financial EU business economy. Europe has seen substantial investment in renewable energies, being the world's third-largest investment place after China and the United States. With around 513 million consumers, the EU energy market is one of the largest common energy market places in the world.

Energy supply and demand trends

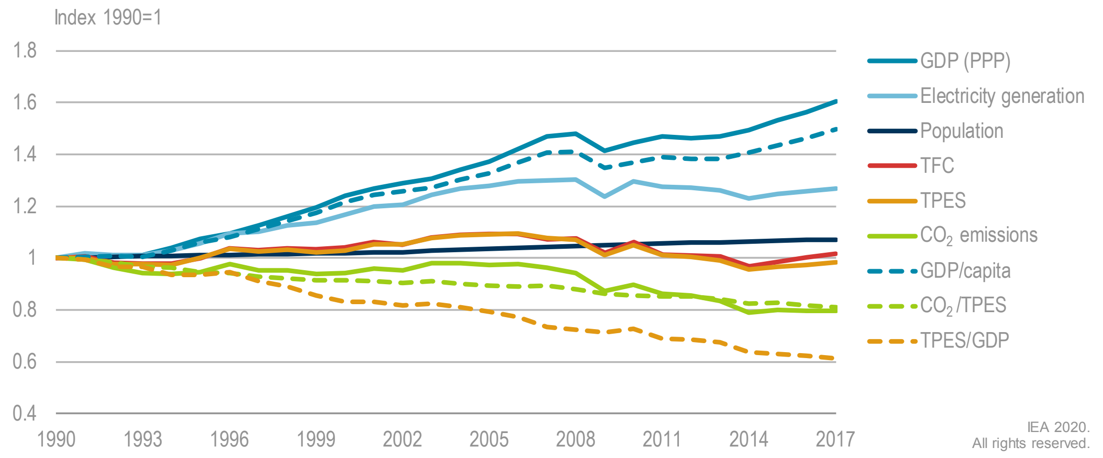
Between 1990 and 2017, the EU population increased by 7% and the GDP per capita grew by 50% (in PPP). Despite this, total energy-related CO_2 emissions decreased by 20% (Figure 2.1). This is the result of a 39% decrease in the energy intensity of the economy (TPES/GDP) and a 19% drop in the CO_2 intensity of the energy supply (CO_2/TPES), reflecting the structural shift of the EU economy, impact of energy efficiency and the move towards more low-carbon energy sources.

By international comparison, the EU energy mix has a diverse portfolio of fossil fuels, nuclear and renewables. The EU is witnessing a continuous shift towards more renewable energy, although fossil fuels still account for 72% of the EU's energy mix, compared with 80% on a global scale. In 2017, oil accounted for 33% of TPES, natural gas for 25% and coal for 14%; low-carbon sources include nuclear (13%), bioenergy and waste (10%) and other renewables (5%). With small production of fossil fuels, the EU is dependent on imports, especially for oil and gas (Figure 2.2).

The EU accounted for around 12% of TFC globally, placing it third after China (22%) and the United States (16%). Fossil fuels accounted for two-thirds of TFC in the EU, again with oil taking the leading position.

In 2017, fossil fuels accounted for 41% of total energy production in the EU, nuclear for 29%, bioenergy and waste for 20% and other renewables for 10%.

Figure 2.1 Energy-related CO_2 emissions and main drivers, 1990-2017

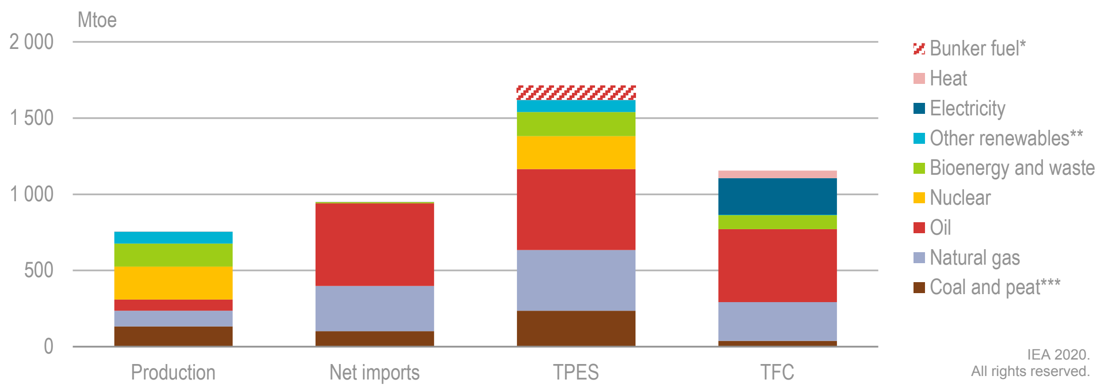


Despite a 50% growth in GDP per capita since 1990, CO_2 emissions have declined by 20%, thanks to reduced energy intensity of the economy and emissions intensity of the energy supply.

Notes: TFC = total final consumption; TPES = total primary energy supply. Real GDP in USD 2010 prices and PPP.

Source: IEA (2019a), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

Figure 2.2 Overview of the EU energy system by source, 2017



The EU imports over half of total energy supply, in particular oil but also coal and gas.

**Bunker fuel* refers to oil products used in international bunkering (not part of the TPES).

***Other renewables* includes hydro, wind, solar, geothermal and tidal/wave/ocean.

****Coal and peat* includes oil shale.

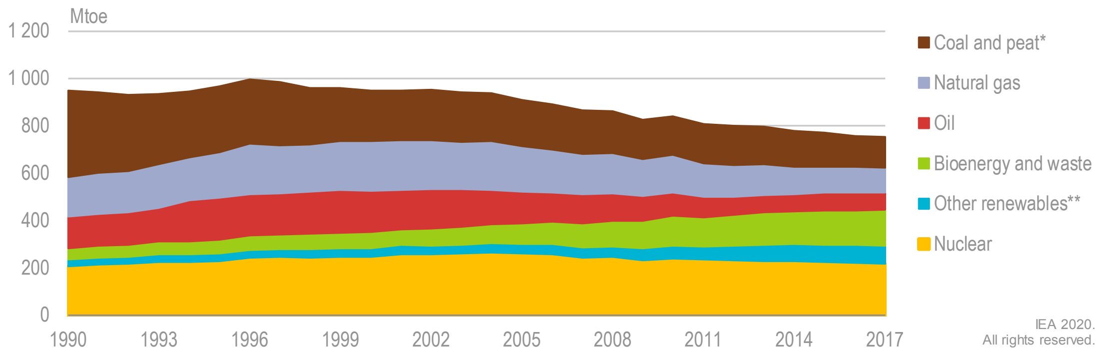
Note: Mtoe = million tonnes of oil equivalent.

Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

Energy production in the EU has been declining for two decades, due to large declines in fossil fuel production (Figure 2.3). Over the decade from 2007 to 2017, oil and gas production fell by nearly 40% each and coal production dropped by 30%.

Nuclear energy production has also been declining, with an 11% drop in a decade. Renewable energy production is increasing, with bioenergy being the largest renewable energy source, but renewable electricity from wind and solar is also increasing rapidly.

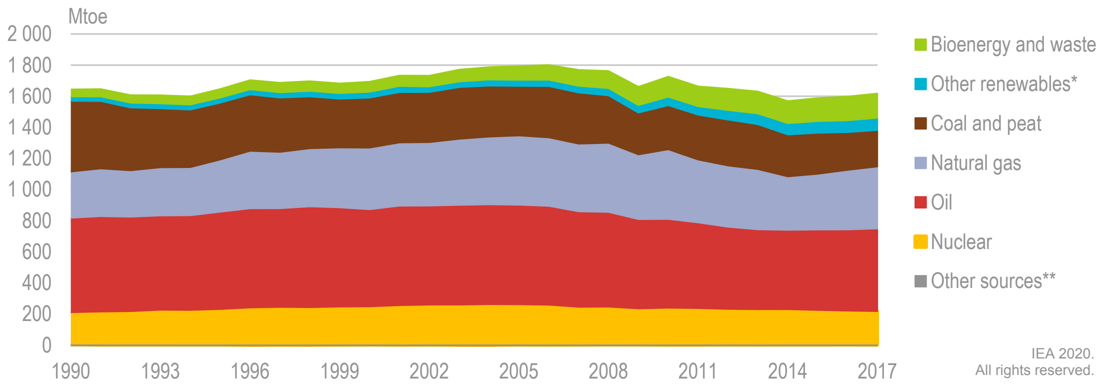
Figure 2.3 Energy production by source, 1990-2017



Energy production in the EU has declined by 24% in the past two decades, with a noticeable shift from fossil fuels towards renewable energy sources.

*_Coal and peat_ includes oil shale.
***Other renewables* includes hydro, wind, solar, geothermal and tidal/wave/ocean.
Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

Figure 2.4 TPES by source, 1990-2017

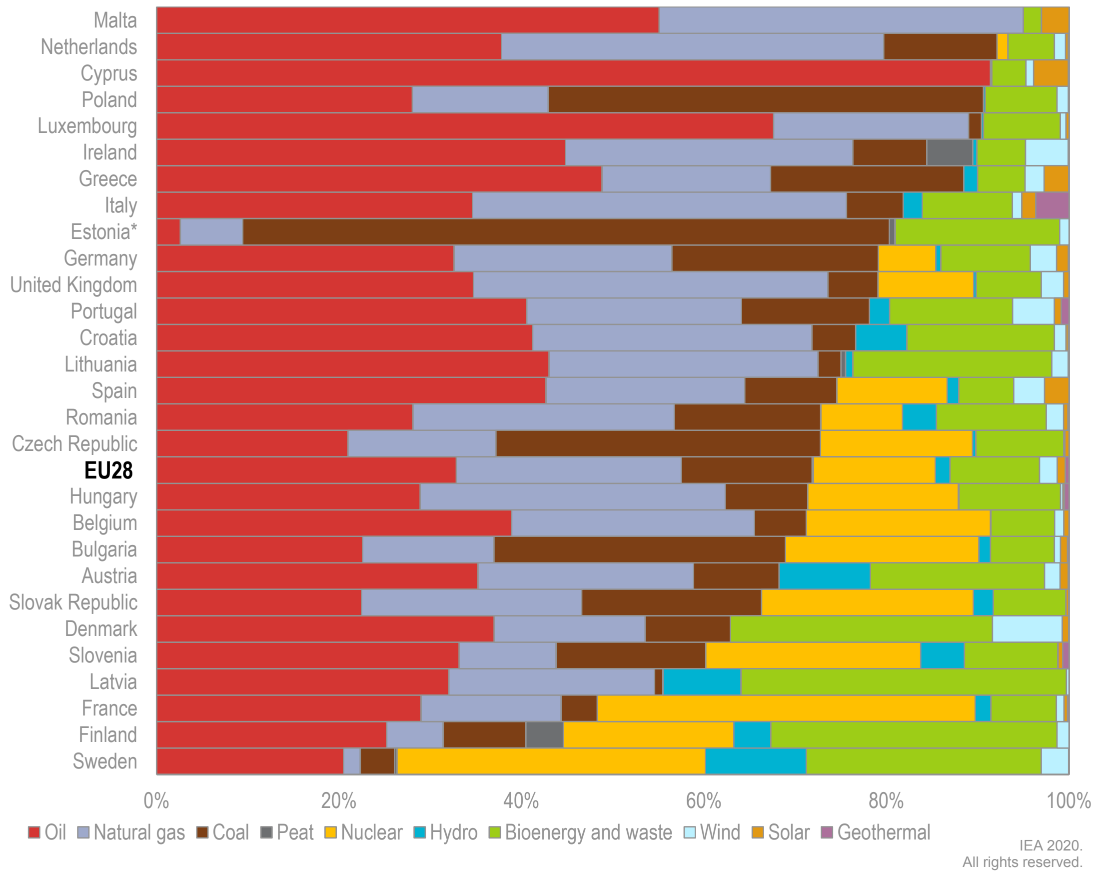


EU TPES has declined by 9% in the past decade, but the trend has reversed since 2014.

*_Other renewables_ includes hydro, wind, solar, geothermal and tidal/wave/ocean.
***Other sources* includes electricity and heat.
Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

TPES peaked in 2006 at 1 800 Mtoe. After that, it dropped by 12% until 2015, but has increased slightly again in recent years (Figure 2.4). In 2017, TPES was 1 619 Mtoe, which was similar to the level in 1990 but a 10% decline from the peak in 2006.

Figure 2.5 TPES in EU countries, by source, 2017



The share of fossil fuels in TPES in EU countries in 2017 varied from 26% in Sweden to over 90% in Malta, the Netherlands, Cyprus,[2] Poland and Luxembourg.

**Coal* in Estonia mostly refers to oil shale.

Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

Going through cycles of energy transitions, many EU countries have switched from coal towards renewables in their energy supply, mostly for electricity generation. From 2007 to 2017, coal supply fell by nearly 30%, while the supply of renewable energy grew by 60% (from a lower base), and the total supply of renewables is now at a similar level as coal

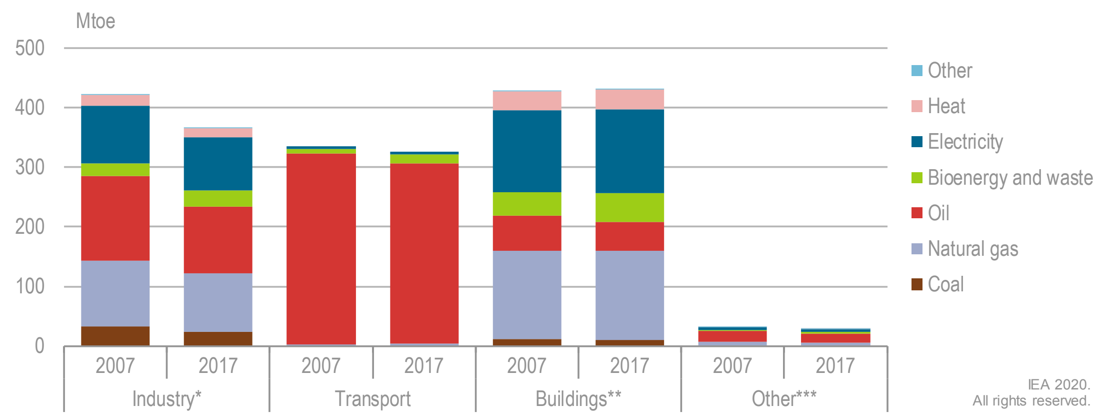
[2] Two footnotes: 1. Footnote by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus issue". 2. Footnote by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

supply. In the coming decade, total supply of renewables will overtake coal supply, as many EU countries plan to phase out coal production and use and close coal-fired power plants.

Oil remains the largest energy source, accounting for a third of TPES. Oil supply has declined by 13% in a decade, but has recently increased since 2014, driven by demand in transport and industry. Natural gas accounts for the second-largest primary energy source after oil and has seen the largest fluctuations in recent decades, due to varying demands from electricity markets.

The energy mix varies strongly across the EU countries (Figure 2.5). Fossil fuels accounted for between 26% (in Sweden) and 95% (in Malta) of TPES in 2017. Oil and gas are the largest energy sources in many countries, while some rely heavily on coal (e.g. Poland, Czech Republic). Estonia has a unique energy mix with around 70% of oil shale in TPES. The countries that are less dependent on fossil fuels usually have a mix of nuclear and bioenergy, and in some cases large hydro resources.

Figure 2.6 TFC by source and sector, 2007 and 2017



TFC is dominated by oil in transport and a combination of oil, gas and electricity in most other sectors. The main change in the past decade has been a declining industry consumption.

**Industry* includes non-energy use.

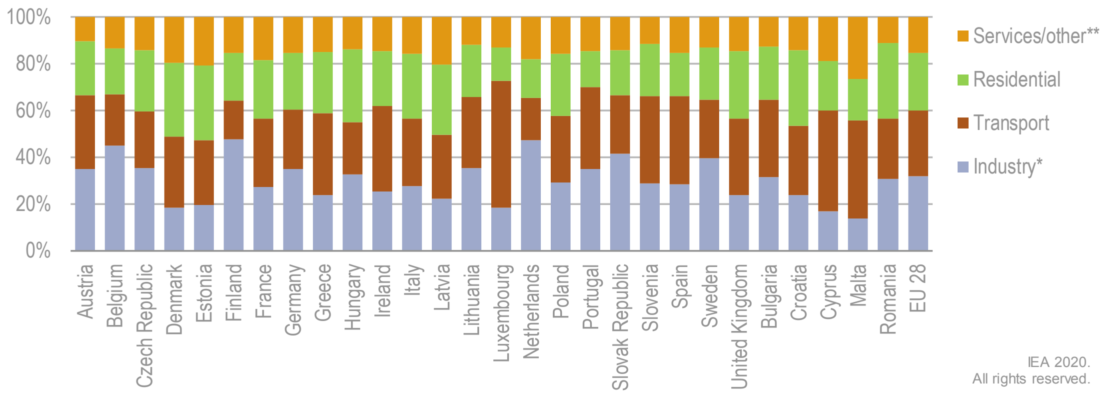
***Buildings* includes commercial and public services.

****Other* includes agriculture, forestry and fishing.

Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

When it comes to TFC, the EU saw a 5% decline in the past decade, mainly because of the 13% drop in industry, which has not recovered from 2008-09 levels (Figure 2.6). Oil fuels dominate TFC at 42%, with a 93% share in transport and 31% in industry. Natural gas and electricity are the other main energy sources in TFC, largely in industry as well as residential and service sectors. Industry accounts for nearly a third of TFC in the EU, but the shares vary between EU countries, from close to 50% in Finland, the Netherlands and Belgium, to below 20% in Estonia, Denmark, Luxembourg and Malta (Figure 2.7). Transport is the second-largest energy consumer with a quarter of TFC in the EU (Figure 2.8). Again the shares show large variations, with transport accounting for over half of TFC in Luxembourg but below 20% in Finland and the Netherlands.

Figure 2.7 TFC by sector and country, 2017



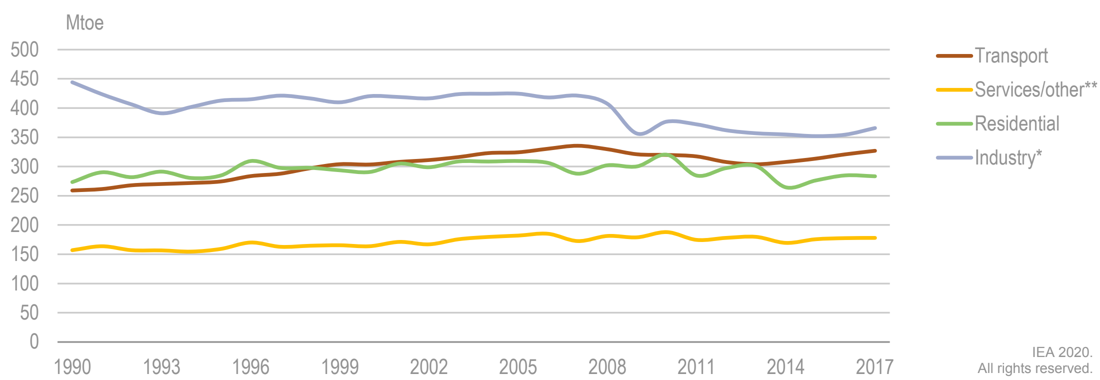
Industry is the largest energy consumer in the EU, but the shares differ between countries.

**Industry* includes non-energy use.

***Services/other* includes commercial and public services, agriculture, forestry and fishing.

Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

Figure 2.8 TFC by sector, 1990-2017



Transport and industry has increased its energy consumption in recent years.

**Industry* includes non-energy use.

***Services/other* includes commercial and public services, agriculture, forestry and fishing.

Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

Impact of Covid-19 on 2020 energy trends

The Covid-19 health crisis and lockdowns during March and April 2020 led to a major decline in energy demand (5% in the first quarter of 2020) in the European Union. For the year 2020, EU energy demand is expected to be 10% below the 2019 levels, almost double the decline experienced during the 2008-09 financial crisis (IEA, 2020).

With the global aviation sector in lockdown, Europe's oil demand declined, most notably for jet fuels. Car sales halved in the EU but electric vehicles' sales have remained robust.

EU electricity demand has declined (and remains sluggish by June 2020), despite the need for electricity in hospitals and residential sectors. Average weekday electricity demand for services declined considerably. In Italy, the hardest-hit country in Europe, declines reached 75% relative to the same period in 2019. With lower electricity demand, coal and gas power plants were running fewer hours and the share of renewable energy increased rapidly, leading to negative electricity prices at EU wholesale markets in some instances in April 2020. With industrial production largely on hold, coal demand in the EU fell by 20% in the first quarter of 2020 compared with the first quarter of 2019, and is expected to be 20% lower for the whole of 2020. By international comparison, the EU also saw the largest reduction in nuclear generation during the Covid-19 lockdown period. Gas demand in the EU also declined (amid a milder winter), but proved rather resilient as gas is mainly used for heating and global gas prices reached a record low in the first half of 2020.

As a result, energy-related CO_2 emissions in the EU declined by 8% during the first quarter of 2020 compared with the first quarter of 2019. Together with the United States and China, the EU will make up the lion's share of global CO_2 emissions reductions (IEA, 2020). This is because the EU already saw the world's largest fall in annual emissions in 2019, taking the lead in global emissions reductions. However, lower economic activity combined with low fossil fuel consumption led to another oversupply in emissions allowances in the EU Emissions Trading System (ETS), which saw a decline in the price of allowances from EUR 25 to EUR 15 in a few weeks. Thanks to the ETS Market Stability Reserve, the price has been resilient to changes in economic activity and is back at EUR 25 per tCO_2 in June 2020.

Key EU energy and climate policies

The EU has integrated energy and climate policy packages for the horizon 2020 and 2030 and is implementing the EGD supporting the goal of climate neutrality by 2050. Since the adoption of the 2020 framework in 2007, the EU has increasingly raised its climate policy action and ambitions. This has meant a stronger interplay of energy and climate policies in EU decision-making.

This section provides an overview of the EU targets and key policies which will be evaluated in detail in the chapter on climate and the related sectoral chapters on transport, industry, buildings and electricity.

EU climate and energy targets (2020)

EU-wide objectives for climate and energy were agreed by heads of state and government in 2007, and enacted in legislation in 2009. These energy and climate objectives are framed around three headline targets for 2020 with a view to:

- Reduce GHG emissions by 20% compared with 1990 levels and conditionally by 30% in the context of a future international climate agreement.
- Increase the share of renewable energies to 20% in gross final energy consumption and to 10% in transport.
- Reduce the total primary energy consumption by 20%, projected for 2020 in the 2007 reference scenario.

The 2020 Climate and Energy Package consisted of EU-wide GHG reduction effort-sharing (Decision 406/2009/EC) in the EU wide carbon market based on the EU Emissions Trading System (ETS) Directive 2009/29/EC and with individual targets for each member state in the sectors outside the EU ETS. Equally, the Renewable Energy Directive (RED) (2009/28/EC) and Energy Efficiency Directive (EED) (2012/27/EU) require member states to set indicative national targets for achieving the EU-wide goals. The package was complemented by the Carbon Capture and Storage Directive (2009/31/EC) and the Biofuel and Fuel Quality Directive (2009/30/EC) as well as the Emission Standards Regulation (EC) No 443/2009.

The 2020 Climate and Energy Package relied on strong EU-wide instruments, including the EU ETS, the internal energy market and harmonised EU-wide energy efficiency policies and measures (eco-design, building codes and energy performance certification for buildings, CO_2 standards for light-duty vehicles).

Energy Union

Since 2015, the European Commission has been implementing the Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy, also known as the Energy Union Strategy. The strategy forms part of a collaborative approach to bringing the EU and the member states' national efforts together under an EU-wide governance framework along five key priorities:

- security of supply, solidarity and trust through co-operation between member states
- an EU-wide fully integrated internal energy market with free flow of energy and best energy deals for consumers
- putting energy efficiency first, to reduce emissions and the dependence on imports, and to drive economic growth and employment
- climate action and decarbonisation of the economy
- promoting research, innovation and competitiveness.

Clean Energy Package (2030)

To implement the Energy Union Strategy, the Commission proposed the Clean Energy for All Europeans package (also known as the Clean Energy Package [CEP]). It consisted of eight legislative acts, which were adopted during 2018 and 2019:

- Electricity Market Directive 2019/944/EU and Electricity Market Regulation 2019/943/EU ACER Regulation 2019/942/EU
- Regulation on Risk-Preparedness in the Electricity Sector Regulation 2019/941/EU and Repealing the Security of Supply Directive
- RED 2018/2001/EU (RED II)
- EED 2018/2002/EU (EED II)
- Energy Performance of Buildings Directive 2018/844/EU (EPBD)
- Regulation 2018/1999/EU on the Governance of the Energy Union.

Prior to the CEP, EU-wide headline targets were in place for 2030 to cut GHG emissions by 40% from 1990 levels, to increase the share of renewable energy and foster energy efficiency, while boosting interconnectivity and tackling emissions from cars, vans and trucks. The CEP has increased the ambition of the Energy Union for renewable energy and energy efficiency action to enable it to meet the overall emissions reductions target for 2030.

- **Energy efficiency first:** the revised EED II sets a target of efficient energy use for 2030 of 32.5% (compared with business-as-usual projections of 2007), and the new EPBD aims to maximise the energy saving potential of smarter and greener buildings and to boost the renovation of existing buildings.
- **More renewables:** an EU-wide target of at least 32% in renewable energy (as opposed to national targets in RED I) by 2030 is fixed under RED II, which includes specific provisions to ensure that public support, if granted, is cost-efficient, to facilitate self-consumption and the creation of renewable energy communities, and to foster renewables in the heating and cooling and the transport sectors.
- **Governance of the Energy Union:** A new governance regulation under which each member state drafts National Energy and Climate Plans (NECPs) for 2021-30 setting out national ambitions (national voluntary targets) and the policies to contribute to meeting EU-wide targets. In a first round, member states shared their draft NECPs with the European Commission which reviewed them and provided country specific recommendation. In spring 2020, most EU countries submitted the revised final plans to the European Commission.
- **More rights for consumers** to produce, store or sell their own energy, including more transparency on bills and choice.
- **A smarter and more efficient electricity market** to increase security of supply while helping integrate renewables and improving cross-border co-operation and the EU-wide assessment of adequacy needs and common rules for capacity markets (a new electricity regulation, an amending electricity directive, risk preparedness and a regulation outlining a stronger role for the Agency for the Cooperation of Energy Regulators [ACER]).

EED II and RED *II*

Energy efficiency policies are set out in the EED II and for renewable energy, RED II is the main framework for EU wide rules for the use of renewables in electricity, transport and heating and cooling. Both Directives entered into force on 24 December 2018.

EED II (Directive 2018/2001/EU) sets out an energy efficiency target of at least 32.5% to be achieved collectively by the EU in 2030,[3] with a possible upwards revision by 2023. The target translates into a maximum of 1 273 Mtoe of primary energy consumption and/or 965 Mtoe of final energy consumption. This means primary energy consumption should be reduced by 26% and final energy consumption by 20% compared with 2005 levels. The EED II also extended the obligation to achieve new annual energy savings of at least 0.8% of final energy consumption during the next period 2021-30 and beyond, coming from new energy efficiency renovations or other measures in end-use sectors. This objective is some 13% more ambitious than in the period 2014-20. EED II strengthened rules on individual

[3] The target is calculated relative to the projections from the PRIMES REF2007 for 2030 (same methodology as before). The PRIMES model is an EU energy system model which simulates energy consumption and the energy supply system. It is a partial equilibrium modelling system that simulates an energy market equilibrium in the European Union and each of its Member States. This includes consistent EU carbon price trajectories.

metering and billing of thermal energy (better information for consumers) and started a transition to remotely readable heating/cooling/hot water meters in district heating/cooling networks and in buildings.

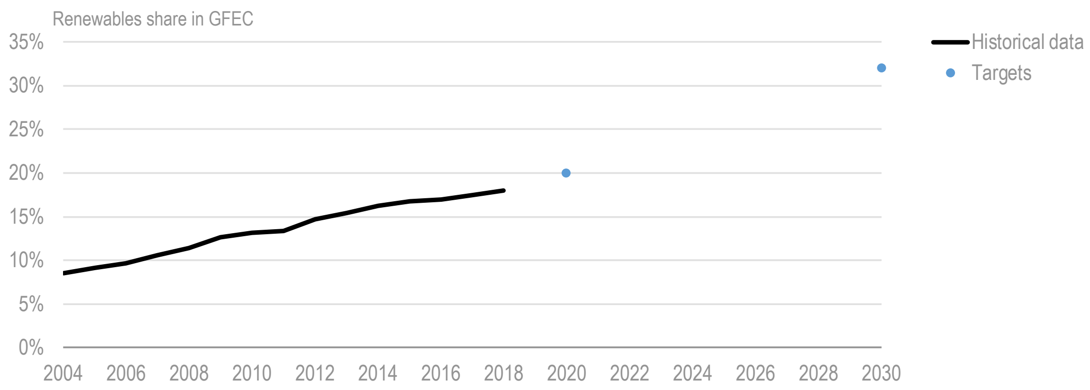
RED II (Directive 2018/2001/EU) sets the rules for the promotion of the use of energy from renewable sources in the EU across sectors. RED II contains a binding EU target for renewable energy of at least 32% renewable energy in gross final energy consumption by 2030. RED II promotes the use of renewables in electricity, transport, and heating and cooling. The 2020 national targets act as a baseline for member states' renewable energy deployment levels for the period from 2021 to 2030. RED II requires member states to endeavour to increase the share of renewable energy in heating and cooling by an indicative 1.3 percentage points as an annual average. RED II also sets a 14% target in transport and extends the EU bioenergy sustainability criteria to cover biomass-based heating and power plants, in addition to biofuels for transport. RED II includes also for the first time dedicated sustainability criteria for forest biomass aimed at ensuring sustainable harvesting and protection of forest carbon stocks.

By 2023, a medium-term review clause in both directives provides for the possibility of the European Commission to revise the targets upwards.

Progress towards the 2020 and 2030 targets

In 2018, EU GHG emissions were 23% below the levels of 1990 – the EU has thus already reached its 2020 target. By the end of 2019, progress towards the renewables and energy efficiency target was not sufficient. The share of renewables stood at 18% in gross final energy consumption in 2019; the EU is thus broadly on track towards the 20% by 2020 goal. However, further efforts are needed to reach the target during 2019-20 and even up to 2030. The share of renewables stood at 32% in electricity, 8% in transport, and 19.7% in heating and cooling in 2018 (Eurostat [2020b], Figure 2.9).

Figure 2.9 Share of renewable energy in gross final energy consumption

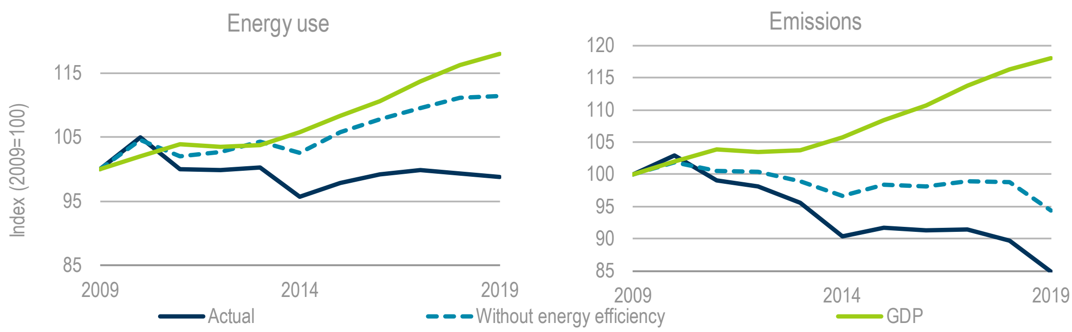


Note: GFEC = gross final energy consumption.

Source: Eurostat (2020b), Renewable energy statistics (web page), https://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics.

Since the global financial and economic crisis in 2008-09, the role of energy efficiency in the EU has been important. Without energy efficiency, energy use and emissions would have been much higher. The rate of improvement has been slowing down and the EU off track towards its 20% target (Figure 2.10).

Figure 2.10 Progress in energy efficiency



Note: Data for 19 EU member states out of EU-28. Data for 2018 and 2019 are estimated.
Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

National Energy and Climate Plans

Part of the CEP, the Regulation on the Governance of the Energy Union and Climate Action (entered into force on 24 December 2018) is fundamental for ensuring that sufficient action is taken to meet the EU's 2030 targets. As the 2030 framework leaves the level of ambition in the areas of renewable energy and energy efficiency to the sovereign decision of each member state, a new governance mechanism was adopted to make sure that the EU-wide targets will be collectively met.

The governance is based on the NECPs covering ten-year periods of 2021-30 (and to be renewed every subsequent ten-year period). Each member state was required to submit a draft NECP by the end of 2018, which was then assessed by the European Commission, which issued country-specific recommendations in June 2019 (EC, 2019b). Taking these recommendations into account, member states were required to submit their final NECPs by 31 December 2019.

The NECPs merged the existing patchwork of planning, monitoring and reporting obligations that member states had under the different pieces of EU legislation across energy, climate and other Energy Union-related policy areas. Countries have to report on progress every two years, and the European Commission will present a summary under the State of the Union report for the EU.

On 18 June 2019, as mandated under the Governance Regulation, the EC published its global assessment of the cumulative impact of the draft NECPs (EC, 2019b).[4] The assessment included recommendations for the member states to improve their draft plans

[4] Final NECPs and the Commission's recommendations to each member state can be found here: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/governance-energy-union/national-energy-climate-plans.

in order to collectively meet the EU GHG emissions reduction targets. According to the Commission's initial assessment at that time, all NECPs taken together fell short both in terms of renewables and energy efficiency contributions, requiring a collective step up of ambition in order to reach the EU's overall climate and energy targets for 2030.

The final NECPs will be evaluated by the European Commission by summer 2020.

EU competition and state aid policy in energy

The Commission places a strong focus on the creation of a level playing field to promote the single market and cross-border trade as well as the implementation of unbundling rules (of generation/supply and networks). The Commission has increased its efforts to control mergers and carry out antitrust enforcement, to foster competitive and open energy markets, keeping energy prices in check for consumers and fostering the unrestricted flow of energy in the internal market.

As regards antitrust enforcement, several high-profile cases include prohibition decisions (Article 7 of Regulation 1/2003) and commitment decisions (Article 9 of Regulation 1/2003) leading vertically integrated utilities to divest their ownership of networks or limiting the duration of long-term contracts. These commitments in exchange for dropping antitrust charges were made legally binding on the companies under investigation, without the Commission establishing an infringement. The commitments had a major structural impact on competition in the internal energy market.

Regarding merger control in electricity and gas markets, the Commission has prohibited several planned mergers and imposed significant remedies on many others.

The trade-off between the need for competitive markets, on the one hand, and the need for public intervention (including public support to low-carbon investment) in the pursuit of climate and energy policies, on the other hand, has been a critical issue for the EU.

The 2014 State Aid Guidelines for Environmental Protection and Energy (EEAG) and the corresponding energy and environmental protection section under the General Block Exemption Regulation (EC, 2014b) provided guidance for public interventions, notably for the design of renewable support schemes, capacity mechanisms and demand-side response (EC, 2014a, 2014b). The guidelines provided for a common approach on these critical market design questions and its main principles now form part of the rules of the CEP. In 2020-21, the EU will be revising its 2014 EEAG.

Long-term climate neutrality (2050)

In November 2018, the European Commission presented a long-term vision for a climate-neutral EU economy by 2050. The communication "A clean planet for all" (EC, 2018) includes scenario analysis with a baseline and eight alternative decarbonisation pathways (six with 80% GHG reduction and two with 100% GHG reduction, keeping global temperature rise to 1.5 degrees Celsius or less). All the scenarios rely on several pillars:

- **Maximise the benefits from energy efficiency, including promotion of zero-emission buildings**: A central role for energy efficiency is highlighted in all scenarios, including anticipated decreases in 2050 primary energy demand ranging from 32-50% below 2005 levels. In the residential sector, the Commission scenarios show energy reductions of 41-57% in 2050, relative to 2005 levels.

- **Maximise the deployment of renewables and the use of electricity to fully decarbonise Europe's energy supply:** All scenarios rely on very high levels of end-use electrification (up to 53% by 2050), combined with full decarbonisation of the power sector. Renewable energy generation is expected to meet more than 80% of electricity demand, and nuclear would account for 15%.
- **Embrace clean, safe and connected mobility:** The EC highlights the essential role of clean vehicles, with the share of electric cars in the EU fleet surpassing 90% in net-zero emissions by 2050. It also shows the significant contribution of sustainable alternative fuels and of improvements in the efficiency of the transport system.
- **A competitive EU industry and circular economy as key enablers to reduce GHG emissions:** In industry, energy demand would need to decrease by between 22% and 31% by 2050 relative to 2015 in Commission scenarios.
- **Develop an adequate smart network infrastructure and interconnections:** The electrification and high renewables deployment requires increased cross-border and regional co-operation.
- **Reap the full benefits of a bio-economy and create substantial carbon sinks:** In the scenarios, bioenergy consumption will increase by around 80% by 2050 relative to today. Land and forest sinks could absorb between 240 million tonnes of CO_2 ($MtCO_2$) and 340 $MtCO_2$.
- **Tackle remaining CO_2 emissions with carbon capture, utilisation and storage (CCUS):** The European Commission underlines the role of CCUS as a valuable option for locked-in fossil fuel infrastructure and for generating negative emissions when combined with bioenergy. CO_2 captured in 2050 ranges from 50 $MtCO_2$ to 90 $MtCO_2$ in all but one scenario (which sees almost 300 $MtCO_2$ captured).
- **Hydrogen and power-to-X** also play an important role in some scenarios, notably in those with a strong focus on electrification.

At the December 2019 European Council, the EU member states endorsed the Commission's vision for climate neutrality by 2050, with the exception of one member state which has asked for more time to implement such a goal.[5] Under the UNFCC Paris Agreement, the EU and the EU member states are both invited to develop and submit 2050 long-term strategies (LTSs). It will be critical that member states ensure consistency between national LTSs to 2050 and the NECPs, in line with the Governance Regulation.

European Green Deal

On 11 December 2019, the European Commission unveiled the EGD, an overarching roadmap of 50 actions over the next five years (EC, 2019a), aimed at making the EU a climate-neutral region by 2050 (Figure 2.11). Building on the EGD, the Commission is preparing a comprehensive implementation plan to guide policy making.

The Commission proposed a number of new financial instruments and funds under the long-term EU budget 2021-27, including a stronger role for the EIB with the InvestEU programme and the creation of the new EU ETS Innovation and Modernisation Funds and

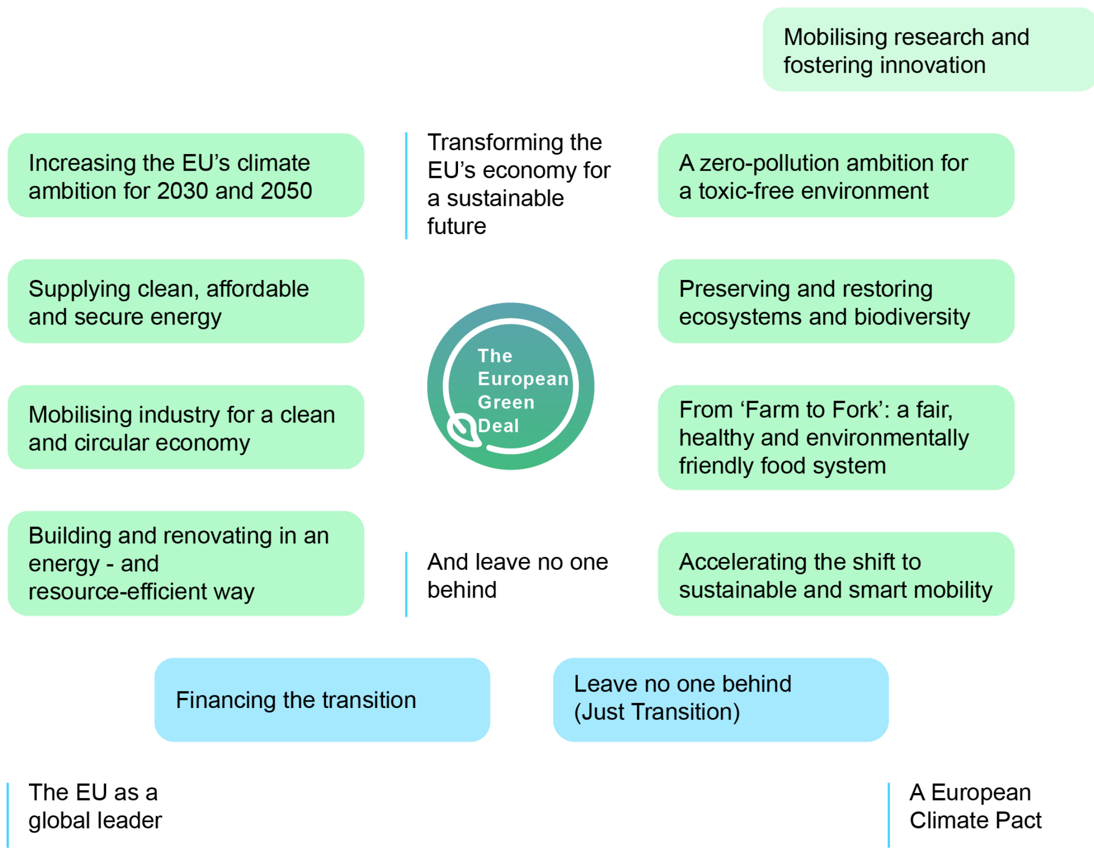
[5] Poland has not endorsed the climate neutrality goal and asked for an additional period of time to finalise its plans by June 2020.

a Just Transition Mechanism over the period 2021-27 for the most affected regions to alleviate the socio-economic impact of the transition.

To implement climate neutrality, the Commission proposed in March 2020 the European Climate Law with a legally binding target of net-zero GHG emissions by 2050 and an EU-wide emissions trajectory for the period 2030-50. Every five years, progress should be assessed based on the NECPs and reports by the EEA, and the Commission would recommend adjustments to the member states.

Beyond energy, dedicated sector strategies are planned (Figure 2.11), including the Sustainable and Smart Mobility Strategy. The new EU Industrial Strategy and the Circular Economy Action Plan, presented in March 2020, complement the energy sector actions. The European Commission plans to introduce a carbon border adjustment mechanism for certain sectors and trade partners, compatible with the WTO rules.

Figure 2.11 Overview of the actions of the EGD



Source: EC (2019a), "The European Green Deal", COM (2019) 640 final, https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf.

Based on modelling, the European Commission plans to present a new 2030 target for the EU's GHG emissions reductions (of at least 50% and potentially 55% in a responsible manner) and review the energy and climate legislation (ETS Directive/Effort Sharing Regulation; land-use, land change and forestry [LULUCF] regulation; EED II; RED II; CO_2 emission performance standards for cars/vans and Energy Taxation Directive). Where needed, concrete legislative proposals will be presented in 2021.

As part of the clean, affordable and secure energy agenda for the next years, the European Commission seeks to work along the broad priorities of EU's energy policy goals to:

- Interconnect energy systems and better link/integrate renewable energy sources to the grid.
- Promote innovative technologies and modern infrastructure.
- Scale up the energy renovation of existing buildings (energy efficiency and renewables).
- Boost energy efficiency and eco-design of products.
- Promote smart integration across sectors.
- Empower consumers and help member states tackle energy poverty.
- Increase cross-border and regional co-operation, also in relation to clean energy sources.
- Promote EU energy standards and technologies at global level.
- Develop the full potential of Europe's offshore renewable energy.

In terms of new initiatives and policies, the Commission will review the final NECPs and propose EU instruments and actions to close the potential gap towards 2030 EU targets. A strategy for smart sector integration (including a hydrogen strategy), the evaluation and review of the Trans-European Network for Energy Regulation (TEN-E), a Renovation Wave Action Plan for the buildings sector, a strategy on offshore renewable energy, and a strategy on methane leakage are all under preparation for 2020. This will be complemented by the revision of EU environmental state aid rules by 2021 and a renewed sustainable finance strategy in 2020, followed by a sustainable corporate governance initiative in 2021.

Financing the transition and the EU economic recovery

The EGD identifies sustainable finance as one of the cornerstones for the EU's future sustainable economy and energy sector. The European Commission estimated that in order to reach the EU's current 2030 climate and energy targets, an investment gap of about EUR 260 billion in additional annual investment needs to be closed (EC, 2019a). However, the impact of the Covid-19 pandemic on Europe's economy has changed the financing and investment needs. Latest IEA analysis in the IEA World Energy Investment 2020 report shows that in 2020, the energy sector will see a global and historic decline in investment, with the largest cut expected in the oil and gas sector, but also in energy efficiency.

Towards a more resilient, sustainable and fair Europe

In April 2020, responding to the Covid-19 crisis, the European Council asked the presidents of the European Commission and Council to prepare an EU recovery plan, in addition to the bond purchase mechanisms, which was made available by the ECB to support national debt. The presidents of the Commission and the Council proposed the broad lines of the EU recovery plan (EU, 2020) based on the objectives of re-establishing resilience of the value and supply chains across the single market, green transition (EGD) and digital transformation (infrastructure focus), reinforcing the strategic autonomy of the EU industrial policy, support for SMEs and start-ups, and screening of foreign direct investment. The basis for the recovery plan should be the multi-financial framework (MFF) and the EIB group and its EU guarantees, building on the triple-A rating of the EU. The recovery plan should indeed support cohesion (common agricultural policy, etc.) and global action (Africa, G20, and G7).

Box 2.1 The recovery plan for Europe

- On 27 May 2020, the European Commission presented proposals for a recovery plan directed at investing in the economic recovery, the European Green Deal and digitalisation, to boost jobs and growth (EC, 2020). The package includes an increased regular EU budget (the Multiannual Financial Framework (MFF)) for the period of 2021-27 (proposed EUR 1.1 trillion, up 10%) and a short-term emergency recovery fund for the period 2021-24, the so-called "Next Generation EU" (proposed EUR 750 billion). According to the proposal this instrument will be financed through loans at EU level and repaid from the EU budget between 2028 and 2058. For repayment new revenue streams for the EU would be created like ETS revenues and digital taxes. This EU package would come in addition to the EUR 3.4 trillion that national governments have already allocated to the recovery since the start of the Covid-19 crisis.
- The recovery funding has three key priorities: 1) recovery and 2) twin green and digital transition as well as 3) resilience and crisis preparedness.
- Under the Recovery and Resilience Facility (proposed EUR 560 bn), the Commission aims at improving national spending (under the European Semester and national Resilience and Recovery Plans), in line with the National Energy and Climate Plans, the Just Transition Plans and sustainable finance taxonomy.
- Energy sector funding is envisaged for EU-wide investment in building renovation, renewable energy and sustainable infrastructure.
- The Horizon Europe research and innovation framework is envisaged to be strengthened with the Strategic Investment Facility to invest in innovation for the transition, including renewable and energy storage, clean hydrogen, batteries, CCUS, and sustainable energy infrastructure.
- With a focus on clean mobility, including rail, EU funding is proposed to boost production of "sustainable vehicles" and alternative fuels and electric vehicle charging points

The role of the EIB

The EIB takes a major role in the EGD with its European Fund for Strategic Investments and by repositioning itself as the EU's "climate bank". In November 2019, the EIB announced a new climate strategy and energy lending policy with the aim of increasing climate ambition and environmental sustainability. It will:

- End the financing of unabated fossil fuel energy projects by the end of 2021.
- Increase financing in clean energy innovation, energy efficiency and renewables.
- Unlock EUR 1 trillion in climate action and environmentally sustainable investment by 2030, through increasing the share of its dedicated financing to reach 50% by 2025.
- Align all financing activities with the goals of the Paris Agreement by the end of 2020.

The EIB's new energy lending policy prioritises investments in energy efficiency and low- or zero-carbon technologies, including decentralised energy production, energy storage, e-mobility and electricity infrastructure. It also sets an Emissions Performance Standard of 250 grammes of CO_2 per kilowatt-hour (gCO_2/kWh) (previously: 550 gCO_2/kWh) for power sector investments.

Green finance from the private sector

Due to the scale of this financing challenge, the private financial sector has a key role to play in addition to the public sector. The EU has shown leadership in sustainable finance.

Following the publication of the recommendations of the G20 Task Force on Climate-Related Financial Disclosures, the European Commission established a High-Level Expert Group on Sustainable Finance (HLEG) in 2016. As part of the EU's plan for a capital markets union, the HLEG produced advice on how to incentivise private capital for environmentally sustainable investment, foster transparency and long-termism in financial and economic activities, and manage financial risks from climate change, resource depletion and environmental degradation. Its recommendations formed the basis of the Commission's Action Plan on Sustainable Finance, adopted in March 2018. Its key actions include:

- Establishing a clear and detailed EU classification system – or taxonomy – to label and identify sustainable activities across all financial sector actors.
- Establishing EU labels for green financial products to help investors identify products that comply with green or low-carbon criteria.
- Introducing measures to clarify asset managers' and institutional investors' duties regarding sustainability.
- Strengthening the transparency of companies on their environmental, social and governance (ESG) policies.
- Introducing a "green supporting factor" in the EU prudential rules for banks and insurance companies by incorporating climate risks into banks' risk management policies.

As a direct follow-up to the Action Plan, the Commission adopted a package of legislative measures to implement several key actions in May 2018:

- Regulation to establish a Sustainable Finance Taxonomy, a unified classification system on what can be considered environmentally sustainable economic activity to be adopted in 2020.
- Regulation on disclosures relating to sustainable investments and sustainability risks, which will introduce disclosure obligations on how institutional investors and asset managers integrate ESG factors into their risk management processes. Financial products investing in energy infrastructure will have to disclose their ESG impact under this regulation. This regulation was adopted by the Council in November 2019.
- Regulation creating a new category of benchmarks to provide investors with better information on the carbon footprint of their investments. The EU Climate Transition Benchmark aims to lower the carbon footprint of a standard investment portfolio and the EU Paris-Aligned Benchmark attempts to select only components that contribute to attaining the 2°C temperature goal set out in the Paris climate agreement. The Council adopted this regulation in November 2019.

The EGD announced that the Commission will present a renewed sustainable finance strategy in the second half of 2020 based on the Sustainable Finance Taxonomy. It will involve a review of the Non-Financial Reporting Directive, the development of sustainable investment labels and EU green bond standards, and the integration of climate and environmental risks into banks' risk management.

Sustainable Finance Taxonomy

The EU Taxonomy Regulation stipulates requirements for projects to qualify as an environmentally sustainable economic activity. The taxonomy creates a classification system based on three principles and six EU environmental objectives: climate change mitigation, climate change adaptation, water and marine resources, circular economy, pollution prevention and control, and biodiversity and ecosystems. The taxonomy sets technical screening criteria for economic activities which 1) make a substantive contribution to one of six environmental objectives, 2) do no significant harm (DNSH) to the other five, where relevant and 3) meet minimum safeguards (e.g. OECD Guidelines on Multinational Enterprises and the UN Guiding Principles on Business and Human Rights). The Commission defines the 'technical screening criteria' to assess the environmental sustainability of an activity with the help of an expert group. The technical expert group (TEG) on sustainable finance was established to support this definition and delivered advice on the criteria in March 2020.

There has been a discussion whether important activities in the energy sector qualify, including nuclear energy, natural gas, incineration of waste, and livestock production as well as carbon capture, utilisation and storage. Power generation activities that use solid fossil fuels are not considered an environmentally sustainable economic activity. According to Article 6 of the regulation, only CCUS technologies that deliver a net reduction in GHG emissions would be considered environmentally sustainable. The regulation disqualifies investment in coal activities as environmentally sustainable economic activity, except if there is no technologically and economically feasible low carbon alternative and as long as it does not lead to a lock-in in carbon intensive assets. Hydrogen and other low-carbon gaes are not covered under the taxonomy.

The TEG published its final reports on an EU taxonomy (including technical annex) as well as further user guidance in relation to its recommendations for an EU green bonds. The TEG has been so far unable to recognize nuclear energy and natural gas as sustainable or non-sustainable, therefore has temporarily classified it as a so-called transitional or enabling activity. However, gas and nuclear energy could potentially be labelled as an enabling or transitional activity in full respect of the "do no significant harm" principle.

Following the political agreement between the Council and the Parliament of December 2019, the Sustainable Finance Taxonomy (Taxonomy Regulation) was formally adopted by the European Parliament on 18 June 2020. The Commission will regularly update the technical screening criteria for transition and enabling activities. By 31 December 2021, it should review them and define criteria to identify activities that have a significant negative impact. The EU is aiming to apply the taxonomy for climate change mitigation and adaptation by the end of 2021 and, for the other objectives, by the end of 2022.

Assessment

The European Union's energy policy framework has been a driver of investment, competitiveness and clean energy transitions across the EU. The EU has emerged as a leader in offshore wind technology and attracts major financial investors, notably in renewable energy. The Energy Union policy framework (2014-19) has fostered greater consistency of national and EU policy making and alignment of goals along the five pillars of security of supply, an integrated internal energy market, greater energy efficiency, climate action and decarbonisation of the economy, and promoting research, innovation and competitiveness. The Energy Union has fostered progress in developing joint indicators and monitoring the state of the Union with regard to key EU policy goals.

A new European cycle started in 2019, which will shape energy policy making for the next five years. As the new EU strategy, the new Commission presented the EGD on 11 December 2019 with the ambition to turn the EU into the world's first climate-neutral region. At the December 2019 European Council meeting, the EU leaders endorsed the goal of climate neutrality. On 4 March 2020, the EC presented the EU Climate Law, which will form the basis for a future legislation in favour of a more ambitious emissions reduction target of at least 50% and possibly 55% by 2030. The IEA applauds the EGD and EU leadership.

In 2020, the Covid-19 crisis caused a major health emergency and economic losses, with long-term impacts for the EU economy, which is expected to see a decrease in GDP by at least 7.4% in 2020. While the EGD set out an ambition to boost investment in the clean energy transition, this green deal can now be instrumental to bring the EU economy back on track. Putting the clean energy transition at the heart of the economic recovery is an opportunity the EU should not miss. This will require consensus across the EU, whose solidarity is being tested under the economic and health crisis in 2020.

Focus on the cost-effective implementation of the 2030 energy and climate goals

To foster consensus on the necessary climate and energy actions in the current environment, the European Commission needs to safeguard the balance of the goals of competitiveness, innovation and economic efficiency, and security of supply as well as the affordability and fairness of the transition. Short-term action needs to support longer-term transformation of the European economy. The energy sector will be critical for the recovery and the implementation of the EGD, as the sector accounts for 75% of the EU's GHG emissions. The implementation of the EGD will require policies, funding and should build on today's energy sector framework, which was adopted under the Energy Union, the 2030 targets and the strength of the energy markets, notably on cost-effective action.

The progress towards the EU energy and climate targets for 2030 will be determined by the ambitions of the member states. Under the Energy Union and the CEP, the EU adopted a unique governance framework – the NECPs. They will foster consistency between EU and national energy and climate policies, while providing member states with flexibility to decide their level of ambition. The process has only started, with the first plans submitted to the European Commission in early 2020, for evaluation by the Commission in the summer of 2020.

Progress in NECPs may not be achieved on an equal footing across the EU. In fact, important gaps were visible based on the assessment of the draft NECPs by the European Commission in 2019, notably when it comes to energy efficiency and technology and innovation. The NECPs can be effective tools for meeting EU energy efficiency and renewables targets, if greater transparency, quantitative assessments and peer reviews were promoted. The EC should request member states to report on the impact of individual measures and how to scale up actions, including from enhanced auction schemes, improved energy efficiency finance schemes or other programmes. In this regard, the biennial progress reports by member states are an opportunity, including for reviewing investment made versus investment requirements.

Interestingly, the NECPs also demonstrate that there could be better alignment of different European policies, notably technology and innovation or industry. The EGD has the potential to look beyond policy silos and achieve a more consistent policy for each sector.

The EU will need foresight and quantitative analysis and projections to ensure the EU can assess on a regular basis the State of the Union with regard to emerging trends and risks. This includes climate change and its impacts on the resilience of the EU economy. Such scientific analysis needs to be the basis for the assessment of the national plans.

Under the EGD, the European Commission should work with member states to ensure greater consistency at national level (for the integration of several policy objectives, including transport, taxation, environment, technology and innovation) as well as better alignment with EU goals. The announced ambition to increase the emissions reductions for 2030, having in mind climate neutrality by 2050, will require the scaling up of actions in the coming years. The NCEPs are a good governance framework for that.

Energy action for the EU recovery

While the immediate priorities during the Covid-19 crisis were on helping citizens during the health emergency, kick-starting the economy and consolidating the fiscal situation, the longer-term recovery measures are an opportunity for modernising the EU energy economy and infrastructure. The scale of investments needed for the recovery and transformation of Europe’s economy is unprecedented and will require an acceleration of funding tools and policies of the EGD.

To ensure cost-effectiveness and kick-start the economy, the EU should put in practice the principle of “energy efficiency first”. The European Commission could pursue a two-pronged strategy to deliver both short-term and longer-term benefits, building on existing policies, notably the existing Energy Efficiency Obligation schemes, including those established under Article 7 of the EED II.

Near-term efforts should focus on policies that create jobs and higher annual savings, including incentive programmes that target hard-to-reach sectors (e.g. SMEs) and which can complement existing EU eco-design policies by increasing the supply and lower the costs of higher efficiency products.

These interventions should go hand in hand with more comprehensive efficiency policies and programmes that focus on delivering longer-term market readiness, deeper energy savings and more comprehensive energy efficiency projects in buildings. Customised incentive programmes are highly effective in delivering more comprehensive energy efficiency projects, especially when targeted to commercial and industrial buildings or and when focused on the operation and maintenance of existing buildings to improve building performance post-occupancy or –retrofit (as opposed to “deep retrofit” measures). These programmes also often accelerate market readiness (e.g. capacity building through training, certification and networks) and complement both the EU’s Ecodesign and Energy Efficiency Performance in Buildings Directives.

Maintaining the financial resilience of Europe’s clean energy sector, its jobs and the competitiveness of the European industry have become growing concerns in a changing geopolitical and economic situation. The new industrial strategy for Europe was presented in March 2020 to support EU leadership in renewables, digitalisation and industrial decarbonisation technologies, including hydrogen and li-ion batteries. Investment in energy infrastructure modernisation and critical energy technology and innovation are critical drivers for the economic recovery.

Amid tight public budgets, putting the common energy market and price signals at the centre will also mean a reassessment of nationally focused subsidy policies, including aid schemes for renewables, capacity mechanisms and regulated prices. The current low price environment is an opportunity to promote tax reforms, including the reduction of taxes on electricity, removal of fossil fuel subsidies and strengthening of carbon pricing. This includes a review of EU energy taxation rules, notably the Energy Taxation Directive, the EU ETS/non-ETS rules and the EEAG, as well as sustainable finance reforms. Despite overall very good progress, the EU faces large disparities in terms of implementing EU energy market rules. Therefore EU rules under the CEP need to be fully implemented to facilitate an internal electricity market with higher shares of renewables.

The EU has made impressive progress in mobilising private and public finance in support of clean energy transitions. The implementation of the sustainable finance action plan needs to ensure complementarity of private and public sector financing with competition and state aid rules. The Sustainable Finance Taxonomy aims to ensure investor transparency. Paris-aligned benchmarks are key actions to promote investment flows onto a path that supports the 2030 climate and energy targets. However, the implementation of the taxonomy should not hamper critical investments for the recovery and the transitions. Natural gas and nuclear energy need to be covered under the taxonomy as transition technologies. If this is not the case, this may have wide impacts on private and public funding for these sectors. The climate strategy and energy lending policy of the EIB position the bank well to play a stronger role in the EU’s clean energy transitions and the EU recovery programmes, as it can use the EU’s triple-A rating as a guarantee for loans and investment.

The IEA commends the EU for prioritising a just transition as an imperative, including the support of the transition in Europe’s coal regions. A Just Transition mechanism will be critical to maintain the political acceptability of a climate neutrality goal while enabling a fair recovery of the EU economy after Covid-19, which safeguards social equality and inclusiveness.

Key recommendations

The European Union should:[6]

- Ensure cost-effective implementation of the 2030 energy and climate framework, and review EU policies with a view to scale up EU energy sector action to achieve short- and long-term benefits from a sustainable, secure and just recovery of the European economy.
- Work with member states to ensure consistency of NECPs, national long-term strategies and the EGD objectives through a regular review of progress.
- Strengthen strategic foresight and quantitative analysis and projections across all policies and sectors of the economy to identify the potential contributions of the energy sector in Europe's transition in the medium and long term.
- Leverage public- and private-sector financing for a wide range of technology solutions needed for clean energy transitions, by boosting EU financial instruments, while ensuring transparency and a level playing field for technologies, in the implementation of the Sustainable Finance Action Plan and other new EU funding programmes.

[6] Please note that recommendations are addressed to the European Union, taking the institutional and decision-making structure of the EU as given.

Annex: EU legal and institutional framework

The EU energy policy is enshrined in two treaties: the Treaty on the Functioning of the European Union (TFEU) and the Euratom Treaty.

The EU general energy policy is set out in Article 194 of the TFEU. The treaty defines EU energy policy as matters relating to 1) the functioning of the energy market; 2) the security of energy supply in the union; 3) the promotion of energy efficiency, energy saving, and the development of new and renewable forms of energy; and 4) the promotion of the interconnection of energy networks. It places energy policy within the context of the establishment and functioning of the internal market, the preservation of the environment and the spirit of solidarity between member states. Under the TFEU, energy policy is a shared competence between the EU and member states. Thus the member states may legislate and adopt legally binding acts to the extent that the EU has not exercised its competence.

The Euratom Treaty is a sectoral treaty (lex specialis in relation to the TFEU) that applies to the nuclear energy sector. It covers all policy aspects (research, development of standards) relevant for the civil use of nuclear energy: nuclear safety, protection against ionising radiation, radioactive waste management, international agreements, security of supply of ores and nuclear materials, and safeguards. It empowers the European Commission to prepare legally binding acts to be adopted by the Council after consultation of the Parliament. The Euratom Community has kept a separate legal personality from the European Union but it is fully integrated with the EU by sharing common institutions and most of the procedural and financial rules, and having the same member states.

Apart from the explicit competences for energy in the TFEU and the Euratom Treaty, EU action in the area of energy is guided by EU primary law on the harmonisation within the internal market (TFEU Articles 24 and 114), environmental protection (TFEU Articles 191-193), taxation (TFEU Article 113), competition (TFEU Articles 101-102) and state aid (TFEU Articles 107-108), economic policy (TFEU Article 122), EU trade policy (TFEU Article 206), the trans-European networks for transport, energy and telecommunication – TENs – (TFEU Articles 170-172) and EU industrial policy (TFEU Article 173).

As a general principle, decision-making in the EU depends on the legal basis involved under the TFEU or Euratom Treaty and will require different degrees of co-operation between the EU institutions.

For some policy matters, member states and the Union share competences (for instance in the areas of environment or the TENs), while in others the exclusive competence lies with the EU (competition, trade) or member states. While EU legislation does exist in taxation – minimum harmonisation under the Energy Taxation Directive – in general, taxation matters are largely a competence of member states and the Council needs to decide unanimously to adopt or change legislation. The European Commission recently proposed to move to qualified voting in certain taxation areas, including energy and environmental taxation. Conversely, in the area of industry, the EU has only supporting competences to help member states achieve their targets and goals.

In most cases, energy policy is a shared competence between the Union and the member states, represented in the Council. The general rule in energy policy is decision-making through ordinary legislative procedure.[8] In this procedure, the European Commission proposes legislative acts, which are negotiated and adopted by the Council, where member states are represented, and the European Parliament. Representatives of the 28 member states in the Council, the European Commission and the European Parliament thus work together to adopt EU legislation in the field of energy, but the scope of their specific involvement depends on the subject matter.

For example, the TENs policy places energy infrastructure under the core EU objectives in Article 170 of the TFEU, in the framework of the internal market integration (TFEU Article 24), interconnectivity and interoperability, linking isolated regions as well as economic, social and territorial cohesion (TFEU Article 174). TFEU Articles 170-172 oblige the EU to propose guidelines and priorities for the identification of projects of common interest and measures on interoperability. Member states have to approve the projects of common interest that are located in their territory.

The Council of the European Union (also known as the Council of Ministers) represents the interests of the EU member states, which take turns holding the Council presidency for a six-month period. The European Council, represented by the heads of state and government, the president of the European Council and the president of the European Commission, decides on the main directions of EU energy policy, notably through European Council meetings. It is chaired by Charles Michel, president of the European Council. Josep Borrell Fontelles is the high representative of the Union for foreign policy and security policy/vice-president of the European Commission. He is not a member of the European Council, but takes part in its work.

The European Parliament exercises political supervision over the EU's activities and takes part in the legislative process. Energy matters are dealt with in several of its 20 committees: in the Industry, Research and Energy Committee, the Environment, Public Health and Food Safety Committee, the Internal Market and Consumer Protection Committee and the Foreign Affairs Committee.

Within the von der Leyen Commission, energy policy is one of the main policy sectors under the overarching climate objectives of the EU. There are several commissioners working together on energy, security, climate and environmental policies, co-ordinated by the executive vice-president (EVP) for the EGD, Frans Timmermans, who is also the commissioner for climate action. The EVP co-ordinates the climate-related policies with Commissioner Kadri Simson, dealing with energy, Commissioner Adina Vălean for transport and Commissioner Virginijus Sinkevičius, in charge of environment, oceans and fisheries, as well as Internal Market Commissioner Thierry Breton, who also is in charge of industry. He liaises with EVP Margrethe Vestager on EU competition policy, i.e. merger control, antitrust and state aid control, in the field of energy.

The competence for energy policy lies mainly with the directorate-general (DG) for Energy, dealing with the general energy policy strategy; the regulatory framework for the internal energy market in gas and electricity; energy networks, including trans-European networks;

[8] There are two caveats to this rule: Article 194 II clarifies that "such measures shall not affect a member state`s right to determine the conditions for exploiting its energy resources, its choice between different energy sources and the general structure of its energy supply, without prejudice to Article 192 (2) c3, and Article 194 (3): unanimity is required for measures which are primarily of fiscal nature.

security of supply; the legal framework for renewable energies; and energy efficiency, as well as ensuring safe and sustainable use of nuclear energy across Europe.

Emissions trading, international climate policies and climate change mitigation and adaptation, including CO_2 standards in transport, fall within the responsibility of the DG for Climate Action.

Important competences and polices with impact on energy issues lie with other DGs.

In the area of EU competition and trade policy, the competence is exclusive for the Union. Within the European Commission, the DG for Competition oversees the enforcement of EU competition policy, i.e. merger control, antitrust and state aid, in all sectors, including energy. The DG for Trade is in charge of trade and investment policies and negotiates on behalf of the member states' EU bilateral and multilateral trade agreements, for instance for the Trade in Services Agreement within the World Trade Organization (WTO) or bilaterally.

The DG for Taxation and Customs Union is responsible for the EU harmonised framework for taxation of energy products and electricity. The DG for Enterprise and Industry co-ordinates industry policies and product legislation (including standards for energy performance with the DG for Energy) and has a strong focus on economic growth and the role of small and medium-sized enterprises (SMEs). It also is in charge of the free movement of goods in the internal market (TFEU Article 34).

The DG for Mobility and Transport promotes an innovative and sustainable transport policy (for air, road, rail, maritime and inland waterways) and is focused on the full deployment of alternative fuels and smart traffic management systems (ITS, ERTMS, SES etc), advancing multimodality by promoting *inter alia* the role of rail, internalisation of external costs (e.g. road charging) and promoting sustainable urban mobility to achieve low-emission mobility and contribute to the achievement of a long-term sustainable development of transport and connectivity in Europe, including the Trans-European Network for Transport (TEN-T) Corridors, and beyond.

Together with the DG for Energy, the DG for Research and Innovation supports EU-wide and international energy technology co-operation and administers EU funding in the field of energy technology research, development and demonstration. The Innovation and Networks Executive Agency manages the energy part of the Connecting Europe Facility and the Horizon 2020 and Horizon Europe programmes.

As the Commission's in-house science service, the Joint Research Centre (JRC) and its energy institutes are in charge of direct scientific and technical support to EU energy policy making, and provide analytical support, modelling and research capabilities. It has a dedicated energy institute at the JRC-Petten.

The DG for Environment deals with environmental impacts and biodiversity; ensures the application of EU environmental law, including pollutant controls; and represents the EU on environmental matters at international level. The European Environment Agency (EEA) provides environmental analysis and data to EU institutions, policy makers and the public. The EEA evaluates progress on meeting the EU climate and energy objectives and compiles the Union's greenhouse gas (GHG) emissions and pollutants inventories, the EU's report to the United Nations Framework Convention on Climate Change (UNFCCC) and the State of the Environment Report every five years next to a range of environmental impact assessments and technical and strategy reports.

The European Investment Bank (EIB) in Luxembourg is owned by the EU member states. Representing their interests and supporting the European Commission, the EIB provides loans and guarantees to support financing of energy sector activities, including energy infrastructure and energy efficiency projects. In 2019, the EIB's new lending policy focused on climate finance and ruled out support to fossil fuel projects.

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3. Climate

Key data (2017)

GHG emissions without LULUCF*: 4 333 $MtCO_2$-eq, -17% since 2005, -23% since 1990

GHG emissions with LULUCF*: 4 084 $MtCO_2$-eq, -25% since 2005, -17% since 1990

Energy-related CO_2 emissions:**

CO_2 emissions from fuel combustion: 3 209 $MtCO_2$, -18% since 2005, -20% since 1990

CO_2 emissions by fuel: oil 41.6%, natural gas 27.8%, coal 28.6%, non-renewable waste 2.0%

CO_2 emissions by sector: power and heat 34.7%, transport 28.9%, industry 12.6%, residential 11.8%, commercial and public services 5.0%, other energy 5.0%, agriculture/others 2.0%

CO_2 intensity per GDP***: 0.17 $kgCO_2$/USD (IEA average 0.23 $kgCO_2$/USD)

*LULUCF = Land use, land-use change and forestry; Source: EEA (2019a), *Annual European Union Greenhouse Gas Inventory 1990–2017 and Inventory Report 2019*, https://unfccc.int/documents/194921. EU GHG 2020 targets include international aviation, and GHG emissions stood at 4 483 Mt in 2017.

**Source: IEA (2019), *CO_2 Emissions from Fuel Combustion 2019* [database], Paris, www.iea.org/statistics/.

***GDP in 2010 numbers and PPP.

Overview

The European Union (EU) has 2020 and 2030 climate targets, which have become the key drivers for EU energy policy. The targets are implemented through EU climate policies, the EU Emissions Trading System (ETS) and non-ETS legislation (i.e. Effort Sharing Legislation and the Regulation on Land Use Land Use Change and Forestry [LULUCF]). The latter break down the EU-wide goals for the non-ETS sectors into national targets.

The EU witnessed a decline in total greenhouse gas (GHG) emissions by 23% since 1990 levels, according to 2017 UNFCCC reporting, overachieving its GHG reduction target of -20% by 2020. With regard to the 2030 target of reducing emissions by 40% from 1990 levels, the assessments are more varied and will depend on the implementation of stated EU and national policies (EC, 2019a, EC, 2019b, EEA, 2019b).

This International Energy Agency (IEA) review of EU climate policies will focus on energy-related CO_2 emissions, which have decreased by 18% since 2005 and by 20% since 1990, the largest emissions reductions in the world from 2018 to 2019. Power and heat remains the largest source of energy-related CO_2 emissions, accounting for 35% of the total in 2017, followed by transport at 29%. The emissions intensity in heat and power generation is a major reason for differences in emissions intensity among EU member states. By international comparison, the EU had a significantly lower emissions intensity of heat and power generation (235 gCO_2/kWh) than other large economies. However, outside power generation, emissions are growing. In fact, total energy-related CO_2 emissions have increased by 1% since 2014.

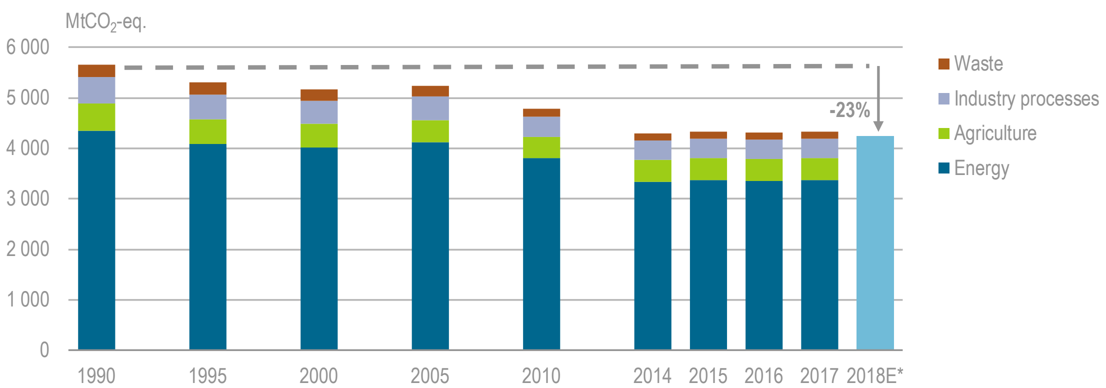
In December 2019, the European Commission presented the European Green Deal (EGD), which aims at making Europe a climate-neutral continent by 2050. This goal is to be enshrined in the European Climate Law, which was proposed in March 2020 (EC, 2019c). Work is under way for a planned increase in the 2030 GHG emissions reduction target to at least 50% and towards 55%, which would be followed by legislation.

As the EU is responsible for only 8% of global emissions and the energy sector accounts for two-thirds, energy and climate action in emerging economies should be a focal point of EU international policy.

EU GHG emissions

The EU has been successful in reducing its GHG emissions over the past decades. In 2017, total GHG emissions were 4 333 million tonnes of CO_2 equivalent ($MtCO_2$-eq) (without LULUCF). However, since 2014, GHG emissions have stabilised, which may pose challenges for meeting the 2030 target (Figure 3.1).

Figure 3.1 EU GHG emissions, 1990-2018



GHG emissions in the EU have been reduced by 23% since 1990, and the EU has already reached its 2020 target. However, since 2014 emissions levels have stabilised.

*2018E - 2018 estimated levels

Source: EEA (2019a), *Annual European Union Greenhouse Gas Inventory 1990–2017 and Inventory Report 2019*, https://unfccc.int/documents/194921.

Since 1990, the EU has seen GHG emissions reductions in line with the 2020 target. In 2018, total GHG emissions in the 28 members of the EU (EU28) and Iceland, without LULUCF, were 23.5% below the 1990 level (EEA (2019a). In recent years, however, emissions have been flat. By country, data published by Eurostat show that in 2017, Germany, the United Kingdom and France were the highest emitters of GHG emissions in the EU28, while Lithuania, Latvia, Romania and Estonia saw an approximately 50%

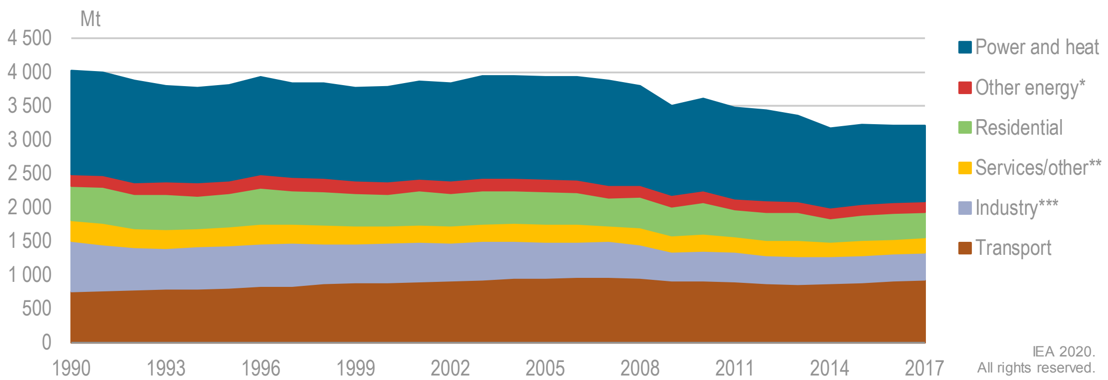
decrease of their GHG emissions since 1990 levels (Eurostat, 2019). Rising emissions are reported for Portugal and Spain (around 20% each).

Energy-related CO_2 emissions

Energy-related CO_2 emissions from combustion processes (in energy transformation or in final energy consumption) account for around three-quarters of total GHG emissions. Energy-related CO_2 emissions in the EU totalled 3 209 million tonnes (Mt) in 2017.

Emissions have been reduced across all sectors over the last decade (Figure 3.2). Power and heat emissions in particular decreased by 27% from 2007 to 2017, reflecting a shift from fossil fuels to renewable energy in power generation. Industry emissions also decreased rapidly, by 23% in the last decade, reflecting a drop in industry energy use after the financial crisis in 2008. Since 2014, however, total energy-related CO_2 emissions have increased by 1%. This was mainly because of the growth in transport emissions as a result of higher energy demand in the sector.

Figure 3.2 EU energy-related CO_2 emissions by sector, 1990-2017



Power and heat is the largest source of energy-related emissions, accounting for 35% of the total in 2017, followed by transport emissions at 29%.

**Other energy* includes oil refineries, oil and gas extraction, coke ovens and blast furnaces, and other energy transformation.

***Services/other* includes commercial and public services, agriculture, forestry and fishing.

****Industry* includes CO_2 emissions from combustion at construction and manufacturing industries.

Source: IEA (2019), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

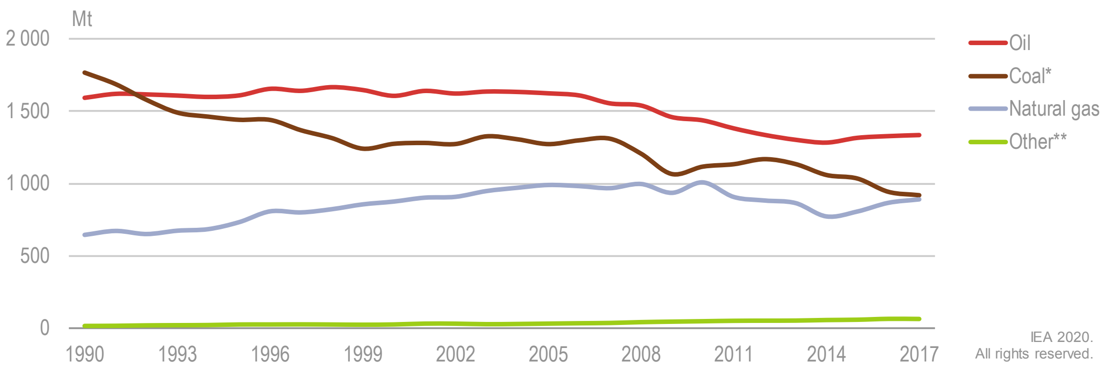
Power and heat generation and transport are the largest emitting sectors. In 2017, power and heat generation accounted for nearly 35% of total energy-related CO_2 emissions and transport for 29%. Energy use in residential and service buildings accounted for 17% of total emissions, industry for nearly 13%, other energy transformation including refineries for 5%, and agriculture, forestry and fishing for 2% (see Chapter 6 on Industry).

By fuel, emissions related to oil use account for the largest share of total energy-related CO_2 emissions (Figure 3.3), followed by coal and natural gas. In 2017, oil emissions accounted for 42% of total emissions, two-thirds of which came from the transport sector.

Coal (including peat and oil shale) accounted for 29%, mainly from power generation, and natural gas for 28% of the total, used across many sectors.

All fossil fuel emissions (except non-renewable waste) have declined in the past decade, but since 2014, emissions have increased from oil, due to the growth in transport emissions, and from natural gas, due to the shift from coal to gas in power generation.

Figure 3.3 Energy-related CO_2 emissions by fuel, 1990-2017



Oil is the largest source of energy-related CO_2 emissions, with two-thirds coming from the transport sector. Gas and coal accounted for 28% each, mainly from power generation.

**Coal* includes emissions from coal products, peat and oil shale.

***Other* includes emissions from non-renewable waste.

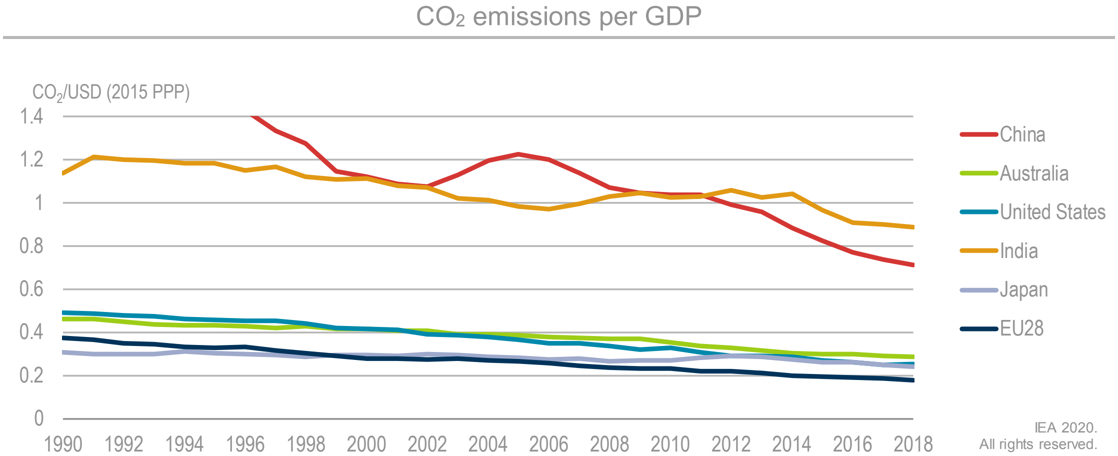
Source: IEA (2019), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

Emissions intensity

Compared with other large economies, the EU has relatively a low CO_2 intensity (Figure 3.4). For CO_2 per unit of gross domestic product (GDP) in particular, the EU is below other major economies, including Japan, India, the United States and the People's Republic of China ("China"). In 2018, the EU emitted 0.17 kg of energy-related CO_2 ($kgCO_2$) per USD (at purchasing power parity [PPP]), compared with 0.24 $kgCO_2$/USD in Japan, 0.25 $kgCO_2$/USD in the United States, 0.29 $kgCO_2$/USD in Australia, 0.71 $kgCO_2$/USD in China and 0.9 $kgCO_2$/USD in India.

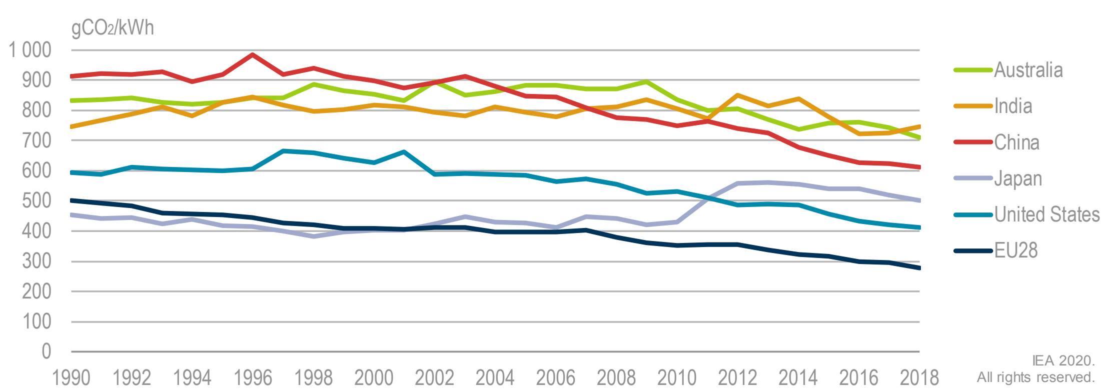
A main explanation for the relatively low emissions per GDP and per capita is the emissions intensity of heat and power generation (Figure 3.5). The EU has significantly lower emissions from heat and power than other large economies, at less than 300 gCO_2/kWh in 2018 (and 235 gCO_2/kWh in 2019), compared with over 400 gCO_2/kWh in the United States, over 500 gCO_2/kWh in Japan, around 600 gCO_2/kWh in China and around 700 gCO_2/kWh in coal-dependent India and Australia. This reflects the large share of low-carbon electricity generation in the EU from nuclear and the growing share of renewables.

Figure 3.4 Carbon intensity in the EU and other large economies, 1990-2018



Source: IEA (2019), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

Figure 3.5 CO_2 emissions per kWh heat and power generation in EU and other large economies, 1990-2018

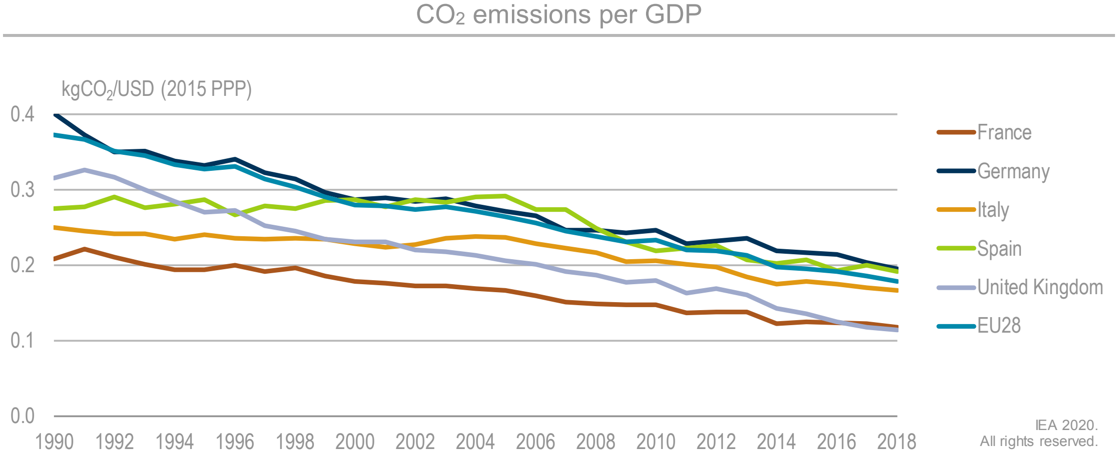


Low emissions intensity in power generation is a main reason for EU's low CO_2 intensities.

Source: IEA (2019), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

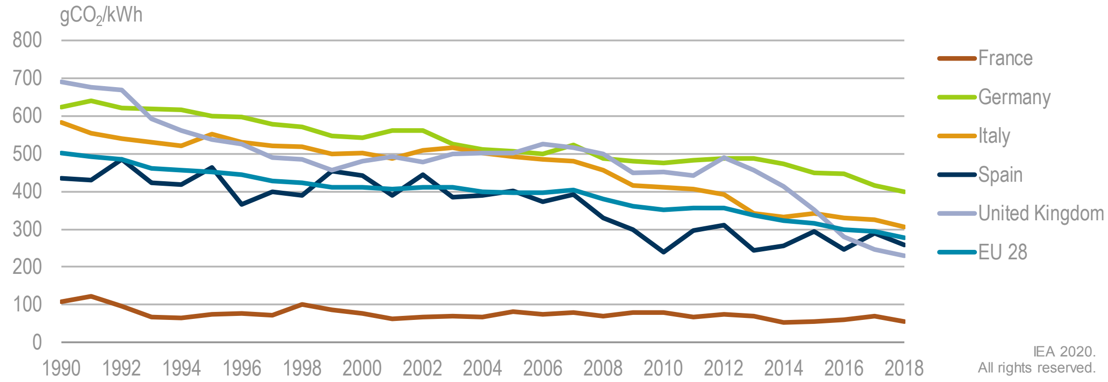
CO_2 intensities vary significantly also between EU countries (Figure 3.6). Among some of the largest economies in the EU, Germany has relatively high CO_2 emissions per GDP and per capita, reflecting the dependence on coal and natural gas in its energy supply. France has the lowest emissions intensities in the comparison, nearly 40% below Germany in CO_2/GDP and nearly 50% below for CO_2/capita. Again, the emissions intensity of heat and power generation is a main factor driving other emissions intensities, where France with its high share of low-carbon nuclear power is significantly lower than other large EU countries, around 50 gCO_2/kWh in 2018 (Figure 3.7).

Figure 3.6 Carbon intensity in large EU member countries, 1990-2018



Source: IEA (2019), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

Figure 3.7 CO_2 emissions per kWh heat and power generation in large EU member countries, 1990-2018



Emissions intensity in heat and power generation is a major reason for differences in emissions per GDP and per capita among EU members, with France ranking low and Germany high.

Source: IEA (2019), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

EU climate targets

The EU has set targets for GHG emissions reductions: total GHG emissions should be reduced by 20% by 2020 and by 40% by 2030 from 1990 levels.

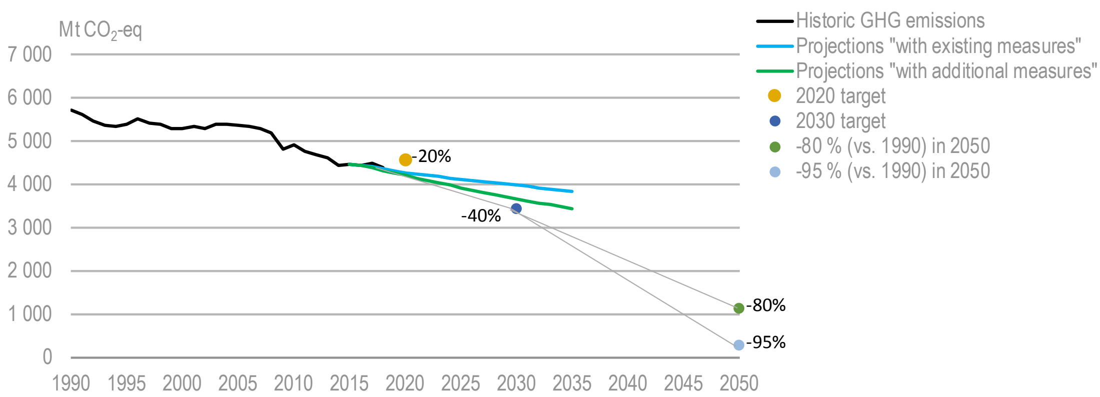
The EU and the Paris Agreement

The 2030 EU climate and energy framework with the 40% target was adopted by the European Council in October 2014 as the nationally determined contribution (NDC) from the EU to the Paris Agreement in 2015. The Paris Agreement is a so-called mixed agreement: some areas of the agreement fall under the responsibility of the EU and others of member states. It therefore was ratified by both the EU and all 28 member states. Under the Paris Agreement, in 2020 the EU is requested to update or submit the next NDC.

While the EU is set to achieve its 2020 GHG reduction target, the picture concerning its 2030 targets is more varied.

According to the European Environment Agency (EEA) aggregated member state projections with focus on national measures the EU (and the United Kingdom) are not yet on track towards its 2030 target of reducing emissions by 40% from 1990 levels and will need to strengthen its policies to do so (Figure 3.8). Based on the current national projections, the EEA indicates that the EU would reduce GHG emissions only by 30% by 2030 (with existing national measures) or 36% (with additional national measures), which is below its 40% target and significantly below a potential 50-55% target.

Figure 3.8 GHG emissions trends, projections and targets in the EU, 1990-2050



EU GHG emissions are not on a trajectory to meet the 2030 emissions reductions target of 40%.

Source: EEA (2019b), The European Environment – State and Outlook 2020: Knowledge for Transition to a Sustainable Europe, www.eea.europa.eu/soer-2020/.; EEA (2019c), Total greenhouse gas emission trends and projections in Europe, www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emission-trends-6/assessment-3.

A comparison of historic emissions reductions and implications of future reduction targets illustrates the magnitude of the emissions reductions effort needed in the EU between now, 2030 and 2050 (Figure 3.8). From 1990 to 2017, the EU achieved savings of 46 million tonnes of CO_2 ($MtCO_2$) per year. However, this amount has to double through 2030 to 81 $MtCO_2$/year in half the time, while up to 2050, 114 $MtCO_2$/year to 157 $MtCO_2$/year need to be reduced, if the EU is to be climate-neutral (95% target).

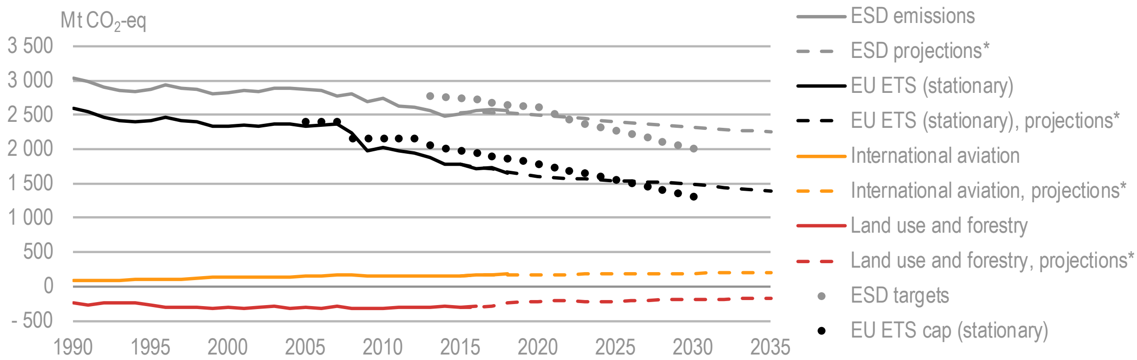
EU-level GHG projections indicate that 45% emissions reductions could be reached if all EU-level targets and policies, as adopted by 2018, are fully implemented (EC, 2019a).

The European Commission’s assessment of the draft NECPs in 2019 concluded that the EU could achieve the 40% target, if new national measures that are proposed in the plans were implemented (EC, 2019b).

Climate mitigation policies in the EU

The EU approach to managing GHG emissions is divided into two parts: large stationary combustion facilities in industry and power and heat generation as well as aviation within the European Economic Area, which fall under the ETS; and all other emissions, which fall under the Effort Sharing Decision (ESD) for 2020 and Effort Sharing Regulation (ESR) for 2030. "Effort Sharing" refers to distributing the EU-wide reduction target across member states based on individual capacities, based on GDP and other factors.

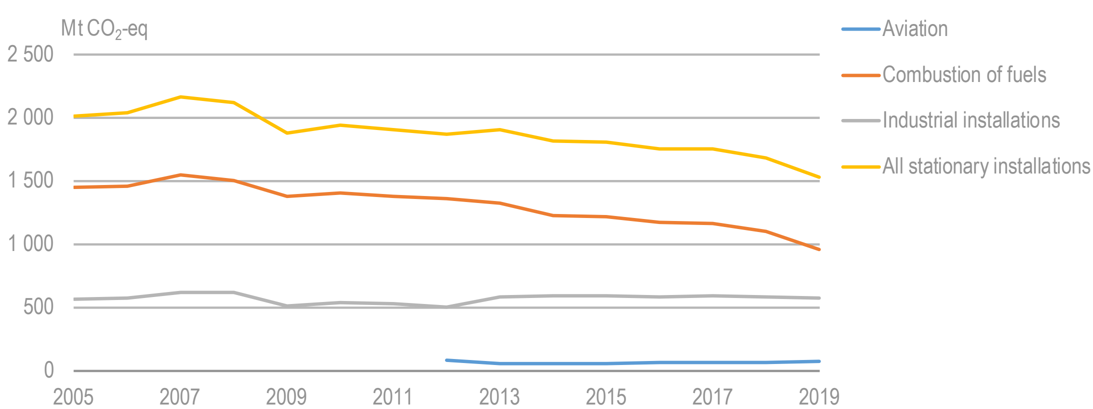
Figure 19 EU ETS and non-ETS emissions and projections, 1990-2035



**Projections* are with existing policies

Source: EEA (2019c), Total greenhouse gas emission trends and projections in Europe, www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emission-trends-6/assessment-3.

Figure 3.10 Historic ETS emissions by activity, 2005-2019



Source: EEA (2019d), EU Emissions Trading System (ETS) data viewer, www.eea.europa.eu/data-and-maps/dashboards/emissions-trading-viewer-1.

ETS emissions

The ETS covers around 40% of the EU's emissions and is the key tool to reduce GHG emissions cost-effectively. It is a cap-and-trade instrument that sets the total amount of GHG emissions allowed to be emitted by its more than 12 000 installations and

1 400 aircraft operators (covering intra-EU aviation activity). The cap is reduced annually to ensure that total covered emissions fall 21% by 2020 and 43% by 2030 from 2005 levels. The fourth trading phase (2021-30) will increase the annual reduction rate of the cap from 1.74% currently to 2.2% from 2021 onwards to align the ETS with the 43% reduction goal by 2030. Companies receive or buy emissions allowances, which they can trade with each other as needed. Since 2005, emissions within the EU ETS have decreased by around 26% (EEA, 2019c), as illustrated in Figure 3.10.

EU ETS reforms

To address a surplus of almost 2 billion allowances in the EU ETS, the EU adopted the Market Stability Reserve (MSR) in 2015. The MSR is designed to help introduce flexibility in the system and increase its capacity to adapt to major exogenous shocks such as an economic crisis or higher-than-anticipated abatement efforts by member states (e.g. coal phase-out). The reserve operates according to predefined rules, and allowances are automatically placed in the reserve or released from it based on the size of total number of allowances in circulation. As part of the revision of the EU ETS adopted in 2018, the percentage of allowances in circulation to be placed in the reserve was doubled for the period 2019-23. The MSR began operating in 2019 and is scheduled for a review in 2021. After 2023, allowances held in the MSR above the total number of allowances auctioned during the previous year shall no longer be valid.

Under the EU ETS, the increase in emissions is capped (with some flexibility provided by the MSR). The EU also amended its carbon leakage rules to improve their targeting of sectors at the highest risk of relocating production, while sectors less exposed to carbon leakage risk will see their free allocation phased out by 2030. In addition, the carbon leakage list will now be updated every five years, and the benchmark values determining the level of free allocation to each installation will be updated twice in phase four of the ETS (2021-30), to avoid windfall profits and better reflect technological progress.

Thanks to these reforms, the surplus of emissions allowances is now being actively reduced, the environmental stringency and the flexibility of the ETS has increased, and the EU carbon price has seen a dramatic rise from EUR 5 to EUR 28 in just two years. Moreover, the MSR has also been able to maintain a resilient ETS price during the Covid-19 pandemic, which caused significant oversupply in ETS allowances. After a fall in the ETS price of allowance in March 2020 to EUR 18, the price was up at EUR 25 in mid-June.

Power sector

CO_2 from fuel combustion covered by the EU ETS accounted for 25% of EU GHG emissions in 2018. It has been included in the EU ETS since 2005. Since 2013, power generators have to purchase their allowances through auctions, with the exception of a limited amount of free allowances active in some countries until 2019. This transitional free allocation in lower-income member states is intended as support for modernisation and diversification of their electricity sectors – and will continue to exist in the next trading phase to 2030 in a more targeted form. Since 2013, CO_2 emissions from fuel combustion covered by the ETS decreased by around 17% to 1.1 gigatonnes of CO_2 equivalent in 2018 (EEA, 2019c), stemming from both the effectiveness of renewable energy support policies and the incentive to switch away from high-carbon fuels under the EU ETS, especially in recent years.

Industry

Industrial installations, which have also been part of the EU ETS since 2005, are currently responsible for around 14% of the EU's total GHG emissions (EEA, 2019c). Manufacturing industries receive a share of their emission allowances for free. This allocation is based on benchmarks that represent the average CO_2 emissions of the best performing 10% of installations producing the same product in the EU. Installations that do not reach these benchmarks will have to reduce their emissions or buy additional allowances. The revision of the EU ETS retains this system of free allocation to address carbon leakage concerns, albeit in a more targeted manner with less exposed sectors seeing their free allocation phased out by 2030. Since 2013, CO_2 emissions from industrial installations decreased by just 0.3% to 587 $MtCO_2$-eq in 2018 (EEA, 2019d). Thus, the EU ETS does not seem to have significantly contributed to the decarbonisation of industrial installations.

Aviation

Currently under the EU ETS, the aviation sector receives for free about half of the allowances it has to surrender. Free allocation is based on an efficiency benchmark established in 2010. The surrendering of allowances is temporarily restricted to flights between airports in the European Economic Area (from 2013-23). The original coverage, which also covered flights to and from countries outside the economic area, was reduced in order to give impetus to the international process (see below). From 2021, the 2.2% cap reduction rate applying to stationary installations will also start applying to aircraft operators. In the current trading phase, CO_2 emissions from aviation increased by 25% to 67 $MtCO_2$-eq in 2018 (EEA, 2019c), indicating the need for further stringency and with the EGD consequently proposing to reduce free allowance to aircraft operators (EC, 2019c).

For aviation outside of the European Economic Area, the EU and its member states have consistently supported the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) under the auspices of the International Civil Aviation Organization (ICAO). The scheme is intended to start in 2021 and aims to offset CO_2 emissions above 2020 levels on covered routes. As decided by the European Parliament and EU member states in 2017, the EU's framework for CORSIA implementation is the EU ETS Directive, which also calls for an increase in the auctioning share of aviation allowances. The CO_2 standards for new aircraft adopted by ICAO in 2017 were implemented in EU law in early 2019.

As an industry commitment, the ICAO is working on mitigating the CO_2 emissions associated with aviation activities, also through a 2% annual fuel efficiency improvement through to 2050.

Maritime transport

The maritime sector is not covered under the EU ETS to date but the EGD proposes among other measures extending European emissions trading to shipping. The EU requires the monitoring, reporting and verification of CO_2 emissions (and efficiency) from maritime transport (Regulation (EU) 2015/757) with a view to future policy development. The regulation is being amended to align it with the International Maritime Organization (IMO) data collection system, which began collecting fuel consumption data in 2019. In 2018 the IMO adopted an initial strategy on the reduction of GHG emissions from ships with the objective to reduce emissions by at least 50% by 2050 compared with 2008 while pursuing efforts to achieve full decarbonisation as soon as possible in this century. As a first step in the implementation of the strategy, the IMO is expected to decide in 2020 on measures that will improve the technical and operational efficiency of both existing and new ships, so these measures are in place by 2023. The IMO in 2020 will also have to decide on strengthening the mandatory minimum requirements for the design efficiency of new ships (Energy Efficiency Design Index [EEDI]). Regarding air pollution, stricter IMO standards have come into effect in 2020 for the sulphur content of fuels.

Revenues from EU ETS auctions

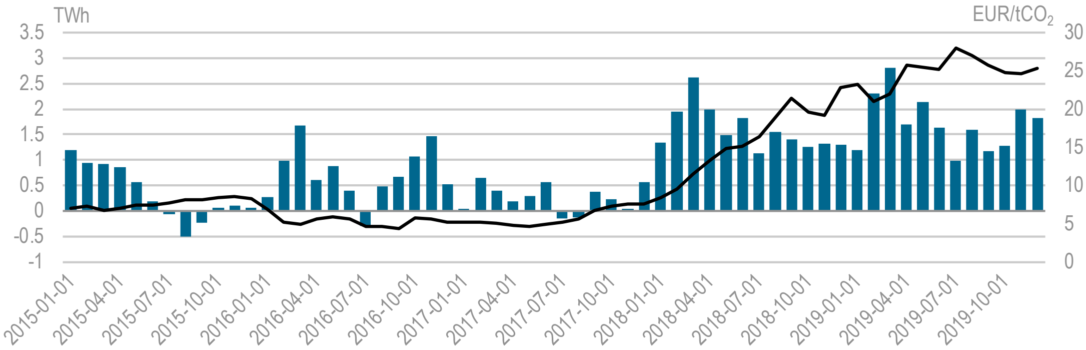
In recognition of the different starting points for member states, the 2018 revision of the EU ETS also introduced the Modernisation Fund, which will support the decarbonisation of the power sector and facilitate a just transition in ten lower-income member states. It could be worth as much as EUR 35 billion between 2021 and 2030. The Innovation Fund will receive its funding from the revenues gained from the auctioning of 500 million allowances between 2020 and 2030. It is the successor programme to the New Entrants Reserve of 300 million allowances, the so-called NER300. The Innovation Fund could be worth as much as EUR 12.5 billion at carbon prices of EUR 25. It will focus funding for demonstration projects on renewable energy; carbon capture, utilisation and storage (CCUS); energy storage; and low-carbon breakthrough technologies in energy-intensive industries. The revised EU ETS Directive further requires that at least 50% of the auctioning revenues received by member states should be used for climate and energy-related purposes.

EU carbon border adjustment mechanism

The European Commission is contemplating the adoption of a cross-border adjustment mechanism for certain sectors by 2021, aimed at preventing carbon leakage and creating a level playing field. The EGD foresees that “should differences in levels of ambition worldwide persist, as the EU increases its climate ambition, the Commission will propose a carbon border adjustment mechanism, for selected sectors, to reduce the risk of carbon leakage” (EC, 2019c). This measure will be designed to comply with World Trade Organization rules and other international obligations of the EU and is negotiated with trade partners. The EGD clarifies that the adjustment “would be an alternative to the measures that address the risk of carbon leakage in the EU’s Emissions Trading System”, e.g. the allocation of free allowances based on benchmarks or compensation for the increase in electricity costs.

Some leakage has been detected in the electricity sector, but it is very small in scope, given the limited electricity interconnection capacity with countries outside the EU. With the EU ETS price up at EUR 25 by end of 2019, electricity imports into the EU grew significantly from Morocco, the Russian Federation, Turkey, Ukraine, the Western Balkans and, which plan large interconnections to the EU and new coal power plants. As illustrated in Figure 3.11, net imports of electricity into the EU ETS countries were up from 3 terawatt-hours (TWh) in 2017 to 21 TWh in 2019 (ENTSO-E, 2019, Sandbag, 2020). This carbon leakage has been highlighted by Estonia, Finland, Spain, as it undermines the EU ETS functioning and emissions reduction targets. Meanwhile, there is growing investment in new coal plants and more interconnections under development in the EU neighbourhood.

Figure 3.11 Trend in net electricity imports into the EU and EU ETS price, 2015-19



Source: ENTSO-E (2019), Power Statistics [database], https://www.entsoe.eu/data/power-stats/

Non-ETS emissions

For the periods 2013-20 and 2021-30, member states have national targets for meeting emissions reduction objectives in the sectors outside the ETS (Table 3.1). These non-ETS emissions are part of the ESD (2013-20) and ESR (2021-30) systems, under which national targets are set for 2020 and 2030. Non-ETS emissions concern mainly transport, buildings, agriculture and waste, and national efforts should lead collectively to EU-wide emissions reductions of 10% by 2020 and 30% by 2030 (compared with the 2005 level). In addition, member states have for the period 2021-30 national commitments under the LULUCF regulation that, based on the accounting rules defined therein, emissions do not exceed removals from LULUCF.

There is some flexibility to reach the 2030 targets. Under the ESR of 2018, three types of flexibility mechanisms can be used to meet a national target. In line with Article 5 of the regulation, a country can use borrowing, banking and transfer to and from other member states; under Article 6, a limited flexibility of an EU-wide maximum 100 Mt over the period 2021-30 is possible for certain member states from the ETS sector, which in practice means cancelling emissions allowances in the ETS and creating corresponding units in the effort-sharing sector. Moreover, under the LULUCF regulation (Article 7), member states can use up to 280 Mt in credits over the entire period 2021-30. Member states with a larger share of emissions from agriculture can use higher flexibility, as the EU recognises that there is a lower mitigation potential for those emissions.

As of 2017, non-ETS emissions were 10% below the 2005 level (EEA, 2019e). This is in line with the 2020 target. However, the aggregation of latest national projections by the EEA indicates that the 2030 EU ESR target would not be reached with existing national measures (WEM projections), see Figure 3.9.

Table 3.1 National emissions reductions targets by 2030 in the non-ETS sectors

EU	**-30%**
Luxembourg	**-40%**
Sweden	**-40%**
Denmark	**-39%**
Finland	**-39%**
Germany	**-38%**
France	**-37%**
United Kingdom	**-37%**
Austria	**-36%**
Netherlands	**-36%**
Belgium	**-35%**
Italy	**-33%**
Ireland	**-30%**
Spain	**-26%**
Cyprus	**-24%**
Malta	**-19%**
Portugal	**-17%**
Greece	**-16%**
Slovenia	**-15%**
Czech Republic	**-14%**
Estonia	**-13%**
Slovak Republic	**-12%**
Lithuania	**-9%**
Croatia	**-7%**
Hungary	**-7%**
Poland	**-7%**
Latvia	**-6%**
Romania	**-2%**
Bulgaria	**0%**

Notes: Member state-specific emissions reduction target for 2030 compared with 2005, for sectors outside the EU ETS.

1. Footnote by Turkey: The information in this document with reference to “Cyprus” relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of United Nations, Turkey shall preserve its position concerning the “Cyprus issue”. 2. Footnote by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

Energy and carbon taxation

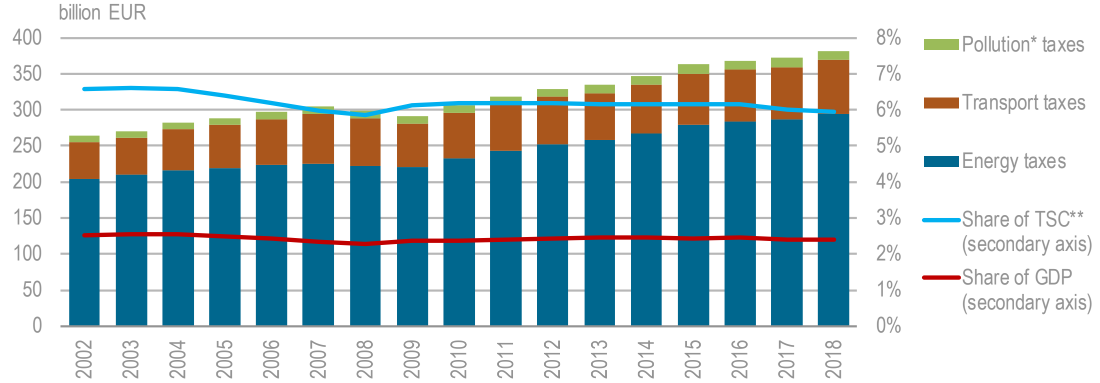
In 2018, EU28 member states collected a total environmental tax revenue of EUR 370 billion, amounting to around 2.5% of EU GDP and 6% of total revenews from taxes and social contributions (Eurostat, 2020).

Energy taxes, mostly excise duties on oil products, made up around 80% or EUR 300 billion and are a stable source of tax revenue. Transport-related taxes accounted for only around 20%. Energy taxes are the main component of environmental taxes which are essentially taxes imposed on fossil fuel consumption. Air pollution is only a small portion of overall tax revenues (Figures 3.12 and 3.13).

In the past years, EU member states have increased the application and use of national carbon taxes and fuel taxation for environmental purposes, which increased retail gas and electricity prices. Several countries have carbon taxes (Nordic countries) or carbon price support (United Kingdom). Energy taxation is becoming an increasingly important economic instrument to foster the cost-effectiveness of the energy transition across the economy.

In aviation, where air service agreements with third countries and Directive 2003/96/EC limit the scope for fuel taxation, a number of member states have partially compensated for lost revenues from excise duty and value-added tax exemptions through national departure taxes (EC, 2019d).

Figure 3.12 Environmental tax revenue by type, EU28, 2002-18

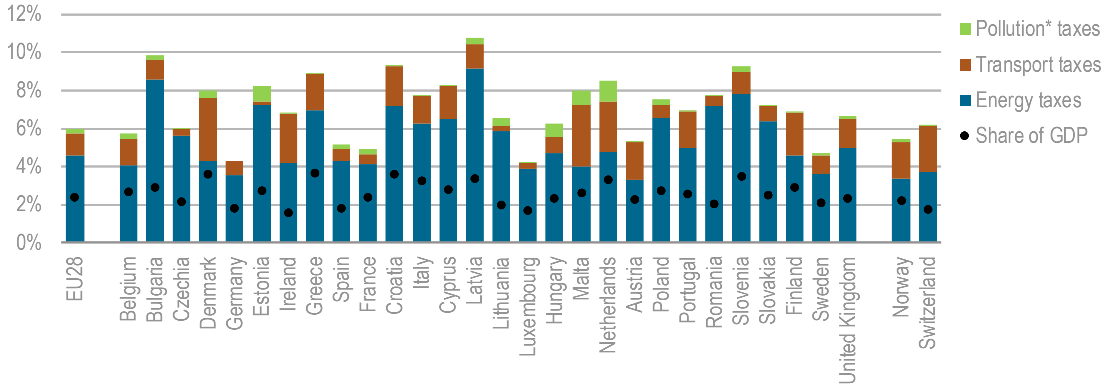


*Pollution includes pollution and resources

**TSC: Total revenues from taxes and social contributions

Source: Eurostat (2020), Environmental tax statistics, https://ec.europa.eu/eurostat/statistics-explained/index.php/Environmental_tax_statistics.

Figure 3.13 Environmental tax revenues, % of TSC and GDP, by member state, 2018



*Taxes on pollution and resources
Note: TSC: Total revenews from taxes and social contributions
Source: Eurostat (2020), Environmental tax statistics, https://ec.europa.eu/eurostat/statistics-explained/index.php/Environmental_tax_statistics.

The legal framework in the EU is very specific. Member states are free to design their own fiscal policies. However, taxation of energy products and electricity is subject to a harmonised legal framework so as to ensure the proper functioning of the internal EU market. The EU harmonised energy taxation framework is set under Council Directive on the taxation of energy products and electricity (2003/96/EC). It sets minimum tax levels for energy products used for heating or as motor fuel, and for electricity. In 2011, the European Commission proposed a revision of the directive to bring it in line with environmental and climate change objectives by splitting the existing energy tax into a tax on the carbon content and one on the energy content of the product. However, considering there has been no progress on the adoption of this directive, the Commission withdrew its proposal in 2015. Apart from energy taxation, climate or environmental taxation is not harmonised at the EU level.

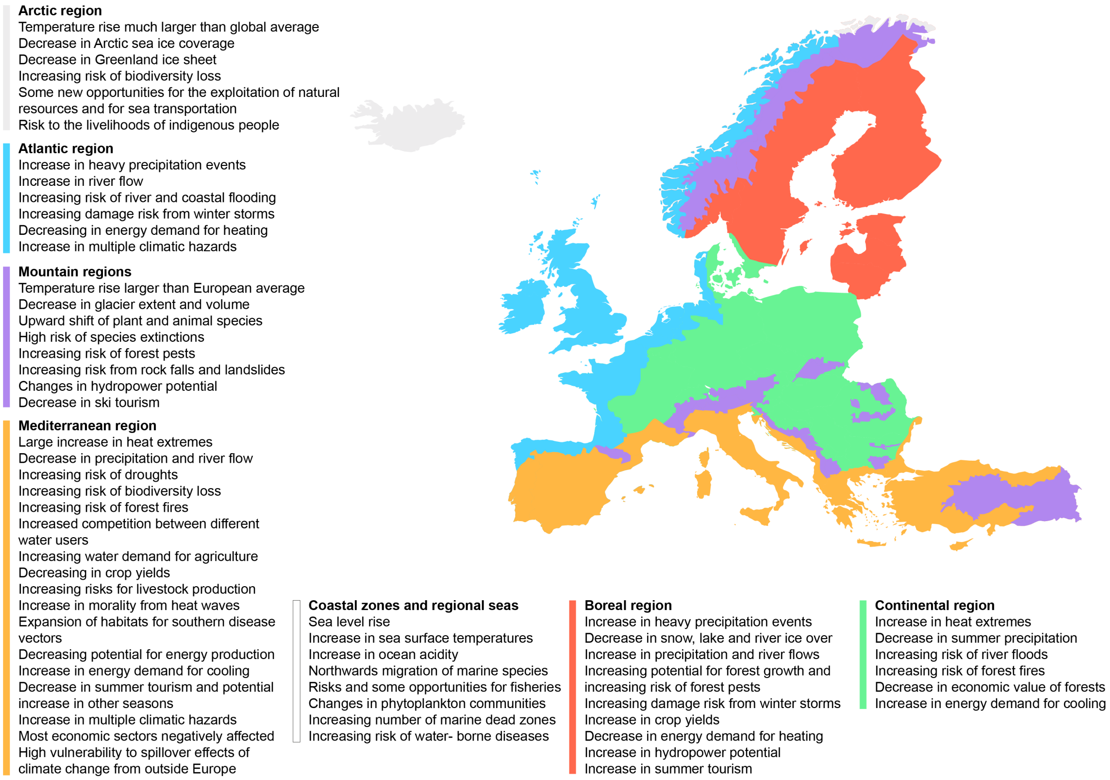
Under EU law, decisions in taxation policy require the unanimity of all EU member states in the Council, which makes the adoption of EU tax legislation a challenging process. In order to better align the Union's taxation framework to the clean energy transition, the Commission proposed in April 2019 to use the so-called passerelle clause to move from unanimity to qualified majority voting in taxation matters relating to the environment. However, such a decision will also require unanimity in the Council to shift to qualified majority voting on taxation matters.

In the context of the EGD, the Commission is at present undertaking work in order to present a new proposal for the revision of the Energy Taxation Directive.

Climate adaptation and resilience

In 2019, the EEA examined the adaptation challenges facing the EU and found that water availability is generally projected to increase in northern Europe and decrease in southern Europe, but with marked seasonal differences (Figure 3.14). The Atlantic region is expected to face more storms and climate hazards, while the Mediterranean and Continental regions will see more droughts, forest fires and extreme heat, which reduces the potential for energy production but increases cooling needs. Many mountain regions already see a change in their hydropower potential.

Figure 3.14 Expected climate change impacts across the EU



Source: EC (2018), A clean planet for all: A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy, https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2050-long-term-strategy.

The EU adaptation strategy of April 2013 complements the activities of member states by promoting greater co-ordination and information-sharing between them, and by ensuring that adaptation considerations are addressed in all relevant EU policies (climate mainstreaming). The EU strategy has also created an online portal of national and local efforts (Climate-ADAPT) and encouraged member states to adopt comprehensive adaptation strategies (currently 26 have adaptation strategies or plans), while providing funding to help them build up their adaptation capacities and to take actions.

The European Commission is revising the EU adaptation strategy as part of the EGD. Under the proposed EU Climate Law, the assessment of climate resilience should be included in the NECPs, which are reviewed on a regular basis.

EU air quality rules

While air quality has improved with pollution control technologies being implemented, it remains problematic with around 400 000 premature deaths every year in Europe. The EU framework for the control of ambient concentrations of air polluting substances is set out under the Ambient Air Quality Directives (2008/50/EC and 2004/107/EC[9]) and their related rules. The directives set air quality standards and requirements to ensure that member states monitor and/or assess air quality in their territory in different zones. The Industrial Emissions Directive (IED) (2010/75/EU) targets harmful industrial emissions across the EU, in particular through better application of best available techniques. Around 50 000 installations undertaking the industrial activities listed in Annex I of the IED are required to operate in accordance with a permit (granted by the authorities in the member states), based on the conditions set in accordance with the principles and provisions of the IED.

The National Emission Ceilings Directive 2016/2284/EU sets 2020 and 2030 emissions reduction commitments for five main air pollutants and establishes an air pollutants emissions reporting system for member states. It defines national emissions totals for air pollutants (sulphur dioxide, nitrogen oxides, volatile organic compounds, PM2.5 [fine particulate matter] and ammonia). Member states needed to submit the first National Air Pollution Control Programmes by 1 April 2019, and data on air pollution impacts on ecosystems by 1 July 2019. The European Commission will review the programmes and release the review together with the Communication on the NECPs by June 2020.

In 2017, total emissions of the main air pollutants were below the respective ceilings set for the EU as a whole. After the end of 2019, new emissions reduction commitments will apply for 2020-29, and later for 2030 onwards. More substantial reductions are needed for all pollutants if the EU is to achieve its emissions reduction commitments for 2030. A recent report by the EEA found that 20 member states are not on track to meet one or more 2030 emissions reduction commitments on the basis of their current policies (EEA, 2019f). The Commission completed the review of the Ambient Air Quality Directives in 2019 (under the so-called "fitness check"). The review (EC, 2019e) concluded that limit values have been effective in driving downward trends and enforceable legislation provided for action in front of national courts with actionable rulings. However, air pollution continues to be a major health and environmental concern, and current air quality standards are not as ambitious as established scientific advice suggests for several pollutants, especially PM2.5.

The Energy Union Governance Regulation requires that the NECPs include an assessment of the impacts of planned policies and measures, including on air pollutants. In its 2018 assessment of the draft NECPs, the European Commission asked member states to ensure the consistency between their NECPs and the National Air Pollution Control Programmes. In the final NECPs, the European Commission expects member states to show the interlinkages between their climate and energy policies and their air pollution and air quality policies.

Assessment

Since the 2014 review by the IEA, the European Union has made significant progress in advancing its energy and climate change policy agenda. The EU has achieved its 2020

[9] Directive 2008/50/EC on ambient air quality and cleaner air for Europe Directive 2004/107/EC of the European Parliament and of the Council relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air (Fourth Daughter Directive).

target to reduce GHG emissions by 20% below 1990 levels, as emissions decoupled from economic growth. Between 1990 and 2017, the EU economy grew by 58%, while GHG emissions decreased by 23% (excluding international aviation).

Over three decades, the EU has achieved around 40 $MtCO_2$ savings per year; up to 2030 this effort needs to double and increase again to 114 $MtCO_2$ to 157 $MtCO_2$ per year up to 2050. The emissions reductions challenge cannot be underestimated. Current trends for 2030 remain unclear, as much will depend on the implementation of EU and national stated policies. The aggregation of draft NECPs indicated that the -40% GHG target would be achieved. EU level GHG projections indicate that 45% emission reductions could be reached if all EU-level targets and policies as adopted by 2018 are fully implemented. According to aggregated member state projections with focus on natonal measures the EU and the United Kingdom are not yet on track towards its 2030 target of reducing emissions by 40% from 1990 levels and will need to strengthen its policies to do so.

Since 2014, reductions in GHG emissions and energy-related CO_2 emissions have stalled. During 2014-17, energy-related CO_2 emissions were around 3 200 Mt per year, of which power and heat generation accounted for 35%, transport for 29%, residential and commercial sectors for 12%, industry for 13%, and other energy sectors for 5%.

The EU ETS has become a key pillar for the low-carbon transition. Thanks to its recent reforms, the price increased from EUR 8 in 2014 to EUR 28 in 2019, and greater flexibility has been introduced into the system, among other reasons to address the build-up of a surplus of allowances. CO_2 emissions reductions in sectors covered by the ETS have been faster than for non-ETS sectors. The power sector is decarbonising, encouraged by energy-specific legislation under the renewables directives and a carbon price incentivising fuel switching from coal to gas and to renewable electricity. With around 300 gCO_2/kWh, the EU's power generation has a lower carbon intensity than its trading partners. The success of the combination of the ETS and sector-specific policies is an important lesson learned.

Despite being covered under the ETS, industry and intra-EU aviation have not seen emissions reductions of the kind witnessed in the power sector. The sectors not covered under the non-ETS, notably transport and buildings, have seen rising emissions. Member states have introduced carbon taxation or similar instruments, which create challenges in the internal market. The non-ETS sectors use national targets and measures to drive emissions reductions.

Hence, further policy stringency and complementary policies, especially in low-carbon innovations that enable long-term, deep emission reductions in these sectors, will be critical for industry and aviation.

With regard to the strengthening of the ETS, enlarging the ETS scope to cover other sectors such as road or maritime transportation and buildings needs to be carefully assessed. The ETS could play an important role in supporting the development of low-carbon industrial products. As the EU is moving to a more stringent carbon price, policy options, such as targeting carbon leakage protection and border carbon adjustments, need to be investigated thoroughly in the context of a broader industrial development strategy. Moreover, the EU ETS is taking a facility-driven and product-benchmark approach and it remains a question how it can take account of emissions from cross-sectoral technologies (e.g. recycling of CO_2 while ensuring its permanent binding) and more generally emissions along the value chain. A life-cycle analysis would be beneficial to underpin the ETS strategic approach in the future to avoid leakage between sectors.

The CO_2 price under the ETS has been an effective tool, particularly in the power sector, but other policies have also worked alongside the carbon price to reduce emissions in the ETS sectors. These include measures at the EU and national levels, notably energy efficiency and renewables but also sector-specific actions to encourage technology innovation.

A priority of the EU should be to continue strengthening the carbon price signal, notably in transport and buildings, as emissions and fossil fuel intensity are on the rise. In transport, the EU has the worlds' most stringent CO_2 standards for light-duty vehicles and regulates CO_2 emissions of heavy-duty vehicles. There are many different options: either increasing the CO_2 emissions standards (as proposed under the EGD), the inclusion of these sectors in the EU ETS or the adoption of a revised EU-wide energy taxation framework (under a reviewed Energy Taxation Directive [ETD]) or reformed road charging or ETS measures for the non-ETS sectors at national level, based on common EU guidelines. The European Commission will need to assess the costs and benefits of these options, including the issue of whether it is useful to maintain the split of emissions into ETS and non-ETS sectors. In any event, a carbon price alone will not be enough to drive the deep decarbonisation necessary under the EU's long-term goal, and targeted policy measures are needed for each sector.

The current EU energy taxation rules are not aligned with broader EU environmental and climate policy aims. Energy taxation does not reflect the air or GHG pollution resulting from fuel combustion, as it mainly focuses on minimum tax levels based on volumes and does not consider the energy efficiency and CO_2 content. The key pillar of Europe's decarbonisation pathway, electricity use, despite being covered under the ETD, is mainly used for raising budgetary revenues. In many countries, taxes on electricity are high and include levies to finance renewable energy support schemes and other purposes. This may create a barrier to the electrification of end uses, notably buildings, heating or transport. There are strong differences across member states and fuels, with a wide range of levies and other taxes on electricity.

The Commission is reviewing the EU ETD and its minimum tax rates, exemptions and product definitions. This long-overdue reform will be a major challenge, given the importance of stable government revenues and the unanimity requirement in the European Council. As the EU plans for significant shifts, such as to electrified transport, it will need to consider adjustments to sources of tax revenue. With a view to align energy taxation with economic growth and climate, social and energy policy goals, the EU and its member states need to adopt a comprehensive tax reform, looking at the interplay of several instruments, including by reviewing the EU ETS (and the carbon leakage list), the ETD for non-ETS sectors, or reformed road charging and vehicle taxation, the energy and environmental state aid guidelines (as regards tax exemptions), and emissions standards adopted in the transport sector. In its first Annual Sustainable Growth Survey of December 2019, the Commission already indicated the role fair and green taxation reforms could play, and this should be further developed in future European Semester cycles.

After a decrease until 2017, emissions from air pollutants have increased again in the EU. Over half of the EU member states failed to submit their national air pollution plans. A recent report by the EEA found that 20 member states are not on track to meet one or more 2030 emissions reduction commitments on the basis of their current policies. More substantial reductions are needed for all pollutants if the EU is to achieve its emissions reduction commitments for 2030. The EGD calls for a zero-pollution ambition. The Commission is reviewing the EU Ambient Air Quality Directives, under the so-called fitness check.

Climate adaptation and resilience of the energy infrastructure are high on the agenda with more extreme weather events, and climate change risks are rising in the EU. The EU needs to step up policy action and initiatives, as impacts of extreme weather events and climate change on Europe's infrastructure represent a serious risk and affect all Europeans. The NECPs should adequately reflect climate risks and the energy-water nexus and set out action in both mitigation and adaptation. The European Commission plans to adopt a new EU Adaptation Strategy. The Commission has intensified the analysis of long-term climate risks and adaptation in the energy sector, which is welcome. However, many impacts are felt and need to be addressed in the short term. Climate change adaptation and resilience needs to be mainstreamed. For instance, the concept of the Trans-European Network for Energy does not reflect the climate change impacts of energy infrastructure.

Recommendations

The European Union should:

- ☐ Continue to strengthen the EU ETS, keeping in focus the need to:
  - > Ensure a consistent carbon price signal with a continuous reduction of the overall cap in line with the cost-efficient path of the EU's climate ambitions and an efficient MSR, while reducing free allocation and adapting to technological change.
  - > Closely examine market interactions with non-ETS sectors to ensure synergies and complementarities, notably the inclusion of additional sectors under the ETS.
  - > Work with member states to ensure an efficient use of the Innovation Fund and the Modernisation Fund, to stimulate more effective use of ETS auction revenues and other low-carbon innovation financing in the development of nascent low-carbon technologies.
- ☐ Work with member states to develop a revised framework for EU energy taxation which discourages high fossil fuel use and technologies and aligns energy taxation with climate objectives.
- ☐ Foster the climate resilience of Europe's energy infrastructure planning of European Networks of Transmission System Operators and members, as part of comprehensive EU energy sustainability and security policies, notably the planning and funding of trans-European networks and energy infrastructure finance.

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4. Transport

Key data (2017)

Energy consumption in domestic transport: 326.9 Mtoe (64.4% diesel, 24.1% gasoline, 4.6% biofuels, 1.9% liquefied petroleum gas, 1.8% jet-type kerosene, 1.7% electricity, 1.0% natural gas, 0.4% others), -2.6% since 2007

Share of domestic transport in TFC: 28.3% (+27.6% in 2007)

Share of domestic transport in energy-related CO_2 emissions: 28.9% (25.2% in 2007)

International bunkering fuel: 94.7 Mtoe (international aviation 53.5%, international navigation 46.5%)

Transport targets for EU member states: 10% renewable energy by 2020 and 14% by 2030*

*Allows for double-counting of second-generation biofuels and has multipliers for electricity

EU targets and strategies

The European Green Deal (EGD) seeks a 90% reduction of greenhouse gas (GHG) emissions from transport by 2050. To support the transition in transport, the European Commission considers that a substantial part of the 75% of inland freight carried today by road has to shift to rail (supported by electrification of Europe's rail system) and that by 2025, about 1 million public recharging and refuelling stations will be needed for an expected European Union (EU) fleet of 13 million zero- and low-emission vehicles (EC, 2019). To support these goals, the European Commission is preparing a Strategy on Sustainable and Smart Mobility to be released by the end of 2020.

Transport sector demand and emissions have seen major trend changes in 2020 in the context of the Covid-19 pandemic. Faced with lockdowns around the world, global aviation activity almost fully collapsed and EU aviation activity, too. Covid-19 and the related lockdown measures across the EU and the globe may have medium-term impacts on public, air and road transport, as behavioural changes and stimulus measures from governments for electric vehicles might show longer-lasting impacts on the sector and fast-forward the transition (IEA, 2020a). Sales of electric vehicles have been very robust in 2020. It will be critical for the Commission to assess these trends when preparing the strategy.

Previous targets for the transport sector were included in the 2011 White Paper on Transport (EC, 2011), which set out a long-term vision for the transport sector to reduce GHG emissions by 60% in 2050 compared with 1990 levels. The white paper promoted low-emission fuels, energy efficiency, multimodality of transport and traffic management.

The 2016 medium-term review of the implementation of the white paper (EC, 2016a) noted that there was still little progress towards its goals; in particular, oil dependency and congestion were not decreasing. A final evaluation of the white paper is due by the end of 2020. The European Strategy for Low-Emission Mobility (EC, 2016b), the Clean Energy Package (2016) and the three Mobility Packages (2017, 2018) have led to the adoption of a range of new policies and measures over the past few years.

Energy demand and supply in transport

Domestic transport[10] accounts for 28% of total final consumption (TFC), coming second after industry, and 29% of energy-related CO_2 emissions in the 28 member states of the European Union (EU28). Transport sector emissions increased in recent years. Direct emissions from aviation account for about 3% of the EU's total GHG emissions, with about half of these emissions covered by the EU Emissions Trading System (ETS). While it is currently a relatively small sector, it has been one of the fastest-growing sources of GHG emissions in the EU by end of 2019.

In 2017, 72% of total transport emissions came from road transport, which therefore needs to be a priority. Road transport accounted for 94% of domestic transport energy demand in 2017 and 73% of total transport demand if including bunker fuels for international aviation and navigation. Despite recent growth in biofuels, most of energy demand is met by fossil fuels, in particular diesel (Figure 4.1).

In 2017, domestic transport consumed 327 million tonnes of oil equivalent (Mtoe) in EU countries, and bunker fuels for international aviation and navigation added another 95 Mtoe. Total consumption peaked in 2007 at 436 Mtoe, after which it dropped to 391 Mtoe in 2013 in the aftermath of the financial crisis, but has recovered to pre-crisis levels in recent years, driven by a period of decreasing oil prices (Figure 4.2).

The vast majority of energy use in the transport sector comes from fossil fuels. In 2017, petroleum products accounted for 94% of total energy consumed in the sector. The rest was biofuels used mainly in road transport, electricity used mainly in rail transport, and natural gas, used in road transport and gas pipeline transport. Diesel has been dominating EU transport energy demand. In 2017, diesel accounted for 67% of total road transport energy use, which was significantly higher than in other large economies such as the People's Republic of China ("China"), Japan and the United States, where gasoline tends to have a much higher share (Figure 4.3). However, this is changing rapidly. In 2019, almost 60% of all new cars registered in the European Union ran on petrol (58.9%, compared with 56.6% in 2018), while diesel accounted for 30.5% of registrations (35.9% in 2018), according to the latest European Automobile Manufacturers' Association (ACEA) statistics (ACEA, 2020).

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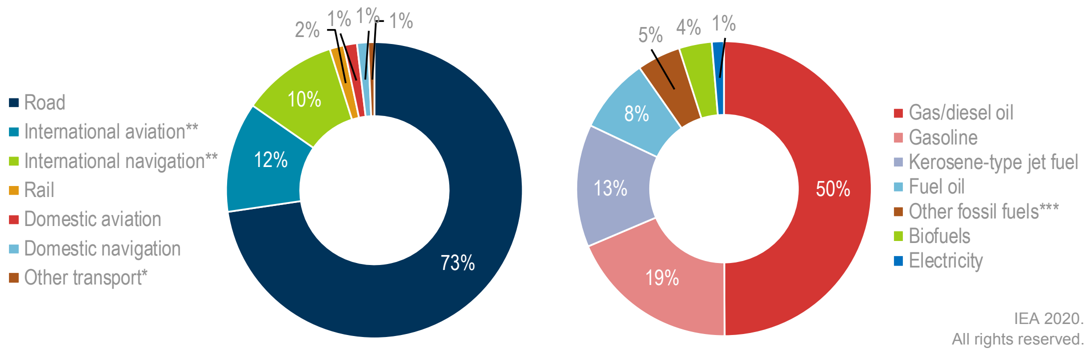
[10] Not including international aviation and shipping between EU countries or outside the EU.

Figure 4.1 Energy consumption in transport by mode and fuel, 2017



Road transport dominates transport energy demand with 73% of total consumption in 2017, and diesel covers half of the demand.

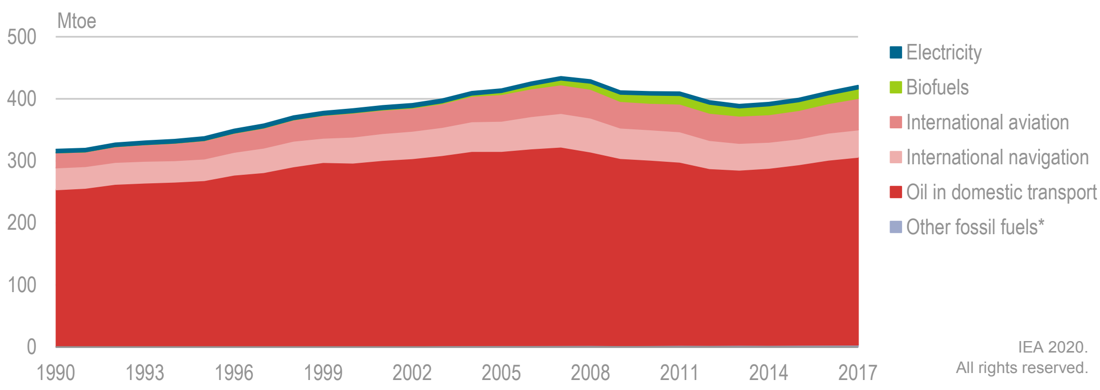
**Other transport* includes pipeline transport and non-specified transport.

**Bunker fuels for international aviation and navigation, both between EU countries and outside of the EU.

****Other fossil fuels* includes liquefied petroleum gas, natural gas and other minor fuels.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Figure 4.2 Energy consumption in transport by fuel, 1990-2017

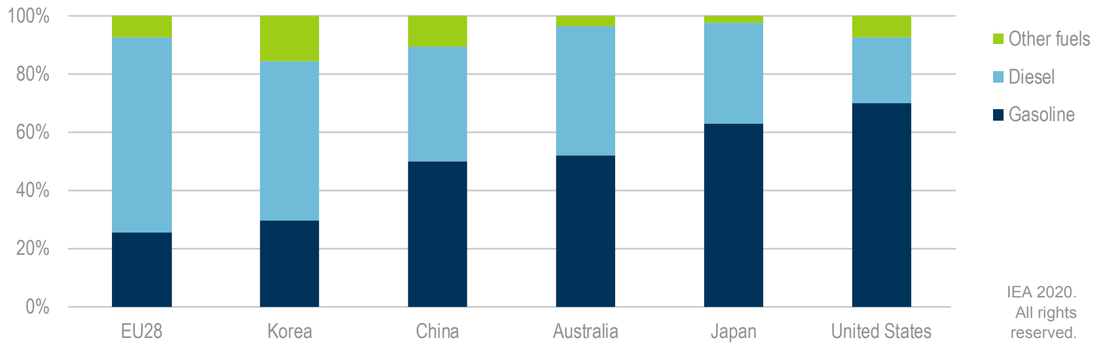


Despite a doubling of biofuels in the last decade, oil-based fuels still account for around 94% of transport energy consumption.

**Other fossil fuels* includes natural gas and coal.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Figure 4.3 Energy consumption in road transportation by fuel, 2017



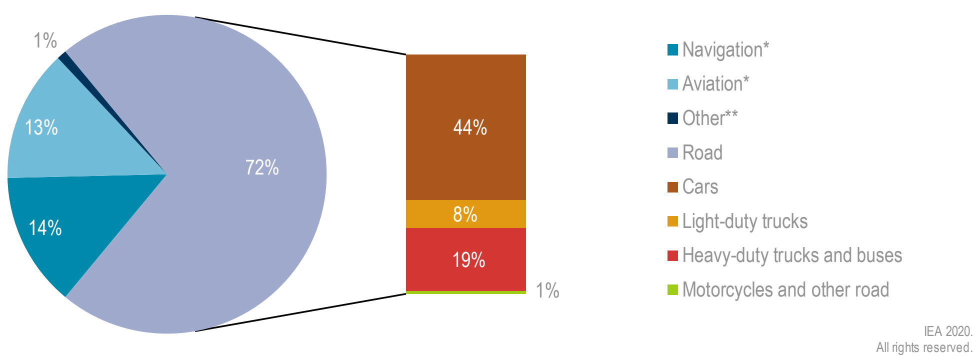
Diesel accounted for 67% of total road transport energy use in EU countries in 2017, compared with 39% in China and 23% in the United States.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

GHG emissions from transport

Emissions from domestic transport accounted for 29% of total energy-related CO_2 emissions in the EU in 2017 and 27% of total EU GHG emissions (EC, 2019b). Furthermore, there are emissions from international bunker fuels used in international aviation and shipping. When including those, total transport emissions were 1 249 million tonnes (Mt) in 2017, up from 973 Mt in 1990. The emissions from transport have been increasing.

Figure 4.4 Transport emissions by mode, 2018



Road transport accounted for 72% of total transport GHG emissions, and shipping and aviation for the remainder.

*Includes emissions from international bunker fuels.

***Other* includes rail (0.4%) and pipeline transport (0.6%).

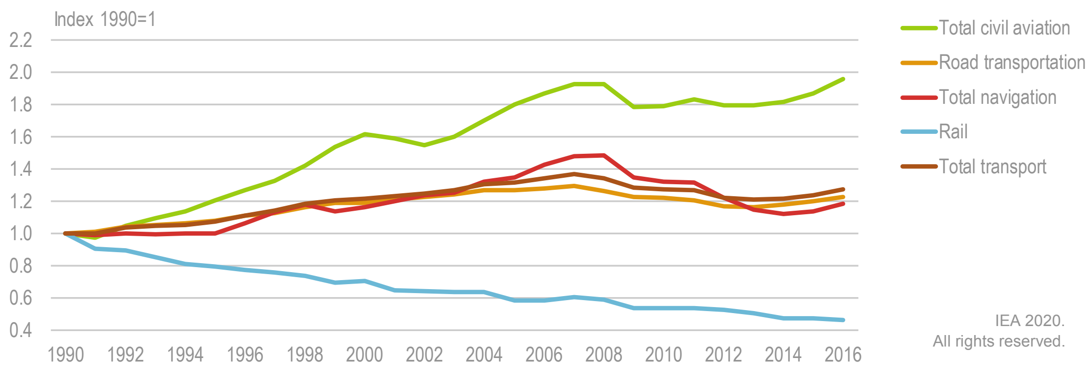
Source: EC (2019b), *Statistical Pocketbook 2019: EU Transport in Figures*, https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2019_en.

Road transport remains the largest emitter, with 71.9% of total transport-related GHG emissions in 2018 (Figure 4.4), followed by emissions from waterborne transport (navigation, 13.4% of the total) and civil aviation (13.9% of the total). Extra-EU and intra-EU international aviation together (bunker fuel emissions related to the departure of flights and fuel sold within the EU for both extra-EU and intra-EU flights) accounted for 90% of total EU aviation emissions (10% are domestic emissions), and similarly, international navigation (bunker fuel emissions) accounted for 88% of total emissions from navigation. Passenger cars account for the largest share of road transport emissions, but heavy trucks and buses and light-duty trucks are also large contributors.

Aviation stands out as the main growth sector in transport emissions in the last decades. From 1990 to 2016, emissions from civil aviation nearly doubled, compared with an overall increase in transport emissions by 28% (Figure 4.5). This reflects a growing demand for international flights, supported by access to more low-cost airlines. Over the same period, road transport emissions grew by 23% and navigation emissions increased by 19%. In road transport, cars accounted for the largest share of the growth in absolute numbers but light-duty trucks increased the most in relative numbers, with a 58% growth in emissions between 1990 and 2016.

Rail is the only transport sector with decreasing emissions since 1990, with a drop by over half due to increased electrification, coupled with a lower carbon intensity of electricity generation in many member states. The share of electricity in EU rail transport energy demand grew from 50% in 1990 to 70% in 2017.

Figure 4.5 Transport emission development by mode, 1990-2016



Since 1990, the largest increase in transport emissions has come from aviation, with an overall increase of 28%, while rail transport emissions have declined with rising electrification.

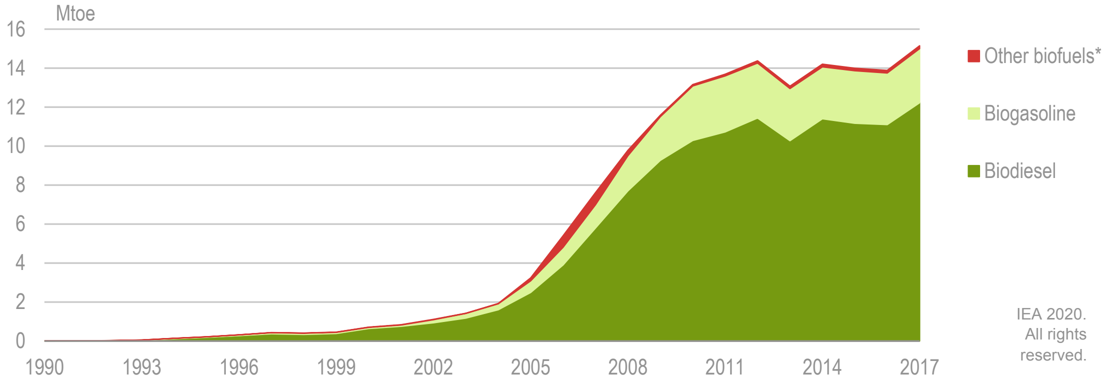
Source: EC (2018), *Statistical Pocketbook 2018: EU Transport in Figures*, https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2018_en.

Biofuels and renewable electricity in transport

Biofuels make the principal contribution to renewable energy in transport. Biofuel supply increased rapidly in the early 2000s, from 1.1 Mtoe in 2002 to 14.4 Mtoe in 2012 (Figure 4.6). Since then, biofuel supply has fluctuated around that level. Biodiesel and hydrotreated vegetable oil (HVO) are blended into fossil diesel, and account for over 80%

of total biofuel supply[11] in road transport in energy terms. The rest is mainly biogasoline (commonly called fuel ethanol), which is blended into gasoline supply.

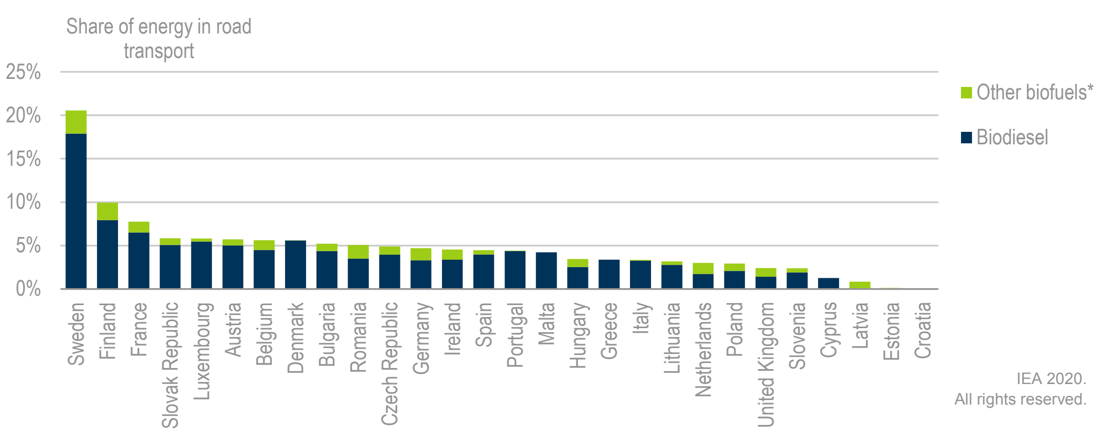
Figure 4.6 Renewable energy in domestic road transport, 1990-2017



Biofuels increased rapidly from around 1 Mtoe in 2002 to over 14 Mtoe in 2012, mostly from biodiesel, but the growth has slowed down since and reached just above 15 Mtoe in 2017.

**Other biofuels* includes biogas, primary solid biofuels and other liquid biofuels.
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Figure 4.7 Share of biofuels in road transport in EU countries, 2017



Despite having the same 2020 target, EU member countries have reached very different shares of biofuels in transport, from over 20% in Sweden to below 1% in some countries.

*Mainly biogasoline but includes also small shares of other liquid biofuels and biomethane.
Note: Biofuels share in total energy use (not volumes), not using any double counting methodologies.
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

[11] In this document, calculated biofuel shares are determined on an energy basis. It should be noted that as biofuels have different energy content than petroleum products, the penetration of biofuels expressed on a volume basis will differ.

Looking across the EU, the shares of biofuels in road transport vary significantly (Figure 4.7). Sweden ranks the highest with a share of 21% biofuels in total energy use in road transport in 2017, more than twice the share of Finland, which ranks second with 10%. Most countries have shares around 5% or below, down to practically zero in some countries. Across the EU, 99.5% of reported biofuel consumption in 2018 met EU sustainability criteria (IEA calculated from Eurostat [2019]).

In 2017, eight member states (Cyprus,[12] Estonia, Greece, Hungary, Latvia, Lithuania, Poland and Slovenia) had shares below 5% biofuels in road transport consumption (Figure 4.7), according to International Energy Agency (IEA) data.

Most (64%) of the biodiesel consumed in the EU in 2016 was produced from feedstocks produced in the EU, mainly rapeseed (~38%), used cooking oil (13%), animal fat (8%) and tall oil (2.5%). Of the remaining 36%, 19.6% was palm oil from Indonesia (13.3%) and Malaysia (6.3%); 6.1% was rapeseed from mainly Australia (2.6%), Ukraine (1.8%) and Canada (1.2%); 4.8% was used cooking oil from various countries outside the EU; and 4.3% was soybean from mainly Brazil (1.5%) and the United States (1.5%), according to Eurostat import data.

Ethanol consumed in the EU is also mainly produced from EU feedstocks (65%), including from wheat (~25%), corn (~22%) and sugar beet (17%), and only a small amount (~1%) from cellulosic ethanol. Ethanol-based feedstocks from outside the EU include corn (16.4%), wheat (2.9%) and sugar cane (2.9%) from various parts of the world. The main third countries producing feedstock for bioethanol consumed in the EU are Ukraine (9.8%), the Russian Federation ("Russia") (2.1%), Brazil (1.8%), the United States (1.7%) and Canada (1.6%).

Renewable electricity consumption in transport in the EU was around 22 terawatt-hours in 2018 (or 1.9 Mtoe), equating to a renewable share of electricity consumed in transport of 33%. Three-quarters of renewable electricity was consumed in rail transport.

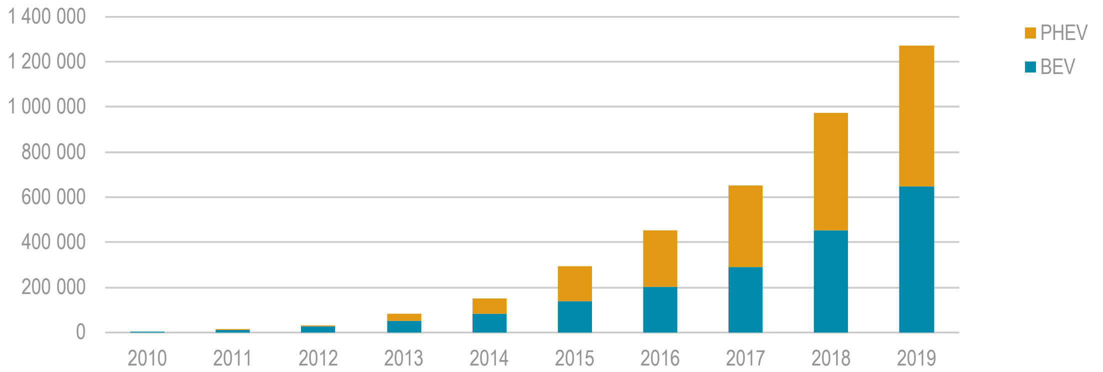
Electricity use and electric mobility

The number of electric vehicles (EVs) is increasing rapidly in the EU. In 2019, the total EV fleet reached nearly 1.3 million, up from just a few thousand a decade earlier (Figure 4.8). This includes both pure battery EVs (BEV) and plug-in hybrid EVs (PHEVs), which account for roughly half of the remainder (other hybrid cars that cannot be charged from an external source are not included). There were around 160 000 charging points for these vehicles (including 10 000 fast chargers). The EC expects 13 million zero- and low-emissions vehicles on European roads by 2025.

[12] Two footnotes: 1. Footnote by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of United Nations, Turkey shall preserve its position concerning the "Cyprus issue". 2. Footnote by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

The growth in EV markets varies among EU countries. In 2019, the EV stock reached 200 000 to 250 000 in the largest markets: the United Kingdom, Germany, France and the Netherlands (Figure 4.9). The highest share of EVs in new car sales was in the Netherlands, with close to 10%, among the highest shares in the world. However, all EU countries are outperformed by Norway, both in market share and total number of EVs. In 2019, Norway had around 325 000 EVs and a market share of new car sales close to 55%.

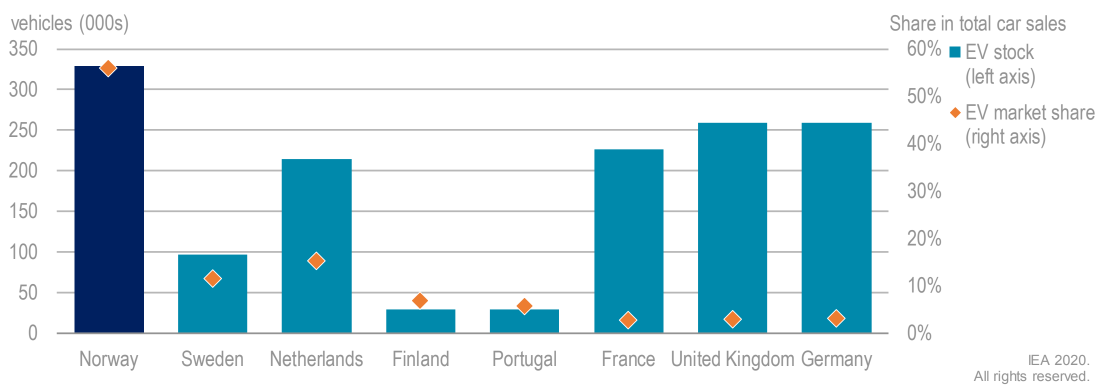
Figure 4.8 Total EV stock by EV type in the EU, 2010-19



The EU EV fleet has grown rapidly in the last decade and reached close to 1.3 million in 2019, half of which was BEVs and the other half PHEVs.

Source: EAFO (2019), European Union, www.eafo.eu/countries/european-union/23640/summary.

Figure 4.9 EV stock and share in new car sales in selected countries, 2019



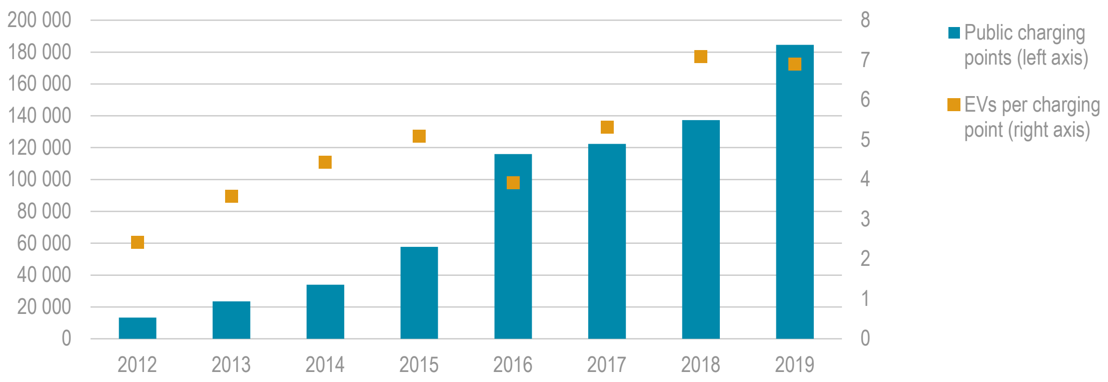
The EV market share in new car sales is growing rapidly in many EU countries, reaching 7-8% in Sweden and the Netherlands in 2019, but still far behind non-EU country Norway at around 55%.

Source: IEA (2020b), *Global EV Outlook 2020*, https://www.iea.org/reports/global-ev-outlook-2020.

EV charging

The number of public charging points is growing across the EU. By the end of 2019, about 184 000 public charging points were available for EV users across the EU. This gives a ratio of less than seven EVs per charging point, which is well within the EU target of up to around ten EVs per charging point stated in the Alternative Fuels Infrastructure Directive from 2014. However, the number of chargers is growing at a slower rate than the EV fleet, and the ratio has increased from around four EVs per public charging point in 2016 (Figure 4.10). Moreover, the public charging points are unevenly spread across the EU, which hinders cross-border journeys with EVs.

Figure 4.10 Public charging points and number of EVs per charger, 2012-19



Public charging points are growing in numbers, but at a slower rate than the EV fleet, and the number of EVs per charging point has increased from around four in 2016 to around seven in 2019.

Source: EAFO (2019), European Union, www.eafo.eu/countries/european-union/23640/summary.

Overview of EU polices and measures in transport

Renewable energy and sustainable biofuels

The EU has promoted the use of renewable energy (including electricity) in the transport sector since 2009, which has led to the introduction of national blending mandates across the EU28.

The first EU Renewable Energy Directive (RED) (Directive 2009/28/EC) requires the EU and member states to meet a 10% target of renewables in transport by 2020. For 2030, EU RED II (2018/2001/EU) maintains (higher) national targets for renewable energy in transport (upon request by the member states).

RED II mandates member states to require fuel suppliers to supply a minimum of 14% of the energy consumed in road and rail transport from renewable energy. For each member state, conventional crop-based biofuels will be capped at a maximum of one percentage point above the share of such fuels in final energy consumption from road and rail transport in 2020, with a maximum of 7%.

Fuels which qualify as advanced biofuels and biogas[13] are permitted to have their energy content double-counted towards the 14% target. These fuels have a dedicated sub-target of 0.2% of transport energy in 2022, 1% in 2025 and at least 3.5% by 2030 (considering double-counting).

Fuels produced from used cooking oil and animal fat feedstocks,[14] such as biodiesel and HVO, can contribute up to a maximum of 1.7%[15] of the 14% 2030 target. However, fuels from these feedstocks are also eligible to have their energy content double-counted, and so they could account for a maximum of 3.4% of the aforementioned 14% target for member states that elect to utilise double-counting.

RED II has strengthened the existing regulatory framework for sustainability criteria for bioliquids used in transport, which must be complied with in order to be counted towards member state renewable energy targets. Article 29 of RED II introduces sustainability and GHG emissions savings criteria for all biofuels, e.g. bioliquids, biogases and solid biomass fuels.

Progress towards the target was 8% in 2018, up from 5% in 2010, thanks in part to multipliers offered for certain biofuels and renewable electricity.[16]

The Fuel Quality Directive requires a reduction of GHG intensity of transport fuels by a minimum of 6% by 2020; this involves obligations for the refining sector.

Carbon pricing and taxation

The transport sector is largely outside the EU ETS, as explained in Chapter 3, except for intra-EU aviation (see below), and electricity used in rail and road transport. The Effort Sharing Regulation covers the transport sector and stipulates national targets for each member state to meet its national emissions reduction target through a series of both national and EU-wide policies and measures.

At the national level, energy and CO_2 taxation measures are among the policy measures to achieve considerable energy savings (and thus emissions savings) in transport. However, very few countries have aligned the carbon and energy content of fuel taxation, in light of the current EU Energy Taxation Directive. There are exemptions for aviation and maritime fuels in many member states. There is also a lack of internalisation, addressing the serious health and environmental impacts from transport fuel air pollutants.

With the increase in electrification and alternative fuels (hydrogen and bioenergy among others), government revenues from fuel excise duties are expected to erode based on the current energy taxation rules. As EVs and mobility services are still using the road infrastructure (but contribute less to public budgets) policy makers need to turn their attention to road and congestion charging.

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13 Produced from feedstocks listed in Part A of Annex IX of the revised RED.

14 Produced from feedstocks as defined in part B of Annex IX of the revised RED.

15 Member states may, where justified, modify that limit, taking into account the availability of feedstock.

16 Mulipliers apply under RED rules for electricity and advanced biofuels.

While road charging is applied in many member states, EU-wide rules for tolls and user congestion charges are in place only for heavy-duty vehicles (HDVs). In 2017, the European Commission proposed to extend the scope of the Eurovignette Directive[17] to also include light vehicles and to phase out time-based user charges, first for trucks and buses (end of 2023), then for light vehicles (end of 2027). Tolls and user charges should also be reflective of CO_2 emissions, according to the Commission proposal.

Aviation

Since 2012, CO_2 emissions from aviation have been included in the EU ETS, and more than 80% of allowances dedicated to airlines are granted for free. However, in practice, due to the trading of allowances, airlines end up paying for around half of their allowances, as was in the case in 2019 (54% of allowances surrendered by airlines were effectively purchased by airlines). Surrendering of allowances is temporarily (2013-23) restricted to flights between airports in the European Economic Area. Free allocation is based on an efficiency benchmark. From 2021, the 2.2% cap reduction rate applying to stationary installations will also start applying to aircraft operators. In the current trading phase, CO_2 emissions from aviation increased by 25% to 67 million tonnes of CO_2 equivalent in 2018 (EEA, 2019), indicating the need for further stringency and with the EGD consequently proposing to reduce free allowance to aircraft operators (EC, 2019a).

For aviation outside the European Economic Area, all EU member states will join the global Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) under the auspices of the International Civil Aviation Organization (ICAO) as of 2021, which aims to stabilise CO_2 emissions at 2020 levels. The CO_2 standards for new aircraft adopted by ICAO in 2017 were implemented in EU law in early 2019. The ICAO is working on mitigating the CO_2 emissions associated with aviation activities, also through a 2% annual fuel efficiency improvement through to 2050.

Maritime transport

The maritime sector is not covered under the EU ETS to date, but the EGD proposes to include maritime transport under the cap. The EU requires only the monitoring, reporting and verification of CO_2 emissions (and efficiency) from maritime transport (Regulation (EU) 2015/757).

The International Maritime Organization (IMO) sets the rules in the maritime transport sector. In 2018, it adopted an initial strategy on the reduction of GHG emissions from ships with the objective to reduce emissions by 50% by 2050 compared with 2008 while pursuing efforts to achieve full decarbonisation as soon as possible in this century. New IMO rules came into effect with regard to air pollution in 2020, phasing out sulphur use. There are mandatory minimum efficiency standards for new ships (Energy Efficiency Design Index [EEDI]) and the requirement to report fuel consumption of ships to flag states since 2019.

[17] COM(2017) 0275 final.

Energy efficiency

Emissions standards for cars, vans and trucks in Europe are among the world's most stringent and will become a significant driver of industrial transformation towards electrification, if properly implemented and enforced.

EU regulations set binding CO_2 emissions targets for new passenger cars and new light commercial vehicles (vans) for 2025 and 2030. From 2021 onwards, the EU fleet-wide average emissions target for new cars is 95 grammes of CO_2 per kilometre (gCO_2/km), which will be phased in during 2020, replacing the current 147 gCO_2/km target. Thereafter, emissions from new passenger cars and vans will have to be reduced by 15% by 2025

and 37.5% by 2030 as compared with the 2021 target, based on the new Worldwide Harmonised Light Vehicle Test Procedure (WLTP). Vans will need to reduce emissions by 31% by 2030.[18]

The EU has adopted standards for new HDVs. As of 2025, manufacturers need to achieve a 15% emissions reduction from 2025 and 30% reduction from 2030, compared with the reference period (July 2019-June 2020). Car manufacturers and HDV manufacturers which do not comply with the above-mentioned targets will have to pay a financial penalty in the form of an excess emissions premium.

The principal means for vehicle manufacturers to meet these requirements is higher EV sales, due to the extra incentives under which EVs count extra ("super-credits system) but also the higher efficiency of the electric motor compared with the internal combustion engine (ICE), which all should foster energy efficiency. However, CO_2 emissions standards for fleet averages currently in place are not necessarily addressing the efficiency of the remaining fleet (conventional cars are going to stay around), which is slowly decreasing with reduced diesel vehicles on the road. On the demand side, the Clean Vehicle Directive promotes the procurements of cleaner vehicles. In the coming years, there is a risk that without stronger energy efficiency policies, notably for HDVs, there is a risk that the car manufacturing industry is overly focused on electrification.

Energy efficiency obligations for transport are being introduced across the EU. Several member states have included transport measures in their national energy efficiency action plans (Austria, Croatia, Finland, France, Greece, Luxembourg, Slovenia and Spain), including energy efficiency obligation schemes (imposed on fuel suppliers, retailers or distributors). This is related to the new rules under the second Energy Efficiency Directive (EED II) (Directive 2018/2002/EU): member states can no longer exclude final energy consumption in transport from their baseline calculation of energy savings for the period 2021-30. To date, only Sweden included transport under its energy efficiency obligation in the first EED (2012/27/EU).

Other EU efficiency measures include rules to improve the aerodynamic performance of trucks, which has a direct impact on CO_2 emissions, through a proposed amendment of

[18] Regulation (EU) 2019/631 setting CO_2 emissions performance standards for new passenger cars and for new light commercial vehicles (vans) in the EU for the period after 2020 (proposed as part of the second Mobility Package). Targets apply to the EU fleet-wide and the average test mass of a manufacturer's newly registered vehicles.

the Weights & Dimensions Directive.[19] Energy labels for tyres[20] are revised, alongside strengthening the requirements on fuel efficiency, noise and safety, and applying to all tyres of cars, vans or HDVs.

Policies to improve efficiency in the transport system

Rail

Rail networks already play a large role today in the European Union, which has some of the most extended railway networks in the world. China has the largest high-speed rail network, but Europe has developed a large network of metro rail, urban rail (light rail) and high-speed trains. Europe has the fourth-highest share of activity on electric trains, after Japan, Korea and Russia (IEA, 2019c).

The EU transport policies support the creation of a Single European Transport Area with strategic transport corridors and projects of common interest by streamlining the administrative procedures for the realisation of the Trans-European Transport Network (TEN-T)[21] including through EU funding under the Connecting Europe Facility (CEF). The 2013 TEN-T Guidelines foresee that all rail lines on the core TEN-T network should be electrified by 2030 and the comprehensive TEN-T network by 2050.[22] The TEN-T Guidelines are under review in 2020.

In 2020, the European Commission will evaluate the rail freight corridors set up across Europe and assess whether the quality of rail freight has been improved (faster, greener, safer and more efficient). Moreover, competition and new rail services can also help increase the role of rail. The EU has been promoting rail competition for a long time, including in the most recent fourth railway package with a view to improve interoperability and open up domestic railway markets (for passengers).

To phase out diesel use in rail and enhance rail efficiency, there is an opportunity for the rolling out of new technologies including hybrid batteries, automatic train operations and hybrid hydrogen and fuel cells, as well as continuing electrification where appropriate.

The IEA *Future of Rail* report has highlighted the opportunities for rail to contribute to the decarbonisation of transport (Figure 4.11) (IEA, 2019c). The IEA high rail scenario requires several policy instruments to support the shift to minimising costs per passenger kilometre or tonne kilometre moved, maximising revenues from rail systems, and ensuring that all forms of transport pay not only for the use of the infrastructure they need, but also for the adverse impacts they generate. A significant modal shift of passengers and goods to rail transport could be achieved, with positive environmental and financial implications.

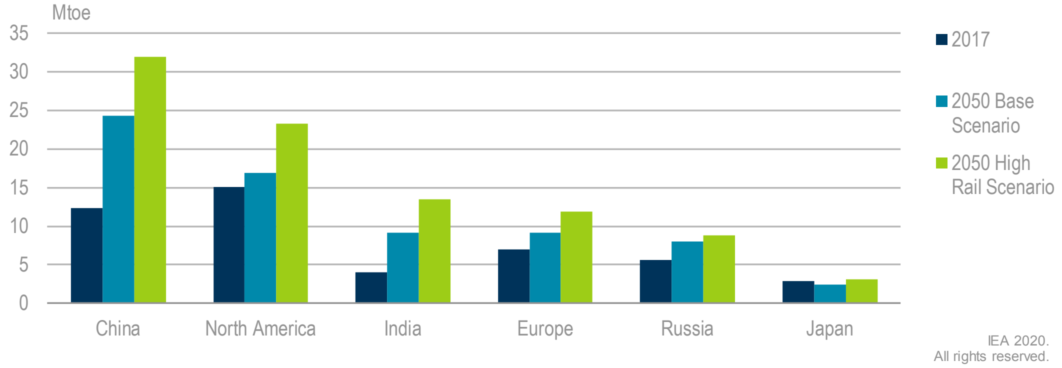
[19] COM(2018) 275 final.

[20] COM(2018) 296 final. A political agreement was reached in November 2019 regarding a new tyre labelling regulation, which will update the current label from May 2021 onwards.

[21] COM(2018) 277 final.

[22] Regulation (EU) No 1315/2013.

Figure 4.11 Projected rail energy demand growth in European and selected regions by scenario, 2017-50



Source: IEA (2019c), *The Future of Rail*, Paris, https://www.iea.org/reports/the-future-of-rail

The European Commission will also consider withdrawing its current proposal and presenting a new one to revise the Combined Transport Directive, to turn it into an effective tool to support multimodal freight operations involving rail and waterborne transport, including short-sea shipping.[23]

Clean vehicles and alternative fuels infrastructure

The EU promotes the roll-out of clean vehicles and alternative fuels infrastructure through a mix of EU funding and EU regulations.

Under the CEF, the EU provides financial support for the expansion of alternative fuels infrastructure (EC, 2017). Beyond 2021, support will continue from the CEF and also be provided by the InvestEU Fund.

The EU also promotes the public procurement of clean vehicle fleets at the national level. The revision of the Clean Vehicles Directive (2009/33/EC) introduces a definition of clean vehicles and sets minimum targets for their public procurement in each member state.

Directive 2014/94/EU on the deployment of alternative fuels infrastructure sets out a common framework for the installation of public infrastructure,[24] including the standardisation requirements for supply of electricity, natural gas and hydrogen in road and waterborne transport.[25] The European Commission is conducting an evaluation of the directive by the end of 2020 to assess progress and examine interoperability and consumer-friendliness of services for infrastructure use.

Under the amended Energy Performance of Buildings Directive (EPBD), requirements need to be adopted by member states for the installation of a minimum number of EV charging points in all existing non-residential buildings with more than 20 parking spaces by 2025. For new and major renovations (affecting the car park or the electric infrastructure) of non-residential buildings with more than ten parking spaces, ducting has

[23] COM(2017) 0648 final.

[24] Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure (OJ L 307, 28.10.2014, p. 1-20).

[25] Delegated Regulation 2018/674/EU.

to be installed for one in every five parking spaces and one charging point needs to be installed per building. For new and major renovations (affecting the car park or the electric infrastructure) of residential buildings with more than ten parking spaces, ducting is required for all parking spaces.

The amended EPBD provides rules for the roll-out of private smart charging infrastructure for EVs and for vehicle-to-building or vehicle-to-grid services (90% of charging events take place in private areas). The amended EPBD also includes provisions to simplify the deployment of charging points by addressing regulatory barriers, including on permitting procedures. Some exemptions will be possible for buildings owned and occupied by small and medium-size enterprises, in outermost regions and, for renovations, when the costs are too high.

Moreover, the EU supports the development of EV manufacturing and battery production in the EU. The EU initiative to promote research to further improve battery cells performance and to improve recycling of battery cells in the EU is supported by state aid approvals and funding from the EU research and development budget. The 2018 Battery Action Plan[26] aims to help member states, regions and the European industry establish competitive, innovative and sustainable battery manufacturing projects in the EU. The related EU Battery Alliance has led to the formation of consortia for projects of common interest for the production capacities for battery cells (see also Chapter 9 on Energy Technology Innovation).

Assessment

The transport sector remains a key challenge for the decarbonisation of Europe's economy, with a large gap between strategic goals and real-world emissions trends. The transport sector is the cause of major environmental impacts across the EU member states, relating to rising CO_2 emissions and still too high level of air pollutants, notably due to widespread diesel use and high congestion levels in certain urban areas. Sports utility vehicles have become the fashion of consumers, with a major increase in their sales just before the introduction of more stringent rules at EU level. Aviation across Europe has also increased with higher availability of low-cost flights and exemptions from taxation applicable to most other products and services in the economy.

The EU has adopted strategies for the decarbonisation of transport (the White Paper of 2011 and the Strategy for Low-Emission Mobility), followed by a suite of measures focusing on improving the energy efficiency of the transport system, the promotion of sustainable alternative fuels in transport (e.g. electricity, advanced biofuels, compressed and liquefied natural gas, hydrogen and others) and low- and zero-emission vehicles as well as the roll-out of associated fuelling infrastructure. The EU promotes the use of renewables in transport to the tune of at least 10% by 2020 and 14% by 2030 (to be implemented at member state level) based on robust sustainability rules. But progress is slower than expected.

[26] COM(2018) 293 final.

The EU has taken significant steps to introduce stringent CO_2 standards for new passenger cars, vans and heavy-duty trucks, and minimum public procurement targets for low-emission fleets, and has supported the roll-out of infrastructure for alternative fuels. The CO_2 standards will require manufacturers to introduce low- and zero-emission vehicles from 2020 onwards in their total vehicle sales in the EU.

To reach EU-wide and national emissions targets and support an economy-wide transformation, transport policies (both at EU, national and subnational levels) need to be better aligned with energy and climate policies. The transport sector needs stronger co-ordination of multiple technology-specific policies, alongside energy and climate policies, including taxation and urban planning.

There is no single solution for sustainable mobility. All technologies have their place in the years to come. Energy efficiency of the vehicles and of the transport system, such as modal shift and deployment of alternative fuels and vehicles, are all essential. When preparing the new Strategy on Sustainable and Smart Mobility, the European Commission should take into account a broad approach.

First, energy efficiency policies are needed to complement the current decarbonisation goals, to ensure the efficiency of both vehicles and the transport system.

Although the current EU car standard is not a fuel economy standard per se, but a CO_2 emissions standard, some of its super credits promote efficiency indirectly. Achieving 95 gCO_2 per km target by 2021 with ICE cars is impossible, as their average stood at 120 gCO_2 per km in 2018. And the targeted 95 gCO_2 per km will have to go down by another 15% by 2025, and by 35% by 2030. European automakers will be able to meet these targets only by massive sales of EVs. In 2020, the super credit system (double counting) can still be used for compliance, so one EV can be counted as two. The credit goes down to 1.67 in 2021 and 1.33 in 2022. Around 50% of the car fleet will still be ICE cars in 2030, and there is an urgent need to accelerate fleet replacement towards cleaner vehicles and promote energy efficiency standards for the non-electric fleet.

Advanced biofuels, biomethane and e-fuels (which are not part of the current credit system) will be needed as part of the solution in the period up to 2030 and beyond. Yet advanced biofuels are starting from a low market penetration, with a number of important advanced biofuel technologies not fully commercialised yet. This is especially true for the aviation and maritime sectors, which have fewer options to reduce emissions than other sectors. A consistent and comprehensive assessment of the development and deployment of advanced biofuels, including in the aviation sector, is needed to achieve an increased share of advanced biofuels. This assessment should encompass consideration of associated fuelling infrastructure, market design, and the suitability of policies to support a robust and informed review of the target for advanced biofuels in 2023 set out in the RED II. The latter recognises the contribution of renewable fuels of non-biological origin (including hydrogen), but implementing rules are needed. The European Commission is preparing initiatives on sustainable aviation fuels (ReFuelEU Aviation) and maritime fuels (FuelEUMaritime), which is very welcome.

As mainly a non-ETS sector today, emissions reduction from the transport sector is largely driven by the ambition and needs of national energy taxation. As discussed in Chapter 3 on climate and the environment, moving transport under the EU ETS is one option to promote a harmonised carbon signal in the transport sector. However, carbon pricing alone will not address all non-pricing barriers, which is why a suite of policies is needed.

Today, transport has many exemptions, for instance from kerosene use in domestic aviation or rebates for company cars. Transport fuel pricing by member states does not reflect the full social (environmental and health) costs. With the erosion of national tax revenues from transport fuels, focus should slowly shift to congestion charges, tolls and the efficiency of the entire transport system. As mobility as a service increases across the EU, new challenges arise for congestion, electrification and traffic management. Some EU countries are already leading globally on the fully automated and connected mobility systems.[27]

The EU promotes the procurement of clean vehicle fleets and the roll-out of infrastructure, including under the new Clean Vehicle Directive.

Rail can play a supportive role in the decarbonisation of transport, and the EU policies on rail are welcome and should be boosted. TEN-T needs to ensure that high-speed train connections can become an acceptable alternative to road and aviation for short- and medium-distance passenger travel within the EU. For freight transport, a wide range of low-emission mobility solutions, including rail and waterborne transport, are likely to play a role, so enhancements to multimodal transport, digitalisation and interoperability should be pursued. The review of the TEN-T policy as foreseen by the Commission is welcome.

The European Union is largely counting on electrification, notably through EVs and increased renewable electricity, to meet the renewable energy transport target for 2030. The transposition of the Clean Energy Package in all member states should provide the necessary framework. With the widespread adoption of EVs, the forthcoming measures need to further address system integration aspects. For instance, smart charging: tariff structures need to recognise the system benefits of smart charging so that consumers are rewarded for charging their vehicles at times when it has the most value for the grid.

A more efficient organisation of the entire mobility system based on EU-wide digitalisation, data sharing and interoperable standards is of utmost importance to make mobility cleaner. This will allow smart traffic management and increasingly automated mobility in all modes, reducing congestion and increasing occupancy rates.

Regional infrastructure and spatial planning should be improved to realise the full benefits of increased use of public transport. Transport policies rely strongly on national and local action, but as many countries feel the pressure stemming from the transformation of transport and mobility, there should be greater co-operation at national and EU levels.

EV charging infrastructure will be needed to meet the renewable energy transport target for 2030. Today, charging infrastructure and services are not harmonised and consumers face high transaction costs besides the high price of EVs. An EU-wide roll-out of charging infrastructure and the adoption of harmonised standards to ensure the interoperability of

[27] COM(2018) 283 final.

services would be beneficial, given economies of scale, growing digitalisation and experience in the EU telecoms sector. Action is also needed at the national and local levels.

Recommendations

The European Union should:

- ☐ Ensure the full alignment of transport policies with energy and climate policies at national and EU levels, notably through the National Energy and Climate Plans, to optimise the contribution from the transport sector to the goal of achieving climate neutrality.
- ☐ Assess the extension of the EU ETS to transport, based on international experience, while recognising that non-price barriers play an important role in transport and will need to be adressed by specific policies regardlessly.
- ☐ Present a comprehensive integrated EU policy for smart and sustainable transport including energy efficiency of vehicles and the transport system, digitalisation and greater contributions from alternative fuels (natural gas, sustainable biofuels, hydrogen, etc.), including through review of EU and national energy taxation.
- ☐ Conduct a comprehensive assessment of the perspectives of advanced biofuels and associated infrastructure development in the EU, such as options for the greater uptake of sustainable alternative fuels, in particular in the aviation and maritime sectors, as part of the review of renewables targets in 2023 as set out in the RED II.

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5. Buildings

Key data (2017)

Energy consumption in buildings*: 432.6 Mtoe (11.1% oil, 34.4% natural gas, 2.4% coal, 32.7% electricity, 11.3% bioenergy and waste, 7.4% district heating, 0.6% others), +1% since 2007

Share of buildings* in TFC: 37.5% (35.2% in 2007)

Share of buildings* in energy-related CO_2 emissions: 17.0% (15.2% in 2007)

Share of renewable energy:** 11.9% (9.4% in 2007)

* Energy consumption in residential sector and the commercial and public services sector.

**Direct use of renewable energy, not including renewable shares of electricity and district heating.

EU targets and strategies

The European Commission announced the adoption of a renovation initiative in 2020 with a view to meeting 2030 emissions reduction targets and the future ambitions of at least 50% or 55%, as the European Union (EU) moves to climate neutrality by 2050. The EU aims to double the current rates of renovation of public and private buildings.

The residential and services sector is the third-largest consuming sector. However, buildings alone are a large energy consumer in the EU, accounting for 37.5% of total final consumption (TFC) of energy in the EU. Space and water heating are the two largest uses, together representing 80% of buildings final energy consumption (Eurostat, 2019). Despite a growth in low-carbon energy consumption, direct use of fossil fuels still accounts for around half of energy consumption in buildings, resulting in (direct and indirect) annual CO_2 emissions associated with building heating of 843 million tonnes of CO_2 ($MtCO_2$) in 2017. Energy-related CO_2 emissions are on the rise and accounted for 17% of the total.

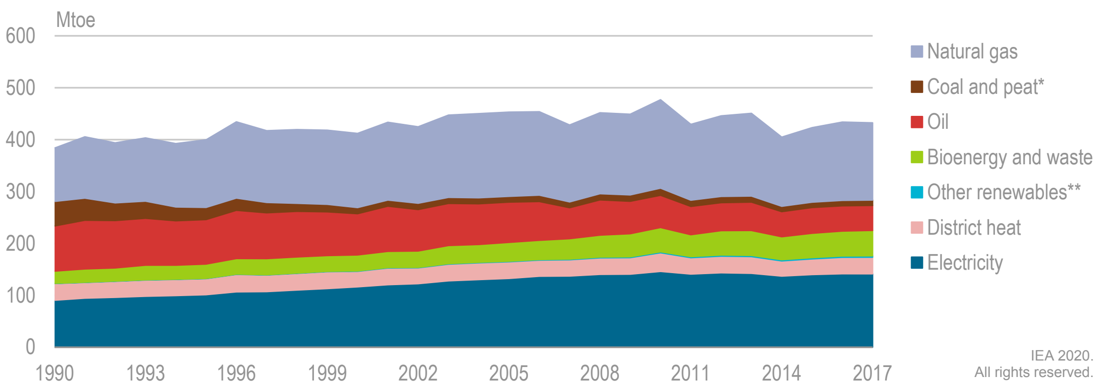
The buildings sector is subject to national policies and measures when it comes to renovation strategies, carbon pricing and building codes. The buildings sector remains outside of the EU Emissions Trading System (ETS). National Energy and Climate Plans (NECPs) include some of those policies and measures. There is no specific climate policy objective for buildings at EU level, apart from the goal that all new buildings must be nearly zero-energy from 31 December 2020 under the EU Energy Performance in Buildings Directive (EPBD). EU buildings legislation has been streamlined in recent years with stronger rules on energy efficiency and smart energy. Buildings already existing today will likely make up a considerable share of the total stock in 2050, making renovation a major priority. An energy systems view on buildings and heat can create a number of synergies. Decarbonising heating is a major challenge for the EU. This will require both energy efficiency improvements for new and existing buildings, including the shift to electric heating or heat pumps, and a fuel switch towards more low-carbon fuels, such as biomass in buildings and district heating systems.

Energy use and emissions in buildings

Total energy consumed in residential and service buildings has been quite stable, in the range of 420 million tonnes of oil equivalent (Mtoe) to 450 Mtoe over the past two decades. Most energy is used for heating purposes, and energy demand shows annual variations due to weather and temperatures. However, the average demand over longer periods has not changed much, with 440 Mtoe per year in the last decade (2008-17) similar to the previous ten-year average of 434 Mtoe.

In 2017, buildings consumed 433 Mtoe, of which natural gas and electricity accounted for one-third each, and the remainder was mainly covered by oil, bioenergy and district heating. As natural gas is usually used for heating, its consumption is more weather-sensitive than electricity, which also powers electrical appliances.

Figure 5.1 Energy consumption in buildings by fuel, 1990-2017



Energy consumption in buildings has been around 440 Mtoe in the last decades, with natural gas and electricity covering a third of total consumption each.

**Coal and peat* Includes a small share of oil shale.

***Other renewables* includes geothermal and solar.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Buildings energy consumption in the EU has witnessed a significant switch from oil and coal towards natural gas, electricity and renewables over the last three decades (Figure 5.1). Coal consumption has dropped by nearly 80% and oil consumption by 45% since 1990.

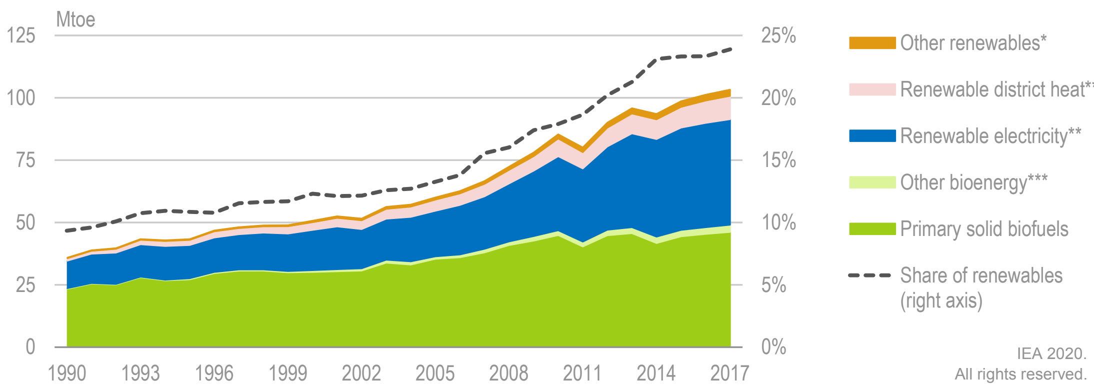
Electricity consumption has increased by over 50%, before stabilising over the last decade. Bioenergy consumption in buildings has doubled since 1990, and accounted for 49 Mtoe in 2017 (14% of building heat consumption) following a 25% growth over the last decade. District heat consumption has remained stable over the last decades, meeting about 9% of buildings heat demand (and 7% of buildings final energy consumption) in 2017. However, fuel supply to district heating networks has evolved significantly, with renewables – mostly biomass – representing 32% of district heat supply in 2017, up from 16% in 2007.

Solar thermal heat consumption has more than doubled over the last decade, and direct geothermal heat consumption has grown 10% over the same period, albeit both from a very small basis. Solar thermal and geothermal together still account for less than 1% of buildings energy consumption in 2017.

Renewable energy in buildings

The share of renewable energy in residential and service buildings in the EU has increased from around 9% in 1990 to 24% in 2017, although with a slower pace in the most recent years (Figure 5.2). In 2017, total renewable energy supply was 103 Mtoe, of which half was the direct use of renewable energy sources and half was electricity and district heat generated from renewable energy.

Figure 5.2 Use of renewable energy in buildings, 1990-2017



The share of renewable energy in buildings has increased to around 24% in 2017, of which half was from renewable electricity and district heat and the rest mostly primary solid biofuels.

**Other renewables* includes solar heat and geothermal.

**The renewable district heat and electricity are calculated as the shares of renewable energy in heat/electricity generation times the use of electricity/heat in the buildings sectors (residential and services) for each EU country, and summed up to an EU aggregate.

*** *Other bioenergy* includes liquid biogases, renewable municipal waste, biogas, liquid biofuels and charcoal.

Note: Does not include the use of renewable electricity or district heating.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Primary solid biofuels (e.g. wood and wood pellets) are the largest source of renewable energy, accounting for 45% of total renewable energy in buildings in 2017. Other biofuels, including liquid biofuels and biogas, added another 3%. Bioenergy consumption nearly doubled in two decades between 1990 and 2010, but has been quite stable in recent years.

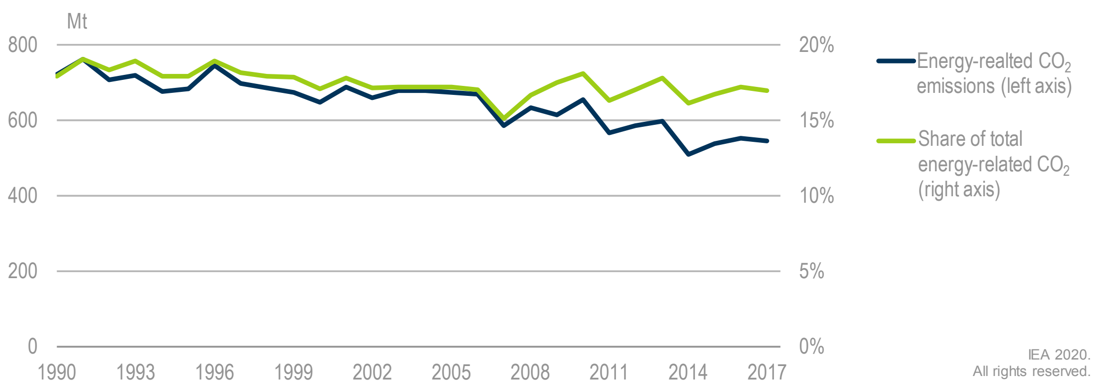
Indirect uses of renewables through renewable electricity and district heat have contributed to most of the recent growth in renewable energy consumption in buildings. While electricity consumption in the buildings sector has remained quite flat over the last decade, the penetration of renewables in the EU electricity generation portfolio (from 16% of electricity generation in 2007 to 32% in 2017) has resulted in a doubling of renewable electricity consumption, from 21 Mtoe in 2007 to 42 Mtoe in 2017. Similarly, although the amount of heat supplied through district heating has remained flat over the last decade, the fuel switch to renewable energy sources translated into an 87% growth in renewable district heat consumption over the period.

CO_2 emissions

Direct and indirect CO_2 emissions from buildings energy use

The shift from coal and oil towards electricity and renewable energy has enabled reductions in direct CO_2 emissions from buildings. Direct energy-related CO_2 emissions from buildings have declined 27% from around 750 million tonnes (Mt) per year in the early 1990s to around 550 Mt in 2017 (Figure 5.3).

Figure 5.3 Direct energy-related CO_2 emissions from buildings, 1990-2017



Direct CO_2 emissions from buildings have declined around 25% from1990 to around 550 Mt in recent years, representing around 17% of total CO_2 emissions in the EU.

Notes: Does not include indirect emissions from use of electricity and heat. Includes residential, services and unspecified emissions.

Source: IEA (2019b), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

The share of buildings emissions in total energy-related CO_2 emissions has been quite stable, with a slight decline from around 19% in the early 1990s to 17% in 2017. This relatively slow decrease reflects that total energy-related CO_2 emissions have fallen in the EU over the past decade.

Indirect CO_2 emissions from electricity and district heat consumed in the buildings sector added another 300 $MtCO_2$ in 2017, making direct and indirect CO_2 emissions together account for over 30% of total energy-related CO_2 emissions.

Buildings energy consumption and policy by end use

The EU has strong eco-design, labelling and minimum energy efficiency standards, which have helped to keep energy demand growth from new appliances in check, notably for space cooling and electricity demand.

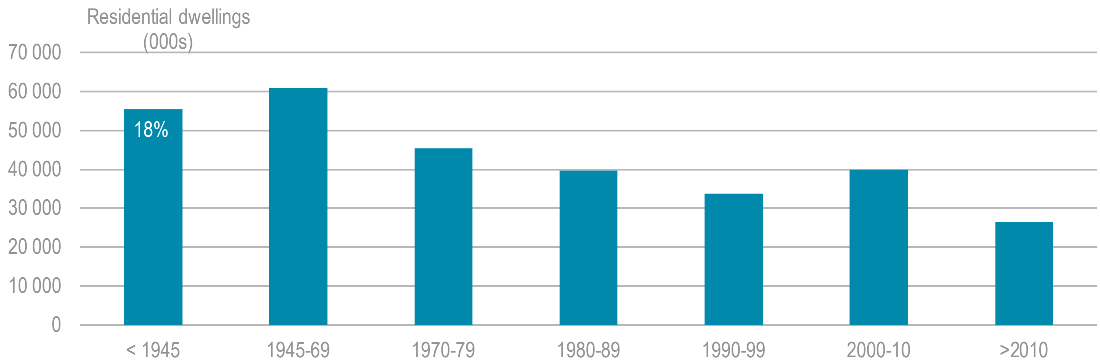
The EU has comprehensive policies and measures for the buildings sector and they have been streamlined over time, notably under the EPBD, which was revised in 2018 and now integrates many aspects of the built environment. EU strategies and support to national roadmaps and initiatives focus mainly on heating and cooling, renovation, and energy efficiency finance.

EU buildings stock

A large share of the European buildings stock is old, with around 40% of buildings built before 1970 when building energy standards were much less strict or non-existent.

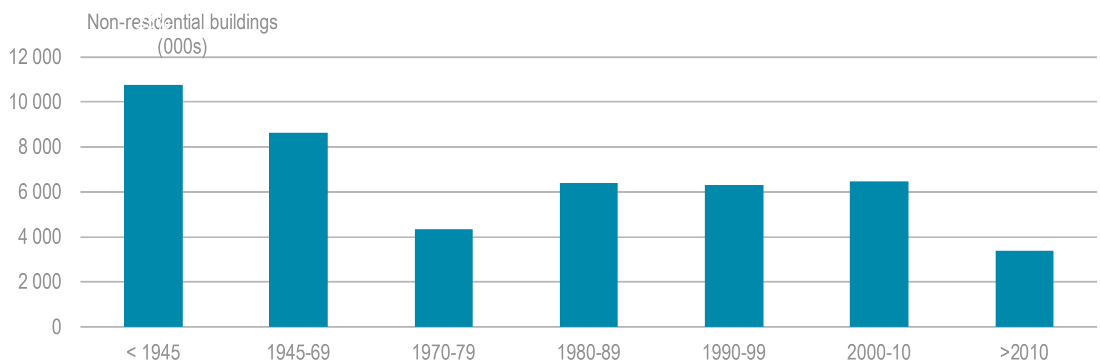
Almost 75% of the buildings stock is energy inefficient (not subject to energy standards and poor thermal performance). Less than 3% of the buildings stock in the EU qualifies for the A-label in energy performance certificates (BPIE, 2017).

Figure 5.4 Residential dwellings in the EU by construction period, 2017



Source: EC (2020), EU Building Stock Observatory, https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings/eu-bso.

Figure 5.5 Non-residential buildings in the EU by construction period, 2017



Source: EC (2020), EU Building Stock Observatory, https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings/eu-bso.

In 2017, the total number of residential dwellings in the EU amounted to 301 million, 53% of which were single-family dwellings and 47% multifamily buildings (EC, 2020). Of these dwellings, only 9% were built after 2010 (Figure 5.4). The number of new constructions has been declining each decade since the 1970s, with the exception of 2000-10.

The total number of non-residential buildings was 46 million in 2017. These include mostly private offices and wholesale and retail stores, plus smaller shares of hotels, restaurants and public buildings such as hospitals and schools. Nearly a quarter of non-residential buildings were built before 1945 and only 7% after 2010 (Figure 5.5).

The European Commission set up the EU Building Stock Observatory to monitor the energy performance in buildings, through relevant indicators, a methodology for data collection and a website. It would be useful if the observatory also monitored progress in renovations.[28]

EU policies for energy use in buildings

Energy Efficiency Directives

The first EU Energy Efficiency Directive (EED I, 2012/27/EU) promoted the renovation of public buildings (Article 5), with a requirement for member states to achieve annual renovations of at least 3% of the total floor area of buildings owned and occupied by their central government.

EU member states are obliged to implement energy savings (in line with Article 7) and many obligations can be fulfilled through the renovation of buildings and boiler replacement in the form of energy efficiency obligation schemes or other policy measures. The EED I also introduced national long-term renovation strategies for the building stock in each EU country, and mandatory energy efficiency certificates, accompanying the sale and rental of buildings.

EPBD

The revised EPBD (Directive 2018/844) promotes: 1) the acceleration of the renovation of existing buildings and 2) the modernisation of the smartness of all buildings, including for the integration of clean mobility. Member states have to transpose the new provisions into national laws and regulations by 10 March 2020, notably the following key aspects:

- **Long-term renovation strategies**, aiming at full decarbonisation by 2050 based on national roadmaps with measures and indicative milestones for 2030, 2040 and 2050, and indicators to measure progress. Following the revision, these strategies need to include a new solid finance component for ensuring the mobilisation of investments into the energy renovation of existing building stock.
- **Better access to finance for building refurbishment and linking financing and the quality of renovation** through: 1) more effective use of public funds; 2) de-risking energy efficiency investments and 3) project aggregation mechanisms and technical assistance. Member states have to link their financial measures for energy efficiency improvements to the energy savings planned or achieved, as shown by several alternative criteria (i.e. energy performance of the equipment or material used, standard values, Energy Performance Certificates [EPCs], energy audits, etc.).

[28] The Directorate-General for Energy website shows building stock characteristics, energy needs and consumption, technical building systems, certification schemes, available financing mechanism and social aspects, such as energy poverty.

- **More transparency and comparability in the calculation of energy performance**, including in relation to the energy performance of buildings standards. This also includes inspections of heating systems and air-conditioning (AC) systems and the inspection of ventilation systems.
- **Better data collection, monitoring and verification of compliance** with building standards when adopting EPCs and installing, replacing and upgrading building systems.
- **Requirements for the deployment of electro-mobility infrastructure** in buildings' car parks over a certain size and other minimum electro-mobility infrastructure for smaller buildings and provisions to simplify the deployment of recharging points by addressing regulatory barriers, including on permitting procedures.

Financing of buildings efficiency

The European Commission has been promoting energy efficiency finance for almost two decades. The Commission promotes the more effective use of public funds through faster deployment of financial instruments, the creation of national financial platforms, the deployment of EPCs, and the organisation of Sustainable Energy Investment Forums in all EU capitals to engage public, private and financial actors, as well as reinforced project development assistance.

The Commission's Smart Finance for Smart Buildings (SFSB) initiative supports the development of flexible energy efficiency and renewable financing platforms at the national level. The European Local Energy Assistance (ELENA) facility supports the SFSB through the creation of dedicated one-stop shops at the local level. ELENA supports energy efficiency investment worth EUR 30 million to EUR 50 million per year (about 25 projects per year) by co-funding 90% of energy efficiency related costs.

The European Commission also has focused action on the de-risking of energy efficiency investments for project promoters, financiers and investors. The Commission is providing access to market evidence and performance track records through the De-risking Energy Efficiency Platform (DEEP), an open-source database for monitoring and benchmarking the performance of energy efficiency investments. The data platform helps project developers, financiers and investors to better assess the risks and benefits of energy efficiency investments.

Energy performance contracting is slowly gaining ground in the EU but is still at a relatively low level compared with the United States or Australia. The contract usually includes measures to improve the energy efficiency of existing buildings in return for payments conditional on the performance of those measures. The 2017 Eurostat Guidance note on the revised treatment of EPCs in government accounts, complemented with the Eurostat-European Investment Bank (EIB) "Guide on the statistical treatment of EPC in government accounts in May 2018", brought clarity to the question of public debt and deficit treatment (Eurostat/EIB, 2018).

The Energy Efficiency Finance Group (EEFIG) and its EEFIG Underwriting Toolkit assist financial institutions in scaling up their deployment of capital into energy efficiency. The EEFIG evaluates barriers for new nearly-zero-energy buildings, deep renovations and energy-smart buildings, including access to EU funding. It also supports the benchmarking of different energy efficiency practices in the EU member states in specific fields (renovation concepts for the renovation of similar apartment blocks, financial instruments to unlock private financing for energy renovation and efficient district heating systems).

Space heating

Most buildings in the EU are still heated by individual boilers. As of 2016, almost half of the buildings had individual boilers dating from before 1992, with a thermal efficiency of 60% or less.

Energy efficiency of boilers is regulated since 1992. Eco-design and energy labelling requirements for space and water heaters were enacted in 2013, banning the sales of the least efficient boilers (EC, 2016).

Space cooling

After the United States and the People's Republic of China ("China"), the EU has the third-largest installed stock of AC units with a total output of 847 gigawatts (GW) (2016), followed by Japan. The EU share in global AC stock is only 6%, as the United States had 4 726 GW and China 2 092 GW installed capacity in 2016 (IEA, 2018).

The market for residential ACs is dominated by China, the United States, Japan and the European Union, but sales are rising strongly in other emerging economies, especially in Asia. EU annual sales were at 75 GW in 2016.

Total final consumption for space cooling in buildings in the EU amounted to 152 terawatt-hours in 2016. Cooling demand grew at a constant rate of 1.4% between 2000 and 2016 and is expected to grow by 1.5% on average up to 2050. Ecodesign and Energy labelling rules of the EU have contributed to the flat trend in EU cooling demand.

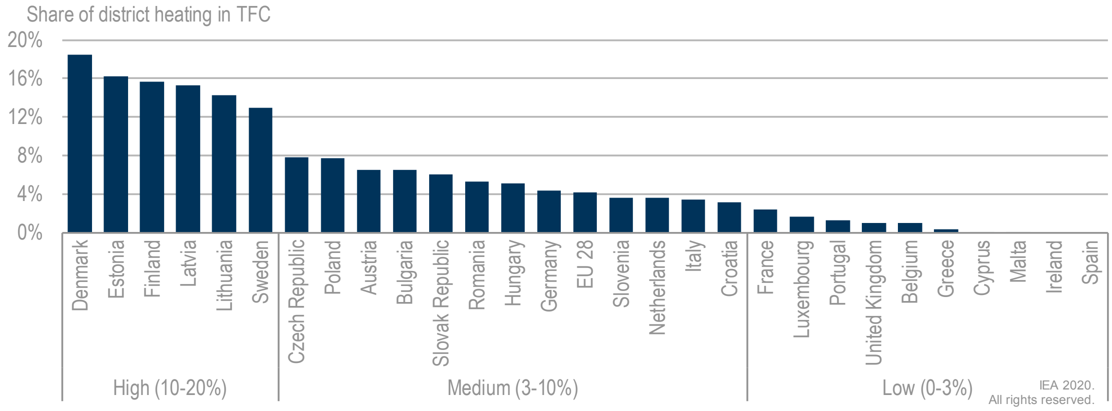
District heating

District heating consumption in EU countries

District heating, used mainly for space heating and hot water production in buildings, is an important energy source in many EU countries. It is largely developed in the Nordic and Baltic regions, but also in the Eastern European countries, where it accounts for around 12-18% of TFC and around 30% of final building energy consumption (Figure 5.6).

District heating markets are different from electricity or gas markets in that companies are usually local monopolies owning production, distribution and sales of heat. In many large district heating markets, the main part of the infrastructure was built several decades ago. As energy efficiency in buildings improves, the overall heat demand goes down. However, total district heating generation in the EU has remained relatively stable around 60 Mtoe in recent decades, indicating a growth in the number of district heating customers.

Figure 5.6 District heating as share of TFC by country, 2017

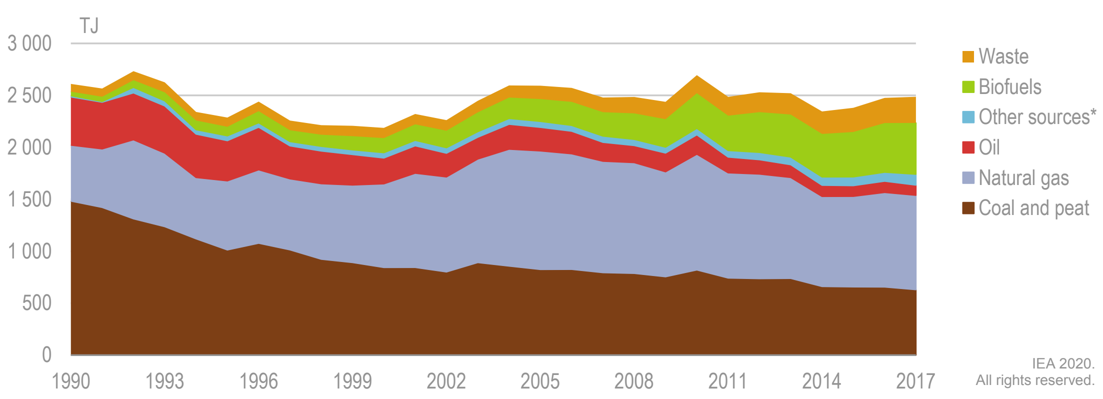


The role of district heating varies significantly among EU countries, from non-existent to accounting for around 15% of TFC in Nordic and Baltic countries.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Besides district heating, there is also district cooling. This market is yet very small and used mainly in some niche applications such as hospitals or other large service buildings. However, demand for cooling is increasing with higher summer temperatures, and the district cooling market will likely grow in several EU countries.

Figure 5.7 District heating generation by fuel in the EU, 1990-2017



District heating generation in EU countries has been quite stable around 2 500 TJ in the last decade, with natural gas, bioenergy and waste increasing and replacing coal and oil as fuel.

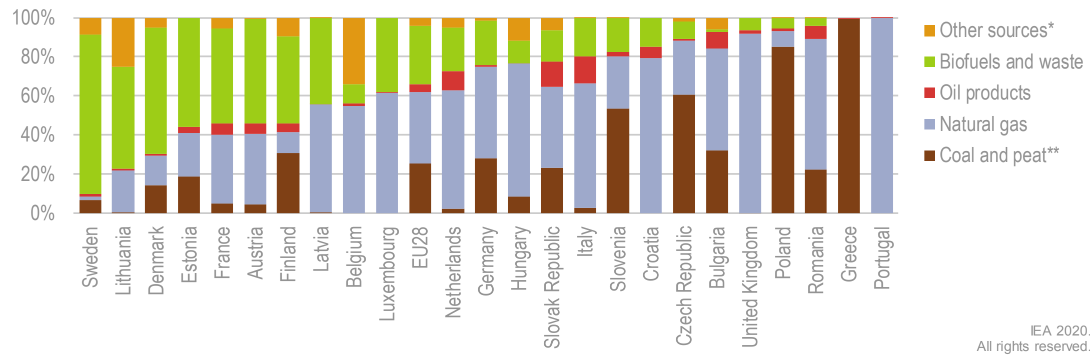
**Other sources* includes electricity, waste heat, geothermal and solar.
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

District heating generation

Natural gas is the largest fuel in district heating, accounting for 37% of total heat production in 2017, followed by coal with 25%. In the last decade, however, there has been a clear shift from coal to bioenergy and waste in district heat generation (Figure 5.7). From 2007 to 2017, the use of bioenergy more than doubled, and it accounted for 20% of total district heating generation in 2017. Similarly, waste incineration grew by 79% and accounted for 10% of district heating in 2017. The large-scale centralised heat production enables efficient flue gas cleaning in combustion of bioenergy and waste, to remove much of the particles and other local pollutants.

The growth in biofuels and waste has been unevenly spread among different district heating markets in the EU. In some countries, bioenergy and waste accounts for the majority or nearly all of district heating production, which has reduced the need for fossil fuels in heating. Again, some Nordic and Baltic countries stand out in this comparison (Figure 5.8). However, the share of non-renewable heat in total final consumption in district heating and cooling is high in several EU countries (Figure 5.9). Austria, Denmark, Finland, France and Sweden use large shares of renewable heat.

Figure 5.8 District heating generation by fuel in EU member states, 2017



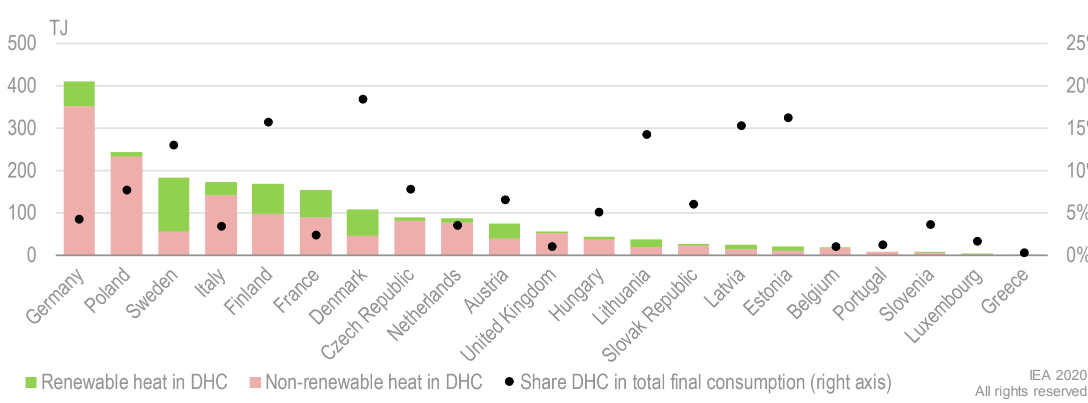
A large supply of bioenergy and other renewable or recycled heat sources has replaced fossil fuels in district heating generation in some EU countries, while in others fossil fuels still dominate.

**Other sources* includes solar, geothermal, electricity and waste heat, including from nuclear.

***Coal and peat* includes oil shale for Estonia.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Figure 5.9. Share of district heating and cooling in TFC and share of renewables, selected EU countries, 2017



Note: DHC = district heating and cooling.
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/

EU policies for energy use in heating and cooling

EU Strategy on Heating and Cooling

In 2016, the European Commission presented an EU Strategy on Heating and Cooling (EC, 2016) to decarbonise heating by both improving energy efficiency in buildings and switching to low-carbon energy sources. This first strategy proposed the integration of several policies with the focus on heating and cooling. The Commission highlights the potential for district heating and co-generation[29] to save energy, reduce CO_2 emissions and offer flexibility to the energy system by cheaply storing thermal energy.

The EU adopted regulations to support efficient and clean district heating, but there is no EU-wide price regulation in place.

Pollution control of heating

Greenhouse gas emissions from large combustion plants are part of the EU ETS, where the emitter can buy and sell emissions credits on a marketplace. The EU also regulates other emissions from large combustion plants (over 50 megawatts [MW]) though the Directive 2010/75/EU on industrial emissions. This includes emissions of ammonia, nitrogen oxides, carbon monoxide, sulphur oxides and methane, and particle emissions. The regulation is based on best available techniques, stated in an updated reference document from 2017 (EC, 2017).

Energy efficiency regulations

The EED I (2012/27/EC) requires EU member states to carry out a cost-benefit analysis of the potential for using co-generation when they plan to build or substantially refurbish a heat, electrical or industrial installation with a total thermal input exceeding 20 MW (Article 14). A cost-benefit analysis should also be performed when building a district heating and cooling network with a total thermal input of at least 20 MW, with the intention to utilise cost-effective waste heat from nearby industry.

Article 14 asked EU member states to conduct a comprehensive assessment of the national potential of efficient heating and cooling by 31 December 2015. Member states must update and report these assessments every five years to the Commission. The next cycle is due by the end of 2020.

The revised EED II (Article 9c, EU/2018/2002) addresses the transition to remotely readable heat meters in systems for collective supply of thermal energy (heating and cooling), including district heating and cooling. After 25 October 2020, all newly installed heat meters must be remotely readable so as to facilitate the provision of frequent consumption information to consumers. By 1 January 2027, all existing meters have to be either upgraded to remote readability or replaced with readable devices (unless it is not cost-efficient).

Consumers in multi-apartment buildings with collective heating systems have the right to receive more frequent and detailed information on their energy consumption, also enabling them to better understand and control their heating bills. The EED II improves the rules for

[29] *Co-generation* refers to the combined production of heat and power

metering and billing of thermal energy use. Member states have to put in place transparent rules for the cost allocation of heating, cooling and hot water consumption in multi-apartment and multi-purpose buildings.

Regulation of renewable energy

Under the new Renewable Energy Directive (RED II) (2018/2001/EU), EU countries shall ensure that information on the energy performance and the share of renewable energy in their district heating and cooling systems is provided to final consumers in an easily accessible manner, such as on the suppliers' websites, on annual bills or upon request. Customers should be allowed to disconnect from an inefficient district heating supply in order to use heat from alternative renewable sources.

The RED II requires member states to adopt measures that allow customers of inefficient district heating or cooling systems to disconnect by terminating or modifying their contract in order to produce heating or cooling from renewable sources themselves. Member states also need to ensure that information on the energy performance and the share of renewable energy in their district heating and cooling systems is provided to final consumers in an easily accessible manner, such as on the suppliers' websites, on annual bills or upon request.

To increase the share of renewables in buildings, member states have to implement minimum renewables shares in their buildings (new and undergoing major renovation), which can be fulfilled by efficient district heating and cooling using a significant amount of renewables and waste heat or cold. The national comprehensive heating and cooling assessments under Article 14 of the EED should incorporate renewable and waste heat and cold potentials for heating and cooling as a mandatory element for the second round of such assessments due by 31 December 2020.

Member states are obliged to endeavour to increase the share of energy from renewable sources in heating and cooling by at least 1.3 percentage points as an annual average from 2021-30, from 2020 levels. Up to 40% of this increase can be filled by waste heat and cold, if member states choose to use these sources. In district heating and cooling systems, member states may implement a 1 percentage point annual average renewables' increase, which can also be fulfilled by waste heat and cold entirely, or opt for third-party access for renewables, waste heat and cold sources and high-efficiency co-generation. Under this option, operators of district heating or cooling systems are to be obliged, based on non-discriminatory criteria, to connect suppliers of energy from renewable sources and from waste heat and cold, or to offer to connect and purchase heat or cold from renewable sources and from waste heat and cold from third-party suppliers.

Heating and cooling price regulation

There is no EU-wide regulation of district heating markets. In fact, regulation varies significantly between different countries. Some use a free market approach (e.g. Finland, Germany and Sweden) without price regulation. There, district heating is assumed to compete with other heat sources. Other countries use different regulatory models such as a price cap based on the main alternative heat source (e.g. the Netherlands) or a cost-plus regulatory model (e.g. Hungary and Slovakia). These models can be combined with requirements of improving cost efficiency over time.

Funding of research in heating and cooling

There have been several research projects under the Horizon 2020 programme focusing on district heating and cooling. One example is the Heat Roadmap Europe, a consortium of 24 organisations including universities, companies, cities and research institutes. The goal of the project is to develop low-carbon heating and cooling strategies, called Heat Roadmaps, by quantifying and implementing changes at the national level for 14 EU member states, which together account for approximately 85-90% of total heating and cooling in Europe.

Another example is the E2District, a three-year Horizon 2020 Research and Innovation project. Both projects started in 2016 and were set up for three years.

EU policies for appliances

The Ecodesign Directive (ED, 2009/125/EC) provides rules and procedures for establishing minimum eco-design requirements (e.g. maximum annual energy consumption) for energy-related products to be placed on the EU market (regardless of their origin). The directive aims at improving product design and thus at increasing products' environmental performance throughout their life cycle ("push the market" effect).

The Energy Labelling Framework Regulation (2017/1369/EU) provides rules and procedures for establishing energy labelling requirements for energy-related products to be placed on the EU market (regardless of their origin). Energy Labelling aims at providing consumers with information about the environmental performance of products and thus at providing incentives for industry to develop more efficient products and innovations beyond the minimum eco-design levels ("pull the market" effect).

Energy labels to be provided by suppliers indicate the level of energy efficiency, energy consumption and other relevant resources (e.g. water use) of their products. The class of efficiency (A-G) is shown on a label which has to be displayed at points of sales (both shops and online sales). This allows consumers to be informed about the efficiency of a product before they make their purchasing decision.

Both the Ecodesign Directive and the Energy Labelling Regulation are framework instruments. They establish legal and institutional frameworks for specific requirements. The requirements are laid down in the implementing regulations adopted by the Commission. The work of the Commission under this framework is guided by Working Plans. The latest Ecodesign Working Plan 2016-2019 was adopted in November 2016.

By mid-2019, 27 product groups had been regulated through 30 Ecodesign regulations, 15 Energy Labelling regulations, 1 regulation on the labelling of tyres and 3 reports to the European Parliament and the Council recognising eco-design self-regulation measures.

Assessment

To meet the long-term target of climate neutrality, the EU needs to step up actions in the buildings sector. Buildings represent almost 40% of total final energy consumption in the EU, and heat demand in the buildings sector accounts for almost 80% of buildings energy use, with oil still making up 11% of heat demand. Natural gas and electricity account for around 30% each and the share of biomass used in heating is also on the rise (12% in

2017, versus 9% in 2007). Energy-related CO_2 emissions are on the rise and accounted for 17% in 2017, up from 15% in 2007. Accounting for indirect CO_2 emissions from electricity and heat, the buildings sector makes up around 30% of total CO_2 emissions.

Upgrading the EU buildings stock to this level should be the ultimate goal. Today, only 3% of the buildings stock satisfies the EPC label A.

Most of the EU buildings stock that will be in place in 2050 has been already built and the EU is therefore right to focus on building renovation. Member states are not progressing in line with the required annual building renovation rates and renovate only 0.4-1.2% each year due to a variety of barriers. The announced Renovation Wave under the European Green Deal sets an important signal in this regard.

The revised EPBD introduces a 2050 vision for decarbonising the national buildings stocks through strengthened national building renovation strategies, which are also an important element of the NECPs. It is encouraging that the revised EPBD will ramp up energy efficiency financing, streamline financial offerings, and provide further support for technical assistance and for the energy services sector, and has new provisions on digitalisation, smart buildings and the roll-out of electric vehicle charging infrastructure through building codes. It also includes reinforced requirements for information provision to owners and tenants, including on cost-effective measures, financial instruments to improve the energy performance of the building envelope and replacing fossil fuel boilers with more sustainable alternatives, including through advisory tools, renovation advice and one-stop shops for building renovation.

Retrofitting of the ageing buildings stock and equipment remains a critical challenge and, when undertaken, compliance with minimum energy performance requirements is sometimes weak, as it is more difficult to enforce than standards for new builds. Deep retrofits provide the opportunity to move towards nearly-zero-energy buildings with net-zero emissions by combining energy efficiency measures with on-building renewables and a switch to renewable heating (and district heating) solutions and electric heat pumps.

In the heating and cooling sector, the historical rate of increase in the share of renewable energy has been less than the rate that is needed to meet future requirements under RED II. RED II mainstreams renewable energy in heating and cooling, as each member state has to endeavour to increase the share of renewable energy in that sector by 1.3 percentage points as an annual average. Achieving this target will require more assistance at the local level, especially in district heating and small and medium-sized enterprises, because of the local nature of energy generation and delivery. The EU Strategy on Heating and Cooling indicates that the European Commission should support local authorities in preparing strategies for the promotion of renewable heating and cooling. Sufficient emphasis should be placed on the relative cost of implementing the various mitigation measures with the goal to channel public/private funds to those technologies that provide best value for money.

Under RED II, operators of district heating or cooling systems may be obliged to connect and/or purchase heat or cold from renewable sources and from waste from third-party suppliers, based on non-discriminatory criteria. In some member states, district heating is seen as an attractive option for companies and consumers and as a means of improving energy efficiency and renewables deployment. Old systems have shrunk due to lack of investment or unfavourable price regulation, low performance, and negative consumer perceptions. Some member states are making efforts to modernise and expand old systems; others, where the technology is hardly known yet, are building new ones.

District heating plays a very diverse role in different EU countries, from not being used at all to providing a majority of heat in buildings, especially in urban areas. In the large district heating markets, the main part of the infrastructure was built several decades ago and was designed to supply a higher heat demand than is needed today. With continuing energy efficiency improvements in buildings, district heating systems will have to be modernised to be able to supply heat in an efficient way. The transition in many coal-using countries involves importantly the replacement of heat production from coal-fired co-generation with new heat sources and technologies, including geothermal.

The energy mix of the heat supply also differs largely between district heating markets, where some have successfully replaced most fossil fuels with bioenergy and waste while others still rely on mainly coal and natural gas. A broader shift from fossil fuels to low-carbon energy sources, including renewables and industrial surplus heat, is needed if district heating is to play an important role in decarbonising heat across the EU.

The Ecodesign Directive is a cornerstone of energy efficiency policy, supporting the switch of stock and appliances to the most energy-efficient technology. The implementation has faced ongoing compliance issues and suffers from a mismatch between technological advancements and regulatory and consultation time frames. The European Commission has supported joint enforcement actions with member states' authorities but the procedures for adopting new regulations are slow. In the next Working Plan, the EU should review products in heating across residential, commercial and industrial sectors (e.g. gas boilers). The EU should also assess the feasibility of better enabling smart data-sharing from suppliers of products to regulatory bodies, which could transform the compliance regime. In this context, the new European Product Database for Energy Labelling (EPREL) will give national market surveillance bodies easier access to data from suppliers.

The Commission estimates that by 2020, the eco-design framework (together with energy labelling) has the potential to deliver around 155 Mtoe of primary energy savings per year. This is roughly equivalent to Italy's annual energy consumption, close to half the EU 20% energy efficiency target by 2020 and about 11% of the expected EU primary energy consumption in 2020. This also results in savings of about EUR 285 annually on individual household energy bills and EUR 66 billion per year of extra revenue for industry, retail and wholesale sectors.

Buildings also play an important role in providing flexibility to the energy system, through energy production, storage and demand response, notably for smart charging of electric vehicles (see Chapter 8 on Energy Sector Integration).

Recommendations

The European Union should:

- ☐ Encourage member states to accelerate quality building retrofits and district heating conversions (away from fossil fuels) by:

- Engaging proactively and directly through the EIB with regional authorities, cities, local banks and other project promoters to develop a pipeline of bankable, aggregated projects.
- Using district heating and cooling assessments to identify the largest and most emissions-intensive district heating systems and assess transformation challenges.
- Making compliance with minimum energy performance standards and credible decarbonisation plans a condition of financing.

- [ ] Develop further initiatives, guidance and best practices for deploying renewable energy and industrial surplus or waste heat in heating and cooling at the local level, especially in district heating and small and medium-sized enterprises. Promote systematic heat mapping and strategic planning of heat demand at local level.

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6. Industry

Key data (2017)

Energy consumption in industry*: 365.8 Mtoe (30.8% oil, 26.7% natural gas, 24.3% electricity, 7.2% bioenergy and waste, 6.6% coal [including peat and oil shale], 4.4% district heating), -13% since 2007

Share of industry in TFC: 31.7% (34.6% in 2007)

Share of industry in energy-related CO_2 emissions: 12.6% (13.6% in 2007)

*Industry energy consumption plus non-energy use, including a small share of non-energy use outside of industry.

EU targets and strategies

The EU has no specific target for the industry sector, which is included in emissions reduction efforts required in the EU Emissions Trading Scheme (ETS) of 43% compared with 2005 levels, but has free allowances for trade-exposed sectors. The industry sector does not have any specific target for energy efficiency or renewables neither, and its inclusion in the EU ETS is compensated for by free allowances (though in decline) and special state aid.

The European Green Deal (EGD) aims for climate neutrality for the EU by 2050. The European Commission aims to propose raising the 2030 target to at least 50% and towards 55% if possible.

EU strategies for the industry sector focus on reversing industrial decline (2014 strategy “For a European industrial renaissance”), completing the internal market, supporting industry as a global business amid strategic concerns in terms of jobs, competitiveness and digitalisation (2016 strategy on “Digitising European industry — Reaping the full benefits of a digital single market”). In 2017, the EU industrial strategy aimed at boosting industrial competitiveness, the revitalisation of regions and the adoption of technologies for a smart, clean and innovative industry of the future (EC, 2017) as well as the social inclusiveness of the transformation.

In November 2019, the High-Level Expert Group on Energy-Intensive Industries released a master plan on the transformation of EU energy-intensive industries to enable a climate-neutral, circular economy by 2050 (EC, 2019). The master plan promotes the creation of markets for climate-neutral, circular economy products, developing climate-neutral solutions and financing. It also focuses on the need to ensure a just transition and considers the need to equip workers with new skills and help communities dependent on these industries to manage the transition.

International Energy Agency (IEA) analysis shows that 59% of total energy savings could be achieved in the less energy-intensive sectors, a ratio that amounts to 70% globally (IEA, 2018). Given the fact that 99% of European firms are small and medium-sized enterprises (SMEs), a focus on them is critical.

As part of the EGD, the European Commission presented a new EU Industrial Strategy in March 2020, including a strategy for SMEs and new Alliances for Low-Carbon Industries.

When implementing the strategy, the Commission should take a comprehensive value chain approach for energy-intensive industries (including life-cycle analysis) to avoid carbon leakage, and devise policies for less energy-intensive industries. A cost-effective policy would integrate actions to develop schemes that spur energy efficiency and CO_2 emissions reductions, fuel switching, and the development and deployment of energy technology innovation.

Supply and demand

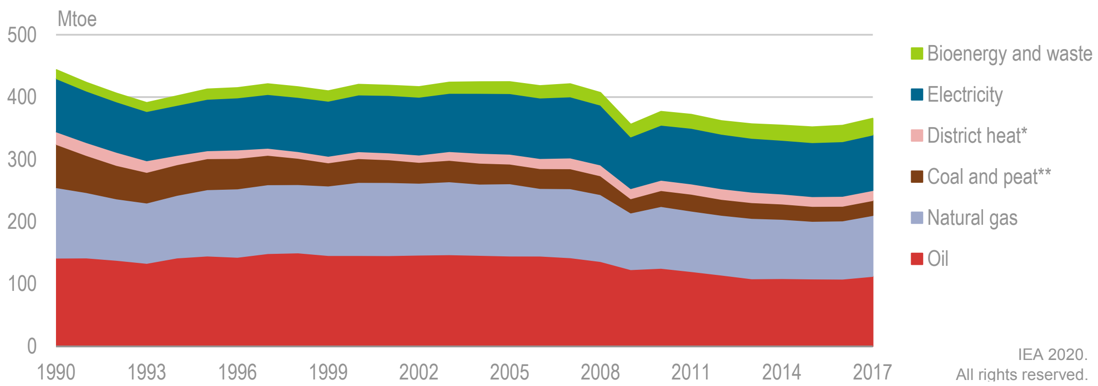
The EU's industry sector is the largest energy consumer in the EU, accounting for a third of the total final energy consumption but only 13% of all EU energy-related CO_2 emissions (and 14% of total EU GHGs). From 2013 to 2018, CO_2 emissions from industrial installations decreased by only 0.3%. The most energy-consuming industrial sector is the chemical and petrochemical industry, followed by the paper and pulp and iron/steel sectors. The paper industry has the lowest emissions intensity (0.7 tonnes of CO_2 per tonne of oil equivalent) among all large industry sectors, due to the use of mostly bioenergy and electricity in the Nordic countries.

The industry sector in the EU, including for non-energy use, consumed 366 million tonnes of oil equivalent (Mtoe) in 2017, equal to 32% of total final consumption (TFC). Industry consumption fell rapidly after the global financial crisis in 2008, from 421 Mtoe in 2007 to 356 Mtoe in 2009, but has remained quite stable since (Figure 6.1).

The chemical and petrochemical industry is the largest consumer of energy sources in the industry sector. When including fuels used for non-energy purposes, the chemical and petrochemical industry accounts for nearly 40% of total industrial consumption of energy sources, of which 60% is for non-energy use (Figure 6.2). Paper, non-metallic minerals, iron and steel, and food and tobacco are other large energy-consuming industries, which together consume about the same as the chemical and petrochemical industry. Most of the large industry sectors have experienced a decline in energy consumption, mostly due to the global financial and economic crisis. Notably non-metallic minerals decreased its consumption by 27% from 2007 to 2017, and iron and steel industry consumption fell by 23%. Food and tobacco was an exception with stable energy consumption over the last decade.

Oil, natural gas and electricity are the largest energy sources in industry. Around 75% of the oil consumption in industry is for non-energy use, mainly as feedstock in the chemical and petrochemical industry and partly in construction. Natural gas is used across many different industries, with the chemical and petrochemical industry accounting for around a third of total gas consumption in industry, nearly half of which is used for non-energy purposes. Electricity consumption is spread across all industry sectors.

Figure 6.1 Energy consumption in industry by fuel, 1990-2017



Industry energy consumption dropped after the financial crisis but has stabilised in recent years and increased slightly in 2017 to 366 Mtoe, around 32% of TFC in the EU.

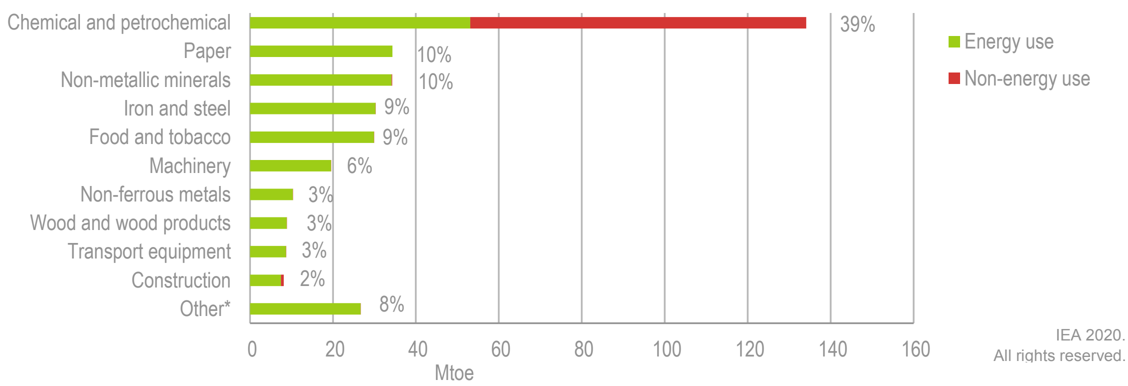
**District heat* includes small shares geothermal and solar

***Coal and peat* includes a small share of oil shale.

Note: Includes fuels in non-energy use.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Figure 6.2 Energy/fuel consumption in industry by subsector, 2017



The chemical and petrochemical industry is by far the largest industrial consumer of energy sources in the EU with 39% of total industry consumption in 2017, most of which is for non-energy use.

**Other* includes pipeline transport and non-specified transport.

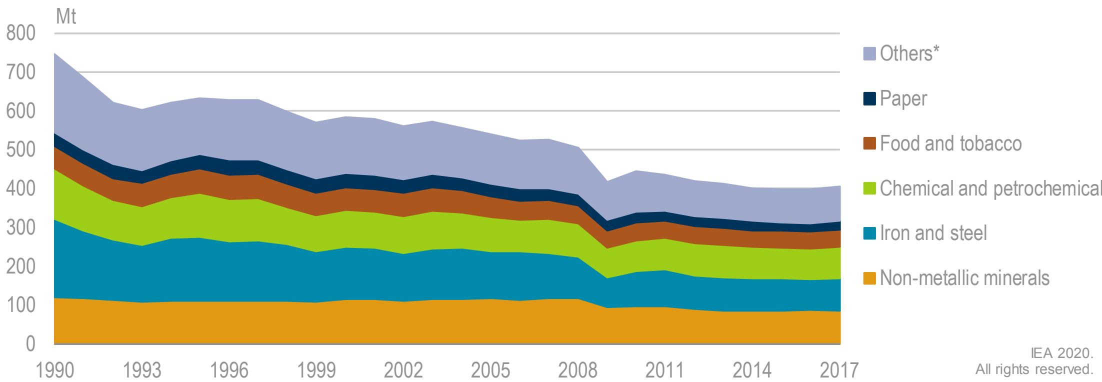
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

CO_2 emissions

In 2017, the industry sector emitted just over 400 million tonnes of CO_2 ($MtCO_2$) from combustion only. Counting other process emissions and indirect emissions, total emissions of the industry sector equalled 519 $MtCO_2$. This accounted for 12.6% of total energy-related CO_2 emissions in the EU. Both actual emissions and industry's share of total emissions have decreased over the last decades, but have remained quite flat since

2014. Non-metallic minerals, iron and steel, and chemicals and petrochemicals are the largest industry emitters, accounting for around 20% of total industry emissions each (Figure 6.3).

Figure 6.3 Industry energy-related CO_2 emissions by sector, 1990-2017



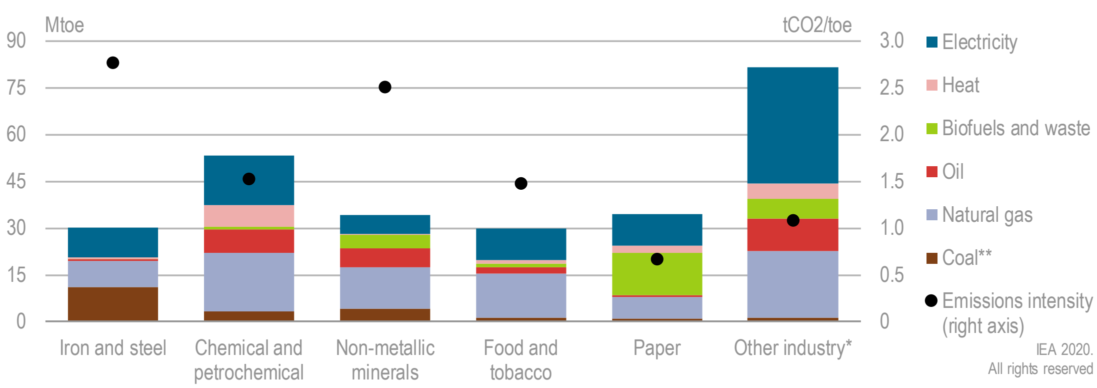
Industry's energy-related CO_2 emissions have declined significantly in the last decades, mainly after the financial crisis, but emissions have stabilised around 400 Mt in recent years.

Note: Mt = million tonnes.

**Others* includes non-ferrous metals, transport equipment, machinery, mining and quarrying, wood and wood products, construction, and textile and leather.

Source: IEA (2019b), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

Figure 6.4 Energy use and emissions intensity by fuel and industry sector, 2017



The iron and steel industry has high emissions intensity due to the large use of coal, while the paper industry has low emissions intensity due to high shares of biofuels and electricity.

**Other industry* includes non-ferrous metals, transport equipment, machinery, mining and quarrying, wood and wood products, construction, and textile and leather.

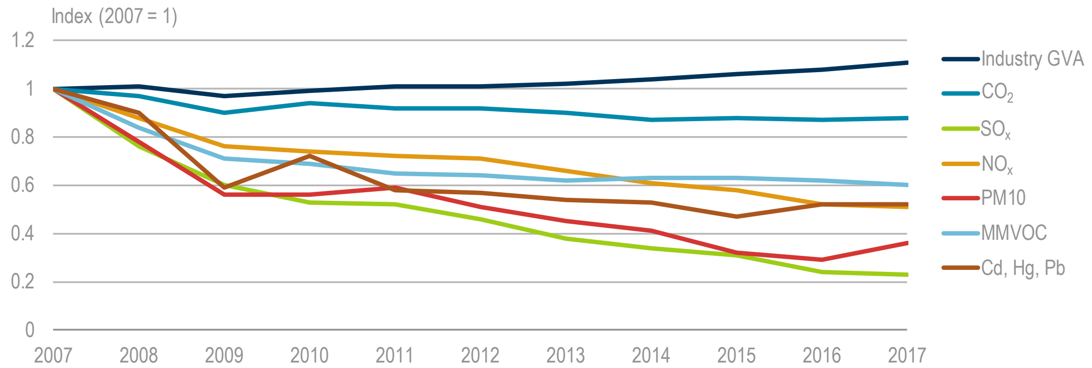
***Coal* includes small shares of peat, oil shale and other energy sources.

Note: Not including fuels used for non-energy purposes.

Sources: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/; IEA (2019b), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

Emissions vary with the energy consumption and energy mix of the different industry sectors. The iron and steel and non-metallic mineral industries together consume less than 25% of energy (not including non-energy use), but emit over 40% of industry CO_2 emissions. This is because of high dependence on fossil fuels,[30] which gives high emissions intensity per unit of energy use (Figure 6.4). The paper industry has the lowest emissions intensity among all large industry sectors, due to the use of mostly bioenergy and electricity. Paper production involves the production of biomass (lignin) as a sub-product of wood that can then be used in co-generation[31] units to produce heat and electricity for the paper mill.

Figure 6.5 Air pollutants from industry, 2007-17



Note: GVA = gross value added; SO_x = sulphur oxides; NO_x = nitrogen oxides; PM10 = coarse particulate matter; NMVOC = non-methane volatile organic compounds; Cd = cadmium; Hg = mercury; Pb = lead.

Source: EEA (2019), Industrial pollution in Europe, www.eea.europa.eu/data-and-maps/indicators/industrial-pollution-in-europe-3/assessment

Air pollutants from industry have been declining despite the growing industry activity (gross value added), but not across all pollutants. Sulphur emissions and PM10 went down strongly during 2010-16, while PM10 has seen a stark rebound since 2016 (Figure 6.5).

Key EU policies in the industry sector

Carbon pricing

Since 2005, the EU ETS applies to industry and electricity, but manufacturing industries receive a share of their emissions allowances for free and energy-intensive industry benefits from a special regime under the carbon leakage list (see Chapter 3 on Climate).

The allocation of ETS allowances is based on benchmarks that represent the average CO_2 emissions of the best-performing 10% of installations producing the same product in the EU. Installations that do not reach these benchmarks will have to reduce their emissions or buy additional allowances. The reformed EU ETS retains this system of free allocation to address carbon leakage concerns, albeit in a more targeted manner with less exposed sectors seeing their free allocation phased out by 2030.

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[30] In the EU, the largest process route to produce steel is basic oxygen furnace (60%) which requires coal (coke) as fuel but also as a reduction agent (in the blast furnaces).

[31] *Co-generation* refers to the combined production of heat and power.

ENERGY SYSTEM TRANSFORMATION

Under EU ETS state aid guidelines (which will expire on 31 December 2020), member states can partly compensate indirect emissions costs faced by industrial sectors deemed to be exposed to a significant risk of carbon leakage due to EU ETS allowance costs passed on in electricity prices. In line with the EGD communication, the draft EU ETS State Aid Guidelines (for the next trading period starting on 1 January 2021) aim at reducing the carbon leakage risk related to indirect ETS costs, and incentivising the modernisation of production processes.

Since 2013, CO_2 emissions from industrial installations have stalled (a small decrease by just 0.3% to 587 million tonnes of CO_2 equivalent in 2018, according to latest data from the European Environment Agency [EEA], while free allowances have almost halved. Thus, the EU ETS does not seem to have significantly contributed to the decarbonisation of industrial installations.

Air quality policy for industry in the EU is enshrined in the Large Combustion Plants[32] Directive (LCPD) and the Industrial Emissions Directive (2010/75/EU). Despite its transitional periods, long time frames and technical implementation, the LCPD was instrumental in achieving major emissions cuts between 2004 and 2015 from LCPs, harmonising the environmental performance of LCPs across the EU and aligning the levels of health and environmental protection that EU countries provide with regard to sulphur dioxide, NO_x and dust pollutants emitted by LCPs. Europe's LCPs have significantly improved their environmental performance over the past decade, releasing fewer emissions of SO_x, NO_x and dust to air per unit of energy consumed. Environmental regulations and improved pollutant abatement technology, and relocation to countries outside Europe in some cases, have led to decreasing pollutant releases to air and water in the EU.

The EU is contemplating the introduction of a carbon border adjustment tax as part of the EGD. This may require a shift in the calculation of the carbon dioxide content of the products, and certification and verification mechanisms for imports. If applied successfully to trade policies, such a tax would reduce the risk of carbon leakage and thus require a review of the carbon leakage system.

Energy efficiency

The Energy Efficiency Directive (EED I) (Directive 2012/27/EU) required large enterprises to carry out a first energy audit by the end of 2015 and continue to carry out audits every four years. Most large enterprises carried out at least one energy audit and auditors were trained and accredited all around Europe. Some countries, however, faced delays, especially due to the difficulty to set up a list of obligated enterprises, based on the available business registries. In addition, the EED also encourages audits in SMEs.

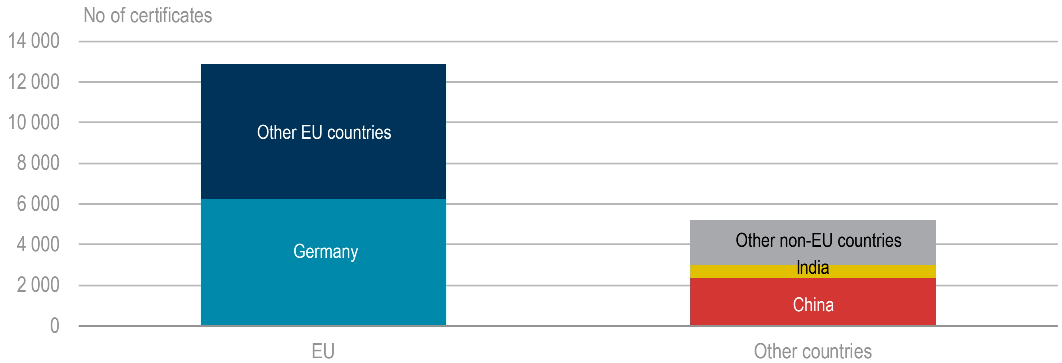
Companies are also encouraged through the EED to put in place an energy management system (EMS) in line with ISO 50001 standards, and if they do so, they can be exempted from the EU EED energy audit requirement. The most recent ISO survey published in 2020 shows that Europe recorded the highest number of certificates compared with other

[32] Large combustion plants (LCPs) include power plants, refineries and large chemical industry and steel.

regions in the world. The number of ISO certificates also continues to increase steadily, with a number of 12 845 certificates in 2018 in comparison with 10 152 in 2015.

Whereas in 2014, ISO 50001 was present in only 14 EU member states, it is now present in all EU member states. Germany is the leader within the EU and by international comparison. The People's Republic of China (hereafter, "China") and India follow Germany in the implementation of energy management schemes (EMS) in industry (see Figures 6.6 and 6.7). The number of certificates, however, sometimes hides the use of certificates at the industrial sites. For instance, in France, there are only 770 certificates, but they cover ten times more (7 700) sites.

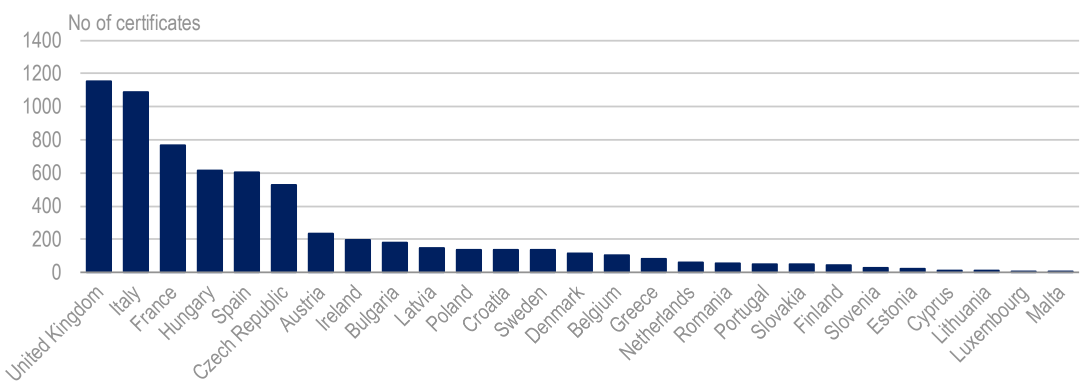
Figure 6.6 Implementation of ISO 50001 certification in the EU versus international



Note: China has a national EMS standard (GB/T 23331), which saw in total 2 552 certifications by the end of 2017, according to the CNCA. ISO certifications tripled in 2016 and grew by 40% in 2017.

Source: ISO (2020), ISO Survey of certifications to management system standards – Full results, https://isotc.iso.org/livelink/livelink?func=ll&objId=18808772&objAction=browse&viewType=1.

Figure 6.7 Implementation of ISO 50001 certification in the EU excluding Germany



Source: ISO (2020), ISO Survey of certifications to management system standards – Full results, https://isotc.iso.org/livelink/livelink?func=ll&objId=18808772&objAction=browse&viewType=1.

The European Commission is currently analysing whether the mandatory audit requirement can be made more effective. In some countries the audit recommendations are linked to policy instruments that oblige energy efficiency investments or provide support for it, or to energy efficiency obligation schemes; in this way companies can participate in achieving the new savings obligation included in the EED II.

The EU Executive Agency for Small and Medium-sized Enterprises and the EU Horizon 2020 research programme can fund companies from different sectors to speed up the market uptake of cost-effective energy efficiency measures, through the development of tailor-made capacity-building programmes on energy audits and EMS (ISO 50001). The EED also requires national authorities to provide specific support for SMEs, through either financial instruments or information campaigns. As a result, hundreds of policy instruments of different kinds (e.g. trainings, standardised tools, financial incentives) have been implemented in the EU28, targeting specifically energy efficiency measures in SMEs.

In place since 2009, efficiency requirements of motors were reviewed in 2019 and new more stringent rules will be effective as of 2021, broadening the scope and increasing the requirements, up to the IE4 level for certain types of motors which is a world-wide première. Ecodesign measures for industrial pumps and industrial fans also contribute to the improvement of energy efficiency in the industrial sector.

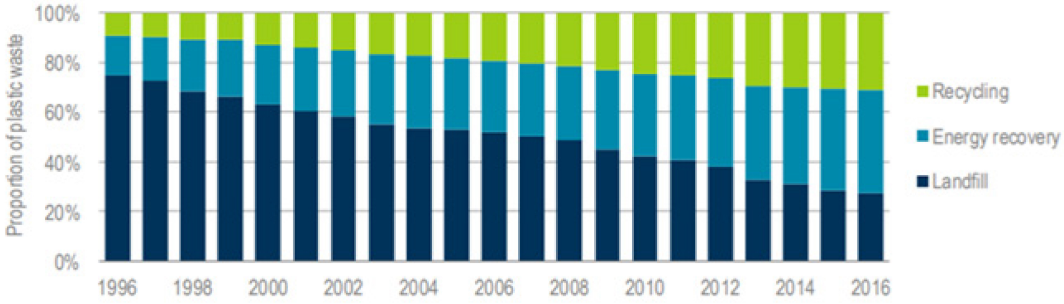
Pathways and policies for decarbonisation

Circular economy – industrial demand and materials

A major energy consumer in the EU is the chemical and petrochemical industry. IEA analysis has shown that global demand for plastics is going to increase strongly, supporting growth of oil demand and thus petrochemical production. While recycling has grown in the EU over the past decades, it still accounts for only 25% of waste management routes (Figure 6.8).

According to a recent IEA study, the transition of the petrochemical industry can be led by carbon capture, utilisation and storage (CCUS) (35%), coal-to-gas feedstock shifts (25%), and energy efficiency (25%) (IEA, 2019c). The contributions to emissions reductions of plastic recycling and reuse and alternative feedstocks are less pronounced.

Figure 6.8 Plastic waste by management route in Europe



Plastic recycling overtook landfilling for the first time in Europe in 2016.

Notes: 1996-2004 = EU15, Norway and Switzerland; 2005-13 = EU27, Norway and Switzerland; 2013-16 = EU28, Norway and Switzerland.

Sources: Plastics Europe (2007), The compelling facts about plastics 2007; Plastics Europe (2013), Plastics – The facts 2013; Plastics Europe (2017), Plastics –The facts 2017.

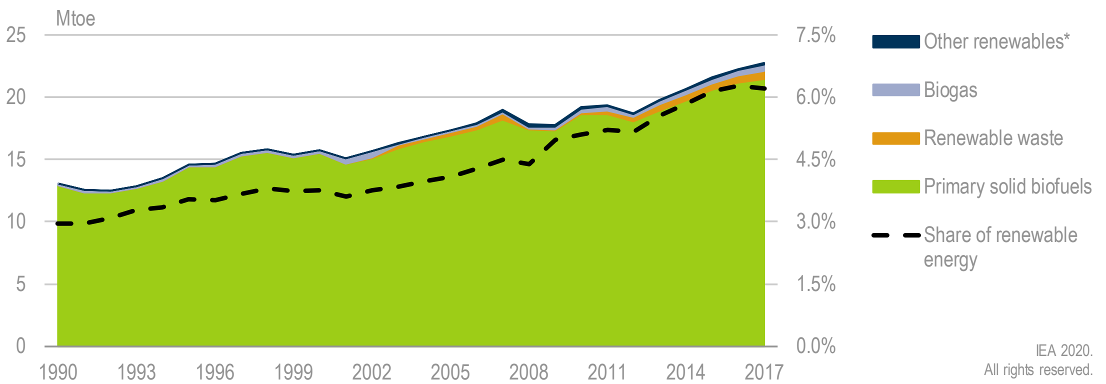
Direct use of renewables (biomass, waste heat)

Around 37% of EU total heat consumption stems from industry heat, after buildings (the largest consumer of heat in the EU). There are high-temperature process industries (iron and steel, aluminium, cement, chemicals) and low-temperature industrial (food and tobacco, pulp and paper, etc.). Besides the direct emissions, there are many indirect emissions stemming from process heat.

Primary solid biofuels dominate the direct use of renewable energy in industry (not counting indirect use in electricity or heat from renewable sources). Renewable energy accounted for around 6% of total energy consumption in industry in 2017, of which 94% was from primary solid biofuels (Figure 6.9). The supply of renewable energy increased from around 13 Mtoe in 1990 to 23 Mtoe in 2017, and its share of total industry energy consumption doubled. This increase correlates with the growth in paper industry energy use, which accounts for over half of total bioenergy consumed in the industry sector.

High-temperature process industries are not able to use renewables, except for electricity. However, EU industry with low-temperature heat processes has a relatively high use of bioenergy/waste, as in in the cement industry, and there is a large use of bioenergy in the paper and pulp industry in Nordic countries.

Figure 6.9 Direct use of renewable energy in industry, 1990-2017



Renewable energy accounts for around 6% of total energy consumption in industry, of which the vast majority is primary solid biofuels, mainly used in the paper industry.

**Other renewables* includes liquid biofuels, solar heat and geothermal.
Note: Does not include the use of renewable electricity or district heating.
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Hydrogen, CCUS and CO_2 utilisation

IEA analysis (IEA, 2019d) has shown that hydrogen can be an effective decarbonisation pathway for industry. In fact, the momentum has grown in the EU, driven by abundant renewable energy production which could be stored by electrolysis and synergies arising from manufacturing of electrolyers and lithuium-ion batteries.

The momentum in the Europe is growing strongly, with hydrogen strategies in Austria, Germany, the Netherlands and the United Kingdom (UK).

The Fuel Cell Hydrogen Joint Undertaking has supported a series of projects designed to improve electrolysers (the size of electrolysers in these projects has increased, from 100 kilowatts, with project Don-Quichote in 2011, to 6 megawatts in the 2016 H2FUTURE project). Austria plans to demonstrate a project to produce hydrogen on-site to use in steel production. The concept of the regional hydrogen collaboration under the "hydrogen valleys" has boosted the development of several large-scale clusters.

The EU has developed a methodology for accounting for the carbon intensity of hydrogen production and has developed a certification system for Europe (CertifHy project). This is a key element of commercialisation of low-carbon hydrogen as a higher-value energy product.

CCUS is expected to play a critical role in supporting the decarbonisation of the energy system. The potential role of CCUS in energy systems is varied depending on the national circumstances and the sector. In the industrial sector, CCUS offers a solution to some of the most challenging CO_2 emissions, including those from key industrial sectors – including cement, iron and steel, and chemicals production – for which few alternative decarbonisation options exist.

CCUS can also enable CO_2 emissions reductions related to hydrogen production from natural gas, which can be used to decarbonise heating, transport and power generation. In many EU countries, gas-based hydrogen production with CCUS is expected to be the most cost-effective production route for low carbon. Moreover, it can protect the value of these assets as emissions constraints are tightened. CCUS also provides the means to deliver CO_2 removal technologies or "negative emissions" technologies, such as bioenergy with carbon capture and storage (CCS) and direct air capture, which will become increasingly important over time to offset emissions from sectors where direct abatement is not economically or technically feasible, such as in aviation transport or agriculture.

Lastly, CO_2 can be used as an input in the manufacturing of fuels, chemicals and building materials. While using CO_2 in products does not necessarily reduce emissions, and many CO_2 use applications may not prove economically viable, CO_2 could become an important raw material for chemicals and aviation fuels. Both applications will continue to rely on a source of carbon, because it provides their structure and properties (carbon-containing chemicals) or because the use of carbon-free energy carriers, such as electricity or hydrogen, is challenging (for example, aviation fuels). Both CO_2-derived fuels and chemicals require large amounts of low-carbon electricity and hydrogen, thus allowing the integration of renewable electricity in other sectors of the economy, such as transport and industry. To support the transition towards variable renewable energies in a net-zero energy system, the CO_2 used has to come from bioenergy or the atmosphere (direct air capture). To achieve cost reductions, scale is needed, and CCUS demonstration outside power generation could create robust business models.

Since the adoption of the Strategic Energy Technology Plan (SET Plan) in 2007, the EU has pursued the demonstration of CCUS with large-scale facilities for CCS in different sectors. The Integrated SET Plan of 2015 focused on enabling whole-chain CCS demonstration projects, including carbon-intensive industries, to developing CO_2 transport and storage infrastructure, and to research options for CO_2 utilisation through industrial symbiosis.

The EU has also completed an EU-wide regulatory framework on the geological storage of CO_2 under Directive 2009/31/EC. Moreover, the EU supports EU-wide carbon dioxide transportation under the Guidelines for Trans-European Energy Infrastructure (Regulation (EU) 347/2013), where projects contribute to the avoidance of CO_2 emissions while maintaining security of energy supply and to the resilience and security of CO_2 transport, and support the efficient use of resources by enabling the connection of multiple carbon dioxide sources and storage sites through common infrastructure, thus minimising environmental burden and risks.

Two large-scale CCUS projects are currently operating in the EU, together capturing and safely storing around 1.6 $MtCO_2$ per year. Six new large-scale CCUS projects were announced in Europe in 2018. By the end of 2019, there were only two long-standing CCS projects operating, both in Norway. There are several projects under development in Ireland, the Netherlands, Norway and the United Kingdom. For example, in Norway, feasibility studies are under way for CO_2 capture from a cement facility and from a waste-to-energy recovery plant. A partnership between Equinor, Shell and Total is developing offshore CO_2 storage in the North Sea to support Norway's plans for a fully integrated industrial project. Gas Networks Ireland is considering the development of CCS at two gas-fired power plants in the Cork area (Ireland), with CO_2 storage taking place off the coast.

Interest in developing CCUS hubs in industrial centres is increasing in a number of locations in the EU, driven by decarbonisation objectives and the potential to attract and maintain industry investment. Porthos is one of the most advanced projects. It aims to build a CCUS hub in the Rotterdam port area (Netherlands) through an onshore pipeline, collecting CO_2 from different industrial sites, and then use a small share of the captured CO_2 (2 $MtCO_2$ to 5 $MtCO_2$ annually by 2030) in greenhouses, while the bulk is stored underground off the Dutch coast. The potential of CCUS hubs is also recognised by the UK government, which has designated several promising locations, including Teeside, St Fergus, Grangemouth, Humberside, Merseyside and South Wales.

Assessment

As part of the EGD, the EU announced a new industrial strategy, including the revision of measures that address pollution from large industrial installations and of ETS pricing. The latter includes the review of the carbon leakage list and the incentives for industry to promote carbon reductions in its supply chain. The revision of the EU ETS state aid guidelines for the next trading period (starting on 1 January 2021) needs to ensure state aid is provided to incentivise the modernisation of production processes.

There are no dedicated EU rules on energy efficiency and carbon reductions in industry, apart from the ETS and the requirement of an energy efficiency management audit. The ETS has not resulted in major emissions reductions from industry since 2012. It is also unclear what impact the energy audit requirement has had on the actual energy savings, perhaps due to the lack of a strategic approach to energy management. Following the example of India (Perform, Achieve, Trade scheme) or Japan, specific targets (through energy efficiency indicators) could be set for key sectors (combining them with white certificates schemes, or the ETS, or other obligations).

Overall, emphasis should be placed on the relative costs and benefits of implementing energy policy measures in industry, so that public funds can be channelled to those technologies and actors that provide best value for money.

In industry, energy efficiency has to play a strong role in the management of the energy transformation. The IEA concludes that the EU could save 32 Mtoe in industry by 2040, under the IEA Efficient World Strategy, compared with a business-as-usual scenario. Savings would come from cost-effective measures including EMSs, minimum efficiency performance standards for motors (motors efficiency could be improved by 34%), industry management networks and greater electrification, including the use of electric heat pumps among others.

Focus needs to be placed on both energy-intensive and less intensive sectors. IEA analysis finds that up to 60% of total energy savings can come from the less intensive ones. For SMEs, the availability of energy efficiency audit funding and energy management training is not likely to be sufficient to unlock the potential in this sector. Wrap-around services, better links to finance and de-risking investments for financial institutions (similar to enhancements made within the Energy Performance in Buildings Directive) may help in this regard.

While the EU has further streamlined its rules on renewables and energy efficiency, especially SMEs are new to the uptake of renewable energy in heating and cooling. Industry thus far has not shown evidence of purchasing renewable heating and cooling to the same degree that it has shown an appetite for purchasing renewable electricity. There may also be opportunities for industrial co-generation systems to supply district heat.

Carbon pricing and carbon leakage need to be reviewed. As the EU is contemplating the introduction of a cross-border carbon adjustment tax, there is an opportunity to compare carbon pricing and equivalent measures globally. While such a tax mechanism will be very important for the industrial development of the EU, its actual design will require special attention to ensure that such a tax and its levels will be compatible with World Trade Organization rules and supported by the EU's major trading partners. Past experience of the Fuel Quality Directive has shown the difficulties with global carbon footprint accounting.

Commendably, the EU has started the engagement with energy-intensive industries, notably through the High-Level Expert Group on Energy-Intensive Industries and its master plan on the transformation of EU energy-intensive industries to enable a climate-neutral, circular economy by 2050. Technology and innovation will be the most important driver to decarbonise these hard-to-abate sectors.

For the petrochemical industry, the IEA recommends the EU adopt a value chain approach, ranging from primary chemical production to waste management. With regard to production, the EU should stimulate investment in research, development and demonstration of sustainable chemical production routes, establish and extend plant-level benchmarking schemes for energy performance and CO_2 emissions reductions targets, pursue effective regulatory actions to reduce CO_2 emissions, require industry to meet stringent air quality standards, and ensure through taxation that fuel and feedstock prices reflect actual market value.

With regards to the use and disposal of petrochemicals, the EU needs to reduce the reliance on single-use plastics other than for essential non-substitutable functions, improve waste management practice around the world, raise consumer awareness about the multiple benefits of recycling, promote product design with disposal in mind and extend producer responsibility to appropriate aspects of the use and disposal of chemical products.

For carbon neutrality, the EU needs to address energy use not only in the energy-intensive sectors but also in other sectors, and for instance take action on the demand side with material efficiency targets (see IEA, 2019e). The EU efficiency standards could promote designs to reduce the use of energy-intensive materials such as iron and steel, aluminium, cement, and plastic, and foster the substitution of these materials with less energy-intensive ones. This can include using timber, where possible, or waste from one sector for other sectors (using steel blast-furnace slag in cement production and waste from other industries as alternative fuels for cement production, for instance). Further, the EU needs to improve recycling processes, including the collection of scrap metals and the reuse of cement. The EU circular economy strategy, announced under the EGD, is a real opportunity for the industry sector.

And last but not least, the new EU industrial strategy needs to promote energy-efficient technologies such as electric arc furnaces for steel production where possible, while closing inefficient ones, and promote the electrification of processes, the use of hydrogen, carbon capture and the use of biomass.

CCUS is considered to be a part of any transition to a low-carbon economy, mostly in industry and heat but also in power generation. To facilitate CCUS, a number of instruments were put in place between 2009 and 2012, including Directive 2009/31/EC on the geological storage of carbon dioxide, the inclusion of CCS in the ETS, the New Entrants Reserve (NER300), the European Economic Programme for Recovery, the inclusion of CO_2 pipelines as infrastructure of common European interest and a network for sharing results between projects.

Today, the EU has only a few CCUS projects, but the momentum is still there. Plans for six new large-scale CCUS projects were announced in Europe in 2018 – which include industrial hubs and several projects with links to hydrogen. The Innovation Fund is potentially a large source of funding for new CCUS projects. Europe has only two large-scale CCS projects to date, both in Norway (natural gas processing). However, there are a large number of smaller projects, including demonstrations of direct air capture and bioenergy with CCS which could be important for net-zero ambitions.

While CO_2 utilisation may prove useful in some applications, and could help to kick-start a market for captured CO_2, it cannot deliver CO_2 emissions reductions at the scale of geological storage. CO_2 use is a complement, rather than an alternative for CO_2 storage. More large-scale CCUS projects are required to demonstrate the feasibility of the technology. Targeting lower-cost or strategic projects in industrial areas, which have opportunities for future expansion into CCUS hubs, could be key to unlocking early public and private investment in CCUS. These hubs could emerge in areas with emissions-intensive industrial processes (e.g. hydrogen or fertiliser plants), low project complexity, and proximity to CO_2 storage or transport infrastructure, and where there is demand for CO_2, for example for enhanced oil recovery or other utilisation options. Implicit to large-scale deployment of CCUS is the availability of an EU-wide regulatory framework to reduce risks and provide clarity for several issues that are unique to CCUS, including legal responsibility for stored CO_2 and cross-chain integration risks.

Recommendations

The European Union should:

- ☐ Work with industry, notably the petrochemical industry and the iron/steel sector, on dedicated decarbonisation strategies that integrate material efficiency approaches, energy efficiency, renewables, waste heat utilisation and circular economy, as well as energy technology and innovation efforts.
- ☐ Incentivise a strategic energy management approach in energy-intensive industry facilities by requiring savings identified through audits to be implemented, and by introducing annual reporting on energy, emissions and energy efficiency actions taken, and ensure these strategies are integrated into the EU ETS carbon leakage policy and long-term industry transformation initiatives.
- ☐ Design measures for less energy-intensive industries, including SMEs, to raise the awareness and capability to utilise their potential for energy efficiency and shift to renewables.
- ☐ Assess the carbon leakage risk for the EU industry sector and evaluate the need for a carbon cross-border adjustment tax, state aid and other measures needed to transform Europe's energy-intensive industry to the manufacturing of low-carbon products.
- ☐ Support demonstration and deployment of low-cost regional CCUS projects, accelerate CO_2 storage assessments and guide investment-related CO_2 transport and storage networks in key regions.

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7. Electricity

Key data

(2017)

Electricity generation: 3 269 TWh (nuclear 25.4%, coal [including oil shale and peat] 21.7%, natural gas 20.3%, wind 11.1%, hydro [including wave, tidal and ocean] 9.2%, bioenergy and waste 6.4%, solar 3.7%, oil 1.9%, geothermal 0.2%, others 0.1%), -2% since 2007

Installed capacity*: 1 011 GW, +27% since 2007

Electricity consumption (excluding transformation)**:** 2 798 TWh (industry 37.0%, services/other 31.8%, residential 28.9%, transport 1.9%), -2% since 2007

Renewable energy leaders: Ireland and Denmark (wind) and Germany, Italy, and Greece (solar)

*Eurostat (2019a),

Overview

The European electricity supply is rapidly changing towards much higher shares of variable renewable energy sources. Wind power has increased rapidly and was the largest source of renewable electricity already in 2017 (Figure 7.1), with offshore leading the growth in the sector. Renewables have become the largest source of low-carbon electricity, as nuclear has been declining. European Union (EU) countries lead globally in wind power deployment, both for onshore and more recently also offshore. Still, fossil fuels accounted for 44% of total electricity generation in 2017. Because of the decline in economic activity and overall decline in power demand in the EU during the Covid-19 pandemic related lockdowns, renewable energy generation has taken the lead as source of power generation, ahead of coal.

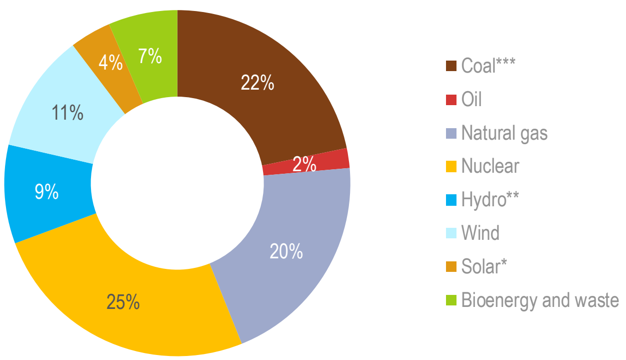
So, the power system of the EU is expected to see a more rapid transformation in the coming decade, with the new 2030 targets of 32% of renewables in final energy consumption, which translates into a renewables share of 50% in electricity. The International Energy Agency (IEA) expects wind power to become the leading fuel of electricity ahead of gas and nuclear well before 2025 (IEA, 2019a).

Over the past five years, the EU has made continuous progress in completing the internal electricity market, with most of the EU's borders and prices under market coupling, while increasing the interconnectivity with the periphery, including the Baltics, Turkey and North Africa.

The EU has upgraded its market design to prepare it for the power system transformation the EU is experiencing. The institutional structures are in place to ensure harmonised network codes and rules for cross-border trading, along day-ahead, intraday and balancing market time frames, as well as enhanced system operation and security of supply rules. The Clean Energy Package (CEP) was adopted in 2019 and has codified these new rules for the wholesale market architecture. So the full implementation of the CEP has only just started. It will bring along greater flexibility, including at the retail market level, allowing active consumer participation, greater distributed energy deployment and demand response. The new electricity market design in the EU is an inspiration for many large regional electricity markets around the world and a source of many lessons learned and best practices in wholesale market integration. In no other region of the world do cross-border electricity grids contribute so significantly to system integration of variable renewable generation as in the EU.

Moreover, electricity is expected to play a key role on the road to climate neutrality under the European Green Deal. The IEA *World Energy Outlook* Stated Policies Scenario (STEPS) expects the share of electricity in final consumption to reach 30% by 2040 (IEA, 2019a) or even towards 40% in 2040, under the Sustainable Development Scenario (SDS).

Figure 7.1 Electricity supply by source, 2017



In 2017, the EU's electricity generation mix consisted of 44% fossil fuels, 31% renewables and waste and 25% nuclear.

**Coal* includes brown coal, hard coal, other coal products, oil shale and peat.

***Hydro* includes tidal/wave/ocean.

****Solar* includes minor shares of geothermal.

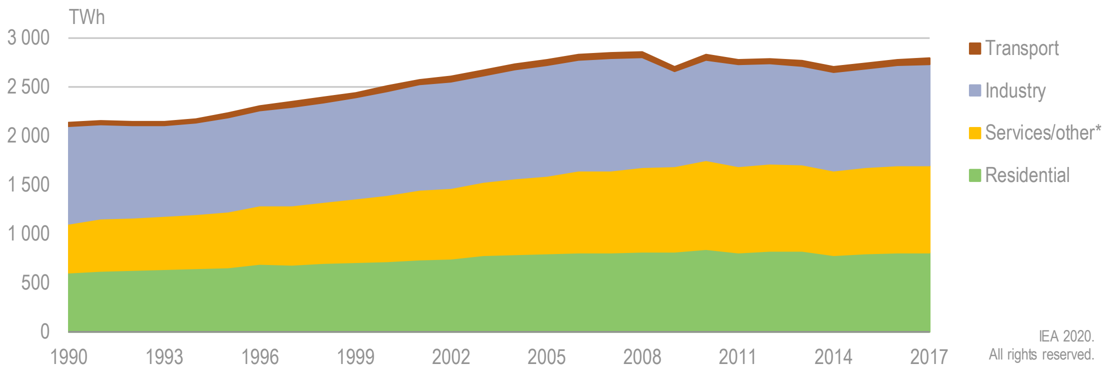
Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

Supply and demand

After a steady increase since the mid-1990s, electricity demand in total final consumption (not including use in energy transformation) has been relatively stable around 2 800 terawatt-hours (TWh) during the last decade. The industry sector is the largest consuming sector with 37% of total demand in 2017, followed by the service sector at 32%, the residential sector at 29% and transport at 2% (Figure 7.2).

After the global financial crisis in 2008, electricity consumption by industry dropped by 14% in 2009. Consumption has picked up since, but is not yet back to pre-crisis levels, with a ten-year decline of 9% between 2007 and 2017. Meanwhile, electricity consumption in the services sector has been on the rise. Residential electricity consumption shows annual variations due to the use of electricity for heating, but the long-term trend has been stable. This indicates that a growth in the number of electrical household appliances has been compensated by efficiency improvements of appliances.

Figure 7.2 Total electricity consumption by sector in the EU, 1990-2017



EU electricity consumption has stabilised at around 2 800 TWh per year over the past ten years, after having increased by 20% the decade before.

**Services/other* includes commercial and public services, agriculture, forestry and fishing.
Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

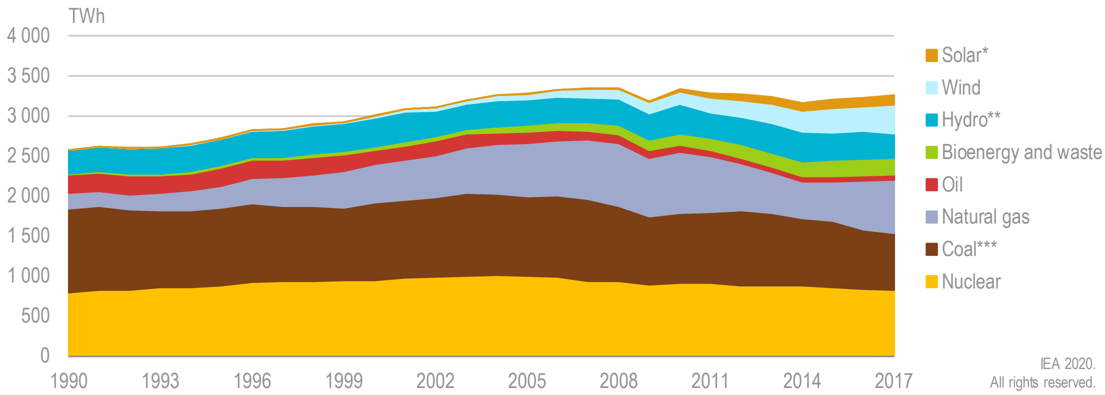
Over the past decade, the share of electricity in total final consumption has remained around 20% and not grown substantially; it has even seen a small decline since 2014.

Stable electricity demand kept generation growth flat around 3 250 TWh per year in the past decade (Figure 7.3), but the composition of the mix has changed significantly with the rapid growth in renewables. From 2007 to 2017, renewable electricity nearly doubled from 516 TWh to 975 TWh. Wind power in particular has increased rapidly; in 2017, it accounted for 11% of the total generation and overtook hydropower (9%) as the largest renewable power source. Solar power has also grown rapidly, but its rate of growth has slowed down in recent years as many countries have changed from feed-in tariffs to auctions in their support for renewable electricity.

Despite the fast growth in renewables, fossil fuels still accounted for 44% of total electricity generation in 2017 (coal 22%, natural gas 20% and oil 2%). Natural gas power has gone through major changes in the last decade, from a peak production of 790 TWh in 2008, down to 458 TWh in 2014, and up again to 663 TWh in 2017. Meanwhile, coal has seen a reverse trend. This reflects changes to prices for gas versus coal on European markets. In recent years, coal use has been declining as several EU countries are actively phasing out coal use in power generation (see Chapter 13 on Coal).

Nuclear energy remains a large electricity source in the EU, accounting for 25% of total generation in 2017. However, nuclear generation has declined by 11% in the last decade, and as of 2014, renewable electricity generation replaced it as the largest source of low-carbon power. Despite its contribution to low-carbon electricity, the future of the ageing nuclear fleet in Europe is uncertain as some countries have adopted phase-out policies, notably Germany, while several countries are building new reactors, including ongoing constructions in Finland, France, Hungary, Slovakia and the United Kingdom besides planned nuclear new builds in Bulgaria, the Czech Republic and Poland (see Chapter 10 on Nuclear).

Figure 7.3 Electricity supply by source, 1990-2017



Electricity generation illustrates the EU transition from fossil fuels towards renewable energy, which share in total generation doubled from 15% in 2007 to 30% in 2017.

**Solar* includes minor shares of geothermal.

***Hydro* includes tidal/wave/ocean.

****Coal* includes brown coal, hard coal, other coal products, oil shale and peat.

Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

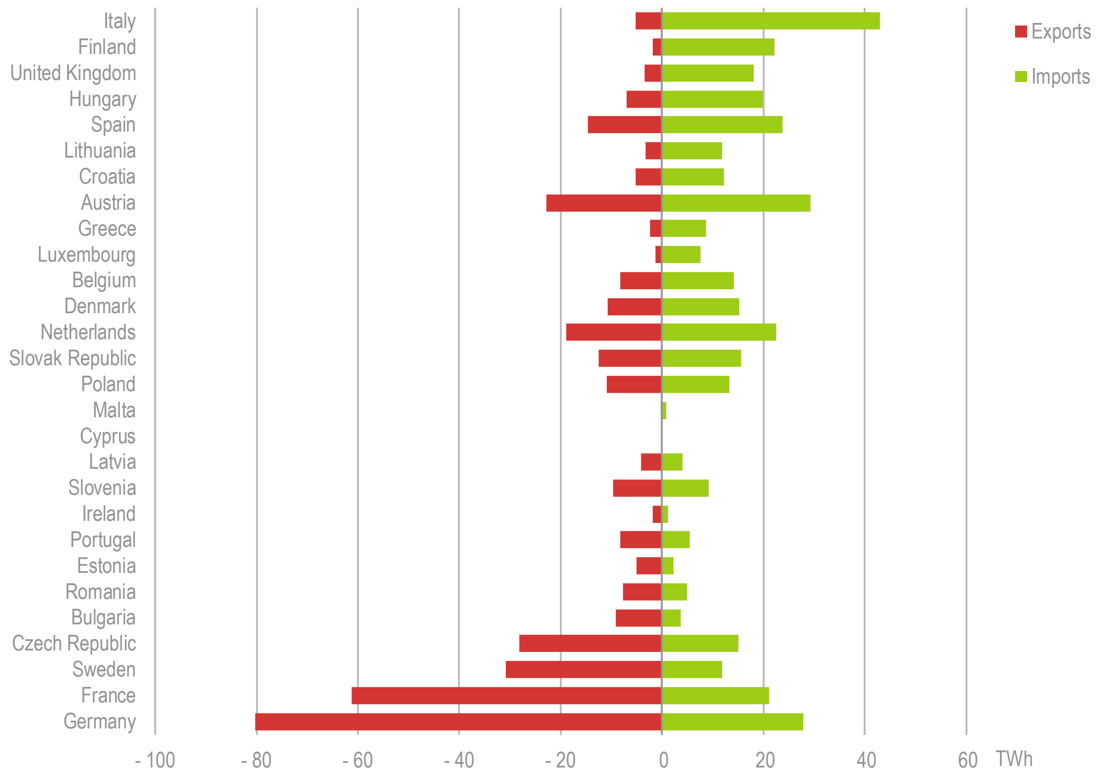
Imports and exports

The EU has large intra-EU trade flows. For instance, Luxembourg and Lithuania rely heavily on electricity imports (net imports of electricity in Luxembourg represented 96.6% of electricity consumption and in Lithuania 79.2%). Large net exports of electricity are witnessed in Estonia (35.4%), the Czech Republic (22.1%), Bulgaria (17.5%) and Sweden (14.6%). In 2017, the largest net importers of electricity in absolute volumes were Italy, Finland and the United Kingdom, while Germany, France and Sweden were the largest net exporters of electricity within the EU (Figure 7.4).

However, net imports of electricity from outside the EU represented only 0.4% of the electricity consumption in 2017.

The EU has placed a major focus on enhancing electricity trade within the EU, making market integration and connecting so-called energy islands a key priority, notably for the EU member states that are insufficiently connected to the EU continental electricity region, such as the Iberian Peninsula and the Baltic Sea region. At the same time, over the past five years, the EU has been increasing its electricity interconnectivity to the neighbouring systems, outside the EU, a process that is guided by the European Commission and the European Network for Transmission System Operators for Electricity (ENTSO-E).

Figure 7.4 Intra-EU power imports and exports, 2017



Electricity trade is large within the EU, with Germany, France, Sweden and the Czech Republic as leading net exporters. Italy, Lithuania and Greece largely rely on imports.

Source: Eurostat (2017), Electricity consumption and trade, 2017, Eurostat (nrg_nrg_cb_e), https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Electricity_consumption_and_trade,_2017_(GWh).png

Building on the Baltic Energy Market Interconnection Plan (BEMIP), the EU is creating an open and integrated regional electricity (and gas) market among EU countries in the Baltic Sea region, ending the energy isolation of Estonia, Latvia and Lithuania. These countries have grown increasingly interconnected with Continental Europe thanks to new electricity lines with Poland (LitPol Link), Sweden (NordBalt) and Finland (Estlink 1 and Estlink 2) and form part of the Nordic power market. However, the Baltic States' power system is still asynchronously connected to Continental Europe – for historical reasons it is operated in a synchronous mode with the Russian Federation and Belarusian systems. The synchronisation with Continental Europe has been under preparation since 2009, starting with the signature of a joint declaration of principles. In June 2018, the prime ministers of Estonia, Latvia and Poland and the presidents of Lithuania and the European Commission signed a joint political roadmap, which is to connect the Baltic States to the Continental European electricity network through Poland by 2025. In May 2019, the agreement on the conditions for a future synchronous interconnection entered into force, following the application made by the Baltic States transmission system operators (TSOs) (Elering, AST and Litgrid) and supported by the Polish TSO (PSE), which are all members of ENTSO-E.

In the south-east region, Turkey's electricity system is synchronously connected (though with only a small connection capacity) after its successful synchronisation with the ENTSO-E Continental Europe region. This process started in 2000 and led to the signature in

April 2015 of a long-term agreement on permanent synchronous operations between Turkish electricity transmission operator TEIAS and the continental European members of ENTSO-E. Since 2016, TEIAS is an observer to ENTSO-E.

Electricity trade with North Africa (mainly between Spain and Morocco) has also increased in recent years. Morocco plans to reinforce the interconnection with Spain through a third 400 kilovolt subsea interconnector and plans to add interconnectors to Portugal. Several EU countries (France, Germany, Portugal and Spain) are working on the implementation of the Roadmap for Sustainable Electricity Trade between Morocco and the European Internal Energy Market, a declaration which was signed in November 2016 during the 22nd Conference of the Parties (COP22) in Morocco and was launched in December 2017.

Assessment framework of the power chapter

Based on the characteristics of the EU power system and its institutional governance, including the level of interconnectivity, market design and system operation as well as the structure of the industry, this report examines challenges and opportunities for the power system transformation to foster environmental goals, economic efficiency of the power markets, and the security and reliability of the system. A good practice policy framework needs to satisfy at least three main objectives:

- Align with environmental goals in support of the clean energy transition.
- Maximise economic value of investments and consumer outcomes.
- Ensure power system security (adequacy/reliability, flexibility and resilience).

The following assessment is therefore divided in three parts (sections A, B and C). In section A the latest trends in the transformation of the EU electricity system with very high shares of renewable energy will be examined. Section B will examine how the regulatory framework is being revised to meet those new demands, while section C explores the electricity security impacts and the need for new ways of system operation and system planning in the EU.

A - The EU power system is decarbonising

The installed power generation fleet of the 28 members of the European Union (EU28) is transforming. The total installed electricity generating capacity increased by 46.2% during 2000 to 2017 to reach 1 000 gigawatts (GW). In 2000, fossil fuels accounted for 58%, and hydro and nuclear for 20% each. The role of nuclear has significantly decreased over the past decades. In 2017, the installed capacity of renewable energy (45%) was larger than fossil fuels (40%), while the remainder came from nuclear (12%) and other sources (including pumped hydro and non-renewable waste, 3%) (Table 7.1).

Table 7.1 Evolution of installed electricity capacity in the EU28, 2000, 2010, 2017

Total EU electrical capacity (MW)	2000	2010	2017
Total	691 626	883 710	1 010 998
Combustion fuels	401 342	487 685	455 115
Hydro	139 014	147 327	155 118
Geothermal	604	762	848

Total EU electrical capacity (MW)	2000	2010	2017
Wind	12 709	84 323	168 933
Solar	177	30 788	109 014
Tide, wave, ocean	214	220	242
Nuclear	137 337	131 731	120 884
Other sources	229	883	843

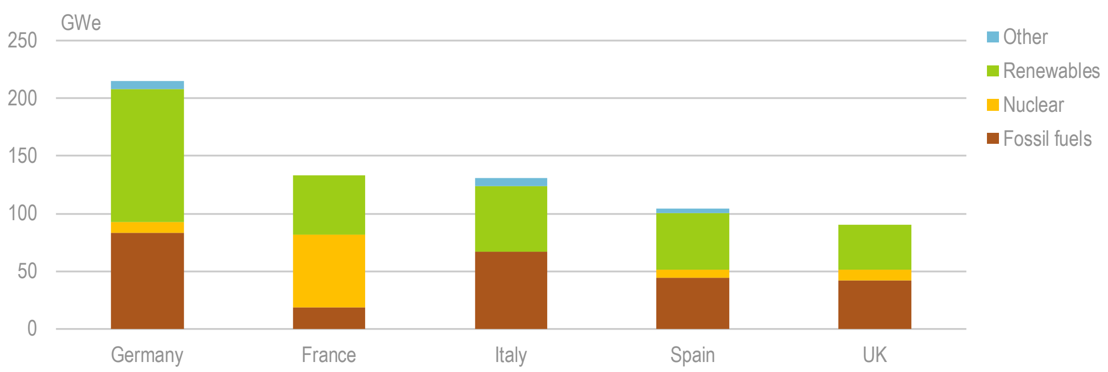
Notes: MW = megawatts. Solar includes solar thermal and solar photovoltaic (PV). Hydropower includes pure hydro, mixed hydro and pumped hydro power.

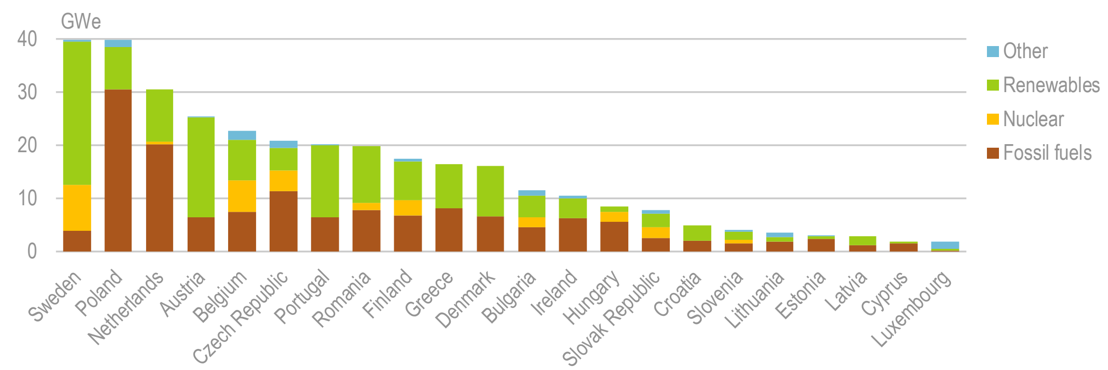
Source: Eurostat (2018a), Installed electrical capacity, https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_and_heat_statistics#Installed_electrical_capacity

Germany, France, Italy, Spain and the United Kingdom (UK) accounted for 67% of total installed capacity. Sweden, Austria, Portugal, Romania, Denmark, Finland and Greece have large renewable capacity installed, if counting all renewable capacity, including hydro and bioenergy (Figure 7.6).

Figure 7.5 Electricity installed generating capacity by country and source, 2017

The five largest countries





Total installed capacity in the EU was around 1 000 GW in 2017. Germany, France, Italy, Spain and the United Kingdom accounted for two-thirds of total capacity in the EU28.

Source: ENTSO-E (2019a), Statistical factsheet 2018 (data for Malta were not available), docstore.entsoe.eu/Documents/Publications/Statistics/Factsheet/entsoe_sfs2018_web.pdf.

EU policies for power sector decarbonisation

While the choice of the fuel mix used for electricity generation falls within the national sovereignty of each member state, the EU has adopted several policies that drive the transformation towards cleaner energy sources, most notably the EU Emissions Trading System Directive (based on 2009/29/EC), the first Renewable Energy Directive (RED I) (2009/28/EC) and most recently, the CEP, which promoted a more ambitious future for 2030, which includes RED II. In the field of state aid, the 2014 Guidelines for Environmental Protection and Energy Aid (EEAG) supported the shift to large-scale renewable auctions.

RED I set an EU-wide target of 20% of renewable energy in gross final energy consumption, which was to be achieved through binding national targets for 2020 for each country, with trajectories set out Annex I of the directive. Progress towards these national targets is measured every year in the State of the Energy Union report. RED I also promoted the co-operation among EU member states (and with countries outside the EU) to help them meet their 2020 national renewable energy targets, in the form of statistical transfers, joint projects or joint support schemes. To meet the 2020 targets a number of member states are expected to use the mechanisms.

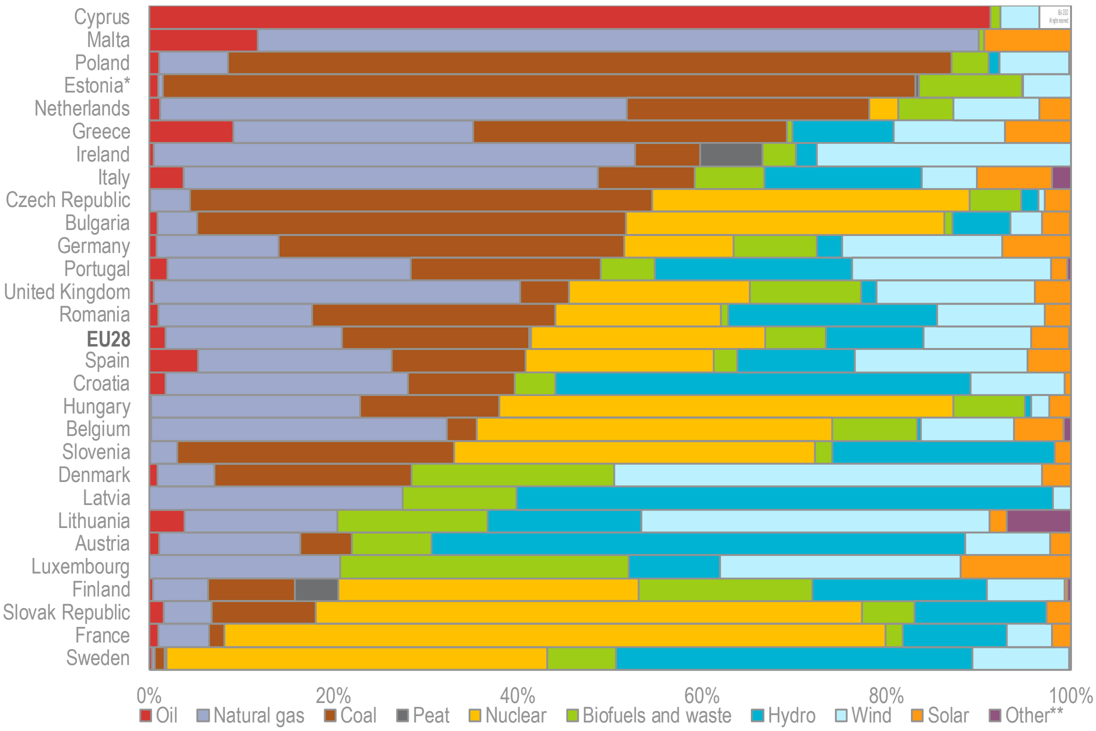
In December 2018, the revised RED II (2018/2001/EU) entered into force as part of the CEP, with a binding target of at least 32% renewable energy share in EU gross final energy consumption by 2030, which can be revised upwards by 2023. Under the RED II, there will be no more national targets set by the EU but instead, it is up to the member states to define their ambitions (as long as they go beyond their previous ones) in the National Energy and Climate Plans (NECPs). Achievement of the 2030 EU target will depend on the ambition and effectiveness of these national strategies and use of co-operation mechanisms. RED II sets out general principles that member states should follow when designing support schemes. RED II also contains rules for the streamlining of permitting, for self-consumption of renewable electricity and remuneration for grid injection, as well as for guarantees of origin. The directive also strengthened EU sustainability criteria for bioenergy, which now cover solid biomass and biogas used in large heat and power plants (above 20 MW fuel capacity).

For renewable electricity, tenders have been increasingly successful in fostering competition and allowing cross-border investment. Under the EEAG the EU has prompted a shift from feed-in-tariffs to feed-in premiums and competitive auctions, which support the integration of renewables in the electricity market. This has led to a spectacular reduction in the level of state aid required per megawatt-hour (MWh) in a very short period of time. Since auctions were introduced in Germany, an almost 50% reduction was observed for solar and zero-subsidy bids for offshore wind in Germany and the Netherlands (even if the public authorities/TSOs still shoulder part of the grid connection costs). Moreover, EU rules require market integration so that renewables installations adjust their output to electricity demand and cannot be paid for generating electricity when electricity prices are negative.

The Electricity Market Regulation (2019/943) sets an emissions performance standard for capacity included under the capacity remuneration schemes in EU member states at the level of 550 grammes of CO_2 per kilowatt-hour or or 350 kg CO_2 per year per kWe installed capacity. The new standard applies to new plants from 4 July 2019 and to existing ones as of 1 July 2025, which discourages new coal plants being constructed in the EU.

At the national level, the electricity mix varies substantially across EU member countries (Figure 7.6). Fossil fuels accounted for around 90% of total generation in Poland, Malta and Cyprus,[33] but for less than 10% in Sweden and France. Among the group of low-carbon electricity leaders, 15 countries rely on nuclear power, which, for instance, accounts for up to 72% of power generation in France. Hydropower contributes up to 58% of electricity generation (in Latvia and Austria) and wind up to 46% (in Denmark).

Figure 7.6 Electricity supply by country and source, 2017



The electricity generation mix varies significantly across the EU countries, with the share of fossil fuels ranging from 2% to 91% of total generation.

*Estonia's coal is oil shale.

***Other* includes geothermal and electricity from excess heat.

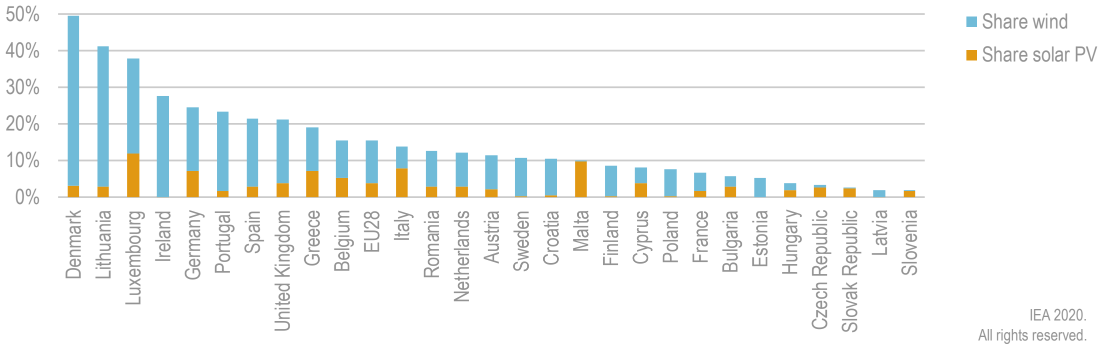
Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

Ireland and Denmark (wind) and Germany, Italy and Greece (solar) are the renewable leaders, in terms of generation, as illustrated in Figure 7.7. As a whole, the EU has increased the share of renewable energy in electricity generation in the last decade. From 2007 to 2017, the share of renewable energy in total electricity generation in the EU has nearly doubled from 15% to 30% (Figure 7.8). Electricity generation from renewables in

[33] Two footnotes: 1. Footnote by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of United Nations, Turkey shall preserve its position concerning the "Cyprus issue". 2. Footnote by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

the EU has largely relied on the growing role of bioenergy in the previous decade, while wind has pushed up its significance since 2011 (Figure 7.8). Wind is the renewable source of electricity that has increased most rapidly in recent years, accounting for 11% in 2017, followed by solar, at 4%. Electricity generation using bioenergy has gradually increased since the 1990s, accounting for 6% of total generation in 2017. Including hydropower, the share of renewables reached 30% in total EU generation in 2017.

Figure 7.7 Electricity generation from wind and solar PV by country, 2018

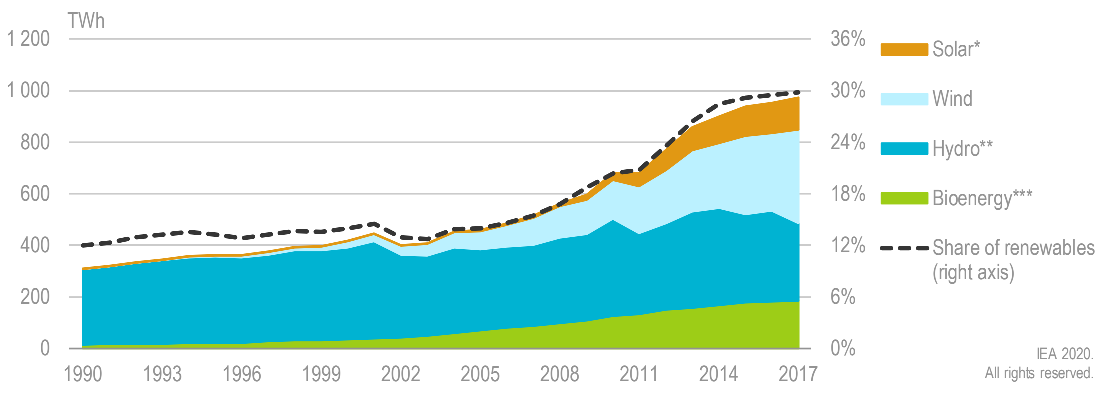


Electricity generation from wind and solar PV shows a very diverse picture, with several countries being the wind and solar leaders while others have very low shares.

Note: Electricity generation in Lithuania and Luxembourg is mostly covered through imports. The share of wind and solar PV therefore reflects the import portfolio rather than domestic generation.

Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/. IEA (2019c), *Electricity Information 2019* www.iea.org/statistics.

Figure 7.8 Renewable energy in electricity generation, 2007-17



Electricity generation growth from renewables in the EU has largely relied on the growing role of bioenergy in the previous decade, while wind has pushed up its significance since 2011.

**Solar* includes a minor share of geothermal.

***Hydro* includes small shares tidal/wave/ocean.

****Bioenergy* includes primary solid biofuels, liquid biofuels, biogases and renewable municipal waste.

Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics/.

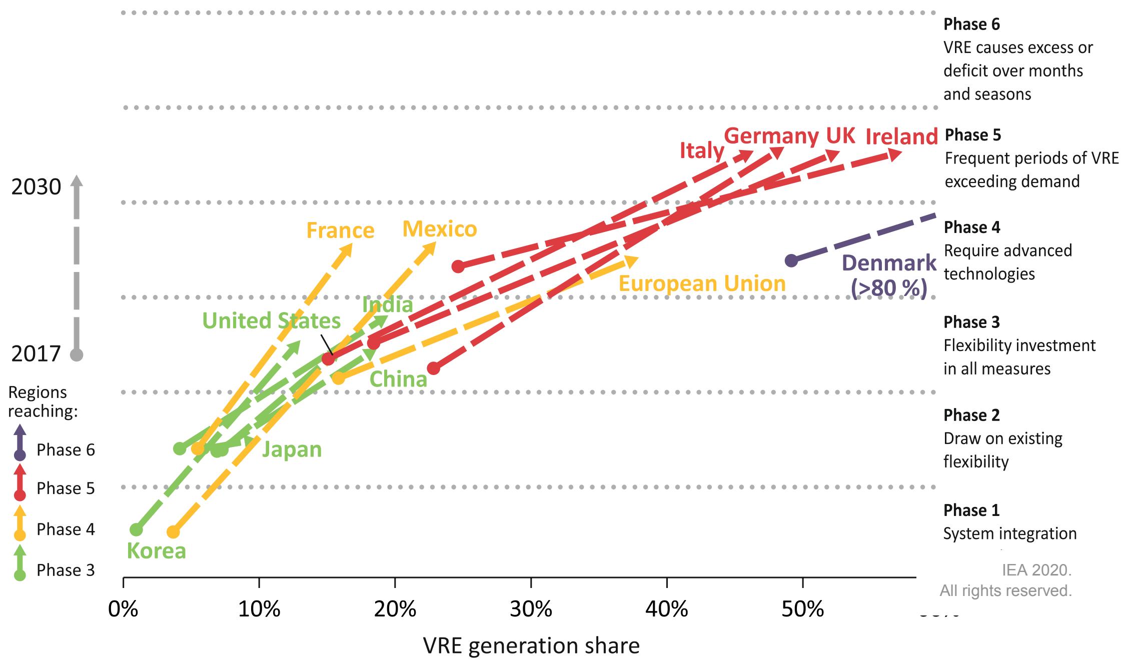
Medium- to long-term outlook for the role of electricity

The role of electricity is expected to increase in the coming decade. The EU long-term vision to 2050 contains in all scenarios high end-use electrification which would see the share of electricity in final energy consumption grow to 53% by 2050, from 20% in 2018. For the EU, the IEA SDS (which has 60% EU emissions reductions by 2030) expects the share of electricity to reach almost 40% by 2040 and 46% by 2050. Not all end uses can be electrified.

In the medium term, the largest transformation will come from the role of renewables. The share of variable renewables (wind/solar) in the electricity mix is expected to reach 50% by 2030 driven by the RED II target.

In the medium term up to 2030, several EU member states (Denmark, Ireland, Italy, Germany) are going to see high and very high shares of variable renewables, while the EU electricity mix as a whole will see shares above 35% and require growing system flexibility needs from advanced technologies, as it enters phase four of system integration (Figures 7.9 and 7.10), which means that a larger portfolio of flexibility services is needed at several moments in time and locations.

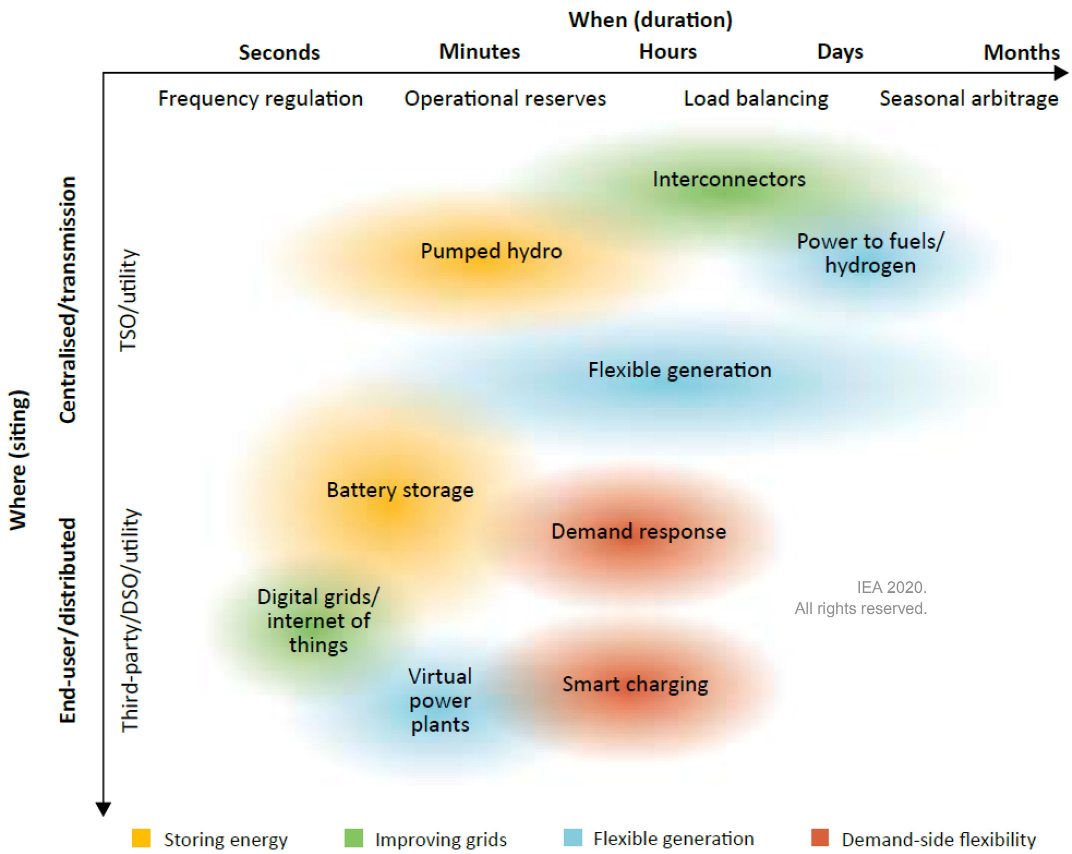
Figure 7.9. System integration in the EU and its main leading markets in comparison with selected international partners



Notes: VRE = variable renewable energy. This report is based on the analysis of policies and data until end of 2019 and does not take into account the withdrawal of the United Kingdom from the EU.

Source: IEA (2018), *World Energy Outlook 2018*.

Figure 7.10 Flexibility needs increase across a larger portfolio of services and time frames



Note: DSO = distribution system operator.

B - Electricity markets to maximise investments and consumer outcomes

Regulatory framework

Building upon the first, second and third liberalisation packages of legislation, the EU adopted a new electricity market design under the CEP, which entered into force on 4 July 2019 with four pieces of legislation:[34]

- Regulation (EU) 2019/943 on the internal market for electricity (Electricity Regulation)
- Directive (EU) 2019/944 on common rules for the internal market for electricity and amending Directive 2012/27/EU (Electricity Directive)
- Regulation (EU) 2019/941 on risk preparedness in the electricity sector and repealing Directive 2005/89/EC

[34] The provisions of the Electricity Regulation entered into force on 1 January 2020. Member states have 18 months for the transposition of the Electricity Directive.

- Regulation (EU) 2019/942 establishing a European Union Agency for the Cooperation of Energy Regulators (recast) (ACER Regulation).

The CEP provisions foster scarcity pricing and aim to reward flexibility for generation, demand response and storage; avoid overcapacity by co-ordinating national resource adequacy assessments, taking a regional and European perspective; and encourage the explicit cross-border participation in capacity remuneration mechanisms (CRMs).

The CEP also establishes common rules on crisis prevention, co-operation among national authorities and reinforcement of regional TSO co-operation through Regional Coordination Centres (RCCs); includes an enhanced bidding zone review process; and fosters the maximisation of cross-border capacity and non-discrimination between internal and cross-border exchanges.

At the retail level, the CEP supports faster switching of suppliers, enables consumers to access dynamic pricing and ensures stronger TSO-DSO co-operation, including better governance and representation of DSOs at EU level through the new EU DSO entity. In line with the unbundling principle, the CEP provides for rules to ensure that flexibility services such as storage are provided in a competitive manner where possible.

Within the context of the third package, common rules for TSOs form the basis for the dynamic regulatory framework based on the so-called electricity network codes and framework guidelines, whose principles are part of the Electricity Regulation and include:

- **Market codes** (day-ahead and intraday capacity allocation and congestion management, electricity balancing, and forward capacity allocation), critical for real-time markets, flexibility for the integration of variable renewables, cross-border balancing, flow-based market coupling, the review of the bidding zones and the TSO-DSO interface for greater flexibility; the market codes notably set up the regulatory framework for EU-wide day-ahead and intraday market coupling.
- **Operational codes** (system operation, emergency and restoration), which enhance security of supply to plan, monitor and operate the EU-wide interconnected grid with new sources of supply, by introducing mandatory regional security co-ordinators, common capacity calculation and emergency restoration procedures.
- **Grid connection codes** (generators, high-voltage direct current, demand side), which will enable the integration of renewables, distributed generation, demand response and smarter consumption.

Moreover, the EU's competition and internal market rules aim to preserve the integrity of the EU single market, i.e. avoid undue separation of electricity markets (e.g. along national lines instead of physical system characteristics) and address distortions of competition and trade that may arise from state aid or anti-competitive company practices in the sector.

Governance and regulation at the EU level

The third liberalisation package created ENTSO-E, bringing together all TSOs. The Electricity Directive (2019/944/EU) establishes a similar body for the distribution sector, the European DSO entity. Power exchanges have also been included under the regulatory framework as Nominated Electricity Market Operators (NEMOs).

The CEP provides for enhanced co-ordination among TSOs, obliging them to establish RCCs. RCCs will perform operational security analyses of the region and recommend to TSOs the most effective and economically efficient remedial actions. RCCs will replace Regional Security Coordinators and shall be operational as of 1 July 2022 (see section below on Power System Security).

Under Regulation (EU) 2019/942, the competences and procedures of ACER, created by Regulation 713/2009, have been strengthened with regard to EU-wide co-ordination of regulatory decisions on cross-border issues that are vital for the market integration. ACER has additional competences to ensure tighter European and regional co-operation, effective implementation of market rules and wholesale/retail market surveillance.

ACER has been given oversight of the RCCs to support the monitoring and implementation of the related cross-border rules, including the configuration of the RCCs. ACER's role is to ensure co-operation of TSOs and DSOs at the European level through their European bodies (ENTSO-E and EU DSO entity), to co-ordinate national regulators, and to approve the European-wide methodologies for cross-border trade, operational security, generation adequacy assessments, the review of bidding zones configuration, and use of congestion income. With regard to electricity emergency preparedness, ACER has to approve the methodology for the identification of electricity crisis scenarios.

The backbone of the EU electricity market is the national TSOs, which are partly ownership unbundled (see Table 7.2). Austria, Germany and the United Kingdom have more than one TSO. Also, third parties can own and operate transmission links, and are exempt from some TSO obligations. The third energy package provided for the unbundling rules and allowed, besides ownership unbundling (OU), two other options, including the frequently used independent transmission operator (ITO), where the transmission company forms part of a vertically integrated company but is independent in its operations, and the independent system operator (ISO), which does not own the networks.

In 2019, there were practically no ISOs in the EU (except Latvia and Romania). Many TSOs are state owned and in many countries the effectiveness of OU relies to a large extent on the separation of control between the owners (Ministry of Finance) and the operational decision-making (Ministry of Energy). This concerns Austria, the Czech Republic, Estonia, Ireland, Lithuania, Slovenia and the Netherlands. The European Commission has a formal review role for TSO certification by national regulators, which also includes security of supply elements when it comes to the financial participation of third-country investors (e.g. the People's Republic of China's ["China"] SGID in the case of the Greek TSO ADMIE or investment in offshore electricity cables).

Each country has a NEMO per bidding zone. For instance, in the case of Austria three NEMOs are in place: EPEX Spot, EXAA and Nord Pool AS. NEMOs develop and maintain the algorithms, systems and procedures for single day-ahead market coupling and single intraday market coupling. NEMOs administer cross-border capacity and collect, validate and transmit the data generated by market coupling.

Table 7.2 The main TSOs in the European Union

Country	Name of the TSO	Abbreviation	Unbundling
Austria	Austrian Power Grid AG	APG	ITO
	Vorarlberger Übertragungsnetz GmbH	VUEN	ITO
Belgium	Elia System Operator SA	Elia	OU
Bulgaria	Electroenergien Sistemen Operator EAD	ESO	ITO
Croatia	HOPS d.o.o.	HOPS	ITO
Czech Republic	ČEPS a.s.	CEPS	OU
Cyprus[35]	Cyprus Transmission System Operator	Cyprus TSO	
Denmark	Energinet.dk	Energinet.dk	OU
Estonia	Elering AS	Elering AS	OU
Finland	Fingrid Oyj	Fingrid	OU
France	Réseau de Transport d'Electricité	RTE	ITO
Germany	TransnetBW GmbH	TransnetBW	ITO
	TenneT TSO GmbH	TenneT DE	OU
	Amprion GmbH	Amprion	ITO
	50Hertz Transmission GmbH	50Hertz	OU
Greece	Independent Power Transmission Operator S.A.	IPTO	ITO
Hungary	MAVIR Magyar Villamosenergia-ipari Átviteli Rendszerirányító Zártkörűen Működő Részvénytársaság	MAVIR ZRt.	ITO
Ireland	EirGrid plc	EirGrid	ITO
Italy	Terna – Rete Elettrica Nazionale SpA	Terna	OU
Latvia	Augstsprieguma tīkls	Augstsprieguma tīkls	ISO
Lithuania	Litgrid AB	Litgrid	OU
Luxembourg	Creos Luxembourg S.A.	Creos Luxembourg	ITO
Netherlands	TenneT TSO B.V.	TenneT NL	OU
Poland	Polskie Sieci Elektroenergetyczne S.A.	PSE S.A.	ITO
Portugal	Rede Electrica Nacional, S.A.	REN	OU
Romania	C.N. Transelectrica S.A.	Transelectrica	ISO
Slovak Republic	Slovenska elektrizacna prenosova sustava, a.s	SEPS	ITO
Slovenia	ELES, d.o.o.	ELES	OU
Spain	Red Eléctrica de España S.A.	REE	OU
Sweden	Svenska kraftnät	Svenska kraftnät	OU
United Kingdom	National Grid Electricity Transmission plc	National Grid	OU
	System Operator for Northern Ireland Ltd	SONI	
	Scottish Hydro Electric Transmission plc	SHE Transmission	
	Scottish Power Transmission plc	SPTransmission	

[35] Two footnotes: 1. Footnote by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of United Nations, Turkey shall preserve its position concerning the "Cyprus issue". 2. Footnote by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

Table 7.3 NEMOs for the day-ahead market

Country	Name of the NEMO
Austria	Nord Pool AS
	EPEX Spot SE
	EXAA AG
Belgium	Nord Pool AS
	Belpex SA
Bulgaria	Independent Bulgarian Power Exchange (IBEX)
Croatia	CROPEX Ltd
Czech Republic	OTE a.s.
Denmark	Nord Pool AS
	EPEX Spot SE
	Nasdaq
Estonia	Nord Pool AS
	Epex Spot SE
Finland	Nord Pool AS
	Epex Spot SE
	Nasdaq
France	Nord Pool AS
	EPEX Spot SE
	Nasdaq
Germany	Nord Pool AS
	EPEX Spot SE
	Nasdaq
Greece	LAGIE S.A.
Hungary	HUPX Zrt.
Ireland	EirGrid plc
	Nord Pool AS
Italy	GME Spa
Latvia	Nord Pool AS
	EPEX Spot SE
Lithuania	Nord Pool AS
	EPEX Spot SE
Luxembourg	Nord Pool AS
	EPEX Spot SE
	Nasdaq
Netherlands	Nord Pool AS

Country	Name of the NEMO
	EPEX Spot SE
Poland	Towarowa Gielda Energii S.A.
	Nord Pool AS
	EPEX Spot SE
Portugal	OMIE S.A.
Romania	OPCOM S.A.
Slovak Republic	OKTE a.s.
Slovenia	BSP Regionalna Energetska Borza d.o.o.
Spain	OMIE S.A.
Sweden	Nord Pool AS
	EPEX Spot SE
	Nasdaq
United Kingdom	Nord Pool AS
	System Operator for Northern Ireland Ltd (SONI)
	EPEX Spot SE
	Nasdaq

Wholesale electricity markets

Europe's market design is based on zonal national "energy-only" markets for electricity which are in place in all EU member states; in some countries CRMs complement the "energy only" markets.

The EU electricity market rules under the CEP promote three goals:

- improved functioning of national markets by limiting state interventions (competitive auctions for renewables, a European and regional approach to CRMs, roadmaps for phasing out regulated retail tariffs and limited to energy poor)
- high availability of cross-border capacity to the market (infrastructure development, balancing, intraday markets and 70% of capacity made available by TSOs)
- optimised cross-border flows (flow-based coupling, price coupling of the regions, bidding zone review).

Cross-border transmission and trade

In 2018, the EU had around 480 000 km of power lines and 467 000 gigawatt-hours (GWh) of trade. This large-scale electricity market serves around 500 million citizens.

Electricity trading takes place over different time horizons as energy suppliers, traders and generators optimise their portfolios ahead of real-time delivery, through forward, day-ahead and intraday markets. Transmission capacity allocation across member states replicates these time horizons. The EU has increased the cross-border harmonisation of the capacity calculation, allocation and congestion management over the past decade.[36]

For day-ahead, transmission capacity is allocated jointly with energy through a collaborative effort between TSOs and power exchanges in a process which is often termed as “market coupling” (implicit allocation). For intraday, capacity is also implicitly allocated but in a continuous process. To match forward trading, transmission capacities are auctioned up to a year ahead by TSOs (explicit allocation) based on explicit cross-zonal capacity allocation and harmonised allocation rules through the single allocation platform, JAO.

Market coupling

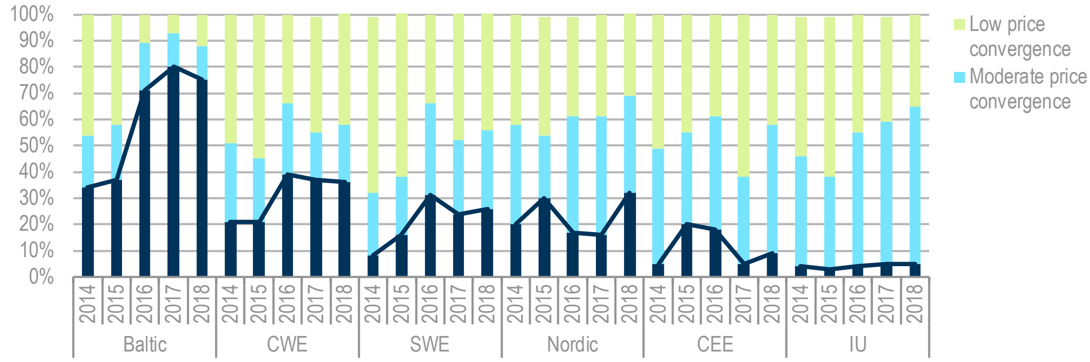
The step-by-step coupling of geographically separate electricity pricing regions has led to the creation of a single EU day-ahead coupling, which operates on more than two thirds of the European borders, involving 25 European countries in 2019. Only 10 European borders still remain to be coupled through the single EU day-ahead coupling. In 2019, 80% of the EU borders were coupled, mostly by single coupling (46 borders) with three borders coupled separately. At the end of 2019, 10 borders were still waiting to be coupled (Bulgaria, the Czech Republic, Hungary and the Slovak Republic).

Similarly, the EU is moving towards a pan-European single intraday coupling, using a stepwise approach across the entire European Union, based on the XBID project, which started in 2018 covering Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Latvia, Lithuania, Norway, the Netherlands, Portugal, Spain and Sweden. The extension to seven more countries was achieved in late 2019, i.e. Bulgaria, Croatia, the Czech Republic, Hungary, Poland, Romania and Slovenia.

[36] There are EU-wide rules for capacity allocation: the Commission Regulation (EU) 2015/1222 of 24 July 2015 establishing a guideline on capacity allocation and congestion management (CACM) contains the rules for day-ahead and intraday capacity allocation whereas Commission Regulation (EU) 2016/1719 of 26 September 2016 establishing a guideline on forward capacity allocation (FCA) sets the conditions for FCA.

Thanks to market coupling, wholesale electricity prices across the EU have converged over time. Figure 7.11 shows that in those regions where market coupling is implemented prices across the bidding zones are converging strongly or moderately.

Figure 7.11 Price convergence in Europe by region, 2008-18

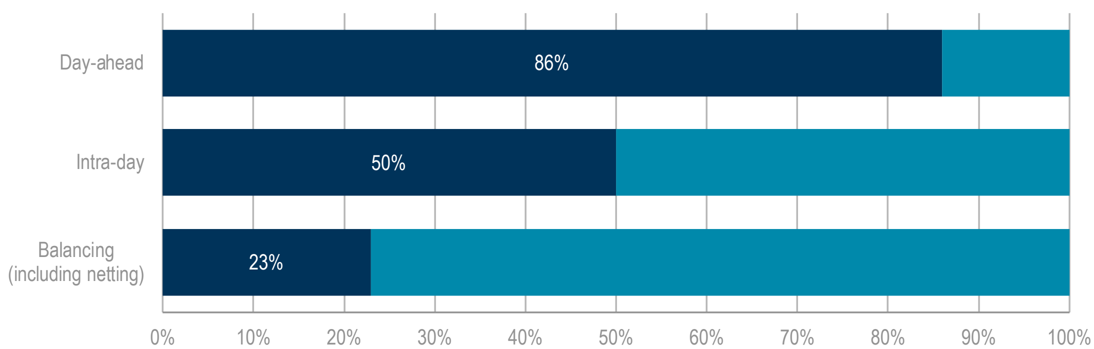


Notes: CWE = Central West Europe; SWE = South West Europe; CEE = Central East Europe; IU – Ireland and United Kingdom

The numbers in brackets refer to the number of bidding zones included in the regional calculations.

Source: ACER/CEER (2019), *Annual Report on the Results of the Monitoring of the Internal Electricity and Natural Gas Markets 2018*, Slovenia, www.acer.europa.eu/en/Electricity/Market%20monitoring/Pages/Current-edition.aspx

Figure 7.12 Availability of net transfer capacity across borders for market players



Source: ACER/CEER (2019), Annual Report on the Results of the Monitoring of the Internal Electricity and Natural Gas Markets 2018, Slovenia, www.acer.europa.eu/en/Electricity/Market%20monitoring/Pages/Current-edition.aspx

Despite the increase in electricity trade across borders in the EU, actual trade and cost-effective dispatch is limited by 1) the available interconnection capacity between regions (capacity calculation regions [CCRs]) and 2) the (insufficient) level of cross-zonal capacity made available to the wider EU market.

With regard to share of the available capacity, net transfer capacity (NTC) has increased in the "right direction" (thus to support trading in the presence of a significant price differential [>EUR 1/MWh]), on 37 European electricity borders in different time frames. In 2018, almost 90% of the NTC was made available to the market, while this is not yet the case for intraday or balancing markets (see Figure 7.12). Significant cross-border capacity remains underutilised, notably for intraday (50%) and the balancing (77%) time frames, according to ACER/CEER (Council of European Energy Regulators).

Despite the increase in electricity trade across the border in the EU, actual trade and cost-effective dispatch is limited by the available interconnection capacity between regions (capacity calculation regions, CCRs).

A novelty to promote more available interconnection capacity has been included in the CEP. TSOs are obliged to offer to the market for cross-zonal trade at least 70% of cross-border capacity from 1 January 2020, under the Electricity Regulation. This complements the existing principle that TSOs shall not limit interconnection capacity to market participants in order to solve congestion inside their own bidding zone or as a means of managing flows resulting from transactions internal to bidding zones (loop flows), while respecting operational security limits, taking into account contingencies.

While there are a number of options (NRAs' derogations or member states' action plans) for the TSOs to reach this binding target through a step-by-step approach, the 70% target will have to be fully achieved by the end of 2025 at the latest for all TSOs in Europe.

Bidding zones

The EU market design is based on price zones or bidding zones, which are still largely determined along the borders of the national territory. For instance, Germany (jointly with Luxembourg) is considered as one bidding zone and so is France, while other countries have several domestic price zones, such as Sweden or Italy because of strong north-south congestion.

In theory, transmission capacity is assumed to be unlimited within each bidding zone (as if the zone were a copper plate), resulting in the definition of a uniform electricity price across that zone. In theory, within a bidding zone there should be no structural congestions, and under EU competition rules trade within a bidding zone should not distort cross-border trade. An internal congestion cannot be transferred to the border.

Under the CEP, congestion needs to be managed by the TSOs in the long term (investment), medium term (bidding zone reconfiguration) and short term (remedial actions) or simply put by "build, split or pay".

In the longer term, cost-efficient network investment is necessary and TSOs can benefit from congestion revenues where bidding zones are designed along internal congestions to build new lines.

In the short term, congestions are addressed by TSOs mainly by limiting *ex ante* the level of cross-zonal capacity made available to the market. In case of congestion in real-time, TSOs apply remedial actions, which are divided into costly (redispatching and countertrading) and non-costly methods (topology changes, phase-shifting transformers). Currently, remedial actions are not optimised at the regional level and many borders have seen the emergence of phase shifters to increase the controls of larger loop flows. However, TSOs co-ordinate remedial actions to some extent, based on the CACM Guideline and System Operation Guideline.

In the medium term, structural congestions within a bidding zone (domestic) should be addressed by reconfiguration of the bidding zone (internal split). To ensure optimal bidding zones, the CEP provides for a medium-term process to review the configurations of the bidding zones. Every three years, ENTSO-E shall report on structural congestion and other major physical congestion between and within bidding zones. The methodology, assumptions and alternative bidding zone configurations to be used in the review shall be proposed by TSOs and decided by NRAs, or ACER if NRAs fail to agree. The methodology shall be based on structural congestions (those which cannot be overcome within three years). Where structural congestion has been identified by ENTSO-E or TSOs, a bidding zone review shall be performed in order to assess whether alternative bidding zone configurations would contribute to manage congestions in a cost-efficient manner. Additionally, where TSOs fail to implement the 70% binding capacity target, the member states can choose (within six months) either to review and amend their bidding zone configuration or define national or multinational "action plans" to reach the 70% target through a linear trajectory before the end of 2025.

An initial assessment process was finished by TSOs in 2018; however, it has not been conclusive. In practice, while member states are the ultimate decision makers and may be inclined to take a political decision, the European Commission may be required to take a decision if the relevant member states fail to agree.

The reconfiguration of bidding zones will change electricity prices and such changes need to be weighted against the high redispatching costs for EU consumers. The direct and indirect welfare losses due to the reduction of cross-zonal capacity made available to the market (in order to limit the congestion) are usually overlooked but represent the most significant part of the welfare losses in Europe.

The fast transformation of electricity systems (with large-scale renewables (offshore wind) and growing distributed wind and solar) requires a combination of *i*) pan-European coordination, governance and market rules to ensure an efficient integration of national markets, including the integration of large-scale renewables through efficient power trades and transmission capacity and *ii*) the need to allow for local solutions, e.g. to facitilate the integration of small-scale renewables.

Retail electricity markets

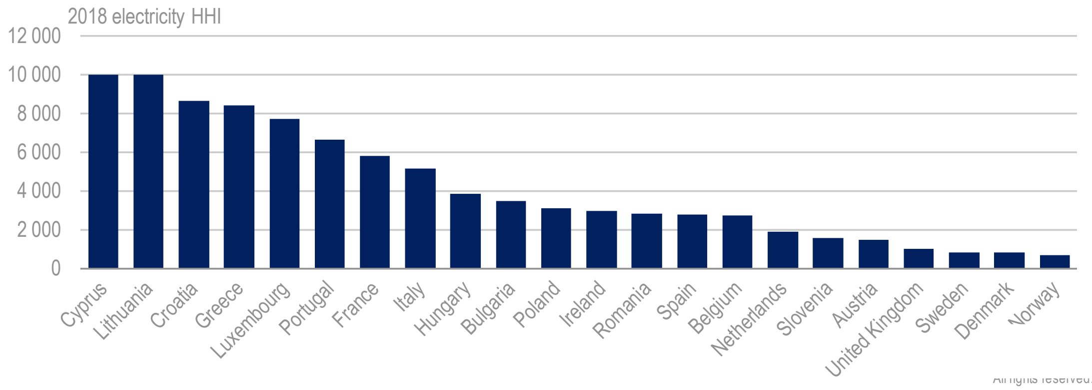
EU retail markets are mainly governed by the national regulatory system. However, broad EU rules apply to market opening, retail price regulation, unbundling of distribution companies, the smart meter roll-out and the definition of energy poverty. In 2019, the CEP set out new rules which foster supplier switching and an enabling role for DSOs, and strengthen consumers and demand-side participation.

Competition and market concentration

Retail markets in the EU showed a rather high concentration in 2018, measured by the Herfindahl-Hirschman Index (HHI). According to the latest data by CEER, the HHI index was above 2 000 in 15 member states and above 5 000 in 8 countries in 2018 (Figure 7.13).

The low level of competition in some markets means that developments at the wholesale level, notably price decreases, have not been reflected necessarily in the EU retail prices.

Figure 7.13 HHI for household market in electricity, 2018



In 15 EU member states, the concentration of the household electricity market was above 2 000 in 2018, but in 8 above 5 000.

Note: HHI = Herfindahl-Hirschman Index. The HHI is a measure for industry concentration taking into account the size of firms in relation to the industry. It is calculated by adding the sum of the squares of the percentage market shares of each market participant. For example, a market consisting of five competing firms, each with a 20% share of the market, would have an HHI score of 2 000 (i.e. 400 x 5). HHI is typically used to help assess the degree of market dominance and potential for market power abuse. Views vary on the interpretation of HHI scores. This study uses the scale developed by the European Union, with scores of 750-1 800 considered indicative of moderate concentration; scores of 1 800 to 5 000 indicative of high levels of concentration and scores above 5 000 indicative of very high concentration consistent with the presence of substantial potential market power.

Source: CEER (2019), *Monitoring Report on the Performance of European Retail Markets in 2018*, CEER Report, https://www.ceer.eu/documents/104400/-/-/5c492f87-c88f-6c78-5852-43f1f13c89e4

Electricity retail pricing

Besides the concentration, many retail markets still have regulated retail prices.

Of the EU28, 14 member states retained some form of intervention in price setting, according to the latest data available by the CEER monitoring report of 2019. End-user price regulation was in place in 9 countries, in Bulgaria, Cyprus, France, Hungary, Lithuania, Malta, Spain, Poland and Portugal (CEER, 2019). In Belgium and Latvia, price intervention only applied to the vulnerable customers. The United Kingdom applied regulated prices in form of price caps on consumers with domestic prepayment meters and consumers on so-called standard variable and default tariffs.

The share of household consumers under regulated prices has been decreasing in Bulgaria, France, Portugal, Romania and Spain. In 2017, price regulation was successfully removed in Poland, Denmark and Greece, and the process is ongoing in Portugal and Romania. In 2018, France, Italy and Lithuania are working on roadmaps for removing intervention in setting end-user prices.

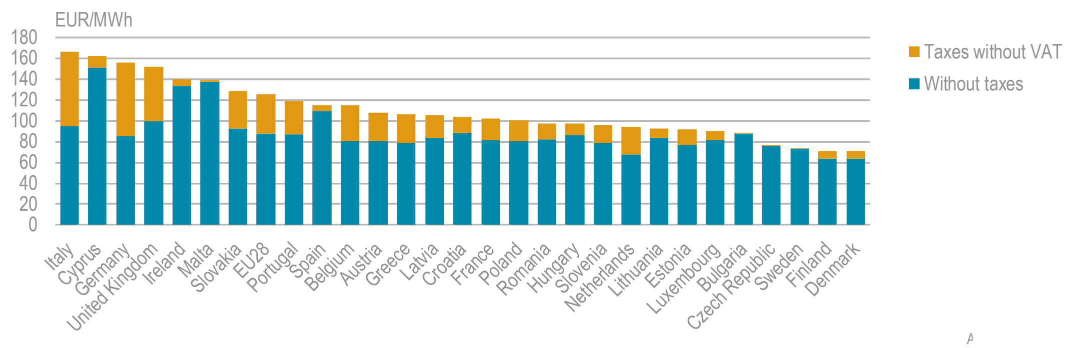
The second Electricity Directive (2003/54/EC) already required member states to ensure that industry and commercial consumers could freely choose their supplier from 1 July 2004 and household electricity consumers could choose starting from 1 July 2007. The third liberalisation package introduced the need to ensure quality of supply in the Electricity Directive (2009/72/EC), which also emphasised the provision of electricity as a universal service to households and small enterprises, allowing the adoption of public service obligations, including through a supplier of last resort.

The Electricity Directive (2019/944/EU) recognises the possible price distortion of regulated prices and requires their gradual removal. However, the directive introduces derogations from marketing and pricing freedom (and thus allows price regulation) for vulnerable consumers and the energy poor and requires that member states measure and define their scope and present an assessment of the necessity by 1 January 2022 and a roadmap for the transition to market-based pricing to the Commission by 1 January 2025.

Retail electricity price trends in the EU

In the first half of 2019, industry prices (in consumption band 500-2 000 MWh) excluding deductible value-added taxes (VAT) ranged from EUR 71/MWh in Denmark to EUR 166/MWh in Italy (Figure 7.14).

Figure 7.14 Electricity prices for industry in EU member countries, first half of 2019

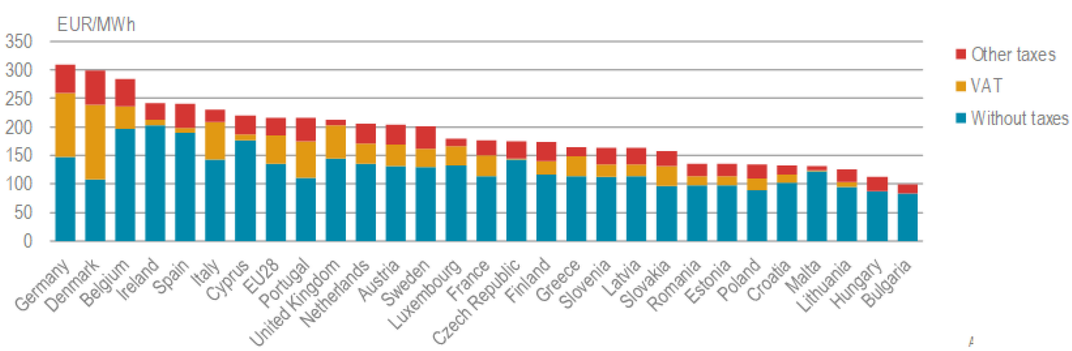


Non-household electricity prices excluding taxes vary from EUR 71/MWh to EUR 166/MWh.

Note: Electricity prices for non-household consumers in the consumption band 500-2 000 MWh (band IC), excluding VAT, for first half of 2019.

Source: Eurostat (2019a), Electricity prices for non-household consumers – bi-annual data (from 2007 onwards), https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_205&lang=en.

Figure 7.15 Electricity prices for households in EU member countries, 2019



Household electricity prices vary from around EUR 100/MWh in Bulgaria to around EUR 300/MWh in Germany and Denmark, which has the highest taxes in the EU.

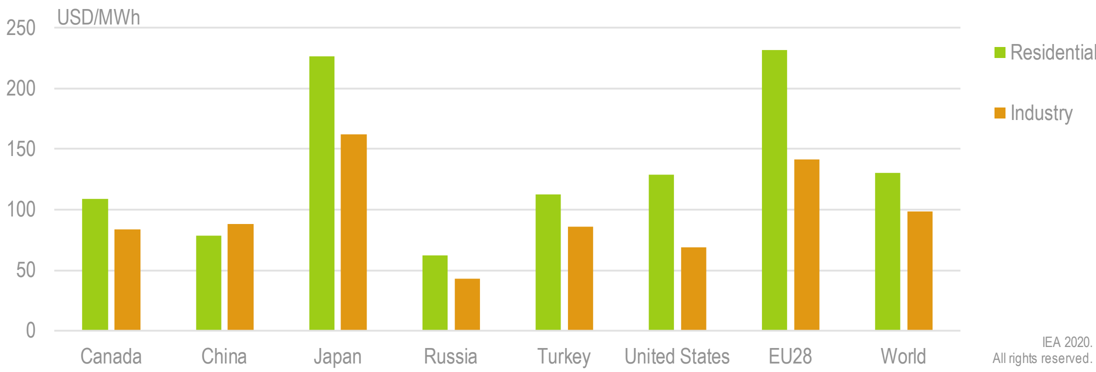
Notes: Germany tax data calculated using the total price from Eurostat (2019b).

Electricity prices for household consumers in the consumption bands 2.5 MWh-5 MWh (band DC).

Source: Eurostat (2019c), Electricity prices for household consumers – bi-annual data (from 2007 onwards), https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_204&lang=en.

Household prices show an even larger spread among the EU countries, from just below EUR 100/MWh in Bulgaria up to around EUR 300/MWh in Denmark and Germany in the first half of 2019 (Figure 7.15). The main reason for the large difference is taxes and levies, which can account for only a few percent of the total price up to nearly two-thirds in Denmark. Taxes imposed on electricity use in industry are in many countries lower, as the industry sector is exempt or faces lower taxes for competitiveness reasons (Trinomics, 2019).

Figure 7.16 International comparison of electricity retail prices in 2017

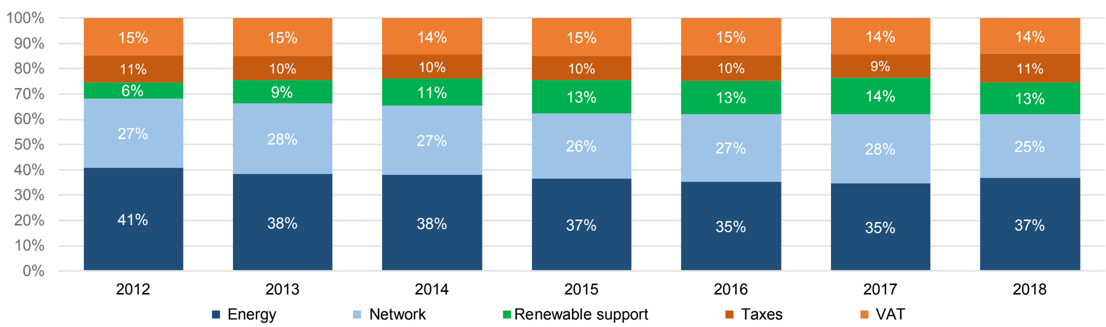


Source: IEA (2019d), *World Energy Prices 2019*, www.iea.org/statistics.

By international comparison, EU28 data show that the gap between industry and household prices for electricity is the largest in the world, above the world average and even higher than in Japan (Figure 7.16). EU retail (real) prices are higher than in the United States, Canada, the Russian Federation, China and Turkey but similar to Japan's.

The price structure has evolved. Network costs accounted for around one-third of the total price on average during 2012-18. Over time, the energy component has decreased, however, and costs of renewable support schemes have been on the rise (Figure 7.17).

Figure 7.17 Breakdown of the EU electricity retail prices for households based on standard incumbent price offers



Source: ACER/CEER (2019), *Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2018*, www.acer.europa.eu/en/Electricity/Market%20monitoring/Pages/Current-edition.aspx.

Switching of suppliers

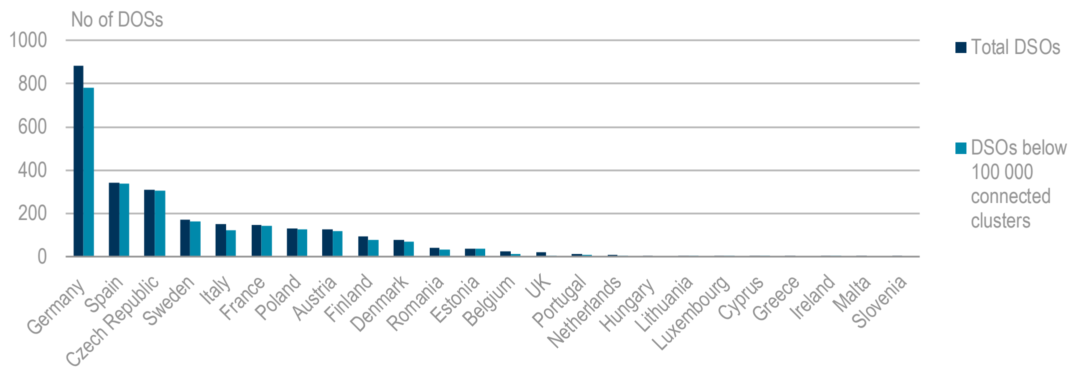
The Electricity Directive 2019/944 requires EU member states to ensure that switching takes place within a maximum of three weeks and technical switching by 2026 within 24 hours, at no extra charges for households and small and medium-sized enterprises. National regulatory authorities monitor switching rates, and some promote active switching campaigns. There is no switching data collected at EU level.

Countries with high switching rates for electricity households (at least 10%) included the Finland, Germany, Great Britain, Ireland, Portugal, Spain and Sweden (CEER, 2019), while the lowest rates can be found Bulgaria, Lithuania and Poland. Belgium and the Netherlands also have high switching rates. Overall, rates vary strongly across the EU, and so do electricity retail prices.

Distribution sector

There are currently around 2 600 electricity (DSOs across the EU, out of which 2 400 are small DSOs with fewer than 100 000 customers. Some countries have many DSOs, for instance Germany (883), Spain (342), the Czech Republic (308), Italy (151) and France (148), while Ireland, Greece, Slovenia and Malta have only one DSO (Figure 7.18). This patchwork of DSOs with different sizes, company structures or governance frameworks makes it very challenging for the EU to design EU-wide harmonised grid codes or network plans or co-operate in the EU DSO entity.

Figure 7.18 Number of electricity DSOs in the EU, by member state, 2016



Source: EC (2016), *Impact assessment study on downstream flexibility, price flexibility, demand response and smart metering*, https://ec.europa.eu/energy/en/studies/impact-assessment-study-downstream-flexibility-price-flexibility-demand-response-smart

DSOs have to be at least legally and functionally unbundled from other activities not relating to distribution (e.g. supply, generation) under Electricity Directive 2009/72/EC if the annual quantity of electricity transmitted to their customers has been 200 GWh or more during three consecutive calendar years. All DSOs below this level can choose legal unbundling. Most legally unbundled DSOs belong to a parent company that is a generator and/or electricity retail company. There is no requirement for ownership unbundling of DSOs in EU law. Member states are allowed to provide for exemptions for small DSOs which serve fewer than 100 000 customers. Accounting unbundling shall be enforced on all DSOs without exemptions. In the EU, DSOs have different sizes, ownership structures and legal requirements, including for their unbundling. This makes the task of distribution regulation and governance challenging.

C. Power system security

Security of supply was one of the key drivers of electricity market integration in Europe. Indeed, the first interconnections to neighbouring countries were built to mitigate emergency situations. Integrating electricity markets diversifies the generation mix and gives access to generating capacity in case of a shortage in any one country.

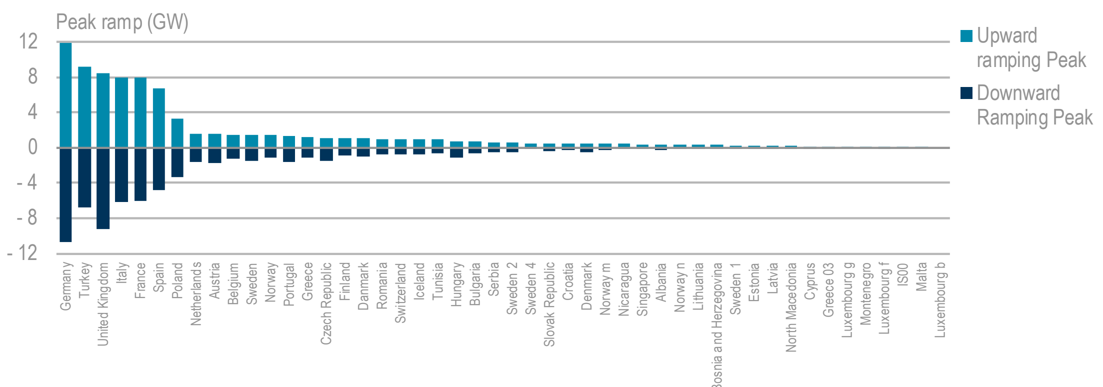
The EU is going through a paradigm shift, as EU market integration and higher electricity trade flows support the system integration of rising shares of variable renewable energy, Today, interconnectivity is becoming a driver of system integration of variable renewables. Recent data reflect that the electricity system operation is changing with higher needs to system management, peak ramp requirements and ancillary services.

First, the number of N-1 contingency events has grown across the EU (Table 7.4), showing significant need for redispatch, countertrading, curtailment and compensation. This is not only an issue for system operators, but is felt across borders and it creates challenges for national regulators as the costs for countertrading are substantial (amounting to several million euros per month and billions per year). Given the high level of cross-border trade, this concerns system operators across the EU, but there is no harmonisation across the EU. In March 2020, 13 regulatory authorities asked ACER to decide on methodologies for the co-ordination and sharing of cost of redispatching and countertrading electricity. The methodology will guide redispatching and countertrading resources among 16 TSOs across the 19 bidding-zone borders.

Table 7.4 N-1 contingency events, Germany

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Cases	2	15	51	172	387	228	312	290	998	970	1 009	977	1 407
Days	2	14	51	105	185	144	156	161	308	344	356	361	349

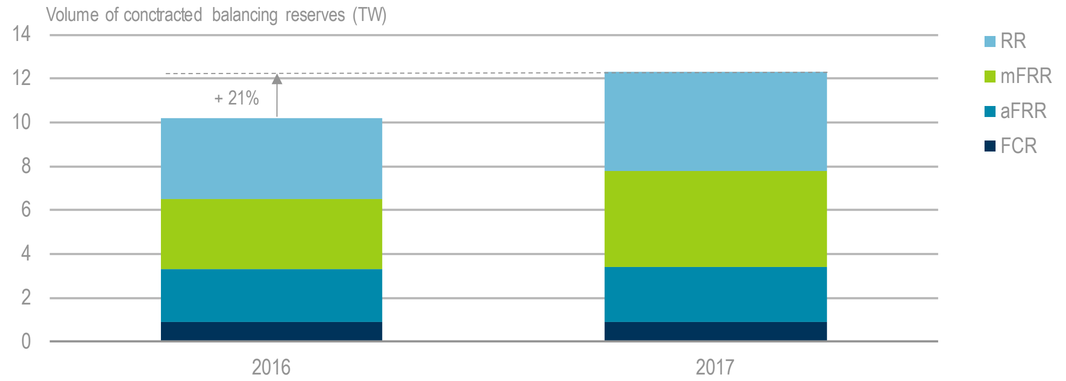
Figure 7.19 Peak ramp requirements in the EU28



Source: ENTSO-E (2019b), ENTSO-E Powerfacts, www.entsoe.eu/Documents/Publications/ENTSO-E%20general%20publications/ENTSO-E_PowerFacts_2019.pdf?Web=1

Second, peak ramping needs and contracted ancillary services have increased, reflecting the rising flexibility needs in a changing power system (Figures 7.19 and 7.20). Within one year, during 2016/17, contracted ancillary services in the EU increased by 21%, according to ENTSO-E.

Figure 7.20 Contracted ancillary services in the EU, 2016-17



Note: TW = terawatts. FCR = frequency containment reserve; aFRR = automatic frequency restoration reserve, mFRR = manual frequency restoration reserve; RR = replacement reserve

Source: ENTSO-E Powerfacts, www.entsoe.eu/Documents/Publications/ENTSO-E%20general%20publications/ENTSO-E_PowerFacts_2019.pdf?Web=1, ENTSO-E (2018a), Survey on Ancillary Services Procurement and Electricity Balancing Market Design, https://www.entsoe.eu/publications/market-reports/#survey-on-ancillary-services-procurement-and-electricity-balancing-market-design, ENTSO-E (2019b),

In the coming years, this trend is going to gain speed. ENTSO-E's Ten-Year Network Development Plan (TYNDP) expects that 8 European countries will reach up to 100% of instantaneous demand covered by renewable generation and 22 countries will reach at least 50% for the most challenging hour by 2025 (ENTSO-E, 2018b).

At the same time, market integration and increasing interconnection also bring about exposure to price and generation development in neighbouring markets. In the coming decade, the EU electricity system is going through a major energy transition; European member states will see fast changes to their already very different generation mixes, partly because of differences in their initial resource endowment. Energy policy factors play a strong role in defining the fuel security and fuel mix. Governments should pay attention to the security implications of fuel policies (including renewables, nuclear, gas and others) on the European power system and notably their neighbouring countries. EU policies have already prepared the ground for greater co-ordination and cross-border integration of day-to-day systems operations and planning. But national policy and fuel choices will certainly play a major role in the coming decades.

EU legal framework for security of electricity supply

Under the Lisbon Treaty, member states rely on their prerogative to ensure security of electricity supply and decide on their level of reliability, based on their national energy mix.

Crises may affect several member states at the same time, as was the case during the prolonged cold spell in February 2012, a blackout in Italy in 2003 and the tripping of an electricity line following the uncoordinated switching off of power lines in Germany in 2006. Since the last IEA in-depth review of the EU in 2014, there have been no major electricity blackouts.

There can be a clear disconnect and friction between the national, EU and regional adequacy definitions. EU member states take very different approaches and tend to focus on their national territories and customers only, ignoring the possible assistance of and the impact on neighbouring countries and customers. This entails serious risks for security of supply and can create barriers to the internal energy market. The CEP aims to support the emergence of a more regional and European dimension of the security of electricity in the EU through national plans and cross-border co-operation through regional measures.

The CEP revised the EU electricity security of supply rules and introduced an EU-wide electricity emergency response mechanism. Regulation (EU) 2019/941 on risk preparedness in the electricity sector repealed Directive 2005/89/EC, which was considered outdated in a more and more integrated EU electricity market (based on the third package), where the changing power system and emerging threats to the electricity infrastructure resilience have implications beyond national electricity security.

Regulation (EU) 2019/941 on risk preparedness in the electricity sector provides a new legal and policy framework for security of electricity supply in the EU. It builds on national risk-preparedness plans that contain measures to prepare for and mitigate electricity crises as identified in the regional and national electricity crises scenarios. Such scenarios will be identified using a common methodology developed by ENTSO-E and approved by ACER. The plans will be assessed by the European Commission, in consultation with the Electricity Coordination Group, which will provide recommendations under certain circumstances (e.g. ineffective measures to address electricity crisis, non-compliance with the regulation).

The regional approach

The CEP relies on the regional collaboration of system operators, member states and regulators in the spirit of increased transparency and solidarity. The new EU security of electricity supply rules are based on a common methodology for the national risk assessments, preparedness plans and emergency measures, including their co-ordination at regional level through TSO regional coordination centres (RCCs) as "service providers" with specific mandates over their member TSOs (RCCs are not going to take over responsibility for system operations from the national TSOs).

As regards emergencies, member states have to issue an early warning to the European Commission and other member states when a seasonal adequacy assessment or other qualified source provides reliable information that an electricity crisis may occur. The member state in question has to provide information as well regarding the causes and planned measures. In case of an electricity crisis, the member state concerned has to inform other member states and the European Commission of the declaration of the crisis, the causes and the planned measures. It also has to follow the measures contained in the risk-preparedness plans to the fullest extent possible. Moreover, in the case of a crisis a member state may require assistance from other member states, which should be provided according to regionally or bilaterally agreed measures.

The preparation of risk assessments and emergency plans should lead to a greater level of information and exchange between member states on the highly sensitive issue of electricity supply security. The Electricity Coordination Group, created in 2012, has been a platform for discussion among member states, national regulators, ACER, ENTSO-E and the Commission on electricity policy. ENTSO-E and the regional security co-ordinators play an important role in the European security of supply architecture. The Electricity Coordination Group will become the main forum for European monitoring, co-ordination and reporting.

Cybersecurity

To support electricity security during a period of rising digitalisation and decentralisation (smart grids and meters), in April 2019, the European Commission adopted electricity sector-specific guidance[37] to provide for horizontal cybersecurity principles and rules for the EU electricity grid, while acknowledging that a one-size-fits-all approach is not possible. In the power sector, the Commission rules address the particularities of real-time requirements, cascading effects and the interaction of legacy technology with smart technology in the era of "Internet of things".

The Electricity Regulation (2019/943/EU) refers to cybersecurity as one of the areas where network codes might be established to increase the resilience of the energy sector and protect the energy systems.

International experience illustrates the benefits of public-private partnerships versus regulation, the use of reward-based approaches to encourage sharing best practices and vulnerabilities, and the need for adapting regulation to encourage adoption across the sector, as done in Australia by market operator AEMO with a "light" version of a framework for less experienced utilities.

The Emergency and Restoration Network Code (Commission Regulation (EU) 2017/2196) sets out rules for the management of the transmission system in case of emergency or blackout, as well as other different system critical states, as defined in the system operation guideline. In the EU, the directive on security of network and information systems (2016/1148) helped the identification of critical infrastructure in all member states.

Operating the power system at high and very high shares of variable renewables

Given the impact that high shares of variable renewables can have, a comprehensive and systemic approach is the appropriate answer to system integration challenges. The IEA assessment framework for system integration is based on a co-ordinated approach, which can significantly reduce integration costs and ensure electricity security. Achieving such a transformation requires strategic action in three main areas:

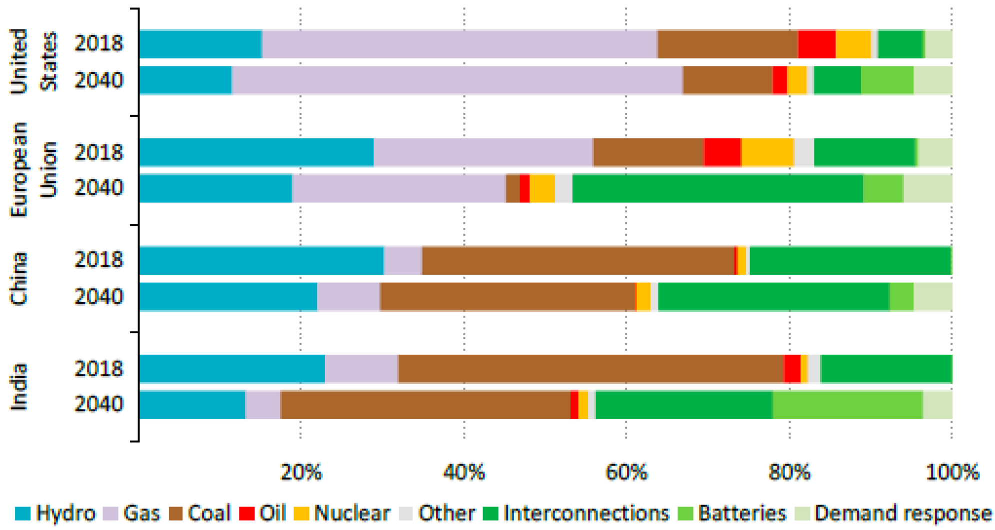
System-friendly geographical planning requires that the deployment of renewables can maximise their net benefit for the entire power system. Such an approach leads to different deployment priorities as compared with a focus on generation or networks costs alone and calls for integrated resource planning.

Improved operating strategies to maximise the contribution of existing assets and ensure security of supply. These include advanced renewable energy forecasting and close to real-time market design.

[37] Recommendation COM(2019) 240 final and Staff Working Document SWD(2019)1240 final.

Investment in additional flexible resources. Even in concert, improved operations and system-friendly planning can be insufficient to manage high shares of variable renewable energy in the long term. Additional flexible resources can be necessary, but specifics depend on the system context. In all systems, however, an increase of flexible resources will become a cost-effective integration strategy at some point, requiring additional investments in systematic expansion of the grid, ensuring an appropriate power plant fleet, unlocking demand response potential and storage.

Figure 7.21 Sources of flexibility in the EU and other regions, IEA STEPS



STEPS – Stated Policies Scenario
Source: IEA (2019a), *World Energy Outlook 2019*.

The EU benefits today from a range of flexibility sources. However, the phase-out of coal, nuclear retirements and impacts of climate change on hydro availability will bring about a reduction of traditional flexibility sources in the EU.

As renewables are expected to reach ever-higher shares in the EU electricity mix by 2030 and 2040, all sources of system integration need to be fully activated, notably interconnections, energy storage and demand response (Figure 7.21). Boosting the flexibility will require further energy sector integration.

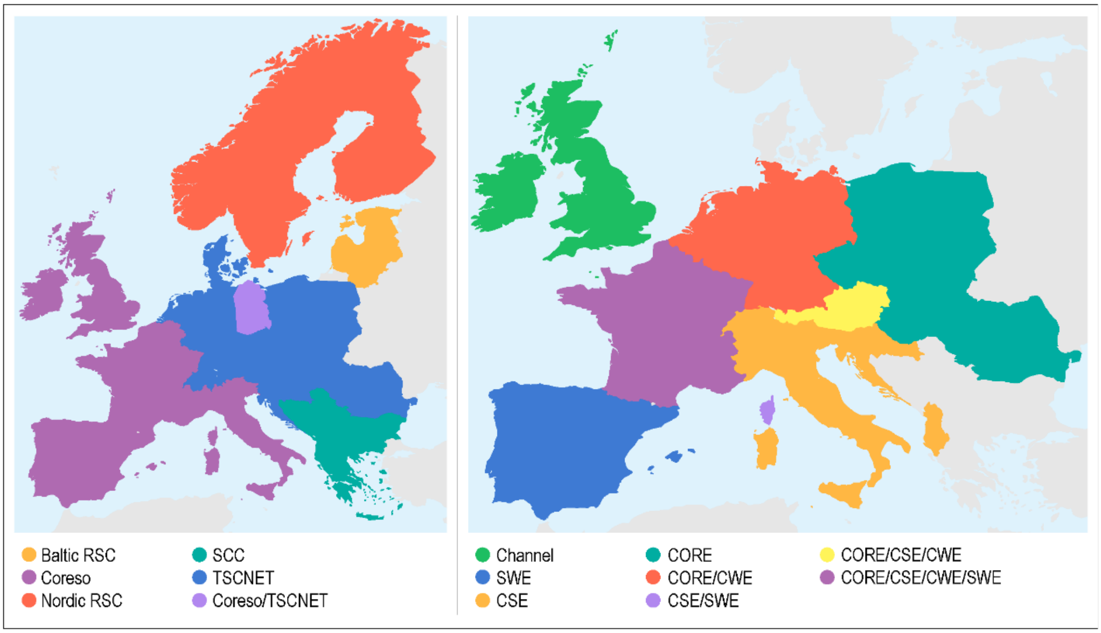
System operation

The EU power system and the transmission system operation are confined by the national grid, and more recently by the bidding zones of interconnected zones. There are no ISOs, as system operation and transmission functions are usually performed together by the TSOs.

EU-wide system operation is constrained by nationally confined systems of the TSOs and largely depends on the capacity of the network operators, the power exchanges and whether member states allow for co-ordination and price zones (beyond the national level) at the level of regionally interconnected systems. RCCs are not ISOs but are co-ordination centres which provide services to the member TSOs. Addressing the insufficient information sharing among TSOs and creating and expanding necessary services to respond to new system operation needs of higher shares of variable renewables will be essential. This includes better forecasting and dispatching.

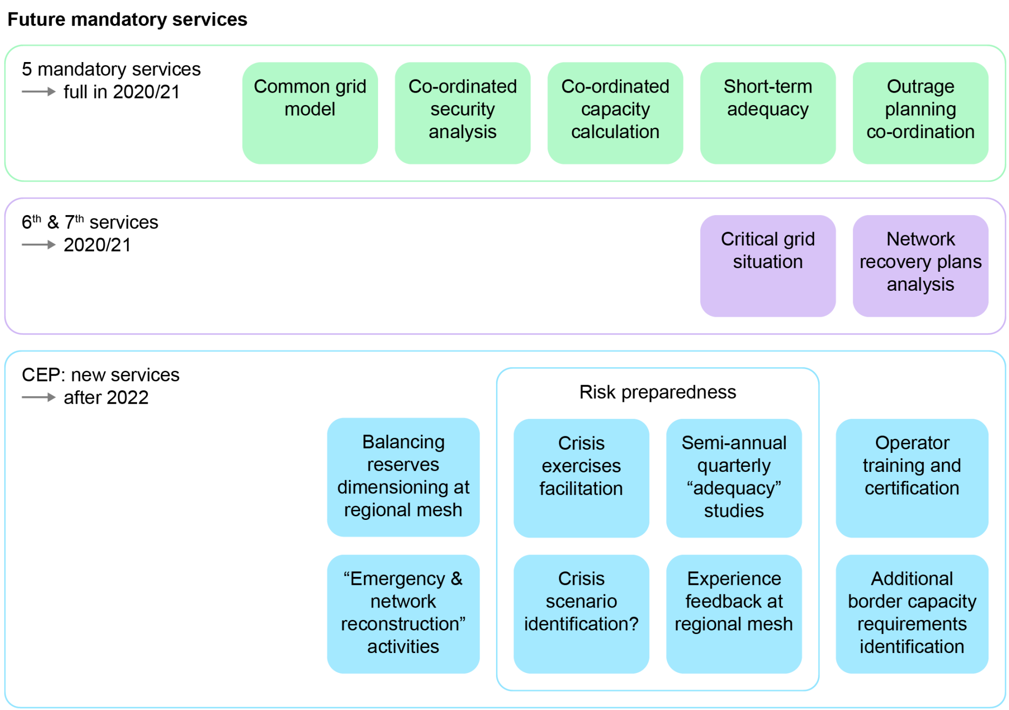
Another challenge to effective EU-wide system operation is the fact that today the EU has several regional groupings for system operation: the CCRs (based on price coupling mechanisms) and the existing voluntary regional security co-ordinators (RSCs) which have been created among TSOs (Figure 7.22). These different formations need to evolve to become RCCs by 2021, when all-new services and more alignment and regulatory oversight should emerge (Figure 7.23).

Figure 7.22 Starting point for regional co-operation in Europe



ENTSO-E presented a Vision on Market Design and System Operation towards 2030 in December 2019 (ENTSO-E, 2019c), which reflects on some of these challenges and presents an important basis for the TSO collaboration in the future. In order to address challenges of operating parts of the European electricity system during periods with very high levels of converter-based wind and solar generation in a particularly reducing inertia system, all stakeholders will have to collaborate on new monitoring and power system controls as well as innovative technological solutions such as grid-forming converters. The common European platforms for the imbalance netting process, the exchange of balancing energy from aFRR, the exchange of balancing energy from mFRR and the exchange of balancing energy from RR are being developed to harmonise these processes across Europe.

Figure 7.23 New services and tasks of the RCCs



Source: CORESO.

There is a need to broaden traditional definitions of system inertia and control areas to wider system areas. ENTSO-E considers that with multiple centres of inertia, distributed around a network, the response of the system can no longer be approximated as a rigid body represented by a single total inertia. Connecting sparsely distributed centres of inertia in Europe's weakly coupled transmission system, regional inertia issues can be addressed by fast frequency response that is sensitive to disturbance location. Approaches to maintaining sufficient inertia and enabling primary frequency response on all generators have already been tested successfully in Ireland and the United Kingdom. These countries have employed rate of change of frequency requirements that apply at all times, and Ireland has more specifically employed inertia requirements that are also applicable at all times. Moreover, the country put primary frequency response as a required setting from conventional and renewable generation in response to small and large disturbances.

System planning

At the EU level, ENTSO-E produces medium-term adequacy assessments (Regulation 714/2009) every year and every two years, the TYNDP, based on the modelling of the European power system's evolution up to 2025, 2030 and 2040.

For the 2030 horizon, the latest TYNDP of 2018 plans the grid for a scenario of 48-58% of EU electricity demand covered by renewables. It contains transmission projects (201 overhead lines, 67 subsea, 23 underground cables) and electricity storage projects (17 hydro pumped storage, 3 compressed air). This investment in networks can achieve a 65-75% reduction in CO_2 emissions compared with the 1990 levels at a total cost of EUR 114 billion (ENTSO-E, 2018b). For the 2040 horizon, the TYNDP forecasts that

65-81% of Europe's electricity demand will be covered by renewables. ENTSO-E assumes that the optimal grid will avoid 58 TWh to 156 TWh of curtailment and reduce up to EUR 3/MWh to EUR 14/MWh the marginal costs of electricity generation (ENTSO-E, 2018b). A no-grid scenario of 2040 has identified that the failure to invest in networks across the EU would cost up to EUR 40 billion per year after 2040 and curtail 150 TWh of renewable electricity (ENTSO-E, 2018b).

The EU has focused strongly on network development in the past years and aims to reach at least 15% interconnection for each member country.

The EU has also a European framework for the identification of beneficial trans-European networks for energy, with electricity cross-border interconnectors and some internal network upgrades that relate to these connectors.

Based on the common regional identification of projects of common interest (PCIs), the EU rules promote streamlined permitting and approvals (through one-stop shops at national level) and European cross-border cost allocation rules. The vast majority of the needed investments for PCIs are meant to be financed by the market, mainly through regulated transmission tariffs. However, some energy projects are not commercially viable and would therefore not be implemented despite the fact that they provide important socio-economic benefits at macro-regional level. In such cases EU funding through the Connecting Europe Facility for Energy is available, to address the financial gap between the socio-economic value of the project at regional/European level (such as security of supply, innovation and solidarity) and the commercial viability through the regulatory framework.

Integrated resource planning is a framework and process for the planning of investments in various electricity assets which considers all system needs, including transmission and distribution, end-use efficiency, electricity generation, demand response and flexibility services that are suitable to the design of the wholesale market and the planning objectives (competitiveness, security of supply, decarbonisation). With sector coupling, higher electrification of end-use sectors and the introduction of hydrogen, system planning will become critical for the EU. The EU does not have such a system-wide approach today, but other markets are already putting in place integrated resource planning. With the emergence of very large offshore wind parks in the North Sea, a new era of system integration will be needed that looks at hydrogen but also large-scale transmission upgrades across the EU. The upcoming EU strategy on offshore wind would need to set out these essential needs and be followed up by new planning processes, which also facilitate the integration of innovative solutions and offshore electricity interconnections among others.

While a focus on increasing the flexibility from all sources (generation, storage, interconnections, demand response and grid investment) is a necessity, more fundamental reforms might be needed with regard to system planning and system security, moving from national to regional approaches towards ISOs and integrated resource planning across the EU.

Power system flexibility – wholesale

The CEP supports power system flexibility by promoting the system and market integration of renewable facilities, prosumers and aggregators as well as active DSOs.

Large new renewables and all new co-generation installations need to follow the general market rules (no longer relying on priority dispatch or exemptions from balancing responsibility). This constitutes a significant and balanced step towards integrating larger renewable energy source installations and high-efficiency co-generation fully into the market in a cost-effective way by increasing the overall flexibility of the market and system, while retaining an attractive environment for existing and the smallest renewables installations.

On balancing markets, renewable energy and demand response products need to be used for the daily procurement for at least 40% of the standard balancing products and for 30% of all balancing products. This enables more competition in balancing, while allowing system operators to rely on long-term procurement of traditional services to ensure system stability.

To foster the integration of variable renewables, the gate closure time now needs to be as close to real time as possible and no longer than one hour before real time. With better forecasting, this will ensure renewables can also access the market and come in when they are available.

To use local flexibility for congestion management (by the TSO), there is an explicit provision to ensure the participation of capacity that is connected to the DSO grid to offer balancing products to TSOs, including in Austria, Belgium, Denmark, Estonia, France, Germany, Hungary, and the Netherlands.

New flexibility market places are emerging across the EU at local, national and regionals levels, either driven by third parties, power exchanges, TSOs, DSOs or both. These include TSO-DSO interfaces (SmartNet Denmark, WindNode, Designnetz, New 4.0 Germany) or cross-border flexibility markets (Nodes, Enervalis, FutureFlow, all driven by third parties), TSO driven flexibility mechanisms, like the national NEBEF in France, or the regional TSO platforms (OSMOSE which encompases the networks of RTE, REE, TERNA, ELES, ELIA, REN), Baltic CoBA (Baltic TSO balancing market) and CrossBow (Southeast Europe cross-border balancing). There are also national flexibility markets (ETPA Netherlands), organised by a third party. At the DSO level, there is SmartNet Spain and Interflex in France.

Power system flexibility – retail

Demand response

Demand response includes mainly industrial consumers that are ready to shift their demand (demand-side management) and active consumers in the residential sector and assumes electric vehicles and heat pumps. France, Germany, Italy, Spain and the United Kingdom are the leading markets for demand response in the EU.

The European Commission assumes the theoretical potential of demand response to amount to 100 GW and expects it to reach 160 GW in 2030 provided full digitalisation, technical availability and economic feasibility. In 2016, around 21 GW of demand response participated in the market; 15 GW come from large industry and 6 GW from residential customers which had dynamic pricing contracts (Nouicer and Meeus, 2019; EC 2016).

Dynamic pricing

Several EU countries have introduced dynamic pricing, such as time-of-use pricing, direct linkage to wholesale pricing in the retail tariff and other forms of dynamic pricing. The availability of such tariff structures is largely defined by the national regulator and the structure of the power system. In 2017, consumers in 13 member states had access to time-of-use contracts with intraday/weekdays/weekend energy price differentiation, and in 8 member states they could opt for real-time or hourly energy pricing (ACER/CEER, 2018).

Smart meters and digitalisation

According to the Electricity Directive, member states are obliged to roll out electricity smart meters to 80% of consumers by 2020, unless the result of a cost-benefit analysis is negative. In the EU, 16 member states committed themselves to installing smart meters by 2020. Several do not intend a wide scale roll-out of smart meters (Belgium, the Czech Republic, Germany, Hungary and Lithuania). By the end of 2017, the roll-out of smart meters had reached more than 50% of the household customers in only nine member states (ACER/CEER, 2018).

With growing digitalisation of the power system, smart meters are going to become a vital prerequisite to the ability of the consumer to participate as an active consumer in the electricity market, notably through demand response and other flexibility options.

Enabling role of DSOs

Data management by the DSOs is also very different across the EU. While some member states are moving towards creating a centralised data hub (Austria, Denmark, Estonia, Finland, Italy, the United Kingdom), others rely on the DSO as facilitator (France, Portugal and Spain) while some appoint one or more data access point manager. In Denmark, Finland and Italy, the TSO is handling the data hub. Germany uses a decentralised model where meter data are physically stored at the consumer's premises by a smart metering gateway, which is accessible to entitled users (EC, 2016).

The Electricity Directive 2019/944 sets out that DSOs can own and operate storage and electric vehicle charging stations only if there is no interest from commercial operators, while similar rules for storage apply also to TSOs. In the case of storage ownership, exemptions are possible for "fully integrated network components", as well as for battery storage, with final investment decision taken by the entry into force of the Directive for DSOs and 2024 for TSOs, in case this storage is needed for ensuring a secure and reliable operation of the distribution or transmission system. Both exemptions do not affect the neutrality of network operators.

The CEP promotes rules for active customers (both household and non-household final customers) engaging in the sale of self-generated electricity or participating in flexibility or energy efficiency schemes. These customers are entitled to direct contracts with aggregators, without prior consent of the supplier. National net metering systems need to account separately for the electricity fed into the grid and the electricity consumed from the grid from 2024 onwards. Network tariffs shall reflect the cost and value of the system infrastructure, including for active customers.

European system adequacy

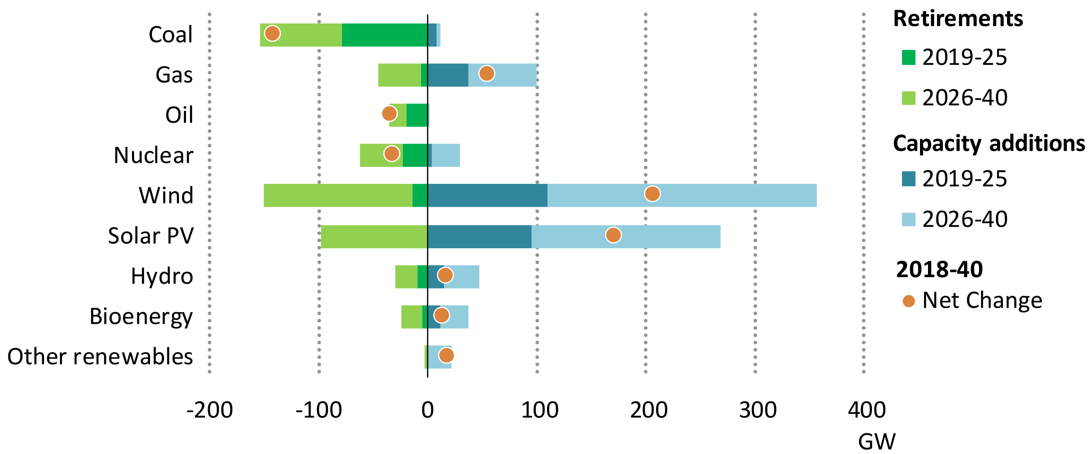
IEA analysis shows that the overcapacity will not last in the coming years. The installed capacity will change in the medium term, as government-imposed retirements increase (coal and nuclear generation) and new generation will largely come from wind and solar PV, and some natural gas, which brings another kind of contribution to the power system.

Both the retirement and the addition of more variable renewable generation plants require a stronger monitoring of system adequacy in the coming years up to 2025 (Figure 7.24).

Replacing a nuclear plant by renewable generation is not a trivial task. System strength or inertia will need to be provided or changed in the system (some wind generators already have such technical capability).

The EU has recently set out the regulatory and technical framework to prepare for the management of this task.

Figure 7.24 Power generation capacity retirements and additions in the EU



Source: IEA (2019a), *World Energy Outlook 2019*.

The CEP has introduced a new concept of European adequacy and greater regional optimisation of generation and system resources, which should change the approach that emerged in the past five years with the rise of CRMs.

Based on the Regulation (EU) 2019/941, a common methodology will be developed by ENTSO-E, to be approved by ACER, to carry out seasonal as well as short-term adequacy assessments, namely monthly, week-ahead and at least day-ahead. Using that methodology, ENTSO-E will carry out the seasonal adequacy assessments (winter and summer) and the RCCs will carry out the week-ahead to at least day-ahead adequacy assessments. However, these short-term assessments fail to consider the medium- and long-term transformation of the EU power system. ENTSO-E has started modelling the power system taking a 2040 horizon but does not yet take an energy system approach. A 20-year integrated energy system plan could help address generation adequacy concerns, taking a broader approach (see below section on system planning).

Capacity remuneration mechanisms

The EU has seen a rise in the adoption of national CRMs aimed at ensuring security of electricity supply, when the market alone does not provide sufficient incentives to invest in the dispatchable capacity needed to respond to fluctuations in supply. CRMs can be designed as capacity obligations, capacity auctions, capacity payments, reliability options, strategic reserves (largely used in the Nordic market, Belgium, Germany and Poland). The EU has a rich patchwork of CRMs.

The EEAG set out a specific framework for the assessment of CRMs. The EU state aid rules provide for approval of national CRMs by the EU. In 2015 and 2016 the European Commission carried out a first-ever state aid inquiry of capacity mechanisms, which provided further guidance on the application of state aid rules in this field. The inquiry concluded that at present, the EU as a whole has overcapacity and that any introduction of CRMs should take a more regional and European approach and avoid market distortions to the greatest extent possible.

Since 2014, the European Commission has adopted 19 decisions[38] on 13 capacity mechanisms/measures, ensuring that member states grant support only when it is necessary and through competitive tender procedures, open to all technologies and cross-border capacity. The introduction of technology-neutral auctions has led to significant savings – compared with administrative procedures previously used – and to the emergence of new technologies, such as demand response and storage, and new market players. Many CRMs have created a testing ground for new flexibility products, which is very positive. Furthermore, the participation of foreign capacity ensures that the contribution of imports to security of supply is properly valued and that capacity mechanisms do not unduly distort the internal market.

Electricity Regulation 2019/943 provides a common set of requirements on capacity mechanisms based on a European generation adequacy assessment. National CRMs should be a measure of last resort – if the European adequacy assessment identifies a shortcoming, member states have to first exhaust market-based reforms. CRMs need to be temporary and least distortive; be open to all potential domestic and foreign capacity providers, with specific attention to new entry; include a competitive price-setting process that ensures competition on prices to minimise the price paid for capacity; ensure incentives for reliability and investment in interconnection; and be designed to co-exist with electricity scarcity prices to avoid domestic overcapacity and trade distortions. While member states can choose their level of security (reliability standards based on the value of lost load), new CRMs will need to be based on verifiable criteria, on a regional and European-wide resource adequacy assessment, and must be in line with guidelines of the European Commission on state aid.

Finally, in parallel to the introduction of capacity mechanisms, member states must implement market reforms to address the regulatory failures that undermine the incentive for energy operators to invest in electricity capacity. These reforms include, for instance, allowing prices to reflect scarcity in the market, which in turn signals the need for investments and gives consumers the opportunity to react and become active players.

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[38] https://ec.europa.eu/competition/sectors/energy/state_aid_to_secure_electricity_supply_en.html#2

ENTSO-E is preparing a common methodology for the assessment of each bidding zone and will present the outcome of the assessment in 2020. The Electricity Regulation also requires common EU-wide standards for the calculation of the reliability standards by the TSOs, so that the need for and scope of CRMs are calculated in comparable manner.

Assessment

The EU has upgraded its electricity market design to prepare the transformation of Europe's power sector for the efficient integration of greater shares of renewables up to 2030. The landmark CEP of November 2018 includes four pieces of legislation – a new electricity regulation, an amending electricity directive, the new risk-preparedness regulation and a regulation outlining a stronger role for ACER. Implementation will have to be the main focus of the European Commission and the EU member states in the coming years.

The CEP builds on a decade of the EU implementing market reforms to complete the EU single market in electricity, notably through the third energy package of 2009, which led to three main achievements: 1) more harmonised cross-border trade and network rules; 2) institutional framework for greater cross-border harmonisation of market rules with independent regulators and system operators; and 3) the enforcement of competition in the energy sector, following the Directorate-General for Competition sector inquiry of 2007, supporting further market opening (EC, 2007). The package has moved the EU towards a fully functioning EU internal market for electricity.

Wholesale electricity markets

Electricity trading activities and market dynamics have developed positively in the past years. Market volumes and short-term trading have significantly increased. Flow-based coupling of market regions has been widely implemented for day-ahead and partly also for intraday markets, with the going live of XBID in June 2018.

Since the last in-depth review, electricity legislation has made a huge step forward. As part of the CEP, provisions for a new electricity market design entered into force in July 2019. These provisions aim at strengthening market functioning, enabling customer participation and preparing the electricity market for the integration of renewables.

Major progress was made by investing in electricity infrastructure and improving congestion management methodologies as well as improved co-ordination between TSOs. Nonetheless, structural congestion remains a significant challenge, in part due to the shifts in demand and supply localisation during the energy transition.

The creation of RCCs is expected to bring considerable progress in integrating system operation at the regional level. Based on the Regulation (EU) 2019/941 on risk preparedness in the electricity sector, a methodology will be developed to carry out seasonal as well as short-term adequacy assessments, namely monthly, week-ahead and at least day-ahead. Using that methodology, ENTSO-E will carry out the seasonal adequacy assessments (winter and summer) and the RCCs will carry out the week-ahead to at least day-ahead adequacy assessments. The methodology is being prepared by ENTSO-E and will be approved by ACER.

The work has only begun and the implementation of CEP market regulation requires further steps in the coming months and years by the member states, ACER, NRAs, TSOs (ENTSO-E), and DSOs (DSO entity) as well as by the European Commission.

A number of challenging and critical aspects include:

- *Identifying and removing wholesale market price caps:* While explicit caps are no longer allowed, care should be taken to identify and avoid implicit price caps (for example due to inappropriate balancing rules).
- *Enforcing the measures to maximise cross-border trade:* Better use of existing infrastructure is a no-regret option, particularly where concerns of public acceptance of new large energy infrastructure exists at local level. In markets with zonal organisation, a framework for the maximisation of cross-border capacities is critical for trading – internal congestions should not result in cross-border limitations. The present provision to limit the deductions that TSOs can make in the forecasting phase and provide a fixed share of the cross-border capacity for regionally optimised trading is a new element and should be monitored closely to ensure the results are economically efficient. In practice, this new method of calculation might cause challenges for system operators at the beginning. Close monitoring is critical up to 2025, when the obligation has to be fulfilled at latest.
- *Assessing the optimal size of bidding zones:* The principle to review geographic coverage of bidding zones is anchored in the capacity allocation and congestion management guideline. A first assessment in 2017 has not led to any adaption of bidding zones. With the CEP, the institutional roles of ACER and the European Commission in the review process have been clarified; this is likely to speed up decision-making. It would make sense to ensure that the assessment also addresses costs of remedial actions and balances this with market liquidity effects.
- *Completing the coupling of market regions*, especially at the level of intraday markets, and ensuring that balancing markets are organised as efficiently as possible.

While these principles could enable Europe to better utilise the flexibility offered by transmission, their implementation is still uncertain. Changing bidding zones appears to encounter stakeholder and government resistance, even in cases where the physical network layout would clearly justify it.

ACER will have important roles in guiding these implementation steps. It is important to make sure ACER has sufficient institutional independence. Adequate resources must be available for its functioning. Similarly, full independence and appropriate resourcing of NRAs is also essential.

The EU does not yet have a fully integrated common market for renewable electricity; further steps need to be taken in this regard. The EU 2030 renewable target is to be achieved bottom-up through an iterative process of the NECPs, in which member states can also use regional co-ordination. However, this does not guarantee regional optimisation of the renewable fleet or that the EU-wide target is met. RED I and II have promoted market-based support schemes, such as auctions, and the integration of renewables into the electricity market, including the use of co-operation mechanisms. However, their use is still low given national subsidy structures, though such mechanisms can make sense for member states with lower potentials to attain their targets in a cost-efficient way by working with member states with higher potentials.

Retail markets

The EU struggles with regulated tariffs in retail markets and needs to address energy poverty. The CEP aims at improving retail competition, ensuring affordable and transparent energy prices for consumers. Government interventions in electricity prices must gradually be removed. At present, in some member states regulated tariffs in retail markets prevail to address energy poverty. When setting out roadmaps for the removal of price regulation, member states should set out more targeted means to address energy poverty, for instance by assisting in insulation to reduce energy consumption.

In order to unlock flexibility of consumers and push demand response, more dynamic energy pricing is essential. In this light, the timely deployment of smart metering infrastructure is important. To date, its effective monitoring and implementation is lagging behind.

Security of electricity supply

The CEP provides a clear framework for security of supply by anchoring a regional (rather than a national) approach. Co-ordinated and harmonised regional adequacy assessments, as mandated by the CEP, are crucial to take consistent decisions. In this context, the creation of RCCs by July 2022 is a step to be welcomed. National and regional risk assessments and risk-preparedness plans including both national and regional measures are part of the new architecture.

In the past years, several member states have introduced some sort of CRM, which offers additional revenues to capacity providers, on top of income obtained in the wholesale energy market. Such mechanisms have the potential of dampening market signals and have an impact on competition in the internal electricity market. Many of these mechanisms involve state aid, so they are subject to EU state aid rules.

The CEP regulates the implementation of CRMs. National CRMs are brought under common principles, an EU-wide assessment of generation adequacy. This is a major improvement from previously nationally determined approaches and can hopefully reduce market distortions in the EU internal energy market in the coming decade. Adequacy concerns need to be identified, against reliability standards, by regional (European) resource adequacy assessments as a binding measure. With the goal to get investment signals mainly from robust price signals in the electricity wholesale and CO_2 markets, this precondition for new CRMs is meaningful and should be enforced. Regulation still leaves some room to complement the European assessment by national assessments. Appropriate measures should be taken so that whenever possible, approval of new CRMs indeed rely on a regional assessment.

In case relevant adequacy problems justify the implementation of a new CRM, its design should not interfere with the wholesale energy market, and should be open to regional trade and be technology-neutral (and open to demand response). Clear phase-out plans for CRMs must be established and enforced.

In the light of strong greenhouse gas emission reduction targets, electricity is expected to become a main energy carrier in 2050 in transport, industry and buildings. Electricity demand could double by 2050. Such demand projections, together with the substantial phase-out of coal-fired generation and the decommissioning of the existing ageing nuclear fleet, requires a longer forward-looking time horizon when it comes to security of supply. The CEP foresees European adequacy assessments looking ten years ahead. It is recommended to prepare a longer-term modelling and horizon scan for potential future systemic risks over 20 years. In order to guarantee that the implications for other regions are analysed, an appropriate review process for regional adequacy assessments should be established.

Investment in generation capacity generally depends on the robustness of price signals and on the ability of wholesale markets to reflect scarcity situations. The early identification of a possible (generation) adequacy issue and retirements could in addition give relevant signals to push investment in new capacity and flexibility.

Electricity networks

Appropriately developed transmission networks are a key element for a robust energy system and security of supply and a precondition for interconnected markets. The EU has focused strongly on network development in the past years and aims to reach a 15% interconnection target by 2030. Biannually, together with national TSOs, ENTSO-E develops and publishes TYNDPs. The Energy Infrastructure Guidelines regulation sets out the regulatory framework for the acceleration of key EU electricity infrastructure, provides the legal basis for the selection of PCIs, and defines a framework for the assessment and cost-sharing of cross-border infrastructure. Some progress has been made in strengthening electricity network infrastructure (e.g. at the Iberian Peninsula). However, severe delays in important major network expansion projects show that network development remains a key challenge, mostly due to permitting issues and the lack of public acceptance. In the light of the transformation of the electricity system, the completion of the missing infrastructure is critical.

The CEP includes provisions for active consumers and distribution system operators as neutral market facilitators, which is a welcome step forward. The vision of an active consumer is clearly enforced through EU rules. The consumer receives the right to generate, store, consume and sell self-produced electricity to organised markets, either individually or through aggregators. This will require a significant reform of distribution tariffs and the creation of a regulatory regime for technology neutral storage (through the collaboration among national regulators), which does not exist today.

In this context, the progress of the necessary transformation of distribution networks is equally important. The interaction of renewable generation and network development has to be closely monitored in the coming years. Aligning new and large renewable projects with efficient and smart network development can save infrastructure costs. Setting the appropriate framework so that network operators and eligible market participants have the information they need for efficient and well-informed decisions and optimal co-ordination is important (especially at the boundary between TSO and DSO).

With the new rules, distribution operators can become neutral but active market facilitators, a progressive approach which the IEA considers as the cornerstone of competitive retail markets, active consumers and greater demand-side participation. However, in practice, the EU has a large variety in the structure, ownership and size of DSOs and the same applies to the national regulators overseeing their regulation. There will be a patchwork of approaches from member states in this area. ACER is tasked to ensure TSO-DSO co-ordination notably through the TYNDPs. An EU-wide DSO association (similar to

ENTSO-E for TSOs) will allow for diverse DSOs across the EU to work together towards the new market rules for distributed generation, including storage, smart metering and demand response.

The CEP incentivises DSOs to introduce dynamic and time-differentiated network tariffs. This is a positive first step towards a more cost-reflective network regulation. In a distribution system with a significant amount of decentralised generation with batteries or other means of storage and flexible demand, current tariff systems will be less and less cost-reflective. Current distribution network tariffs often do not provide sufficient economic signals to alleviate network congestion. In order to incentivise grid-friendly behaviour of customers and generators, tariff regulations should be reviewed, and where necessary adapted. Network regulation should further be assessed to whether the efficient use and deployment of new technologies is adequately incentivised ("copper" versus "smart solution").

The European Commission makes a strong push for the phase-out of retail market regulation for all consumers, while allowing protection of vulnerable consumers through temporary use of social tariffs. To date, retail price regulation is still widely used across the whole EU. Price regulation will still be allowed, but it has to be temporary until new energy efficiency measures result in better management of consumption and reduction of energy poverty. Regulated tariffs need to be targeted and linked to the assessment of energy poverty, which member states will have to perform and report to the Commission every two years.

System integration of variable renewables

The EU has successfully increased the share of variable renewables (wind/solar) in electricity, from 9.7% in 2013 to 16% in 2018. Some EU member states, notably Denmark, Ireland and Spain, operate some of the highest combined wind and solar shares anywhere in the world.

The past five years were characterised by fast technological improvements and cost reductions in wind and solar PV and a lack of comparable progress and even cost inflation for other low-carbon technologies while climate ambitions increased. The expectations for the further growth of variable renewables have become increasingly optimistic. Under the policies already announced and under implementation, the share of wind and solar PV will exceed 40% by 2040, a share previously reached only in small and well-interconnected systems such as Denmark. If wind and solar penetration accelerate to such a level, it is essential that critical policy measures facilitating system integration are implemented in a timely fashion.

Both international experience and system modelling suggest that increasing shares of variable renewables can be integrated in a secure manner by appropriate market reforms, amended system operation and planning, and targeted investments that unlock flexibility in the power system. The four main sources are dispatchable generation, transmission interconnection, demand response and storage. In addition, system-friendly renewable deployment, including the use of high-load-factor wind turbines and smart inverters for solar, can reduce the need for additional flexibility sources.

Considerable progress has been made in system-friendly deployment and adopting system operation methods to high renewable shares. Renewable forecasting has improved, system operation moved closer to real time, improved digitalisation provides a better understanding of network conditions, and an increasing proportion of new renewable deployment is applying system-friendly project implementation choices. On the other hand, the large majority of flexibility continues to be provided by dispatchable capacity, primarily legacy gas and hydro plants. There is very little investment in new dispatchable capacity and even the business model of existing plants remains uncertain. Impressive innovation took place in new demand response and storage solutions, but overall they still play a minor role. In the current regulatory framework, there is still uncertainty about the viability of their business model.

Different renewable production patterns and different demand characteristics across Europe provide a valuable portfolio for effectively smoothing out the variability of renewable production. Therefore, a genuinely integrated single market for electricity is not only desirable from the point of view of market functioning but is also a valuable enabling factor for the integration of wind and solar PV. With the roll-out of market coupling, the utilisation of existing transmission infrastructure has improved, but considerable segmentation persists in the intraday and balancing time horizon. Despite the policy priority on expanding interconnection capacity, new transmission projects tend to face delays and social acceptance barriers.

Although the experience with system integration has so far been favourable, legitimate concerns emerged on whether the current speed of the system transformation is appropriate given the ambitious renewable and climate agenda. The EU aims to address this with the CEP. Several of the CEP provisions contain relevant improvements from a system integration perspective.

CEP aims to make system-friendly deployment the norm by phasing out priority dispatch and mandating technology-neutral balancing requirements for utility-scale renewable producers. New wind and utility-scale solar facilities are to be equipped with appropriate communication and monitoring tools that enable system operators to have close to real-time information on them. On the other hand, a substantial proportion of the existing renewable fleet has not been retrofitted in this way, which limits the effective control of system operators. In some countries, renewable producers get the full wholesale price as compensation in case of curtailment, which dampens incentives for system-friendly location choices, especially in the context of large price zones in the EU market. Generation components in the network tariffs can provide location incentives but they do not play a major role in European tariff design. The EU renewable target is to be achieved bottom-up through an iterative process of the NECPs, in which member states are obliged to include regional co-ordination. However, this does not guarantee regional optimisation of the renewable fleet.

CEP aims to facilitate a stronger contribution from demand response by expanding the role of close-to-real-time price signals, clarifying the roles and improving the incentives for aggregators of distributed resources. Various studies and pilots show how local flexibility can interact with wider integrated day-ahead and intraday markets. In principle, capacity mechanisms should be open to demand-side participation and system operators should open the markets for system services provided by aggregated distributed resources including demand response. However, there are still concerns about the incentives for network operators, especially at the distribution level: unbundling rules on DSOs are weaker than for TSOs. In most countries the electricity network still generates revenues on the basis of a physical regulated asset base, which might create a bias in favour of physical asset solutions over distributed or smart resources. While the electrification of the car fleet is accelerating, the large majority of electric car charging is not yet system-friendly and the roll-out of flexible, aggregated smart charging is lagging behind.

The CEP aims to enhance the use of transmission interconnection by aiming to maximise transmission capacities available to the market. Due to volatile loop flows exacerbated by renewable production, transmission reliability considerations have led to constraining the transmission capacity available for the market. The CEP sets a 70% ambition as the share of interconnection capacity made available to markets while respecting operational security limits, and in addition it sets the principle of bidding zones corresponding to the physical network configuration. System operators are to refrain from pushing internal congestion to the border.

Initiatives are under way to expand the current day-ahead market coupling to intraday and then complete the integration of cross-border balancing markets for various services as well. If properly implemented, these initiatives have the potential to facilitate the integration of variable renewables by taking advantage of more precise intraday forecasting, enabling renewable producers and traders to fine-tune their portfolios. Integrated balancing will enable system operators to deal with increased variability in a cost-efficient fashion.

While the integration of variable renewables into the power system is already well advanced, the integration of renewables in other end-use sectors is the next level of integration. As many countries seeks to boost electrification, notably in transport, the EU will need to prepare the ground for such high electrification with very high shares of variable renewables. The next chapter, on Energy Sector Integration, will examine those new trends in more detail, expanding the system integration analysis of this chapter.

Recommendations

The European Union should:

- Prepare for large-scale electrification with very high shares of renewables as the EU strives towards the decarbonisation of end-use sectors, notably transport.
- Implement and fully enforce the new electricity market design framework to foster efficient market functioning:
  - *On the wholesale level*, implement measures to strengthen short- and long-term price signals, and ensure the capacity made available for trading between bidding zones is maximised (including across national borders) and geographic size of bidding zones optimised.
  - *On the level of retail markets*, ensure that customers can effectively participate in the electricity market. Continue to phase out regulated prices for customers while ensuring targeted social aid to the energy-poor and redirecting state aid to energy efficiency policies that quickly deliver improved social, health and comfort outcomes, while reducing consumer energy costs.
- Implement and guarantee a regional approach to security of supply by building on regional co-ordination and regional and European adequacy assessments. Make sure the CEP regulatory provisions for the approval on new CRMs are strictly enforced.

- Carry out longer-term electricity modelling at regional/EU levels with a view to systematically keep under review potential risks in the European energy system adequacy assessments, and to better and timely identify critical challenges in the electricity sector, notably the anticipated decrease in existing conventional dispatchable capacity, sufficiently early. Establish an appropriate review process for regional adequacy assessments.
- In co-operation with national regulators, facilitate a reform of network regulation in line with an energy system with more distributed generation and active consumers. Tariff regulation should be reviewed to ensure cost-reflectiveness and efficient use of the network and deployment of new technologies.
- Facilitating the timely completion of the integration of European electricity markets to enable the portfolio synergies for renewable integration by:
  - Completing the roll-out of intraday markets and the integration of balancing markets. Encourage also the utilisation of co-operation mechanisms under RED II to ensure cost-effective deployment in line with targets.
  - Working together with member states and national regulators, unlock demand-side flexibility by ensuring that demand-side solutions have a fair level playing field on wholesale markets, on capacity markets where they exist and in markets of system services. Where necessary, ensure the reinforcement of unbundling at the DSO level. Provide clear guidance on how local flexibility markets can interact with integrated day-ahead and intraday market.
  - In step with electrification of the transport sector, accelerate the roll-out of smart, flexible charging solutions. Ensure that charging infrastructure design and information technology standards support flexible charging and reduce barriers to entry for smart charging demand response providers.
  - Based on regional and European-level capacity adequacy assessments, ensure electricity systems have appropriate operating flexibility and ramping ability in the context of a rapid shift from dispatchable to variable renewable generation.

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8. Energy sector integration

Key data

(2017)

Share of electricity in TFC*: 22.9% (industry 33.8%, buildings** 31.6%, transport 1.7%)

Share of direct use of renewables in TFC: 8.7% (industry 8.6%, buildings 11.7%, transport 4.6%)

Share of renewables in power generation: 29.8% (wind 11.1%, hydro 9.2%, bioenergy*** 5.7%, solar 3.7%, and geothermal 0.2%)

*TFC excluding fuels used for non-energy purposes.

**Includes residential buildings and commercial and public service buildings plus agriculture, forestry and fishing.

***Includes primary solid biofuels, liquid biofuels, biogases and renewable municipal waste.

Overview

The European Commission has examined several pathways for the decarbonisation of the European energy system in its long-term strategy for 2050 (EC, 2018): the greater use of energy efficiency and renewable energy, and direct electrification are considered critical to help decarbonise transport, industry and buildings. Several European Union (EU) countries, notably Germany and the United Kingdom, have been integrating renewable energy and energy efficiency policies with a view to help increase the direct and indirect use of renewables. These efforts have been referred to as sector coupling or smart energy integration.

Full direct electrification is not possible for all end uses. The International Energy Agency (IEA) Future Is Electric Scenario of the *World Energy Outlook 2018* assumed that around 60% of end uses can be electrified and that hard-to-abate sectors (transport, industry) need to explore a range of technology options, including the direct use of bioenergy or the conversion of renewables and other fuels into syngas, hydrogen, alongside greater use of carbon capture, utilisation and storage (CCUS). Therefore, energy sector integration goes beyond electrification (and indirect use of renewable energy) and entails the multidirectional coupling of key sectors. A broad view of energy sector integration takes into account a range of energy technologies and builds on the system integration of renewable electricity, digitalisation, and the development of active demand response and energy storage across several sectors.

Energy sector integration is not a means in itself but should offer opportunities for increasing energy efficiency and supporting decarbonisation across sectors, while increasing energy security, reliability and adequacy, and creating scale for the deployment of technology and innovation. Cost-effective sector integration is a gradual process and depends on a country's unique energy system, market structure, regulations, energy mix and technologies.

Policy makers and regulators should adopt a system approach to remove barriers towards energy system integration. Today, market and regulatory rules are designed for each separate energy carrier, such as gas, electricity and heat. Such carrier-specific regulations can become barriers to greater efficiency and decarbonisation. This includes adjusting operation and planning of energy systems across multiple pathways and/or geographical scales to deliver reliable and cost-effective energy services with minimal impact on the environment. Energy sector integration therefore enables the physical, operational, market, regulatory and behavioural changes that allow energy sectors to interact in an integrated, controlled and efficient manner. Furthermore, policies and support schemes should be monitored and adjusted to ensure that the integration is delivering the desired benefits.

In the EU, the discussion about sector integration strongly focuses on the smart system integration (linking energy efficiency and renewables) but also linking power systems with gas systems. This chapter examines the opportunities and challenges for greater energy sector integration in the EU, based on lessons learned in several EU countries across the end-user sectors buildings, transport and industry, with a view to identify where EU energy policy action can support energy system integration including by lowering regulatory barriers that would benefit the overall decarbonisation strategy of the EU.

EU smart energy strategy and policies

The Clean Energy Package (CEP) of 2018 supports ambitious policies for renewable energy deployment and energy efficiency actions and actions to promote smarter energy use and power system integration of renewable energy. The Energy Efficiency Directive (EED II) and Renewable Energy Directive (RED II) set out targets and policies for power generation, heating and transport; however, they leave out other end-use sectors, such as industry and buildings, but those are affected by targets and policies directed at heating.

The European Commission's long-term strategy to 2050 set out several technology pathways for the decarbonisation of Europe's energy system. The strategy underlines the need for the future energy system to integrate several markets and energy subsystems in a smart manner. The strategy expects the share of electricity in total final consumption (TFC) to grow to 75% by 2050 and low-carbon gases to reach a share of 70% of total EU gas consumption (EC, 2018).

On 25 June 2019 the Transport, Telecommunications and Energy Council adopted conclusions on "the future of energy systems in the Energy Union to ensure the energy transition and the achievement of energy and climate objectives towards 2030 and beyond". In its conclusions, the council called upon the European Commission to "undertake an analysis of sector coupling and sector integration technologies, including the production of hydrogen, in particular examining regulatory and market barriers, and explore possible initiatives regarding the efficient integration and deployment of such technologies and energy carriers" (TTE, June 2019).

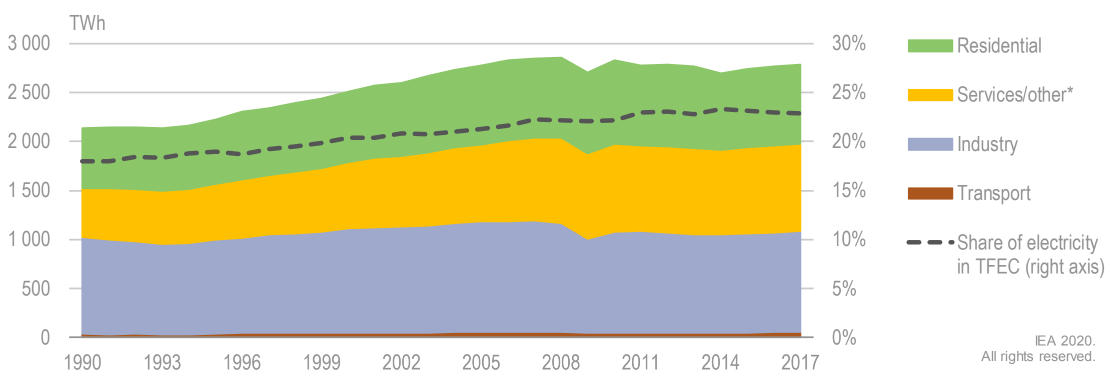
Under the European Green Deal, the European Commission announced plans (EC, 2019a) for a EU smart sector integration strategy (in 2020), and an EU gas package (in 2021) as well as new initiatives to promote energy technology innovation and deployment across the EU. The EU industrial strategy of 2020 also declares hydrogen a strategic priority for the EU (EC, 2020). The upcoming EU Council presidency of Germany, in the second half of 2020, is expected to focus on sector coupling of the gas and electricity sectors, and the creation of a European hydrogen market.

Key trends in the EU

To assess the level of energy sector integration, the IEA suggests examining a few key indicators, notably the role of electricity, energy efficiency improvement rate, CO_2 emissions across end-use sectors and the share of renewables in TFC in different end-use sectors (see key data above).

Since 1990, the share of electricity in TFC of the EU increased from around 18% in 1990 to 23% in 2011, but has been stable since (Figure 8.1).

Figure 8.1 Electricity in TFC by sector and total share, 1990-2017



The share of electricity in TFC has remained stable around 23% in the past decade.

***Services/other* includes commercial and public services, agriculture, forestry and fishing

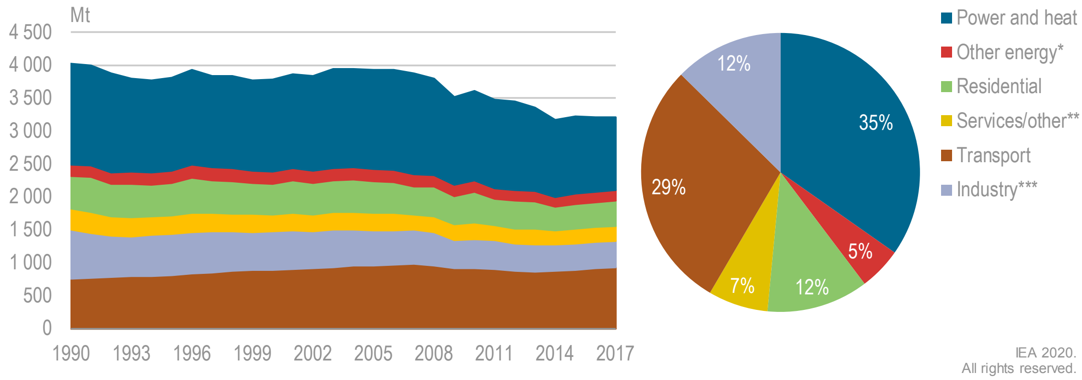
TWh – Terrawatt hour

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

In the decade 2007-17, CO_2 emissions from TFC fell by 10% despite a recent increase from transport emissions, which account for nearly half of total direct emissions in end-use sectors (Figure 8.2). Direct emissions from the end-user sectors accounted for 60% of total energy-related CO_2 emissions, and the transport sector accounted for nearly half of that.

The direct use of renewables in gross final energy consumption has been increasing faster, as the share of renewables doubled during the period 2005-18. Renewables saw the most dynamic development in the electricity sector, where their share surpassed 30% in 2016 (Figure 8.3). However, the use of renewables in the transport and industry sectors remains low, while their share has been growing in heat and buildings to reach 11.3% in 2017. Growth in renewable energy supply has led to a decline in energy-related CO_2 emissions from the end-use sectors.

Figure 8.2 Energy-related direct CO_2 emissions in TFC by sector, 1990-2017



Direct emissions from the end-user sectors accounted for 60% of total energy-related CO_2 emissions, and the transport sector accounted for nearly half of that.

Note: Mt = million tonnes.

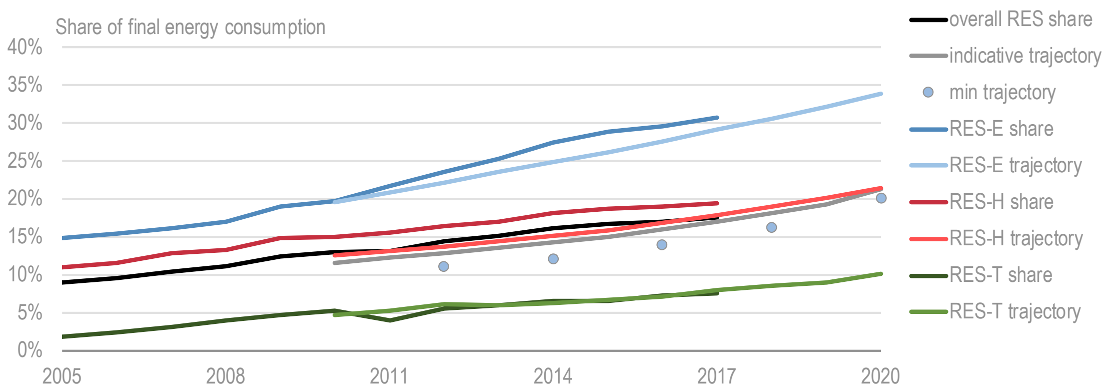
**Other energy* includes oil refineries, oil and gas extraction, coke ovens and blast furnaces, and other energy transformation.

***Services/other* includes commercial and public services, agriculture, forestry and fishing.

****Industry* includes CO_2 emissions from combustion at construction and manufacturing industries.

Source: IEA (2019b), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

Figure 8.3 Share of renewables in final energy consumption, by sector and progress towards the targets



Notes: RES = renewable energy sources; NREAP = National Renewable Energy Action Plan; RES-E = electricity from renewable energy sources; RES-H = renewables in heating; RES-T = renewable energy sources in transport.

Source: EC (2019), Renewable energy progress report, https://ec.europa.eu/commission/sites/beta-political/files/report-progress-renewable-energy-april2019_en.pdf.

Assessment framework

Energy system integration can in its simplest form be understood as connections between energy carriers (heat, electricity and gas) and final energy consuming sectors (buildings, transport and industry) (Figure 8.4). Through increased energy system integration, energy carriers can serve and decarbonise a wider spectrum of end uses, thanks to direct or indirect use of renewable energy in transport, industry or buildings along with increasing use of storage, conversion and active demand-side technologies.

Energy sector integration needs to support the achievement of three key energy policy objectives including:

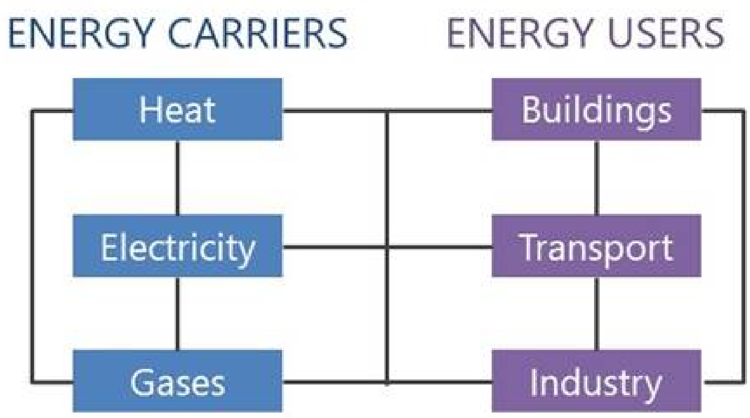
- Decarbonisation, including integration of variable renewables and low-carbon energy sources.
- Providing an efficient end use, thus reducing energy costs, improving system energy efficiency.
- Increasing fuel choice, reliability, flexibility and energy security through diversification of energy supply.

Therefore, policy makers need to focus on three priorities:

First, energy carriers are going to be more and more decarbonised with a range of fuels and new conversion technologies which will support and require more cross-sector interaction. Electricity is on a path towards decarbonisation and the driver of the energy transitions in EU countries. The decarbonisation of heat is progressing in many countries with an increasing focus on sustainable supply of sustainable bioenergy. And many countries look to use hydrogen, biomethane and synthetic gases as a means to decarbonise natural gas as a carrier.

Second, the provision of secure, affordable and efficient services are needed, thereby requiring a stronger alignment of sector- and fuel-specific regulations.

Figure 8.4 Energy carriers to serve multiple energy uses



Third, energy sector integration can boost reliability by moving from unidirectional to bidirectional interactions across one or multiple sectors, based on three different levels, as shown in Table 8.1.

The first level of energy sector integration includes direct electrification of end uses in several demand sectors and the direct use of renewables, mainly in transport, heating and cooling. This level of integration is growing in the EU but will not be enough to achieve full decarbonisation. The electrification of transport does only support decarbonisation, where the electricity generation has become largely low-carbon. In the gas sector, the increased feed-in and blending of natural gas with biomethane, synthetic gases or hydrogen will lead to greater diversification and decarbonisation, but come with efficiency losses. To avoid carbon leakage between sectors, an integrated approach is needed. While providing diversification, this first level of unidirectional sector integration does not on its own fulfil the three objectives of sector integration, outlined above.

In the second and third levels of sector integration, there are many opportunities for demand sectors to play more active roles through demand-side response, flexibility markets and even providing new energy supply options.

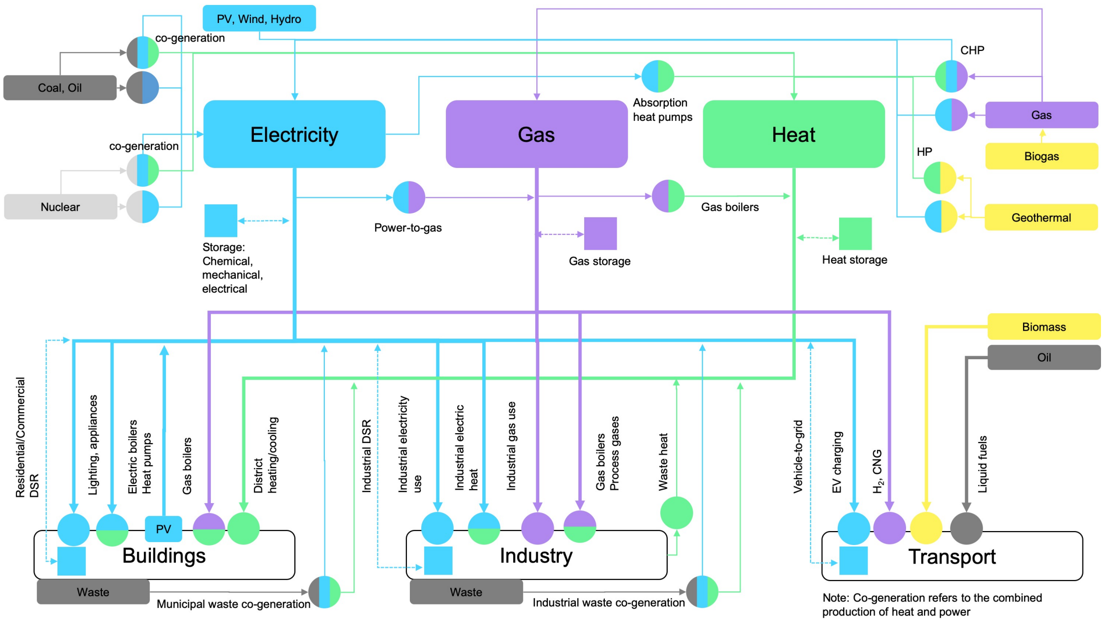
Examples are smart meters/grids that allow demand response through load shedding/load shifting in buildings, industry and the power system, and smart charging that allows demand-side flexibility in electrified transport.

Supply-side flexibility and storage (heat storage, heat pumps) are also considered critical for system integration. Digitalisation is a key enabler of such solutions that can open up bidirectional interaction between sectors.

Table 8.1 Increasing levels of energy system integration

	Level 1	Level 2	Level 3
Diversification of energy supply/decarbonisation			
Diversification and development of energy conversion technologies (heat pump, electrolyser, etc.)			
Development of energy storage capacity			
Reactive sectoral consumption (demand-side response) – still one-way energy flow			
Bidirectional energy flows between sectors: active contribution of sectoral energy storage capacities			

Figure 8.5 Full energy sector integration offers multidirectional links among sectors



Notes: PV = photovoltaic; DSR = demand-side response; EV= electric vehicle; H_2 = hydrogen; CNG = compressed natural gas; HP – heat production. *Co-generation* refers to the combined production of heat and power.

EU case studies of energy sector integration

Energy sector integration has historically emerged mostly in the heat and power sector and is under way in the transport and buildings sectors. Industry is now the focus of EU efforts, as technology and innovation progresses. At the same time, the integration of gas and electricity systems has become a critical enabler, notably with the emergence of hydrogen production and use (see Figure 8.5).

The following sections examine different case studies in the European Union to illustrate key opportunities and regulatory and market challenges.

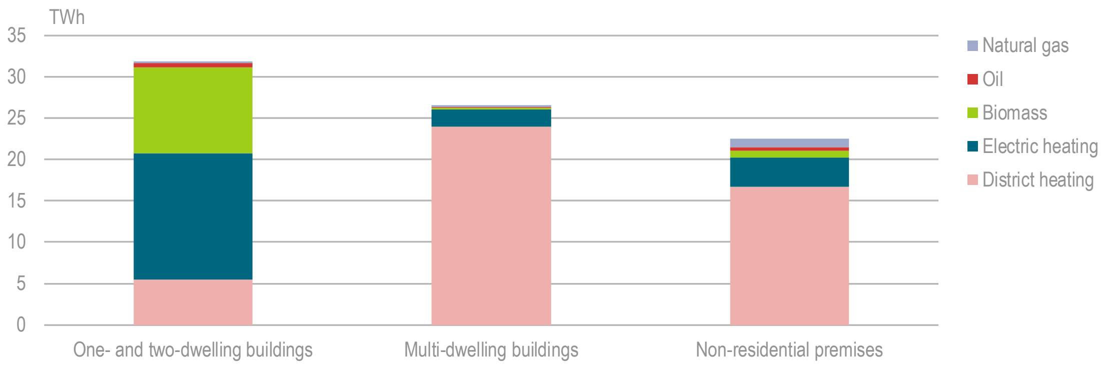
Decarbonising heating and cooling

Sweden – heat and power integration through co-generation district heating and heat pumps

Interdependencies between heat and electricity already exist at a significant level in Sweden. One aspect is the large use of co-generation; the other is the use of electricity for heating with a wide deployment of electric heat pumps. Moving towards even greater energy system integration could be done by improving demand-side response systems.

District heating accounted for nearly 60% of heat demand in total buildings and 90% of heating in multifamily residential buildings in 2017 (Figure 8.6). Co-generation accounted for 74% of the district heating production and nearly 10% of total electricity generation. This coupling between heat and power allows district heating operators to respond to price signals in the power market. Many district heating systems also use large heat pumps, which – together with CHP – enables them to both produce and consume electricity. Large water tanks for thermal storage increase flexibility in heat production. The large access to district heating systems in Sweden allows for utilising industrial waste heat and integrating the industry sector with buildings. The Open District Heating programme in Stockholm allows data centres or other industries or services to sell excess heat to the district heating network (Open District Heating, 2020).

Figure 8.6 Energy consumption for heating in buildings by fuel and building type, Sweden, 2017



District heating has increased significantly in the last decades and together with heat pumps, it has replaced nearly all oil heating in Swedish buildings.

Notes: Energy for space heating and water heating. *Electric heating* include electric boilers and heat pumps
Source: SEA (2019), *Energy in Sweden, Facts and Figures 2019*, www.energimyndigheten.se/statistik/energilaget/?currentTab=1#mainheading.

Electric heating, mainly through the use of heat pumps, is the main heat source in buildings not connected to district heating systems. In 2017, electricity accounted for around half of total space and water heating in one- and two-dwelling buildings (Figure 8.6). Heat pump installations have increased rapidly, adding around 100 000 heat pumps per year in Sweden for over a decade (IEA, 2019c). The use of heat pumps allows for efficient and nearly emission-free heating, thanks to the low-carbon electricity supply in Sweden. However, an issue with the use of electric heating is that it leads to higher peak demand for electricity on cold winter days.

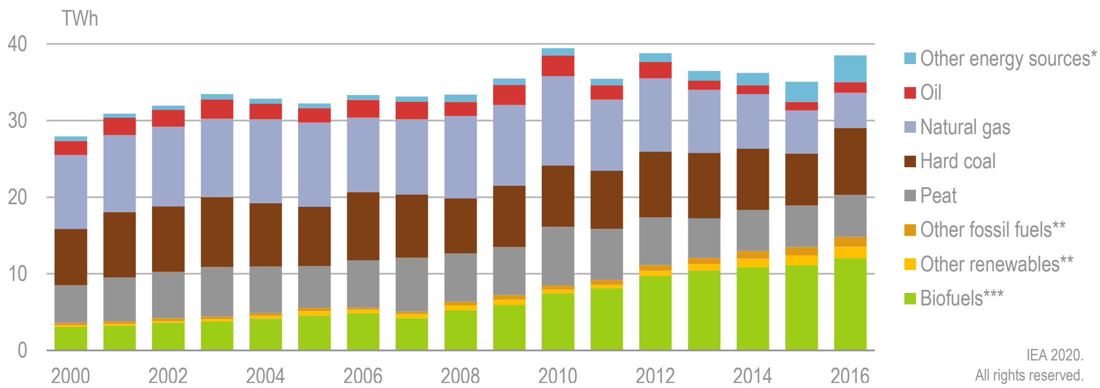
Smart demand-side response systems can provide needed flexibility to shift peak load from heat pumps. Buildings have a thermal storage capacity that allows for short-term changes to the heat supply without affecting the indoor climate. Energy efficiency in buildings has a key role to play for energy system integration, since the better the building envelope is, the higher the thermal storage capacity is. This is tested in some Swedish pilot studies, such as the VäxEl project, where heat pumps in 346 households in Uppland are aggregated and controlled to provide flexibility for the power system (Sustainable Innovation, 2020). Demand-side flexibility can also be provided from buildings connected to district heating systems, which was analysed in the research project *Valuation model for demand-side flexibility* (*Värderingsmodell för efterfrågeflexibilitet)* (Energiforsk, 2019).

Finland – the role of co-generation in sector integration

Co-generation and related district heating and cooling has been a traditional way to improve energy efficiency, promote renewables and link heating with electricity for flexibility. The question is whether co-generation will be able to contribute to the flexibility needs in the future.

The traditional role of co-generation, providing both baseload power and heat, is impacted by lower power prices in the Nordic market, and more variability in the Nordic power system, with wind coming into the generation mix. Many producers are switching to heat-only boilers and consumers to individual heat pumps. The share of co-generation in district heating generation in Finland has declined by 10 percentage points in ten years, as low electricity prices have driven new investments towards heat-only boilers.

Figure 8.7 Fuel mix in district heating generation, Finland, 2000-16



**Other energy sources* include hydrogen, electricity and industrial surplus heat.

***Other fossil fuels* and *Other renewables* refer mainly to municipal and industrial waste.

***B*iofuels* includes solid wood fuels and a small share of black liquor from pulp and paper industries

Source: IEA (2018), *Energy Policies of IEA Countries: Finland 2018 Review*, Paris.

Furthermore, despite a remarkable increase in biomass, 50% of district heating is still produced from fossil fuels (Figure 8.7). As the government has plans to phase out coal by the end of the 2020s under the Powering Past Coal Alliance, biomass-fired co-generation will play an important role. The Finnish government supports the switch to biomass-fired co-generation and new heating technologies. Continued growth in biomass to replace the coal in district heating requires the establishment of clear sustainability rules for biomass imports and the assessment of domestic biomass availability.

The economics of district heating and cooling and co-generation are under pressure also from changing heat loads, requiring more flexibility of heat. For co-generation/district heating and cooling to remain an efficient pillar of the decarbonisation of industry and buildings, heating and cooling needs to be flexible and low-carbon. Finland can reduce the volatility of the heat load with strong building standards, align energy taxation to carbon content to promote low-carbon heat, and support biomass use with more biofuels and provide for greater flexibility (intraday/balancing) in the Nordic power market for new technologies, such as heat storage from accumulators in co-generation production and smart meters in the heat networks (IEA, 2018).

Germany – decarbonising heat supply

The German government is focusing on energy efficiency first and aims at boosting renewable energy use not only in electricity but also for decarbonising heat supply, as well as in heat networks, such as district heating. The decarbonisation of heat supply can be achieved by combining direct use of renewables, including solar heating, biomass, geothermal heat or biogas (fed into gas networks), and indirect use, including district heating or electric heating, produced from renewable sources. These indirect uses can also serve as heat storage and thus provide the flexibility necessary for the transformation to low-carbon heat supply. Electric heating can be supplied locally by heat pumps in buildings or through large-scale power to heat production in district heating systems.

Given Germany's heavy dependence on fossil fuels for heating, along with its rapid growth in renewable electricity, there is an opportunity to both increase the direct role of renewables in heat generation and pursue sector integration, to use more renewables-based electricity for heating.

Large-scale electrification of heating can pose challenges to the electricity grid by shifting energy demand to the power sector, but through sector coupling it can also bring opportunities for improving efficiency in the energy system overall. However, high electricity costs, driven by levies, charges and taxes (including the surcharge in Germany to subsidise renewables), are impeding opportunities to use more electricity in the heating sector, especially in a context of low taxation on fossil fuels (IEA, 2020).

Germany is a leader in sector integration (often referred to as sector coupling in the German context). The German government is preparing a suitable policy framework for the process of increasing sector integration, in order to promote energy efficiency and flexibility requirements, as well as economic viability. To this end, various instruments are being analysed to determine an optimal solution to reduce price distortions and improve the competitiveness of renewable technologies in the heating sector.

Decarbonising transport

Ambitious decarbonisation of the electricity sector will have positive spillover effects on the CO_2 savings potential of transport electrification. Electrification of transport is advancing slowly in the EU with the deployment of around 1.3 million EVs in 2018. More stringent CO_2 standards for internal combustion engines coming in during 2020 will boost the sales of EVs and their share in the car fleet in the EU. Among the barriers, smart charging, battery costs and range, as well as interoperability across the EU market, remain the most important barriers for electricity and transport co-integration.

Given the magnitude of the transport decarbonisation challenge (see Chapter 4), a mix of options is needed, including greater efficiency of the transport system amid new transport and mobility services (including autonomous driving or Mobility as a Service [MaaS]), stringent car efficiency standards, the direct use of renewables through biofuels and synthetic gases as well as hydrogen. To achieve full sector integration, digitalisation is a strong driver and enabler, including through smart appliances (charging) and data hubs.

Finland – Mobility as a Service

Finland aims to transition from the individual vehicle ownership paradigm to a service market enabling easy access to a range of integrated mobility options. Different modes of transport are foreseen to work seamlessly together and to be accessible with a single payment method. The MaaS concept envisions the creation of a high-quality and affordable basket of market-based services that meet the mobility needs of customers, especially in cities.

Finland's Ministry of Transport and Communications launched in 2016 the Transport Code project, an overall reform of transport market legislation, accompanied by tests and pilot projects. The Transport Services Act of July 2018 established common rules for all providers of mobility services. All public and private transport service providers are required to disclose essential data such as routes, timetables, actual location and projected itinerary, prices, and other accessibility information. Ticketing and payment systems will become increasingly open, online and interoperable. For example, transport service providers will be required to apply application programming interfaces (APIs), i.e. smartphone "apps", allowing users to purchase entire trips, regardless of whether these consist of a single leg by one mode, or are multi-stage and multimodal. The act positions Finland as a global leader for MaaS.

MaaS requires public transport agencies to move beyond simply providing public transport services, to the role of a partner and facilitator, exploring and exploiting new business opportunities and facilitating demonstration projects, removing obstacles, and promoting compatibility. Public authorities can work in concert with private companies to develop district stations as transport nodes to improve standards in travel chains and mobility services, and to create automatic transport development areas in urban areas. Public agencies will nonetheless maintain an important role in establishing minimum standards, for example for safety, security and data privacy. The critical steps in transitioning to this new model include:

- First, streamlining and/or scrapping existing regulations, eliminating rules that favour incumbents or that unnecessarily burden businesses.
- Next, creating a level playing field for open competition, based on transparent and easily accessible data that enable public authorities to monitor and measure performance.
- Finally, targeting public efforts towards research, development and innovation and procurement of promising technologies and business models.

Finland aims to establish itself as among the global leaders of digitally enabled transport services. It seeks to create an ecosystem of complementary and coherently integrated transport modalities. Together with digital and physical "enablers", these form the basis for open data on which a variety of personalised service business models compete. One of the points of departure for MaaS is to include information as embedded in, rather than separate from, provision of transport services. The Finnish authorities recognise the potential benefits – in convenience, reliability and resource efficiency – that could be accrued by making data that are in the sole possession of public transit agencies or private companies openly available through APIs to service providers. By shifting competition to the provision of convenient trips and mobility services, new incentives are established to focus on remaining gaps in data coverage or provision of mobility services. The results could be both the further improvement of the availability and quality of transport data, and the more flexible and efficient targeting of scarce public monies.

Netherlands – smart charging of EVs

The Netherlands has a high share of EV sales, with 6.6% of new passenger vehicle sales being electric (third in the world). As penetration grows, smart charging of EVs will become more important to reduce the impacts on distribution grids and provide further flexibility to the electricity system.

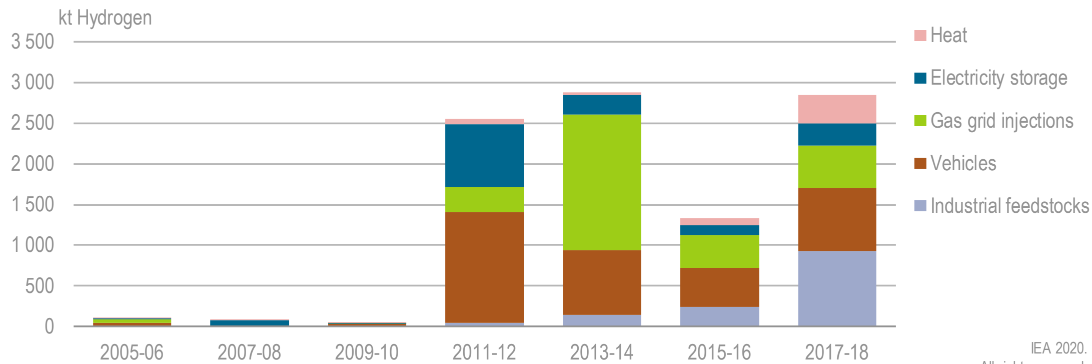
Charging platforms need interoperability and the Netherlands is a leader, with clear standards and an obligation on charging stations to use an open protocol and accept all types of charging from operators.

Decarbonising industry – hydrogen

The IEA hydrogen report (IEA, 2019b) has examined the EU member countries' policies, targets and incentives for hydrogen and the demonstration projects for clean hydrogen. Europe has put a strong emphasis on the production of green hydrogen from surplus renewable electricity. However, the number of full load hours when this surplus electricity occurs is typically rather low and the electrolysis process is very energy-intensive with large losses that could make the investment hard to justify, unless there are grid bottlenecks.

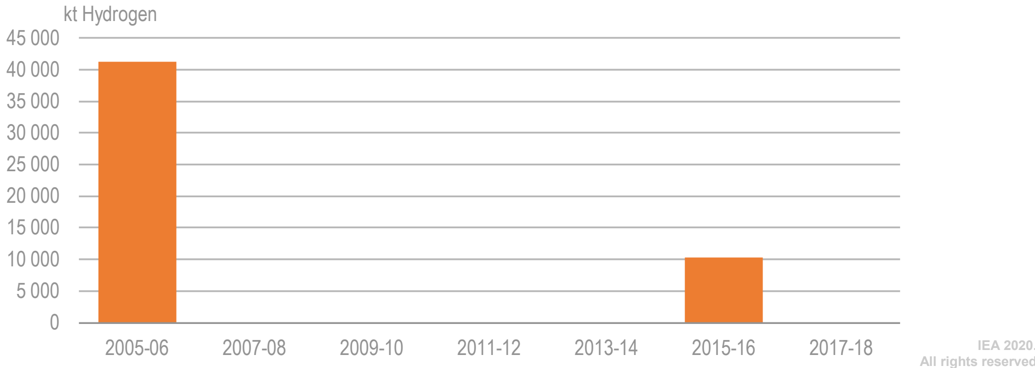
Europe has been a pioneer in getting clean hydrogen projects off the ground in recent years. Electrolysis capacity additions have been ramping up, with 1 000 tonnes to 3 000 tonnes of hydrogen output being added annually, for a variety of small-volume applications.

Figure 8.8 Clean hydrogen production in Europe, electrolysis



CCUS projects relating to clean hydrogen projection have been few and far between, but they are large – between 60 and 240 times bigger than the average-sized electrolysis project installed during 2015-19.

Figure 8.9 Clean hydrogen production in Europe, CCUS



Important regulatory barriers remain under the EU regulation that may hamper the further integration of the gas and electricity sectors. This includes the regulation related to unbundling of gas and electricity transmission system operators (TSOs) and their legal right to own and operate electrolysers.

ACER/CEER presented its views on what regulatory changes may be needed for sector coupling. ACER/CEER underlined that for electricity, existing unbundling rules under the Clean Energy Package already allow TSOs and DSOs investments in storage and recharging stations for electric vehicles. However, for gas, existing unbundling rules may need to be modified to new circumstances (ACER/CEER, 2019). The European Commission has completed a consultation on the regulatory changes needed for the future energy system integration. By the summer of 2020, the Commission plans to present a strategy for system integration and hydrogen which should indeed set out proposals on how to improve the regulatory framework.

There are several countries in the European Union which have already adopted or are in the process of adopting a national hydrogen strategy and concrete plans for energy research, development and demonstration (RD&D). In the Netherlands and in Germany, gas TSOs are planning to operate electrolysers and blend hydrogen into the gas grid.

France highlights in its hydrogen roadmap the need to replace existent uses of fossil hydrogen in industry and refining, by hydrogen from renewables and the potential role of hydrogen as long-term storage option for the power sector.

Hydrogen for heating is being discussed in the United Kingdom. Germany envisages sourcing its production of hydrogen from renewables (20% of hydrogen production, which will require up to 5 gigawatts [GW] by 2030 and by 2040 another 5 GW of electrolysers) and from imports of hydrogen-based fuels from northern Africa (based on the national hydrogen strategy of June 2020). The Netherlands looks into opportunities for its ports to become hydrogen hubs (linked to industrial hydrogen users and the opportunities to produce hydrogen from offshore wind or in combination with CCUS) and using the existing gas grid for hydrogen. Belgium aims to use surplus wind power for electricity and heating thanks to a planned hydrogen plant on the North Sea coast (port of Ostend in 2022), set to be the world's first commercial-scale project of its type.

Other barriers include the sector-specific design of support policies and regulatory approaches. Today, the EU relies largely on the production of hydrogen from natural gas, which may change in the future as electrolysers will convert large-scale renewable electricity. The gas infrastructure is able to accommodate blended biomethane into the gas, provided that certain levels of safety are warranted, but blending of hydrogen into the gas is not allowed in many EU countries. It is also not included under the Sustainable Finance Taxonomy. Once this regulation is changed, other opportunities of sector integration will emerge, which will include large-scale use in transport and industry.

Assessment

In the coming years, the EU needs to prepare the ground for a future energy system, which is expected to be based on greater electrification and new fuels and technologies. This new system will likely see a stronger interdependency of the end-use sectors, thanks to rising shares of variable renewables, electrification and the expansion of low-carbon gases. This will require a review of the policy measures that promote energy efficiency, renewables, electricity/gas markets functioning, infrastructure development, and energy technology and innovation.

The EU has a living laboratory of different member states' approaches, which brings about a broad variety of lessons learned and best practices. Based on the case studies examined in the heating and cooling section, enabling policies for decarbonisation of the heat carriers include:

- Strengthening efficiency of the building envelope to reduce volatility of heating/cooling demand.
- Reviewing the regulations related to energy fuel taxation and subsidies, to reflect the full carbon content of energy carriers, to accelerate the switch to renewables and low-carbon technologies and heat pumps.
- Supporting technology development and penetration of renewables in co-generation and district heating systems, and support the development of heat storage (heat accumulators) in district heating systems.
- Installing smart meters in the electricity and heat networks, to foster flexibility through demand response and efficiency.
- Supporting the development of flexibility markets at wholesale level (balancing power, reserves) and retail level, to boost demand response and smart energy (metering, digitalisation etc).

In the transport sector, experience shows that even with more interconnected and integrated transport modes (such as MaaS), the efficient service provision and the use of low-carbon electricity remain essential pillars if cities want to avoid the congestion and pollution stemming from the use of internal combustion engine-driven service deliveries.

Looking at the examples given in this chapter, sector integration can have notable benefits including:

- Accelerated decarbonisation and reduced greenhouse gas emissions, especially for sectors such as transport or heating, which often have high dependence on fossil fuels.
- Diversification of supply to increase energy security, relevant for countries that lack domestic supplies of fuels, or where fossil fuels dominate certain sectors, e.g. oil in road transportation.

- Lower energy costs and more efficient overall system energy use.
- Increased energy efficiency as end uses can be provided by more efficient processes (EV versus internal combustion or heat pumps versus oil boilers).

To enable effective sector integration, several policy principles are going to be critical for policy makers when defining their policy approach to this new concept.

First it should be noted that many conversion technologies will require higher energy use or have significant efficiency losses (hydrogen, CCUS or high electrification) that should be taken into account when balancing costs and benefits of sector coupling. In this regard, prioritising energy efficiency remains a no-regret policy option, but new efficiency policies will be needed which take into account horizontal links across the sectors, and the energy efficiency performance at a variety of supply chain levels.

While energy efficiency has been strengthened in relevant directives and in the context of the CEP beyond 2020, the policy framework has not changed significantly, especially when compared with other initiatives. Given the changing energy landscape, the rapid pace of technological advancements and the increasing attention paid to energy sector integration, applying the "energy efficiency first" principle at the energy system scale requires new ways of thinking and forging synergies with other policies (including taxation), planning processes and investments.

Mainstreaming of energy efficiency remains critical, for instance for the integration of electricity and gas systems, or electrification of heat and transport. New electric technologies have efficiency benefits compared with traditional fuel switching, and can help reduce the overall energy needs of the EU. Reforms made under the CEP, aimed at enabling active consumers and Citizen Energy Communities to participate in markets, can create real energy efficiency opportunities for citizens and businesses alike. Energy efficiency has to be part of energy system resource planning, so that energy efficiency resources are considered within existing investment decision-making frameworks.

Second, electricity is likely to remain heavily taxed in many EU countries, as the electricity retail price includes a number of subsidies and levies, notably for renewable energy deployment. This high price level presents a significant barrier to the broader electrification of end-use sectors.

Third, a large-scale transformation will require a new approach to energy system planning, infrastructure investment and system operations. The EU has already started efforts by promoting interconnected energy markets, but more interconnections and new regional infrastructure hubs are envisaged to allow a real technology push in key areas, including hydrogen and CCUS.

Due to Europe's climatic conditions, a high renewable share in the European system is likely to face seasonal fluctuations beyond the time horizon of battery storage or demand-response solutions. Production of hydrogen could help to integrate renewable production by overcoming seasonal fluctuations, especially in regions with transmission bottlenecks, provided that technologies prove reliable and cost-effective and gain social acceptance. Hydrogen is now anchored in the EU energy agenda, and the political momentum is high with around 260 projects all across the different sectors (transport, industry, refining, etc). The Fuel Cell and Hydrogen Joint Undertaking, the Hydrogen Europe industry coalition and individual member states drive action across the EU. RED II clarified the definition of storage and extended the scope of guarantees of origin to renewable gases, including hydrogen. Taking a regional approach across several sectors has proven a very effective strategy, and Europe needs to remain fuel-neutral, otherwise it will lose momentum.

The existing European gas infrastructure has a much larger storage capacity than what can be expected from electric storage options. In addition, low-carbon hydrogen, either produced from low-carbon electricity or from gas reforming with CCUS, can enable the decarbonisation of other sectors such as heavy-duty transport or high-temperature industrial heat, where direct renewable options are constrained. While there is an increasing strategic interest in hydrogen as an energy carrier and the first pilot projects are under way, the business model and regulatory treatment of hydrogen-based system coupling is still uncertain. The industry still faces a high level of strategic uncertainty over the scale and mode of future hydrogen capacity and infrastructure development. Significant cost reductions through innovation and scaling up are essential, and an appropriate investment framework would need to be created.

The European Commission has already adopted new rules to clarify the injection and feed-in of hydrogen (through the RED II implementing rules) and is preparing a new framework for gas. These are important steps in the EU energy sector integration, but they remain fragmented. The Commission is working on a smart-sector integration strategy in 2020.

Across all sectors – electricity, heating and cooling, and transport – cross-border co-operation can be key for achieving renewable energy targets. RED I and II allow for mechanisms through which member states can co-operate on renewable energy, such as statistical transfers, joint projects and joint support schemes. Statistical transfers are particularly relevant to facilitate short-term target achievement since they enable member states that have reached a higher renewable energy share than their national target to transfer their surplus to another member state. However, such transfers have been little used thus far; only two agreements specifically on statistical transfers have been concluded – between Luxembourg and Lithuania and between Luxembourg and Estonia.

To build a broad strategy that allows full energy sector integration, the EU is assessing barriers and challenges in the current efforts, to link and allow bidirectional flows of existing and new energy carriers in between production and final energy consuming sectors. Several policy principles are therefore useful for the smart integration of the energy sectors. EU-level action can foster greater efficiency across the common markets and geographical areas and could include elements to:

- Foster low-carbon, efficient and secure carriers (heat, electricity, gas).
- Ensure unbundling rules are reviewed and adapted to new energy storage activities, demand response and others.
- Reduce regulatory, market and policy barriers by integrating policies (energy efficiency and renewable policies, gas and electricity sector policies.)
- Adapt the design of energy markets to strengthen price signals for sector integration (avoid pancaking of tariffs, dynamic/locational pricing, etc.) to ensure there is a viable business case to support the needed investment, services and participation.
- Review energy taxation applied to fuel use in end-use sectors, including electricity consumption, to align it with climate objectives.
- Assess energy sector-wide infrastructure needs and planning of networks (projects of common interest), by planning electricity, gas/CO_2 and heating networks together.

- Foster the co-ordination across sectors (transport, industry, services, agriculture) at the EU level and create a governance for sector integration based on the National Energy and Climate Plans (NECPs).
- Ensure public acceptance and participation, acknowledging the key role consumer behaviour plays in enabling demand response to allow sector integration to proceed. Foster the transparent co-ordination of several sector-specific policies and stakeholders.
- Address emerging threats and risks arising from higher electrification, including cybersecurity risks, including by creating a dedicated co-ordination group of government authorities to exchange information with the system operators and regulators.
- Complete the creation of an EU framework for digitalisation with the data transparency rules that can support the market and flexibility while protecting final end users' privacy.

For infrastructure planning, the current Ten-Year Network Development Plan process should go beyond joint scenario planning and bring together gas and electricity in one integrated list of projects. While doing so, the plan should become more forward-looking and look ahead 20 years, to identify infrastructure requirements stemming from deep decarbonisation. Regarding system operations, a more integrated planning of the system would require better co-ordination of electricity and gas market design and price structures. A review of the unbundling rules is necessary to ensure cross-sectoral integration, allowing low-carbon gases to be mixed, as well as a review of tariff regulation, to understand the alignment needs between gas and electricity tariffs. Lastly, RD&D is important for decreasing the capital costs of new projects.

Recommendations

The European Union should:

- ☐ Operationalise the "energy efficiency first" principle and examine opportunities to scale up energy efficiency at the system level in a range of end-use sectors.
- ☐ Based on the NECPs, review member states' policies on energy sector integration, define the EU scope and review the interaction of different end-use sectors.
- ☐ Identify and lift all regulatory, market and taxation barriers to energy sector integration, notably from overlapping policies and measures.
- ☐ Create a clear, market-based regulatory framework for hydrogen production and energy system coupling facilities, and establish an investment framework that enables the cost-efficient scale-up of hydrogen production and infrastructure.
- ☐ Ensure system planning, operation and system use will take an energy system perspective and address system security risks, including cybersecurity threats.
- ☐ Ensure EU energy RD&D policy efforts support sector integration through joint calls in several areas and smart systems.

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9. Energy technology innovation

Key data

(2019)

EU low-carbon energy R&D spending from EU budget (without nuclear): EUR 1.58 billion (with nuclear budgets for the construction of ITER: EUR 1.97 billion)*

Share of energy R&D in EU budget (Horizon 2020): 11%

EU energy early-stage venture capital market: EUR 530 million

Private sector low-carbon energy RD&D spending*: EUR 19.1 billion

Number of EU low-carbon energy patents (2016):** 5.92 million patents and 11.6 patents per million inhabitants (19.9% in renewable energy, 23.6% in efficient systems, 21.8% in smart systems, 17.8% sustainable transport, 1.1% nuclear safety, and CCUS remainder)

* Based on latest IEA reported data and estimates. Additional spending lines for energy RD&D (e.g. nuclear energy R&D including under Euratom, demonstration under NER300) may not be reported and counted here.

**European Commission (2019), Energy Union Indicators webtool (database) https://data.europa.eu/euodp/fr/data/dataset/energy-union-indicators.

Overview

Energy technology innovation, including research and development (R&D), is one of five pillars of the Energy Union.[39] The Energy Union Strategy, launched in 2015, intends to provide an umbrella governance framework for the European Union (EU) and its member states to collaborate towards a set of common objectives. The energy innovation pillar aims to support breakthroughs in low-carbon technologies by co-ordinating research and helping to finance projects in partnership with the private sector. At the highest level of Energy Union governance, National Energy and Climate Plans (NECPs) help the EU to monitor and align national and EU action, including on energy technology innovation.

Energy innovation also contributes to the broader goals of EU research and innovation policy. Currently, these goals are focused on promoting open innovation, open science and openness to the world. The stated objectives of the EU research and innovation policy are reforming the regulatory environment, boosting private investment in research and innovation, maximising impacts, ensuring open access to scientific publications, and building a global research area.

[39] The title of this pillar is "research, innovation and competitiveness". The others are energy security, solidarity and trust; a fully integrated internal energy market; energy efficiency contributing to moderation of demand; and decarbonising the economy.

Policy, decision-making and consultation competences for energy technology and R&D are spread across multiple institutions and actors in the EU (a mapping is contained in Table 9.4 in Annex I). Responsibilities for the suite of initiatives targeted at energy technology innovation are shared within the European Commission among the Directorates-General for Energy (DG ENER), Research and Innovation (RTD), Mobility and Transport (DG MOVE), Climate Action (DG CLIMA), Communications Networks, Content and Technology (DG CNECT), Internal Market, Industry, Entrepreneurship and SMEs (DG GROW), and Education and Culture (DG EAC) and the Joint Research Centre (DG JRC). The primary co-ordination roles sit with DG ENER and DG RTD. Numerous other institutions and bodies, including counterparts at the member state level, have a role in shaping and executing EU energy innovation policy. This introduces a high degree of complexity for decision-making and evaluation. The EU has been working to address this issue, notably through the Energy Union Strategy and the NECPs, including through modifications to the landscape of EU energy innovation to align with political priorities and technology needs.

Since the last International Energy Agency (IEA) in-depth review in 2014, the energy innovation landscape has evolved in several ways at the EU level. The European Investment Bank (EIB) plays a larger role in funding innovation through InnovFin grants, loans and equity. Stakeholder input to priority-setting has been updated by rationalising the European Technology Platforms and European Industrial Initiatives to become European Technology and Innovation Platforms (ETIPs) in 2016, adding bioenergy, deep geothermal and nuclear (dropping hydrogen, which is covered by the Fuel Cells and Hydrogen Joint Undertaking). The Innovation and Networks Executive Agency was inaugurated in 2014 to implement the Connecting Europe Facility (CEF) (for transport, energy and digital), as well as parts of Horizon 2020, the “smart, green and integrated transport” and “secure, clean and efficient energy”. More attention has been given to supporting small companies to bring clean energy technologies and ideas to market, with funding channelled from Horizon 2020 to the European Institute for Technology and Innovation (EIT).

Recent EU strategies for clean energy innovation

The unique legal context and purpose of the EU shapes the nature of policy developments at the EU level. This stands in marked contrast to national governments, which do not have the same cross-border purpose. While the European Commission has the right of initiative for policies, it needs to demonstrate added European value prior to the adoption of new policies, i.e. that they deliver clear benefits over and above measures taken at national, regional or local levels. Interventions must be assessed for their proportionality to the objective. As a result, the EU is limited in terms of the range of actions it can take and often focuses its efforts on issues of harmonisation, standardisation, cross-border integration or structural differences between regions. Energy research and technology policy is no different, and the developments described in this section reflect this. The objectives and actions reflect the areas and ways in which the EU has competences, such as cross-border collaborative projects, pan-European training and large-scale projects that cannot be financed by a single member state alone.

In 2015, the Innovation Union made adjustments with the aim of introducing a more strategic approach to innovation policy, notably by setting the framework conditions for boosting private-sector activity, using public funding to address innovation gaps, within a new set of high-level priorities relating to “open” innovation.

As part of the Clean Energy Package (CEP), the Commission presented a strategy for Accelerating Clean Energy Innovation which raised the importance of clean energy innovation where "concrete action can be strengthened in the short term, refocused and the synergies improved to support jobs, growth and investment in Europe” and noted “the core investment has to come from the private sector” (EC, 2016). The Commission proposed 20 actions through policies and regulatory frameworks; financial instruments to boost private investment; funding energy science and technology and its market adoption; leveraging Europe's global role; and supporting key actors in the energy system. In 2014, the Commission reviewed state aid rules for energy and environment, aligned standardisation with energy priorities, and increased funding for demonstration. It committed to report annually on progress, most recently in the progress report on accelerating clean energy innovation (see EC, 2019a).

In 2018, the European Commission presented a European long-term strategy for 2050 with a vision for a prosperous, modern, competitive and climate-neutral economy (EC, 2018a). Among the 12 identified priority actions were “boost the EU's industrial competitiveness through research and innovation towards a digitalised and circular economy that limits the rise of new material dependencies”, “start testing at scale breakthrough technologies”, “accelerate near-term research, innovation and entrepreneurship in a wide portfolio of zero-carbon solutions, reinforcing the EU's global leadership” and “mobilise and orient sustainable finance and investment and attract support from ‘patient’ capital (i.e. long-term venture capital)”.

In 2019, the European Commission reviewed the draft NECPs of member states, which are mandatory and aim to align national policies with the EU CEP. A review of the draft NECPs highlighted a lack of consistency between the technology priorities in the drafts and EU technology priorities (EC, 2019b).

In 2019, as the von der Leyen Commission took office, it published political guidelines that include a European Green Deal (EGD). The strategies and investment plans of the EGD also aim at stimulating innovative activity in clean technologies. The EGD pledges to mobilise innovation and research, promote record investment in cutting-edge research and breakthrough innovation by using the EU budget to grow finance to develop a market for innovative companies.

Overall, the Strategic Energy Technology Plan (SET Plan) remains the guiding strategy for implementing energy innovation priorities. Adopted in 2008 as a first step to establish an energy technology policy for Europe, it was refreshed in 2015 with an integrated governance structure and a set of key performance indicators (KPIs) for the measurement of performance in four core priorities – renewables, consumer benefits, energy efficiency, the transport sector – and two technology options: carbon capture and storage (CCS) and nuclear (EC, 2015). Alongside the SET Plan, a Global Technology and Innovation Leadership Initiative and a Strategic Transport Research and Innovation Agenda were launched. In co-operation with industrial stakeholders, researchers and member states, quantitative KPIs for cost and performance were published in 2016 for each of 14 technology areas. The new structure was designed to enhance connections between technology areas and reduce silos.

The ten objectives outlined in the integrated SET Plan are:

- To sustain technological leadership by developing highly performant renewable technologies and their integration in the EU's energy system.
- To reduce the cost of key technologies, especially offshore wind, ocean energy, solar photovoltaic (PV), solar thermal, algae, biomass residues, bioenergy and biofuels.
- To create technologies and services for smart homes that provide smart solutions to energy consumers.
- To increase the resilience, security and smartness of the energy system.
- To develop new materials and technologies for, and the market uptake of, energy efficiency solutions for buildings.
- To continue efforts to make EU industry less energy-intensive and more competitive.
- To become competitive in the global battery sector to drive e-mobility forward.
- To strengthen market take-up of renewable fuels needed for sustainable transport.
- To step up research and innovation activities on the application of CCS and the commercial viability of carbon capture and utilisation (CCU).
- To maintain a high level of safety of nuclear reactors and associated fuel cycles during operation and decommissioning, while improving their efficiency.

A framework for energy innovation policies

Technology innovation processes are complex and decision makers must pay attention to a variety of elements that characterise successful energy innovation systems. The IEA groups these elements into four core functions: A) resource push; B) knowledge management; C) market pull; and D) socio-political support (Table 9.1).

While the appropriate policy measures to address each function can vary widely with the size of a country's economy, the technologies it prioritises and the strength of its existing R&D base, successful energy innovation ecosystems have effective policies in each of the four areas. In some cases, the policies might operate at different levels, such as local, national or supranational, as in the case of the EU. The following sections of the chapter present the institutional and policy landscape across these four functions.

In most countries, government efforts are focused towards resources push, and significant impacts on innovation are also made via market pull. This is largely because government innovation objectives target new technologies for public goods that are not yet widely valued by markets and because firms tend to underinvest in innovation due to so-called "free rider" issues. For both reasons, a key contribution of governments is undertaking the complex task of allocating taxpayer resources to researchers with the highest potential to develop impactful new ideas. The EU is no different in this respect, as described throughout this chapter, and has the additional challenge of allocating resources effectively across member states that can have varying national resources, competences and potentials for innovation.

Table 9.1 Four functions of a successful innovation ecosystem for energy

Core function	Description (e.g. key elements, indicators, possible policy instruments)
A. Resource push	• Technology innovation requires a sustained flow of funding for research, development and demonstration (RD&D). Given the high risks of early-stage technology development, governments play an important role in strategically investing these resources, based on national priorities and financing gaps. Tracking public and corporate funding for RD&D activities can help identify funding priorities. • Successful RD&D projects are driven by a skilled workforce (e.g. researchers, engineers) and research infrastructures (labs and universities). A variety of indicators may inform policy making, such as the number and quality of research and academic institutions, of graduates, of R&D support staff; and number of researchers. • To guide the search, decision makers need to identify gaps and priorities, and may lay out a national energy RD&D strategy or roadmaps for individual technology areas.
B. Knowledge management	• New products and processes usually combine novel and existing ideas that have been generated by researchers and codified by knowledge management institutions to make them accessible and attributable. This process may be tracked thanks to publication and patenting statistics. • The effectiveness of innovation relies on strong networks for knowledge exchange among research teams, academia, industry, policy makers and international partners. Promoting co-ordination and collaboration among these actors can maximise knowledge spillovers from a range of other relevant fields to the energy sector.
C. Market pull	• To enable the entry of new products into markets, policy makers need to align incentives through the innovation value chain and provide market signals that the new technology can be profitable if successful, thereby fostering the overall “ease of doing innovation” environment. • Among the most powerful tools for stimulating innovation that are available to policy makers are performance-based market instruments that value the attributes of the new technology. Policy instruments to support early deployment may include carbon pricing, tax incentives, public procurement, standards or financial incentives that complement capital grants (resource push), including the enabling of demonstration projects. These can benefit from clearly scheduled timetables for introduction or strengthening, to provide a lead time to innovators.
D. Socio-political support	• In many cases, successful innovation requires domestic support from citizens or, at a minimum, no effective opposition. The enthusiasm or approval of consumers will determine the uptake of end-use technologies. Likewise, the actions of vocal groups of opponents can derail a new technology at the final stage of market introduction. Inclusive processes (e.g. by seeking feedback from citizens and advocacy groups) that ensure robust governance and promote transparency can help identify concerns at an early stage and smooth the innovation phases. • Policy makers need to be aware of the perspectives of industry stakeholders (e.g. by consulting industry associations) to help ensure that private-sector efforts can be aligned with national policy goals. Technologies with strong political advocates will stand a better chance in the later stages of the innovation process, all other things being equal. • Multilateral co-operation in international fora is an increasingly important part of strategies to accelerate energy innovation, such as high-level international political commitments providing legitimacy to national efforts, as illustrated by Mission Innovation.

A. Resource push

EU research framework programmes

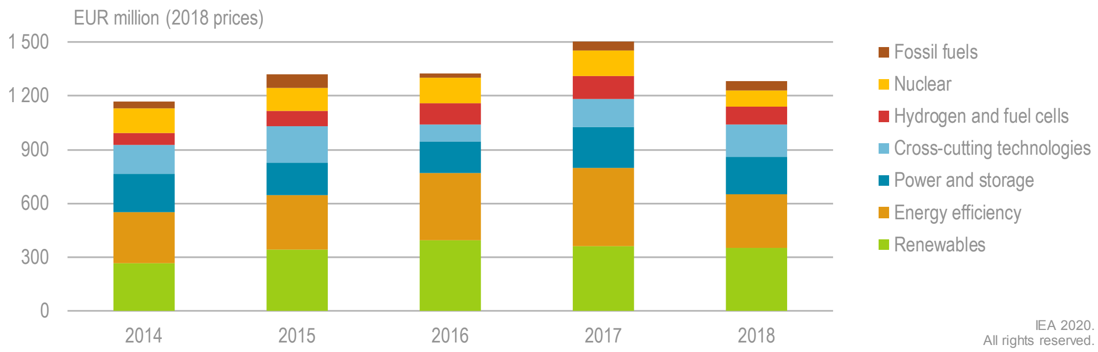
The vast majority of resources provided to the energy innovation system from the EU level are in the form of budget commitments in the EU research framework programmes (FPs), of which Horizon 2020 is the latest. The FPs operate over the same seven-year time periods as the EU multi-annual financial framework. The Horizon 2020 programme (EC, 2011) runs from 2014 to 2020 and had a budget of EUR 77 billion. The stated objectives of Horizon 2020 were:

- To increase spending on R&D to 3% of gross domestic product (GDP) by 2020.
- To spend at least 35% of the budget on climate-related expenditures.
- To contribute to building an economy based on knowledge and innovation across the whole EU.
- To achieve a functioning European Research Area (ERA).
- To provide dedicated support for RD&D on information and communication technology, nanotechnology, advanced materials, biotechnology, advanced manufacturing and processing, and space.
- To overcome deficits in the availability of debt and equity finance for R&D and innovation-driven companies and projects at all stages of development, including development of EU-level venture capital.
- To stimulate all forms of innovation in small and medium-sized enterprises (SMEs), targeting those with the potential to grow and internationalise across the single market and beyond.
- To make the transition to a reliable, sustainable and competitive energy system, in the face of increasingly scarce resources, increasing energy needs and climate change.

The energy part of the budget (including nuclear) has grown since the 7th FP (FP7), from EUR 2.4 billion for 2007-13 (around 5% of the total budget) to EUR 8.3 billion for 2014-20 (11% of the total budget) under Horizon 2020. Horizon Europe does not currently envisage a dedicated budget for energy, but foresees EUR 15 billion for 2021-27 (16% of the total budget) for energy, climate and mobility actions. This would equate to a similar level of spending as under Horizon 2020 if the respective shares for the three areas are maintained.

Half of the Horizon 2020 energy budget in 2018 was allocated to renewable energy (27% of the total) and energy efficiency (23%) (Figure 9.1). Funding on renewables was spread across different energy sources including solar, wind, bioenergy, geothermal and ocean energy. Of the energy efficiency funding, around a third was directed at industry and smaller shares to buildings, transport and other energy efficiency areas. Power and storage and other cross-cutting technologies together accounted for 30% of total energy RD&D in 2018. Money to cross-cutting research in particular has increased in recent years, doubling its share in the total budget since 2016. The nuclear research budget, on the other hand, fell by a third in 2018, and its share of the total budget was only 7%. The rest of the budget was spent on RD&D for hydrogen and fuel cells (8% of the total) and fossil fuels (4%).

Figure 9.1 Energy-related RD&D spending per sector from EU Horizon 2020 programmes, 2014-18



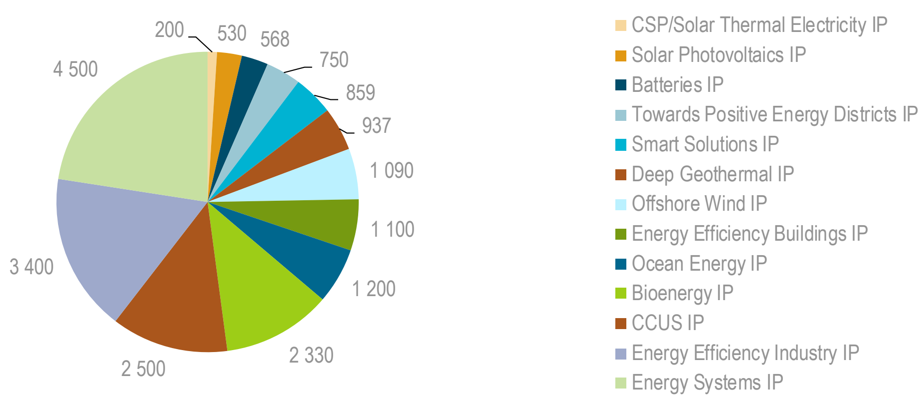
Renewable energy and energy efficiency receive over half of the total energy RD&D budget under the Horizon 2020 programme.

Source: IEA (2019a), *Energy Technology RD&D Budgets 2019*, www.iea.org/statistics.

Horizon 2020 integrated elements of the competitiveness and innovation framework programme that targeted SMEs. Through InnovFin, Horizon 2020 includes a broader range of financing tools than the FP7 and its Risk-Sharing Finance Facility.

However, current EU spending is not in line with the planning under the SET Plan implementation, which includes over EUR 20 billion of spending on energy technologies between 2018 and 2030, of which a significant share would presumably come from member states and the private sector (Figure 9.2).

Figure 9.2 SET Plan expected volume of investments in research and innovation (EUR million), 2018-30



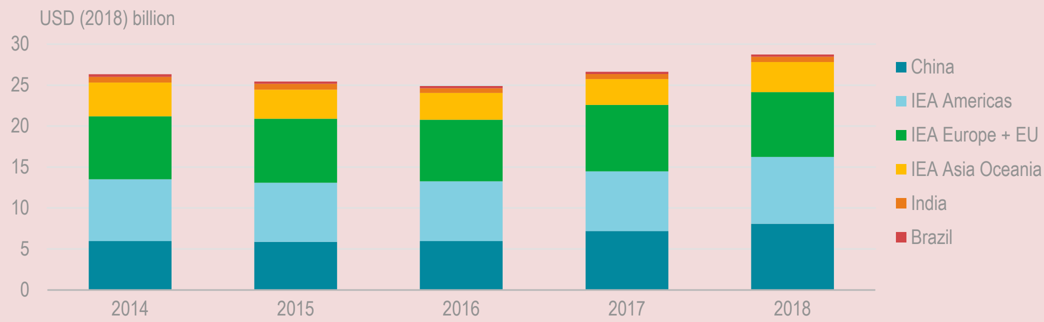
Note: IP = Implementation Plan.

Source: EC (2018c), SET Plan delivering results: The Implementation Plans – Research & innovation enabling the EU's energy transition, https://setis.ec.europa.eu/sites/default/files/setis%20reports/setplan_delivering_results_2018.pdf.

Box 9.1 International benchmarking

The European Union, including its member states, is the world's third-largest funder of public energy R&D, after the United States and the People's Republic of China ("China"), as illustrated in Figure 9.3. In 2018, the EU spent EUR 1 281 million on energy-related RD&D, which was 16% lower than in 2017, but a similar level as in the years before. Among the EU countries, the governments of France, Germany and the United Kingdom are the biggest investors in energy-related RD&D. Under Mission Innovation, the EU is committed to double its relevant clean energy RD&D funding from about EUR 1 billion to EUR 2 billion in 2020.

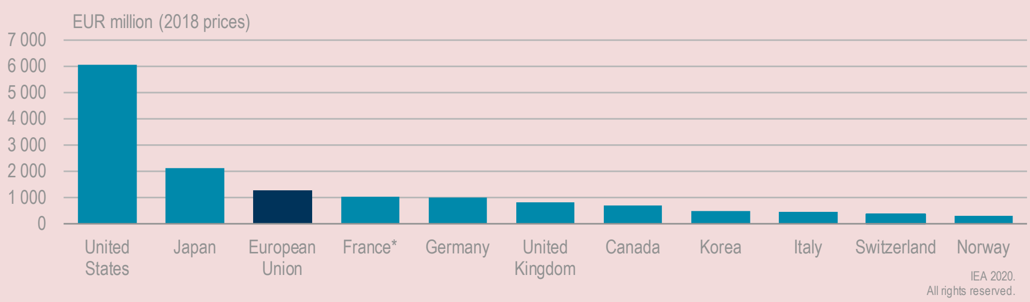
Figure 9.3 Evolution of global energy RD&D public spending by region or country



Source: IEA (2019b), Clean energy transitions: Accelerating innovation beyond 2020. Focus on India, Paris, https://www.iea.org/reports/clean-energy-transitions-accelerating-innovation-beyond-2020

At EUR 1.28 billion in 2018, the EU budget for publicly funded energy RD&D (without nuclear) was slightly larger than that of Germany, half the size of Japan's equivalent budget and one-third of that of the United States. The Horizon 2020 budget alone is larger than any IEA member country except the United States and Japan (Figure 9.4).

Figure 9.4 Energy-related RD&D spending by IEA country, 2018



The energy RD&D budget of the EU under the Horizon 2020 programme is now larger than that of all but two IEA member countries: the United States and Japan.

*France data are from 2017.

Note: EU budget on clean energy RD&D spending does not take into account New Entrants Reserve (NER300), ITER and Euratom nuclear research funding.

Source: IEA (2019a), *Energy Technology RD&D Budgets 2019*, www.iea.org/statistics.

The vast majority of Horizon 2020 funds are disbursed to collaborative research projects as grants. These projects can typically run for up to five years, and most require involvement of organisations from at least three member states. Most of these grant awards are to academic institutions and research institutes. However, compared with its predecessor, Horizon 2020 provides for more types of innovation support. So-called Horizon Prizes have been launched in the field of energy to induce innovation by rewarding researchers who can meet a quantified challenge that has not yet been solved. Horizon 2020 funds also fund innovation activities and equity investments of the EIB and EIT.

Horizon 2020 also disburses funds to individual researchers or networks of researchers to develop skills and new lines of enquiry. Marie Sklodowska-Curie actions and European Research Council (ERC) grants are the primary examples. The ERC grants account for 17% of the overall Horizon 2020 budget, i.e. EUR 13.1 billion (2014-20). Since 2007, more than 9 500 projects have been selected for funding. The programmes include support for innovative training networks and work exchanges. For example, consortiums of institutions have combined to train students on innovative controls for renewable sources, integration into smart energy systems, and smart value generation by building efficiency and energy justice for sustainable living.

Box 9.2 How does the EU set its priorities for energy R&D funding?

The priorities for Horizon 2020 funding are articulated by the SET Plan. Within each technology area, the ETIP and European Energy Research Alliance (EERA) consultative bodies provide formal and informal representation of the views of industry, researchers and member states. A public consultation on energy technologies and innovation supported the 2015 SET Plan revision (EC, 2013). This consultation showed a preference among stakeholders for actions related to energy efficiency, renewables, system-wide projects and energy storage. It also recommended targeting funds to demonstration projects, applied research, and projects that favour economic growth and job creation. Most respondents expressed support for the co-operation systems of the ETIPs. The largest single groups of respondents (25%) represented companies, notably manufacturers and utilities. Private respondents, research institutions and industry associations significantly outnumbered non-governmental organisations and national governments (3%). Most respondents active in a specific sector were from the energy efficiency sector, followed by energy systems and networks.

In combination with the expert knowledge of European Commission officials in the directorates-general, this input is translated into three-year work plans that focus on specific parts of the value chain for the different parts of the energy system. For example, the 2018-20 work plan for energy includes 20 calls for proposals on buildings energy efficiency, 8 on other types of energy efficiency, 16 for system-level renewables, 9 for biofuels, 7 for consumer-level renewables, 18 for smart grids and communities, 5 for other renewables, 7 for CCUS, 5 for batteries, and 5 for other consumer-related issues (EC, 2019c).

To guide prioritisation within each technology area, the relevant ETIP steers a process of defining an Implementation Plan that includes strategic targets and milestones. This process typically involves representatives of ERRA and industry, but it is a strength where member states are involved. One intention of this process is to align with EU policies and member state priorities (and avoid duplication). Depending on the technology, targets can be a mixture of cost targets, technical performance targets, research milestones, and targets for capacities of pilot and demonstration projects. The first 14 Implementation Plans were published in 2017, with some targets established for as early as 2020. They supersede the seven 2008 technology roadmaps of the European Industrial Initiatives. There is no published timetable for their revision, but this could potentially form part of the annual SET Plan reporting framework.

Horizon 2020 has placed more emphasis on public-private partnerships that steer project funding towards projects agreed jointly among public, private and research stakeholders across Europe. For example, Sustainable Process Industry through Resource and Energy Efficiency (SPIRE) involves mainly energy-intensive sectors (cement, ceramics, chemicals, engineering, minerals, non-ferrous metals, steel and water) and directs Horizon 2020 calls for topics it prioritises. The Fuel Cells and Hydrogen Joint Undertaking is a more established version of a similar concept, begun in 2008. To aid prioritisation and synergies between projects, networks of researchers (notably through the ERA-NETs) have been expanded under Horizon 2020 to cover around ten specific energy topics. The latest additions are for offshore wind and smart cities.

Nuclear research

Nuclear research has been supported by the European Research Programme for decades. The associated budget is made of three parts: the nuclear fission indirect actions, the nuclear fission direct actions and the fusion research programme.

The nuclear fission indirect actions finance or co-finance collaborative research projects by the nuclear research stakeholders of the Euratom Community (and beyond, under some conditions), mainly the research labs, industry, technical safety organisations and waste agencies. The nuclear fission direct actions finance the activities of the DG JRC, created by the Euratom Treaty, and active on nuclear projects on four main sites in the EU (Karlsruhe, Germany; Petten, Netherland; Ispra, Italy; Geel, Belgium). The fusion research programme finances collaborative research on nuclear fusion, not including the financing of ITER. ITER is under construction in Cadarache, France, as a large worldwide international project aiming at demonstrating the possibility for a fusion reactor to produce more energy than it consumes. The ITER project is co-financed by the countries that are members of the ITER consortium (intergovernmental agreement) and the Euratom Community. Euratom contributes 45% of the total budget, and the other members 9% each. The Euratom budget for ITER is not coming from the Euratom Research Programme, but from a dedicated budget line in the EU budget.

The historic evolution and structure of the Euratom research budget, as part of the global EU research budget, is given in Table 9.2. Euratom budgets (as per the Euratom Treaty) are five-year budgets, extended by an additional contribution for two more years to align them with the seven-year cycle of the Multiannual Financial Framework of the EU (under the Treaty on the Functioning of the European Union [TFEU]). The budget proposed for the Euratom research programme for the next period is lower than what it was for the previous one. The revised MFF proposal by the European Commission in May 2020 revised the spending for nuclear by around 20% in each area. The budget for the next period, 2021-2025/27, is the proposal by the Commission; the final budget may differ as the result of the ongoing interinstitutional discussions and decisions.

The budget for collaborative nuclear fission indirect actions is of the order of EUR 60 million per year and covers several domains: reactor systems and safety (around 40%); waste management, decommissioning and geological disposal (around 25%); radiation protection and non-energy (i.e. medical) applications (around 20%); and research infrastructures, training and mobility (around 15%).

Table 9.2 Euratom research budgets over time

Research Framework Programme	Total EU funding (EUR billion)	Total EURATOM funding (EUR billion)	EURATOM funding for indirect actions in fission, fusion and JRC direct actions (EUR million)	ITER funding for its construction (EUR billion)
FP4 (1994-98)	11.88	1.23	170 – 794 – 271	
FP5 (1998-2002)	13.70	1.26	191 – 788 – 281	
FP6 (2002-06)	17.88	1.35	209 – 824 – 319	
FP7 (2007-13)*	50.52	2007-11: 1.45	287 – 654 – 514	2007-20: 6.6 (cap) 2007-2011 : 1.3
		2012-13: 0.55	118 – 197 – 233	2012-13 : 1.3
FP8 Horizon 2020 (2014-2020)	86	2014-18 : 1.79	355 – 710 – 724	2.7
		2019-20 : 0.771	152 – 350 – 269	
FP9 Horizon Europe (2021-27)	100	2021-25 : 1.674 (2021-27 : 1.981*)	0.809 – 0.370 – 0.802	5.6**

* With the start of the FP7, the framework programmes span over 7 years, while the EURATOM budget kepts its five-year cycle. Therefore, the EURATOM budget has two spending periods in each EU framework programme to adjust.

** The budget envelopes are proposals by the European Commission.

Source: EC (2020), The EU budget powering the recovery plan for Europe, COM (2020) 442 final, https://ec.europa.eu/info/sites/info/files/about_the_european_commission/eu_budget/1_en_act_part1_v9.pdf

The Euratom Scientific and Technical Committee, the only committee established by the Euratom Treaty itself, recommended in its 2017 opinion that the budget for fission research within the Euratom Framework Programme be increased; that synergy be sought with other EU research fields, among others materials and medicine; that the basic research and the fusion programme and activities be pursued in parallel to ITER, to boost the demonstration and reactor stage for fusion energy (Euratom, 2017, 2018). Two independent expert groups reported on the interim evaluation of direct and indirect actions implemented under the 2014-2018 Euratom programme. In 2016, a separate panel of experts conducted a mid-term review of the European joint programme on fusion research, implemented by the EUROfusion consortium.

Support to early commercial projects

Under Horizon 2020, the EIB has introduced InnovFin financing tools to assist innovative demonstration projects, particularly in the field of energy, and assist innovative SMEs. The stated objective of InnovFin is to help the EU to catch up with its global competitors in terms of both private and public investment in research and innovation. Based on existing risk finance available before Horizon 2020, the range of instruments has been expanded and now includes loans, guarantees and equity-type funding.

One of the InnovFin tools is the InnovFin Energy Demo Projects. This provides loans, loan guarantees or equity-type financing between EUR 7.5 million and EUR 75 million to first-of-a-kind commercial-scale demonstration projects, including for renewable energy technologies, smart energy systems, energy storage and CCUS. Loans can be for up to 15 years and are conditional on the projects having the potential to facilitate subsequent commercial deployment, generating bankable commercial revenue and co-funding from other public or private sources. In 2016, the Horizon 2020 capital available for this programme was doubled to EUR 350 million. InnovFin Energy Demo Projects is now capitalised by some of the unspent funds from the NER300, which exceed EUR 1 billion.

Among InnovFin Energy Demo Projects awards, in early 2018, a loan of up to EUR 52.5 million was approved under this programme to start construction of a battery manufacturing plant to be constructed by Northvolt. A EUR 10 million credit line was provided to AW-Energy for a wave power demonstrator. It also supports the GreenWay Group to install electric vehicle chargers in Slovakia. Alongside InnovFin Energy Demo Projects, other InnovFin instruments have supported energy innovators. InnovFin MidCap Growth Finance facility provided EUR 20 million to Heliatek, an organic solar PV film developer.

The New Entrants Reserve 300 (NER300) of the Emissions Trading System (ETS) is a mechanism established in 2010 that set aside 300 million EU emissions allowances to be monetised to provide financial support to first-of-a-kind projects for innovative large-scale low-carbon technologies. The instrument raised EUR 2.1 billion, which is eligible for disbursement by the European Commission only after the project enters operation and is disbursed on a pay-for-performance basis. Originally designed as a CCS support measure, the first two rounds of awards, in 2012 and 2014, were able to award funding only to one CCS project, which was cancelled in 2016 for lack of co-funding. In total, 39 projects in bioenergy (including advanced biofuels), concentrated solar power (CSP), geothermal power, solar PV, wind, ocean energy and distributed renewable management (smart grids) were supported by the NER300. Of these, six have entered operation – including projects for advanced biofuels, biogas, offshore wind and onshore wind – and 14 withdrew after the award. The EUR 1 billion unspent has been recycled to InnovFin Energy Demo Projects and the CEF. It is likely that more of the budget will also be transferred to these instruments as other projects fail to meet the terms of their contracts.

Support to entrepreneurs to commercialise new energy technologies

The EU programme for the Competitiveness of Enterprises and SMEs (COSME) for the period 2014-20 has a total budget of around EUR 2.3 billion. It fulfils an important function by providing relatively small amounts of financial support to innovative entrepreneurs in early stages of their development in the form of loan guarantees and equity. It also provides access to entrepreneurial training and helps identify possible financing sources. It is an “on demand” process, i.e. not run as a competitive, regular award process. While it has no specific energy mandate, its EUR 2.3 billion budget (2014-20) has supported energy SMEs and collaboration platforms with loans up to EUR 150 000 and equity investments. For example, it has supported the REINA PLUS and GEO-ENERGY EUROPE networks. In addition to COSME, EUREKA Eurostars received funding of EUR 287 million under Horizon 2020 to support R&D-intensive SMEs that have a European or international outlook. Other Horizon 2020 actions to support innovative SMEs include InvestHorizon, Access 4 SMEs, Alfinator, TechCapMarkets and the Early-Stage Investing Launchpad (ESIL).

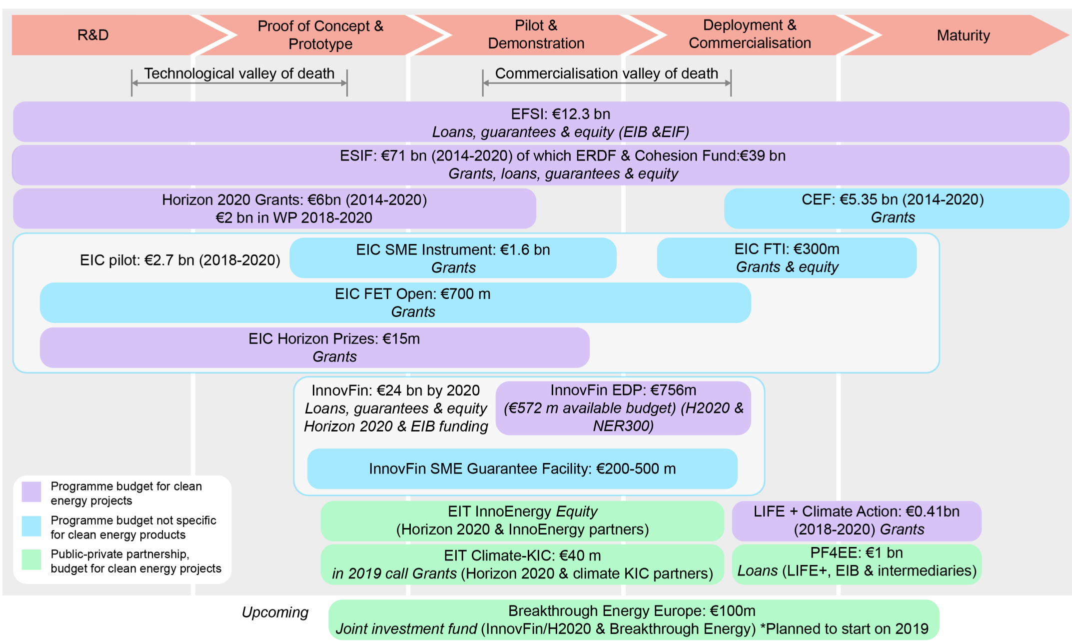
Through its constituent organisations EIT InnoEnergy and Climate-KIC (Knowledge and Innovation Community), the EIT invests EU budget in emerging energy technology start-ups. The EIT is described in more detail below in the section on Knowledge Management.

In May 2019, EUR 50 million was committed from InnovFin to a new Breakthrough Energy Ventures Europe fund to take equity in EU-based clean energy entrepreneurs alongside EUR 50 million from Breakthrough Energy Ventures, an investor-led fund. The rationale is that there is not sufficient private capital willing to make VC investments with the time horizons required for high-potential clean energy technologies. No investments have yet been made.

Investments in new infrastructure to support energy innovation

The CEF, which has a budget of EUR 5.35 billion over 2014-20 for energy infrastructure projects, can include grants and studies for first-of-a-kind installations of novel technologies such as smart grids and CO_2 networks. The European Regional Development Fund, which prioritises investments in the low-carbon economy in less-developed regions of the EU, has a budget of EUR 183 billion for 2014-20.

Figure 9.5. EU funding and financing for clear energy (up to 2020)



Notes: EIB = European Investment Bank; EIF = European Investment Fund; EFSI = European Fund for Strategic Investment; ESIF = European Structural and Investment Funds; ERDF = European Regional Development Fund; FTI = Fast Track to Innovation; EDP = EIB Energy Demo Projects; LIFE = EU's funding instrument for the environment and climate action; PF4EE = Private Finance for Energy Efficiency (EIB and EC)

Source: Trinomics (2018), Energy and the MFF, Study for the European Parliament ITRE Committee, http://trinomics.eu/wp-content/uploads/2018/03/Energy-and-the-MFF.pdf

Future EU funding for energy innovation

In 2018, the European Commission proposed a regulation establishing Horizon Europe (EC, 2018b) as the framework programme for research and innovation for the period of 2021-27. Under Horizon Europe, the climate, energy and mobility cluster is one of five clusters under the global challenges and industrial competitiveness pillar with a proposed budget envelope of EUR 15 billion out of the total budget of Horizon Europe. The programme will prioritise projects that promise solutions for several overarching missions: adaptation to climate change, including societal transformation; healthy oceans, seas, coastal and inland waters; and climate-neutral and smart cities. Moreover, there is a requirement that 25% of EU expenditure contribute to climate objectives over the period.

The stated objectives of Horizon Europe are:

- To support the creation and diffusion of high-quality new knowledge, skills, technologies and solutions to global challenges.
- To strengthen the impact of research and innovation in developing, supporting and implementing EU policies, and support the uptake of innovative solutions in industry and society to address global challenges.
- To foster all forms of innovation, including breakthrough innovation, and strengthen market deployment of innovative solutions.
- To optimise the programme's delivery for increased impact within a strengthened ERA.

Horizon Europe will continue to be the major funding source for collaborative projects on technology development and basic science and research.

As part of the EGD, the EU aims to become climate-neutral by 2050 and help companies become world leaders in clean products and technologies. This gives increased responsibility to energy research and more focus on helping turn research into highly competitive clean energy companies. The overall ambition is to continue simplifying the different programmes so that the different elements of the innovation value chain are adequately and distinctly addressed (Figure 9.6).

A new European Innovation Council was created with a EUR 10 billion budget for the period of seven years with the aim to translate research into commercialised results of clean energy companies, and identify and fund Europe's most innovative start-ups and SMEs. This structure is currently at a pilot stage. It is expected to have the potential of becoming a one-stop shop for innovative SMEs, simplifying the current range of funding opportunities across the EU and providing access to blended finance solutions.

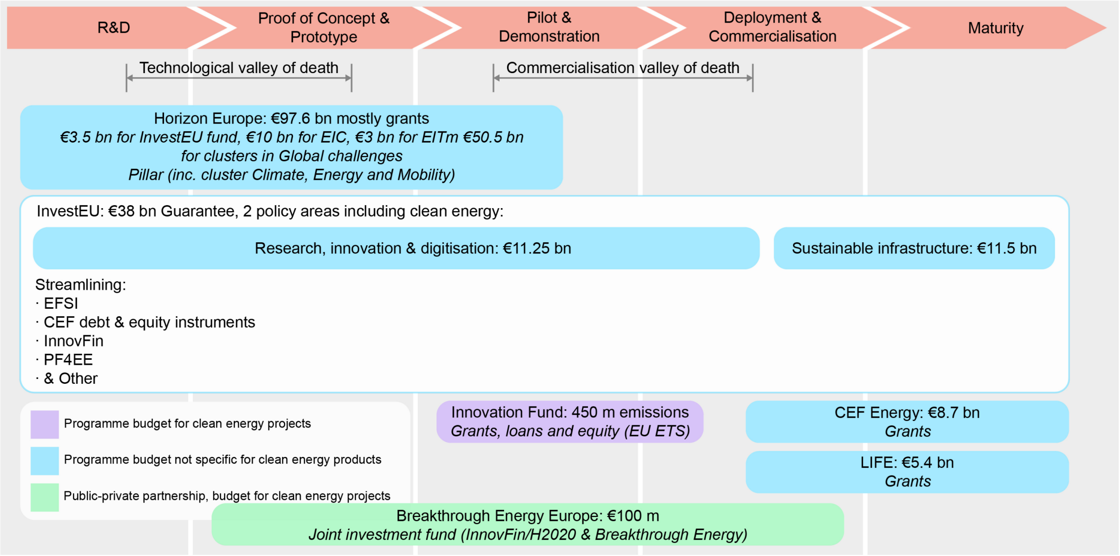
The role of partnerships will be critical to foster effective prioritisation of funding, to reach impact and pan-European efficiency. These partnerships could involve member states, private entities and researchers in managing calls and projects and raising co-funding. For energy, the result could be a smaller number of larger public-private partnership structures. In addition, more openness to international collaboration is anticipated, including enabling non-EU countries to participate if they pay their way.

InvestEU succeeds the Investment Plan for Europe ("Juncker Plan") and will merge the European Fund for Strategic Investments and 13 EU financial instruments. It will absorb the COSME and InnovFin programmes. A European budget guarantee will be the main pillar of the programme, which can be blended with EU grants and will be implemented via financial partners: EIB, European Bank for Reconstruction and Development, the World Bank, the Council of Europe Bank, and national promotional banks. The financial partners are expected to contribute in risk-bearing capacity. A part of the EU budget is set aside with some funding from the Horizon Europe budget.

InvestEU will focus on four main policy areas: sustainable infrastructure; research, innovation and digitisation; small and medium businesses; and social investment and skills. The CEF will be renewed, with a proposed significantly larger budget for energy, which will include more eligible technologies and has the potential to create early commercial opportunities for innovative technologies via public procurement. Figure 9.6 illustrates the Commission's budget proposals, which are subject to negotiations and will change during 2020.

The Innovation Fund will succeed the NER300, and significant efforts have been made to learn the lessons of its predecessor. Financed from the revenues of the EU ETS, the Innovation Fund is worth EUR 10 billion (at EUR 25 tCO_2 market prices) and will support projects from 2020 onwards by sharing the risk with project promoters. It is intended to support first-of-a-kind and innovative large-scale commercially operational projects in the following areas: 1) low-carbon technologies and processes in energy-intensive industries, including products substituting carbon-intensive ones; 2) CCU and the construction and operation of CCS; and 3) innovative renewable energy generation and energy storage. Differences compared with NER300 are that the Innovation Fund will not earmark funds for specific technologies up front; it will include more types of decarbonisation options for industry; it will make it easier to receive financing up-front capital expenditure and it will fund small-scale projects (capital cost under EUR 7.5 million) with a simplified procedure if that is where the funding gap is.

Figure 9.6 Future EU funding to support the entire innovation value chain (2021-27)



Note: This chart reflects the initial proposal for the MFF by the European Commission in 2019 and not the revised MFF of 2020.

Source: Trinomics (2018), Energy and the MFF, Study for the European Parliament ITRE Committee, http://trinomics.eu/wp-content/uploads/2018/03/Energy-and-the-MFF.pdf

B. Knowledge management

The EU has a number of instruments to help ensure that knowledge arising from energy R&D in Europe is shared as freely as possible and can be combined, recombined and translated into new ideas and products.

At the highest level, the push under Horizon 2020 and Horizon Europe for more open innovation and open access publishing plays a key role. The proposal for Horizon Europe incorporates the findings of the Horizon 2020 Interim Evaluation in this area. It aims to step up the involvement of civil society in research and innovation and ensure that grant beneficiaries engage in research data sharing by default (EC, 2019c). European Cooperation in Science and Technology (COST) is an intergovernmental framework to support open science and technology networks across the EU.

Since 2010, the European Commission has funded the EIT. The EIT brings together leading organisations from business, education and research to form dynamic cross-border partnerships, to overcome fragmentation in the EU innovation landscape, and to simulate innovation and competitiveness. Among the KICs that receive EIT funding to execute this mission are one on climate (Climate-KIC) and one on energy (EIT InnoEnergy). In addition to using Horizon 2020 budget to provide grants and support promising small companies to grow, these KICs have established cross-border networks for knowledge exchange and matchmaking services to connect value chain actors. To date, the Climate-KIC has provided around EUR 35 million of funding to projects that have received more than this amount in co-funding (Climate-KIC, 2019). EIT InnoEnergy has invested over EUR 200 million in equity and spent over EUR 400 million in total since its creation. Its projects have raised over EUR 1.5 billion in additional finance.[40]

The EU has a range of stakeholder engagement groups to jointly plan R&D programmes and share knowledge:

- The EU aims to develop a favourable environment for R&D activities by establishing an ERA. The goal is to remove obstacles to cross-border co-operation, increase the effectiveness of activities and facilitate the voluntary co-ordination among national research funding agencies. **ERA-NET and ERA-NET Plus** aim at co-ordinating national research projects with the main research funding provided by national programmes, supplemented by EU budget for co-ordination costs. In the case of ERA-NET Plus, also additional top-up funding is provided by the EU.
- **Article 185 Initiatives** refer to Article 185 of the TFEU, which provides a legal basis for the EU to participate in R&D programmes of the member states in order to help the co-ordination of RD&D and support a more coherent use of resources. The Article 185 Initiatives are more ambitious and have a wider scope than ERA-NET activities: their agenda definition is brought from the national to the European level.
- **Joint Programming Initiatives (JPIs)** do not define their objectives or scope according to a scientific field, but aim to address societal challenges and therefore, in contrast to ERA-NETs and Article 185 Initiatives, take a multidisciplinary approach. The Joint Programming process, launched in July 2008, is a structured and strategic process in which member states agree, voluntarily and with a variable geometry in terms of participation, on common Strategic Research Agendas. A High-Level Group on Joint Programming consisting of representatives of member states and of the European Commission, and assisted by the Council Secretariat, has been set up to implement the Joint Programming process by identifying themes. So far, ten JPIs have been launched.

[40] https://investmentround.innoenergy.com/.

- **Joint undertakings** (under Article 187 of the TFEU) can be set up by the EU for the efficient execution of EU research, technological development and demonstration programmes. To date, the EU has set up several Joint Technology Initiatives.
- **KICs – Climate and InnoEnergy –** bring together stakeholders from higher education, research and business in the energy RD&D area. Set up in 2010 by the EIT, the Climate-KIC has partners with 47% from business, 32% from academia and 21% public bodies. Created in 2009, InnoEnergy brings together 8 companies, 7 research institutes, and 13 universities and business schools.
- **European industry alliances** are a more recent model of co-operation aimed at launching EU industrial leadership in specific technical growth areas. The European Battery Alliance (EBA), launched in 2017, and the Clean Hydrogen Alliance, to be launched in 2020, are among the first examples (see Box 9.3).

The European Commission is currently reviewing these instruments with a view to increasing effectiveness by attracting private funding towards common objectives and ensuring commercialisation of favourable RD&D results. Managing the interface between structures like joint undertakings and industry alliances, which can overlap in the stage of early deployment, is a key consideration.

Knowledge sharing via international collaboration programmes

IEA Technology Collaboration Programmes

The European Commission through DG ENER or DG RTD participates in 24 IEA Technology Collaboration Programmes (TCPs) that include all existing collaborations relating to renewable energy and nuclear fusion. While Commission participation in the TCP mechanism has increased 20% since the last in-depth review (IDR) in 2014, substantial potential remains for further collaboration in areas that align with EU strategic priorities. For example, at present the Commission participates in only one of the five TCPs relating to buildings end uses, and has no participation at all in the five TCPs relating to the transport sector.

Mission Innovation

The European Commission is a member of Mission Innovation (MI), an umbrella initiative with a subset of voluntary initiatives, known as Innovation Challenges (ICs), mutually agreed as areas of common interest and importance to MI members. ICs cover the entire spectrum of RD&D, from early-stage research needs assessments to technology demonstration projects. MI membership consists of 24 countries and the Commission. As of 1 July 2019, the Commission co-leads three challenges: Converting Sunlight Innovation Challenge (IC5), Affordable Heating and Cooling of Buildings Innovation Challenge (IC7), and Renewable and Clean Hydrogen Innovation Challenge (IC8), and participates in all other existing ICs: Smart Grids (IC1); Off-Grid Access to Electricity (IC2); Carbon Capture (IC3); Sustainable Biofuels (IC4) and Clean Energy Materials (IC6).

Under MI, the EU envisages doubling the spending to EUR 2 billion, from the baseline of EUR 1 billion that was calculated as average spending of the period during 2013-15. Through DG RTD, the European Commission participates in the MI Steering Committee and contributes in kind to the functions and tasks delivered by the MI Secretariat.

C. Market pull

The EU has a wide range of ambitious regulatory and market measures to stimulate the uptake of low-carbon energy technologies in its member states. These are largely detailed in the other chapters of this review and are mostly managed by the European Commission services (DGs ENER, CLIMA for climate action and MOVE for transport). Technology status is usually taken into account during impact assessments for new legislation, and explicitly informs Best Available Techniques Reference Documents, which member states are required to take into account in rule-making. The EU does not have significant scope to use public procurement to create markets, something that is often done at the member state level. However, a revision of the 2014 State Aid Guidelines on Energy and Environment would enable member states to support the innovation activities in their country.

The size and scope of EU energy governance is extensive, which means that "market pull" measures are present in some degree for all new energy technologies. While there is no formal process to assess the balance and efficiency of innovation support via "resource push" and "market pull" measures, in some specific cases, such as the EBA, a holistic approach is considered (Box 9.3).

Box 9.3. The European industry alliances – a new partnership concept

European Battery Alliance

The development and production of batteries is a strategic imperative for Europe in the context of the clean energy transition and is a key component of the competitiveness of its automotive sector. Launched in October 2017 by European Commission Vice President Maroš Šefčovič, the EBA is a co-operation platform with key industrial stakeholders, interested member states and the EIB. Building on the 2018 Strategic Action Plan for Batteries, the key objective of the EBA is to create a competitive and sustainable battery manufacturing industry in Europe, which could have a market of up to EUR 250 billion a year (200 gigawatt-hours per year) or more, served by at least 10 to 20 gigafactories. The EU added value is stated to be a cross-border approach covering the whole value chain, from extraction and processing of raw materials; the design and manufacturing phases of battery cells and battery packs; and their use, second use, recycling and disposal. Batteries Europe Platform, the research and innovation platform of the EBA that was launched in mid-2019, will set the strategic research agenda and help co-ordinate public funding from Horizon 2020, Horizon Europe, member state-funded important project of common European interest (IPCEIs) and regional development funds. In late 2019, the European Commission approved EUR 3.2 billion of state aid for an IPCEI, jointly notified by Belgium, Finland, France, Germany, Italy, Poland and Sweden, to support research and innovation in the area of batteries. The funding should unlock EUR 5 billion of private investment. The Commission further found Poland's investment aid to LG Chem for a vertically integrated manufacturing plant for the production of lithium-ion batteries in Poland to be in line with EU state aid rules. In mid-2019, the EBA and EIT InnoEnergy launched a Business Investment Platform for the battery value chain that aims to shorten time to investment and reduce the associated risk for financial institutions and businesses.

Clean Hydrogen Alliance

In March 2020, the European Commission presented a new European Industrial Strategy. One of the key pillars is the creation a new governance structure: a European industrial ecosystem can bring together academic and research institutes, industry and SMEs. Building on the EBA, the Commission plans to initiate a range of alliances on low-carbon industries, raw materials, industrial clouds and platforms for other key technologies and business areas. The creation of a new European Clean Hydrogen Alliance has been announced in this context.

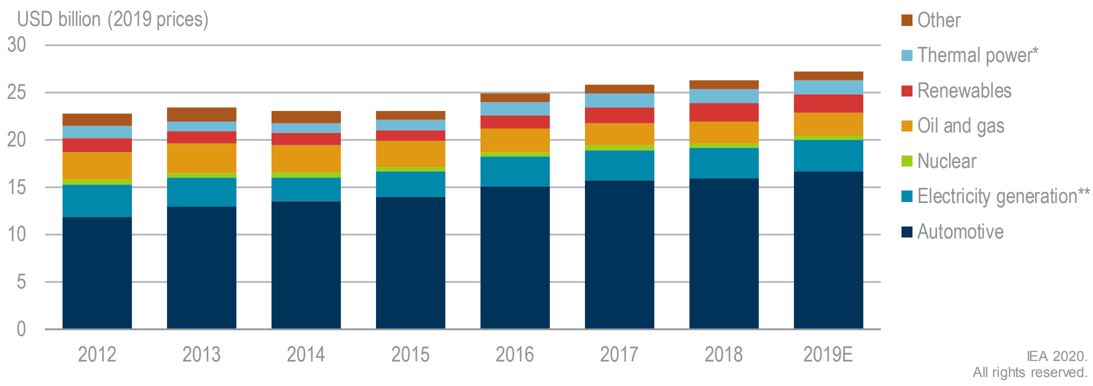
Private energy R&D investment

Companies spend revenue on technology research to give them a competitive edge in the marketplace. While some of this effort is made in anticipation of entirely new markets that could be created by novel products, much of it is aimed towards higher profitability or market share in existing markets. In this sense, market-based policy interventions that improve the competitiveness of a product or component currently at an early stage of development "pull" private resources into R&D efforts. Corporate spending on energy R&D and venture capital investment in energy technology start-ups provide insights into this effect.

The DG JRC of the European Commission estimated the aggregated EU member states' private sectors spending on clean energy R&D to average around EUR 16 billion per year over the past decade, with a large focus on sustainable transport, batteries and e-mobility as well as energy efficiency in industry.[41]

In 2019, the EU saw over USD 27 billion (EUR 19.1 billion) in energy R&D spending by the private sector, a 3% year-on-year growth, mainly driven by the car industry (see Figure 9.7). This represents about 30% of global investments, and about 80% are estimated to be for the development of low-carbon energy technologies.

Figure 9.7 Private-sector investment in research and innovation in the EU28



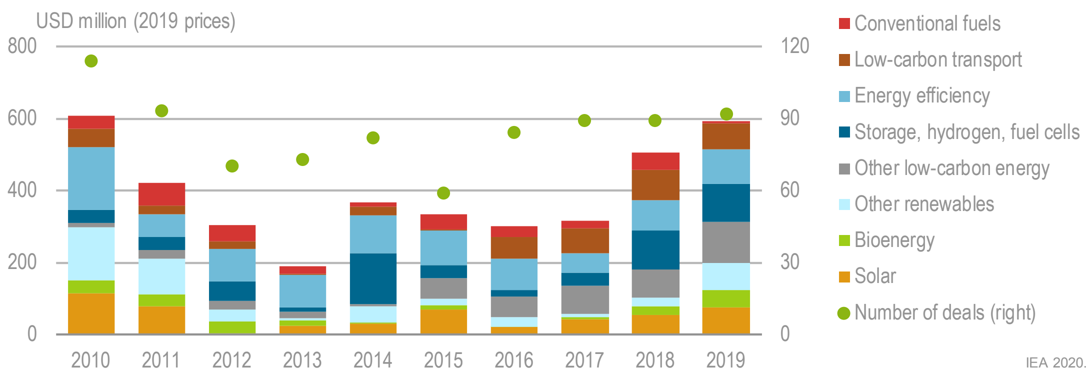
Source: IEA (2019a), *Energy Technology RD&D Budgets 2019*, www.iea.org/statistics.

[41] The IEA estimates private-sector energy R&D spending using a different methodology. While DG JRC uses patent data and corporate reports, the IEA relies more on corporate reporting and corporate revenue as data inputs.

Although the total sums are small relative to public and private R&D spending, venture capital investments in energy (seed, series A and series B rounds) have increased in recent years, surpassing the levels of the so-called “cleantech boom” up to 2012 (see Figure 9.8). The composition of technologies has evolved in this time frame, with Europe showing a higher proportion of deals for energy storage, smart grid and hydrogen technologies than other regions. Transport, especially electric mobility, has been the other major growth area. Excluding large deals (those over USD 50 million, which are largely Chinese and skew the results), 30% of deals were for start-ups in Europe, a much higher share than in previous years.

Increasing this further has become a major policy goal of the EU, as venture capital funding can provide a path to commercialisation for a new idea. However, without other types of finance, such as blending with grants, it remains mostly suited to digital technology and small-scale hardware.

Figure 9.8 Early-stage venture capital deals in EU-based clean energy technology start-ups



Notes: “Early-stage” includes Seed, Series A and Series B deals. EU includes the United Kingdom, as well as Norway. *Other low-carbon energy* includes CCUS, nuclear, smart grids and electricity equipment. “Conventional fuels” includes technologies related to the cleaner extraction or use of fossil fuels, as well as improvements to traditional vehicle fuel efficiency.

Source: IEA analysis (2020) based on Cleantech Group i3 database.

D. Socio-political support

The EU has an active engagement with the private sector via a range of public-private partnerships, the latest of which are the ETIPs. The European Commission plans to adapt and strengthen these institutions further under Horizon Europe, which will be the second major reorganisation since the publication of the last IDR.

While the input from the private sector is generally constructive and helps to make public and private efforts more mutually reinforcing, frequent changes to roadmaps and targets can risk losing buy-in from stakeholders. To bring the voice of civil society into energy innovation policy planning, stakeholder consultation surveys are used for most major proposals. An interesting structure is the joint undertakings (Box 9.2). The European Commission also surveys EU citizens’ views on energy technology and policy knowledge and preferences through its Eurobarometer programme (EC, 2019d).

Box 9.4 Fuel Cells and Hydrogen Joint Undertaking

The Fuel Cells and Hydrogen Joint Undertaking (FCH JU) is a unique structure for energy RD&D, bringing together public and private entities since 2008 in a specific legal entity with multi-year budgeting. Its stated purpose is to accelerate the market introduction of hydrogen energy technologies in Europe, develop an industrial base for their production and contribute to climate change mitigation. FCH JU has its own budget (to which the EC contributes 50%) and manages its own calls for projects, meaning that hydrogen in Horizon 2020 is almost entirely managed via FCH JU. Its decisions are taken by three partners: EU, represented by the European Commission; the industry grouping Hydrogen Europe; and the research grouping Hydrogen Europe Research. Currently its members include 118 companies, 67 research organisations and 16 national associations. For 2014-20 its budget is EUR 1.3 billion (50% from the Commission, 43% from industry, 7% from the research community), up from EUR 0.9 billion for 2014-20.

The FCH JU has supported 246 projects. It has played a pivotal role in the commercialisation of end-use appliances, notably hydrogen-fuelled buses in Europe by funding demonstration projects and bringing together key stakeholders on the supply and demand sides. Fuel efficiency has increased threefold and refuelling time has halved. There are currently more than 40 FCH JU-supported buses on the road (of an estimated 65) fuel cell buses in operation around Europe. The most recent projects will bring the number of hydrogen buses close to 400, with fleets as large as 40 in some cities. FCH JU projects have been involved in the installation of 29 hydrogen refuelling stations for 325 vehicles, which is planned to rise by 20 hydrogen refuelling stations and more than 1 100 vehicles. Among other activities, FCH JU launched ene.field, supporting the installation of over 1 000 residential co-generation fuel cell technology projects in ten EU countries. A further five-year project was launched in June 2016 to install 3 000 units with customers, with over one-third of the financing from FCH JU. The CertifHy project is a global pioneer in accounting for the carbon intensity of hydrogen production and has developed a certification system for Europe.

Established by a European Council decision in 2008, FHC JU has entered the third period of existence following the second period 2014-20, under Horizon 2020, with the purpose of accelerating the market introduction of hydrogen energy technologies in Europe, develop an industrial base for their production and contribute to climate change mitigation. Half of the Hydrogen Europe members are SMEs, and 27% (EUR 77.7 million) of the FCH JU financial programme is dedicated to smaller businesses, exceeding the Horizon 2020 target of ensuring at least 20% of its funding is allocated to SMEs. FCH JU represents Europe in international collaborations, for example with the United Nations Industrial Development Organization, the International Maritime Organization, the US Department of Energy, and Japan's New Energy and Industrial Technology Development Organization. In 2016, the FCH JU started a regions and cities initiative by reaching out to all those European regions and cities having an interest in the potential use of fuel cell and hydrogen products to help them to achieve their decarbonisation goals. Interested parties sign a memorandum of understanding (MoU) that helps them assess the business case for fuel cell and hydrogen applications, connect with industry players, help map local capabilities and identify funding sources. More than 90 regions/cities representing 22 European countries have signed this MoU or are involved. As the focus is now shifting to the production of hydrogen in Europe (not the end use and applications, the EU has recently created an industrial alliance, similar to the Battery Alliance (Box 9.3).

Monitoring, evaluation and tracking of results

The European Commission undertakes special and periodic evaluations of its measures in support of energy innovation. In addition, it also undertakes regular tracking of selected metrics of progress.

Since the last IDR of the EU, a number of special reviews have been undertaken (Table 9.3). Each of these reviews made strong recommendations for improvements. In the case of the NER300 review, the recommendations were used as the basis for the Innovation Fund proposal.

Table 9.3 Selection of reviews of EU measures related to energy technology innovation since the last IDR

Year	Measure under review	Period reviewed	Type of review	Reviewer
2015	FP7	2007-13	Ex-post high-level review (new FP7 funding ceased in 2013 but some projects were still ongoing in 2019)	Group of 12 people from different member states appointed by the Commissioner for Research
2017	Horizon 2020	2014-16	Interim evaluation	DG RTD
2016 EIT review	EIT	2008-16	High-level review	5 external reviewers appointed by the Commissioner for Education, Culture, Youth and Sport
2016	EIT	2008-16	Performance audit	European Court of Auditors
2017	COSME	2014-16	Interim evaluation	External consultant appointed by DG GROW
2017 review of NER300 (by ICF, SQ, Vita, 2018)	NER300	2011-17	Lessons learned study	Three external consultants appointed by DG CLIMA
2017, 2018, 2019	Innovation and Networks Executive Agency (INEA), Executive Agency for SMEs (EASME), Euratom	Prior year	Annual reviews	European Court of Auditors
2016, 2018	20 policy actions for clean energy innovation*	Prior two years	Biennial reviews	DG RTD
2018	Horizon 2020	2014-18	Performance audit of simplification of financial measures	European Court of Auditors

Year	Measure under review	Period reviewed	Type of review	Reviewer
2018	Demonstrating CCS and innovative renewables at commercial scale	2008-18	Performance audit	European Court of Auditors
2019	Centrally managed EU interventions for venture capital	1998-2018	Performance audit	European Court of Auditors
2019	EU policies for developing energy storage	2018	Review paper	European Court of Auditors

* Clean energy innovation policies reviewed included: state aids; subsidies; in-depth analysis of legislative proposals; standardisation; public procurement; InnovFin Energy Demo Projects and synergies between financial programmes; Cleaner Transport Facility; exploitation of results towards investors; EuropeanH; research and innovation priorities in Horizon 2020 work programme; smart specialisation; Mission Driven Pilot; flagship energy innovation inducement prizes; Mission Innovation; joint deployment programmes in developing countries; SME internationalisation; SET Plan; governance of the Energy Union; Strategic Transport R&I Agenda; smart, sustainable and inclusive urban demonstration projects and best practices in cities.

In 2017, the European Commission published an interim review of Horizon 2020, the flagship funding programme for innovation, including research (EC, 2017). The review was very positive about the performance, while acknowledging it was too early to draw conclusions on many of the objectives of the programme.

The interim evaluation considered all aspects of Horizon 2020, except public-private partnerships, the EIT and Euratom, with the following questions:

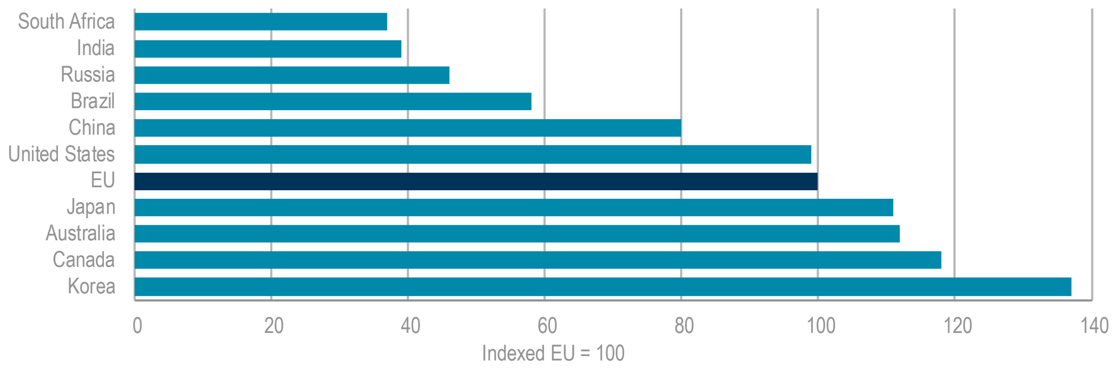
- How relevant has Horizon 2020 been so far? (i.e. Is it tackling the right issues and responding to stakeholder needs?)
- How efficient has Horizon 2020 been so far? (i.e. Are the processes efficient and is it cost-effective?)
- How effective has Horizon 2020 been so far? (i.e. What is the overall progress towards the overarching objectives of social, economic and environmental impact?)
- How coherent has Horizon 2020 been so far? (i.e. Is it coherent with other EU, national and international initiatives?)
- What is the European added value of Horizon 2020 so far? (i.e. Does it have a clear benefit above and beyond member states' activities?)

The review concluded that Horizon 2020 was performing well against measurable, short-term indicators related to compliance and funding efficiency, but very few projects were yet finished. It noted that it is difficult to capture all direct and indirect results and impacts of a comprehensive programme such as Horizon 2020, which operates in a multifaceted policy context, raising the challenge of the attribution of the changes observed. Despite this, the Horizon 2020 interim evaluation was hampered by data availability, measurability and reliability challenges and by the lack of clear predefined intervention logic. It further noted that most monitoring indicators focus on input and output and not on results and (societal) impacts, and there are monitoring gaps, including lack of data beyond a project's lifetime. Based on the FP7 timeline, an ex-post evaluation of Horizon 2020 can be expected in 2022. A review of the type of longer-term impacts that feature among the stated objectives of Horizon 2020 has not yet been planned and was not undertaken for FP7.

Ongoing tracking of selected metrics is undertaken by DG JRC for energy technology innovation. This is a mandated part of the annual review of the Energy Union. DG JRC publishes trends in public and private spending on energy R&D in the EU as well as patenting by EU inventors in collaboration with the European Patent Office. As of 2019, the European Commission has a mandate to review annually the energy innovation components of the NECPs of member states. The 2019 review highlighted a lack of consistency between the technology priorities in the draft NECPs and EU technology priorities (EC, 2019b).

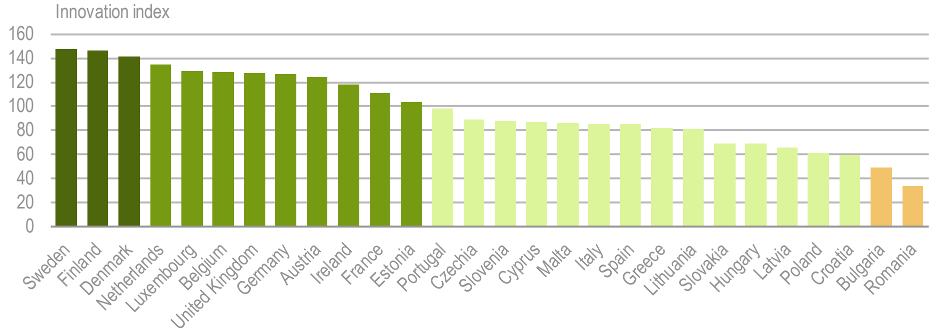
More broadly, the EU produces scorecards for innovation across all sectors to benchmark EU and member states' performance (Figures 9.9 and 9.10). In the latest ranking of 2019, the EU is close to the United States but far from Australia, Canada, Japan or Korea. The scoreboards do not focus on energy or clean tech. They identify innovators and moderate innovators (see Figure 9.10 in yellow and green, respectively). DG RTD and DG JRC are, however, working with consultants on a possible composite indicator to compare countries' performance in clean energy innovation. The European Commission also reviews member states' innovation plans in the country-specific recommendations under the so-called European Semester budget reviews.

Figure 9.9 EU performance in innovation compared to international partners



Note: Bars show countries' performance in 2018 relative to that of the EU in 2018.
Source: EC (2019e), *European innovation scoreboard*, interactive tool, https://interactivetool.eu/EIS/EIS_2.html#

Figure 9.10 Performance of EU member states' innovation systems



Notes: Colours indicate innovation leaders (Sweden, Finland, Denmark), strong innovators (Netherlands, Luxembourg, Belgium, United Kingdom, Germany, Austria, Ireland, France, Estonia), modest innovators (Bulgaria, Romania) and moderate innovators (remainder).

Source: EC (2019e), European innovation scoreboard, interactive tool, https://interactivetool.eu/EIS/EIS_2.html#

Assessment

Overarching governance

The EU has taken steps since the last IDR to better align its innovation policy with its energy and climate targets. The addition of innovation as a component of NECPs for the period up to 2030 is a good example of this effort to improve governance and co-ordination. Given the ambitions of the EGD, more cross-sector approaches with a high level of co-ordination across the European Commission will be needed. The governance framework of Horizon 2020 left a number of inter-institutional co-ordination and ownership challenges, such as regarding the respective roles of DGs ENER and RTD. Proposals have been made to improve this situation under Horizon Europe. However, the number of participating institutions in the EU energy innovation landscape has grown since the last IDR, and now gives specific roles to DG EAC and DG GROW, as well as more integration with DG MOVE, DG CLIMA and DG CNECT, plus the executive agencies. This raises the risks of duplication and lower efficiency, but there is evidence that processes will be put in place to manage decision-making and communication. Despite the challenges, it appears vital that the capacities of the various DGs and member states are harnessed towards common goals if EU energy R&D is to be aligned effectively with EU trade, market access and industrial agendas. The EBA is a test case in this regard.

Horizon Europe and the EGD are tasked with a so-called "missions-based approach", which could help international alignment and give renewed momentum to global initiatives such as MI, in which the European Commission is very active. The challenge rests in selecting the specific missions to tackle – in terms of technology area, situation in the international value chain and metrics for success. While this is a complicated analytical and co-ordination task at the European level, it is within the capabilities of the European Commission.

At the international level, while the European Commission is already an active participant in 24 IEA TCPs, participation in TCPs relating to energy end uses remains limited and could be raised.

Aligning instruments with the needs of innovators

EU funding programmes have consistently increased the allocation to energy RD&D. Horizon Europe is anticipated to dedicate EUR 15 billion to climate, energy and mobility, and 35% of EUR 100 billion to climate action. The EU is expected to be in line with its pledge under MI. EU funding for energy research continues to underpin the European energy research and demonstration landscape through its scale and ability to connect researchers across borders.

The interim evaluation of Horizon 2020 found that most recipients of funding review the changes to funding procedures positively. Efforts to centralise project management functions in specialist agencies have been well received. However, annual reviews of the INEA, EASME and Euratom agencies show room for improvement. Large corporate players remain reluctant to become involved in Horizon 2020 projects due to the long timetables, bureaucracy and need to partner with organisations from at least two other member states. For companies, Horizon 2020 tends to be attractive mostly for pilot projects with complex stakeholder configurations. Further, it is important to ensure that research institutes and companies of all EU member states have equal opportunity, knowledge and accessibility to all programmes. The missions-based approach should ensure missions to be impactful and relevant. Partnerships or missions should be reviewed and continued or closed, when they've accomplished their mission.

The greater involvement of the EIB in earlier-stage and riskier energy projects compared with five years ago is a very positive sign. In particular, the greater variety of instruments available to SMEs and large corporations alike – from loans to equity – represents a break with the past in terms of the ambition to be complementary to research funding programmes. Ensuring that its instruments are further aligned with the needs and risk profiles of key technologies for a net-zero emissions future is critical, including establishment of the roles of the EIB, the CEF and the plethora of other funding opportunities for start-ups that the European Commission manages. While Breakthrough Energy Europe will aim to address the critical gap in patient venture capital for clean energy technologies, the European Court of Auditors found more generally that the European Commission has increased its support to the venture capital market without fully assessing market needs and impact of its support. For example, the European Commission generally shares losses with private investors, limiting the benefit of public involvement.

While it remains too early to comment on whether the Innovation Fund for first-of-a-kind commercial scale projects will avoid the disappointments of the NER300, the effort to incorporate the lessons learned is impressive. However, the challenge of ensuring co-funding within project deadlines remains, and the question of how to support uncompetitive second-, third- and fourth-of-a-kind projects has not yet been addressed in a way that ensures a long-term pipeline of sustainable investments.

The EU should also carefully review the progress of existing partnerships and align them to the needs of the EU innovation chain. Some of the KICs and joint undertakings are very important to kick-start a technology collaboration in the stage of R&D, while others are more important to create scale and leverage private industry investment in demonstrated technologies. Although the FCH JU public-private partnership has not yet been replicated for other technologies during its 11-year existence, it remains a good example of what is possible when there is willingness to collaborate between stakeholders and blend budgets.

The EU should ensure that these success stories are communicated to the public. The decision to push for more public-private partnerships under Horizon Europe is laudable. To maintain faith in the stated targets of ETIPs, it will be important not to lose the sectoral communities represented by existing partnerships while disconnecting the co-ordination of stakeholder input from the bodies that receive or co-ordinate funding.

Monitoring and evaluation

Regular monitoring, tracking and evaluation of the performance of policy and funding instruments for energy innovation is fundamental for ongoing improvement and ensuring value for money. A deep assessment of Horizon 2020 will be useful on an ongoing basis and not only in the interim or at the end of the programme, including by technology area and project. A regular evaluation of progress of projects could be an easy way to also communicate success stories to the public.

The EU is committed to ex-ante impact assessments and has undertaken a variety of reviews of policy measures in recent years. To further strengthen this process, the European Commission could consider:

- Establishing up front the criteria against which the reviews will be performed, how the data will be collected and the most appropriate timing for assessing performance.
- Ensuring that the stated objectives of the policy measures are the ones against which performance is appraised.
- Connecting the dots between the various reviews to look at the performance of energy innovation support in general.
- Undertaking reviews in a systematic manner with oversight from independent external experts that are not selected by the body under review, such as the European Audit Office.
- Continuing to monitor performance on an ongoing and transparent basis, with incorporation of a wider set of indicators across the energy innovation value chain, as proposed by DG RTD.

Recommendations

The European Union should:

- ☐ Ensure more alignment and complementarity of EU and member states' direct energy funding programmes, regulations and policies that stimulate private-sector investment and other measures (financial and fiscal rules). Leverage the NECPs as a mean of alignment and complementarity to meet EU SET Plan priorities.
- ☐ Strengthen the timely and regular monitoring and assessment of the results of EU energy RD&D programmes, including an early review of the FPs and a project-by-project review of results (towards Horizon Europe goals). Establish ex ante the criteria for tracking clean energy progress, against which the suite of innovation policies will be judged ex post.

- Consolidate and simplify the multitude of initiatives and advisory groups to scale up partnerships across the innovation value chain. Scale up EU partnership by linking to international RD&D and innovation missions.
- Ensure that EU-level funding for early-commercial large-scale projects and related industrial partnerships are efficient and aligned to the objective of delivering climate neutrality by 2050.
- Engage in the identification of global best practice in terms of energy innovation policies and support, to help EU leadership and to help innovators as well as other countries learn from the EU to boost the necessary technologies for a net-zero world.

Table 9.4. Annex - Institutions and actors for energy technology and R&D in the EU

Institution	Reports to	Responsibilities			
		Resource push	Knowledge management	Market pull	Socio-political support
DG for Research and Innovation	College	Overall responsibility for Horizon programmes (grants, prizes; defines Horizon calls for most energy and transport R&D); establishes the SET Plan framework with DG ENER; overall responsibility for nuclear R&D (except ITER).	Leads the EU open innovation agenda; leads Commission role in MI and bilateral research programmes; sets Horizon project requirements tor dissemination of results	-	Funds projects on social aspects of energy technologies; funds European Technology Platforms
DG ENER	College	Establishes the SET Plan framework with DG RTD; co-defines and manages Horizon 2020 calls for energy and transport R&D and co-creates Horizon Europe calls; including for smart cities; responsibility for ITER nuclear project; Sets the framework of the CEF for energy	Manages the European CCS Demonstration Project Network, H2020 Lighthouse Projects, European Innovation Partnership on Smart Cities and Communities (EIP-SCC), the Smart Cities Information System and the Covenant of Mayors.	EU directives and regulations for renewables, efficiency, gas networks and electricity networks	Undertakes Eurobarometer surveys of Europeans' attitudes on EU energy policy
DG CLIMA	College	Responsible for NER300 (2012-19) and Innovation Fund (2020-30); co-defines Horizon calls for energy and transport R&D and co-creates Horizon Europe calls	Knowledge-sharing conditions of NER300 demonstration projects	ETS	Undertakes Eurobarometer surveys of Europeans' attitudes on climate change
DG MOVE	College	Establishes the Strategic Transport Research and Innovation Agenda; sets the framework of the CEF for transport; co-defines Horizon calls for energy and transport R&D and co-creates Horizon Europe calls	-	EU directives and regulations for vehicle safety, fuel economy and infrastructure	Undertakes Eurobarometer surveys of Europeans' attitudes on urban mobility and transport infrastructure
DG CNECT	College	Defines and manages Horizon	Helps oversee European Innovation Partnership for Smart Cities and Communities	Co-chairs Smart Grids Task Force with DG ENER; shares regulatory best practice for smart cities	-
DG GROW	College	Defines the COSME programme and budget	-	-	-
DG EAC	College	--	Responsible for the EIT		
DG JRC	DG RTD	Undertakes energy R&D projects and studies in support of DGs RTD, ENER and CLIMA	Tracks progress against SET Plan KPIs and patents and budgets via the Information System for the SET Plan (SETIS)	-	-

Institution	Reports to	Responsibilities			
		Resource push	Knowledge management	Market pull	Socio-political support
EIB	Member states	InnovFin (loans, guarantees and equity); InnovFin Energy Demonstration Projects (EDP) for demo projects; investment loans and equity/quasi-equity for R&D projects	-		--
EIT	DG EAC	-	Manages the EU budget for Climate-KIC, InnoEnergy and Urban Mobility KICs, among others.	-	-
INEA	DG RTD	Evaluates and manages Horizon calls and projects involving consortia; implements CEF grants and studies for network innovation	-	-	-
EASME	DG GROW	Evaluates and manages Horizon calls and projects for SMEs and the COSME programme			
ERC and ERC Executive Agency	DG RTD	Manages and allocates Horizon 2020 budget for grants to individual researchers undertaking frontier research	The ERC aims to enhance the dynamic character, creativity and excellence of European research at the frontiers of knowledge	-	-
ETIPs	DG RTD	Industry-led forums providing input to R&D funding priority-setting (bioenergy, deep geothermal, ocean, smart networks, PV, renewable heat and cooling, nuclear, CCS, wind)	Industry-led forums helping to share technology and policy updates	-	Industry-led forums helping to foster co-operation between stakeholders
EIT InnoEnergy	EIT	Provides grant funding and seed equity investment to energy technology start-ups	Manages networks of public and private actors to exchange knowledge and collaborate on energy innovation projects	-	-
EIT Climate-KIC	EIT	Provides grant funding and seed equity investment to climate and energy technology start-ups	Manages networks of public and private actors to exchange knowledge and collaborate on climate innovation projects	-	-
EIT Urban Mobility	EIT	Provides grant funding and seed equity investment to transport and energy technology start-ups	Manages networks of public and private actors to exchange knowledge and collaborate on urban mobility innovation projects	-	-

Institution	Reports to	Responsibilities			
		Resource push	Knowledge management	Market pull	Socio-political support
FCH JU	DG RTD	Public-private partnership that manages Horizon 2020 budget for fuel cells and hydrogen by attracting co-funding for EU funds and identifying priorities and projects	Co-operation among representatives of industry, scientific community, public authorities, technology users and civil society	-	Develops common agenda for industry and engages civil society in projects
European Innovation Partnership for Smart Cities and Communities	DG ENER	Marketplace for cities and technology providers to identify projects and funding	A network for public and private stakeholders to exchange information	-	-
EERA	DG RTD	Seeks to increase collaboration and reduce R&D duplication between academia, member states and industry in areas including wind, PV, CSP, CCS, materials for nuclear energy, geothermal, smart grids, marine energy, biofuels; formal role in priority setting	A network for public and private stakeholders to exchange information	--	

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10. Nuclear

Key data

(2017)

Number of reactors: 126 reactors in 14 EU member states

Installed capacity (May 2019): 124.6 GW

Electricity generation: 830 TWh

Share of nuclear: 25.4% of electricity generation

Overview

The European Union (EU) has the largest operating nuclear fleet in the world. However, the EU is entering a critical stage of its nuclear electricity development. The average age of the nuclear fleet is reaching the end of its design lifetime. At a time when decarbonisation shapes the political agenda, member states, investors and utilities will need to make decisions on engaging in lifetime extension (LTE) and/or long-term operation (LTO) and in new construction of nuclear plants.

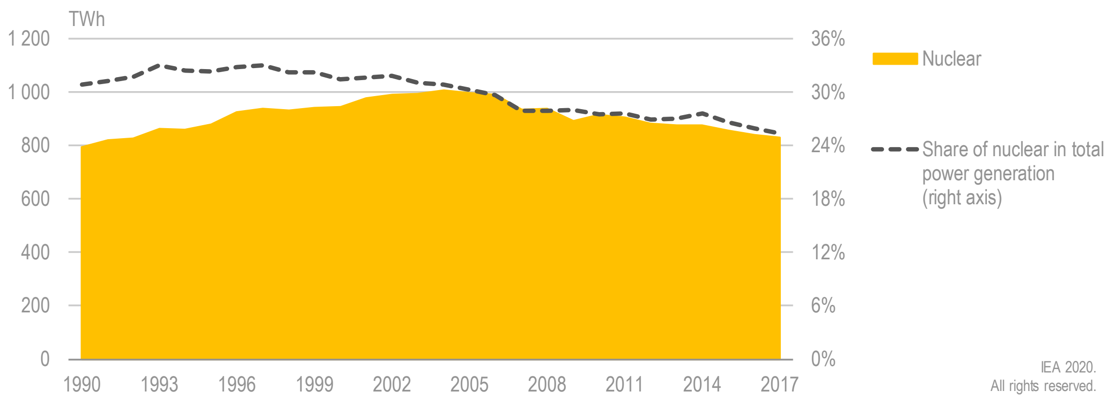
The European Commission's long-term outlooks to 2050 expect the share of nuclear electricity generation to decrease from 25% in 2017 to around 15% in 2050, generated by an installed capacity of about 100 gigawatts (GW), compared with 125 GW in 2017 (EC, 2017, 2018). Since most of the nuclear plants in operation today will be shut down by 2050, most of this capacity will have to come from new-built units. The European Commission estimates the investment needs at around EUR 50 billion for LTE/LTO programmes, and up to EUR 450 billion for the new-built plants, according to the European Commission Nuclear Illustrative Programme (PINC) (EC, 2017).

Going forward, it is important for the EU to ensure the coherent alignment of all policies, legislation and implementation tools, including EU public and private financing instruments and taxonomy, which are relevant for nuclear energy. This is necessary to enable nuclear sector stakeholders, including policy makers, investors, utilities, the research community and universities, the safety authorities, and the waste management agencies, to effectively play their respective roles.

Nuclear power generation in the EU

In 2019, 14 EU member countries had nuclear power. The capacity was built mainly in the 1970s and 1980s. During the 1990s and early 2000s, the share of nuclear power generation was relatively stable, reaching 33% of total power generation. Since then, however, nuclear power generation has been declining in some EU countries. In 2017, nuclear power generation amounted to 830 terawatt-hours (TWh) (Figure 10.1). The share of nuclear in total power generation has decreased only slightly from 28% in 2007 to 25% in 2017, which represents a large share of reliable, decarbonised and affordable electricity supply.

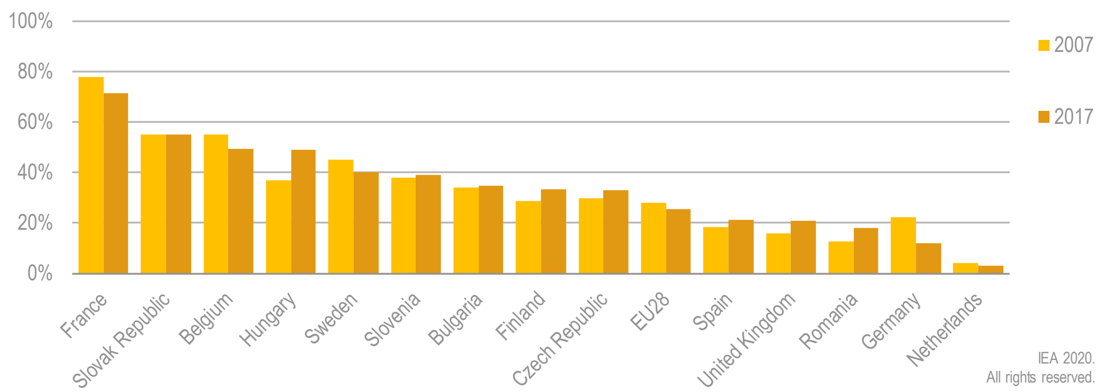
Figure 10.1 Nuclear power generation in the EU, 1990-2017



Nuclear power generation increased until 2004, when it peaked at just over 1 000 TWh (33%), but has since fallen to 830 TWh (25%) in 2017.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Figure 10.2 Share of nuclear in power generation in EU countries, 2007 and 2017



The share of nuclear in total power generation varies from a few percent to over 70%.

Note: EU28 = 28 members of the European Union.
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Among EU member states, France had the highest share of nuclear power in its national electricity mix (72%), followed by the Slovak Republic (55%), Belgium and Hungary (both 49%), and Sweden and Slovenia (40%). Five countries have a share between 40% and 20%, and for three countries the share is below 20% (Figure 10.2).

There are several reasons for the declining role of nuclear in the EU power mix. By 2015, around 91 reactors have closed in the EU. The nuclear phase-out decision in Germany in 2011 led to the immediate closure of 8 units out of a total of 17 in operation; the remaining plants will close before the end of 2022. Another reason is the extended downtime of a number of units (e.g. in France, Belgium and Sweden) for repairs, refurbishment and preparation of LTE/LTO. The overall decline is also due to delays in the commissioning of new-build nuclear plants (Finland and France). Acceptance of the sector varies among EU member states.

Table 10.1 Reactors shut down in the European Union, prior to 2015

	BWR	FBR	GCR	HTGR	HWGCR	LWGR	PHWR	PWR	SGHWR	Total
Belgium								1		1
Bulgaria								4		3
Estonia	1		1					1		3
Germany	9	1		2	1		1	14		28
France		2	8		1			1		12
Italy	2		1					1		4
Lithuania						2				2
Netherlands	1									1
Sweden	2						1			3
Slovak Republic								2		3
United Kingdom		2	27						1	30
Total	15	5	37	2	2	2	2	24	1	91

A large number of reactors have already shut down in the EU, with some in active decommissioning.

Note: BWR = boiling water reactor; FBR = fast breeder reactor; GCR = gas-cooled reactor; HTGR = high-temperature gas-cooled reactor; LWGR = light water graphite reactor; PHWR = pressurised heavy water reactor; PWR = pressurised water reactor; SGHWR = steam-generating heavy water reactor.

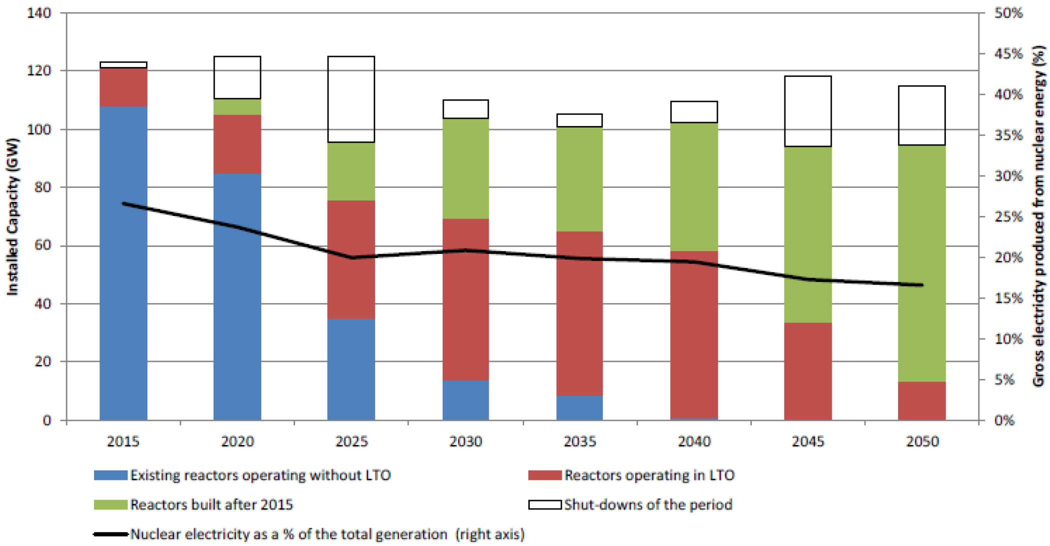
Source: EC (2017), Nuclear Illustrative Programme, https://ec.europa.eu/energy/sites/ener/files/documents/nuclear_illustrative_programme_pinc_-_may_2017_en.pdf.

Nuclear outlook

The EU's nuclear fleet is ageing after the large construction wave in the 1970s and 1980s and the much more modest rate of construction since then. The EU has the largest operating nuclear fleet in the world, and comes second, behind the United States, in terms of average age of the plants: the average reactor age is around 35 years in the EU. The original licence lifetime was 40 years in most cases (30 years for reactors of Russian design in operation in Central Europe). The nuclear fleet is now at a point where LTEs and LTO are starting on a large scale.

The European Commission reviewed this in its nuclear outlook, PINC, in 2017, as illustrated in Figure 10.3. This outlook is in line with the 2050 scenarios in the European Commission's 2050 long-term strategic vision (EC, 2018) and the latest International Energy Agency (IEA) analysis for the role of nuclear power in an energy system with zero greenhouse gas emissions (IEA, 2019b).

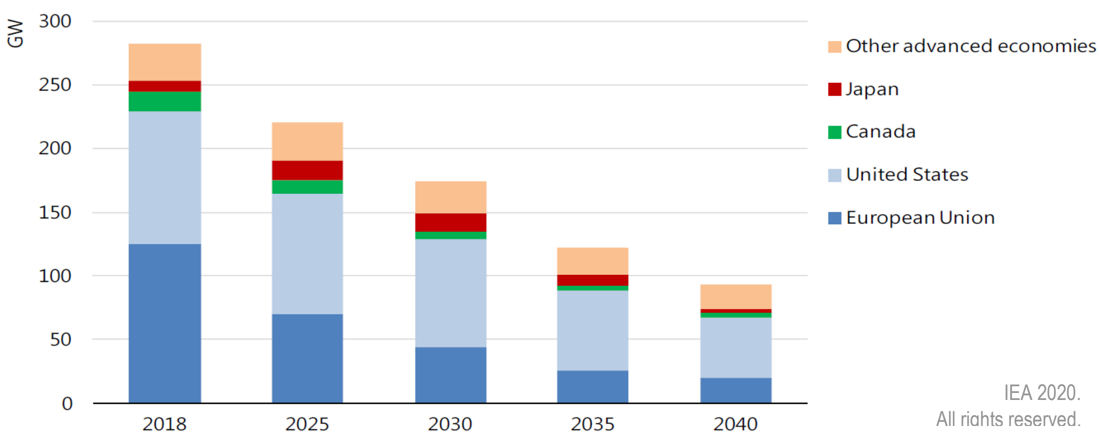
Figure 10.3 Outlook for nuclear electricity in the EU 2015-50



The share of nuclear in EU's electricity mix is expected to decline to 15% in 2050 under the EU Long-Term Strategy of 2018.

Source: EC (2017), Nuclear Illustrative Programme, https://ec.europa.eu/energy/sites/ener/files/documents/nuclear_illustrative_programme_pinc_-_may_2017_en.pdf.

Figure 10.4 Operational nuclear capacity in advanced economies (Nuclear Fade Case)



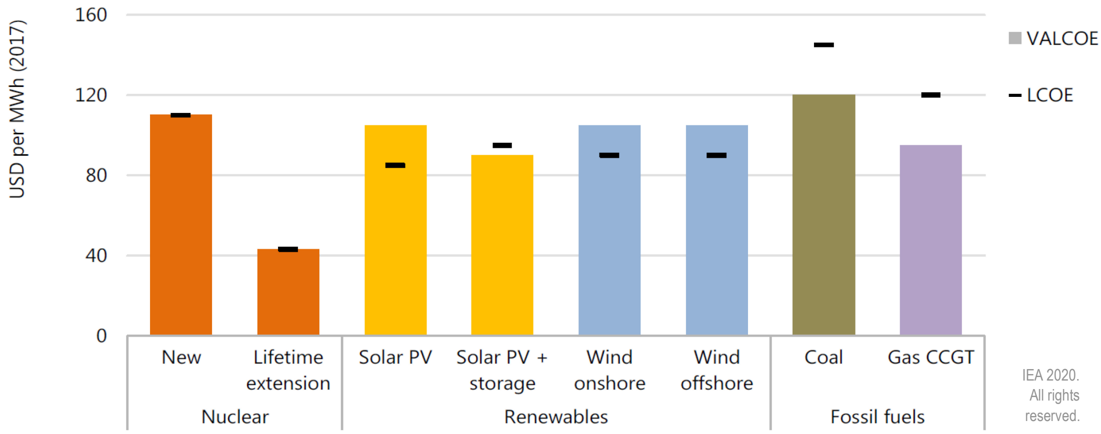
Without LTEs, EU nuclear capacity is on a trajectory to fall by more than two-thirds until 2030.

Source: IEA (2019b), *Nuclear Power in a Clean Energy System*, https://www.iea.org/publications/nuclear/.

According to IEA analysis, without LTE in the so-called IEA Nuclear Fade Case (IEA 2019b), the EU nuclear capacity would fall from 126 reactors in operation today to 37 reactors by 2030, with 89 being in decommissioning phase (Figure 10.4), beyond the 91 already shut down prior to 2015.

The latest IEA analysis shows that LTE/LTO of nuclear plants is cost-competitive compared with other investments (IEA, 2019b) (Figure 10.5).

Figure 10.5 Projected LCOE and value-adjusted LCOE, 2040 in the EU



While building new nuclear might become more expensive than renewable alternatives, LTEs of existing nuclear power are usually very cost-competitive.

Notes: LCOE = levelised cost of electricity; MWh = megawatt-hours; VALCOE = value-adjusted levelised cost of electricity; PV = photovoltaic; CCGT = combined-cycle gas turbines. Nuclear lifetime extension LCOE is based on USD 1.1 billion investment to extend operations for 20 years. Storage paired with solar PV is scaled to 20% of the solar capacity and four-hour duration. LCOEs are calculated based on an 8% weighted average cost of capital for all technologies. Other cost estimates from IEA (2019c), *World Energy Outlook 2019*.

Source: IEA (2019b), *Nuclear Power in a Clean Energy System*.

Without LTE/LTO, the EU would see the largest nuclear fleet decline across advanced economies, with the share of nuclear in the electricity mix falling from 25% in 2017 to 5% in 2040. According to the IEA analysis, this would lead to a higher cost of the clean energy transition and would require higher investments in new generation. The generation gap resulting from already planned coal phase-outs in EU countries together with such nuclear shutdowns would need to be filled by wind and solar power, and natural gas for flexibility, which are not perfect substitutes for nuclear power. Such a Nuclear Fade Case in the EU would require higher efforts on system integration and sector coupling than planned for today.

There are 7 GW of nuclear reactors under construction in EU countries, as shown in Table 10.2. These new plants have seen important delays and cost overruns for multiple reasons. These reasons need to be carefully analysed and the lessons learned taken into account for future constructions with a view to ensure continuation of nuclear power once the existing reactors are shut down. This is a key responsibility for the nuclear sector.

Table 10.2 Nuclear power generating gross capacity by country in May 2019 and projections for 2030

Country	Existing gross capacity (GW) in 2019	Gross capacity under construction (GW) in 2019	Projections for 2030
Belgium	6.2	0	-
Bulgaria	2.0	0	2.0
Czech Republic	4.2	0	4.3
Finland	2.9	2	3.5
France	65.9	2	62.0
Germany	10.0	0	-
Hungary	2.0	0	3.4
Netherlands	0.5	0	0.5
Romania	1.4	0	2.8
Slovak Republic	2.0	1	1.9
Slovenia	0.7	0	0.7
Spain	7.11	0	3.2
Sweden	9.0	0	7.1
United Kingdom	10.4	3.4	7.4*
Total	124.6	7	96.8

Note: Projections for 2030 are made based on the stated policies of each member state and decommissioning and construction dates are subject to change which will affect totals.

*Projections include 2.7 GW of power from reactors at Heysham 2 and Torness which are due to be decommissioned in that year.

Source: IEA (2019b), *Nuclear Power in Clean Energy System*; IEA (2019c), *World Energy Outlook 2019*.

A sustained schedule for the construction of new nuclear reactors in those countries that want to use nuclear might overcome most of the cost overruns and delays in the EU in the last decade, which was characterised by a limited number of "first of its kind" new builds. The 1970s experience from the European national nuclear programmes and the more recent global experience (for instance in the People's Republic of China and Korea) indicate that such a programme would help spread the design, engineering and licensing costs, benefit from lessons learned during the first constructions, strengthen the supply chain, and build and maintain competence and expertise. The industry estimates a reduction of 15% in construction costs in the case of building pair units on the same site, and up to 30% when engaging in the construction of a set of six identical units.

EU policies in the field of nuclear

EU member states take very different views when it comes to the use of nuclear energy, the LTO of existing plants or investment in new nuclear capacity. Finland, France, Hungary, Slovakia and the United Kingdom are building new plants. Belgium (complete phase-out by 2025), Germany (complete phase-out by 2022) and France (reducing to 50% by 2035) have made political decisions on the reduction of the role of nuclear in their electricity mix. Sweden leaves the door open for new builds on existing sites, while favouring market-driven investment aiming at 100% renewables. Spain is strongly engaged in the deployment of renewable energies and sees nuclear power only as temporarily needed during the transition. Austria is historically strictly against the use of nuclear power. Poland considers nuclear energy as an important contributor to help the decarbonisation of the country's energy sector, which is heavily dependent on fossil fuels for both electricity and heat production, and seeks to initiate a nuclear power programme. Bulgaria, the Czech Republic and Romania have pro-nuclear policies. Given such diversity in approaches, EU policy in the field of nuclear is considered very politically sensitive.

Given these differences, the EU programmes concern mainly nuclear safety and safeguards, radiation protection, waste management and disposal, as well as research and development (notably the Euratom research programme and the ITER project).

The Euratom Treaty, establishing the European Atomic Energy Community, was signed on 25 March 1957 by the six founding countries as a promotional treaty. Today, all EU countries are formally members of the Euratom Community, as is the European Commission. Being untouched since its foundation, the Euratom Treaty has a different interinstitutional mode of operation than the Treaty on European Union. Indeed, the European Commission and the Council are the main actors under the Euratom Treaty, despite its being an intergovernmental treaty. The Commission has the sole responsibility to propose legal acts (directives, regulations, recommendations), which are then discussed, amended and agreed by the Council, before being transposed into national law by the member states. The enforcement of the implementation is a duty of the European Commission. The European Parliament has a consultative role, with the notable exception of decisions on the budget, since the "Euratom budget" is an integral part of the European Union multiannual financial framework (MFF).

The EU imports all of its uranium needs. For fuel cycle services (conversion, enrichment, fuel fabrication, reprocessing), there are only a few suppliers in the world. The EU industry covers most of the EU operators' needs for these services and could expand capacity if needed. The EU industrial capacity in the nuclear fuel cycle is key to security of supply. Therefore, the EU common nuclear supply policy, under the umbrella of the Euratom Supply Agency, aims at a reasonable diversification of supply sources at all stages of the fuel cycle, avoiding excessive dependence on third-country suppliers.

Concerning the back end of the cycle, several member states have opted for an open cycle, i.e. direct disposal of used nuclear fuel instead of reprocessing and disposal of vitrified waste. Both options are in line with the Euratom Radioactive Waste Directive, as the member states are responsible for national policies. Three EU countries are leading the path towards geological disposal of used nuclear fuel and high-level nuclear waste: Finland, France and Sweden. Finland's waste management organisation Posiva is in the final stages of construction of a deep underground repository in granite rock with a used nuclear fuel encapsulation facility. In 2019, work started on the encapsulation facility. The commissioning and start of operation of both the repository and the encapsulation facilities is scheduled for 2023. To guarantee the successful scientific and technological demonstration, the long-term management of used nuclear fuel and high-level radioactive waste needs to be industrially deployed.

Under the Euratom Treaty, the main secondary legislations are the Nuclear Safety Directive (2009/71/Euratom, as revised by 2014/87/Euratom), the Nuclear Waste Directive (2011/70/Euratom on the responsible and safe management of spent fuel and radioactive waste) and the revised Basic Safety Standards Directive (2013/59/Euratom).

The revision of the Nuclear Safety Directive was carried out in the aftermath of the Fukushima Daiichi accident. After the accident, EU-wide risk assessments (so-called stress tests) were carried out, following the European Council's request to review the safety of all EU nuclear plants on the basis of a comprehensive and transparent risk and safety assessment. These stress tests were further designed as targeted reassessments of the safety margins of the plants, developed by the European Nuclear Safety Regulators Group (ENSREG), together with representatives of the safety authorities of all EU member states. In line with the Safety Directive, further topical peer reviews are organised every six years. The first such peer review was done in 2019 on the topic of LTO.

The Waste Directive requires member states to put in place national frameworks and policies, where possible under co-operative regional arrangements. In line with the Waste Directive, a first status report was issued to the Council and the European Parliament in 2017; the second was due in 2019.

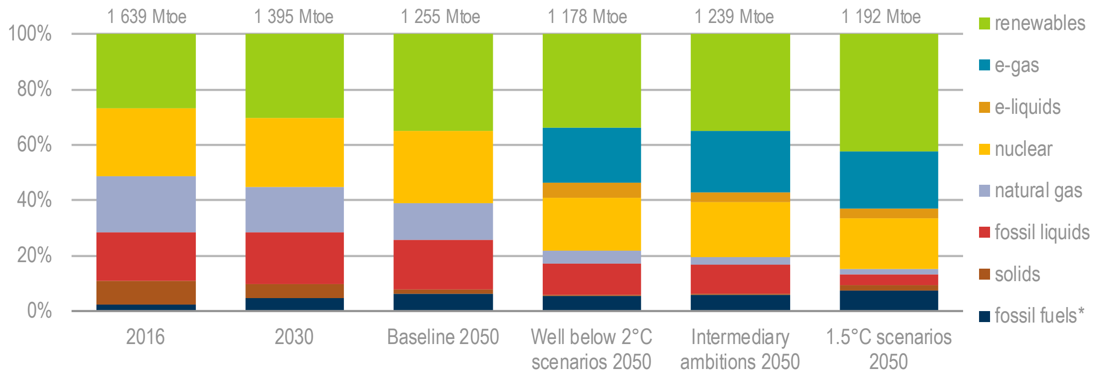
The role of nuclear in energy, environmental and security policies was discussed in the EU Security Strategy of 2014 (security of fuel supplies) and the European Commission's long-term strategic vision of November 2018, but the decision to deploy nuclear energy is the individual responsibility of the member states. The European Commission provides an outlook for nuclear energy at EU level on a regular basis through the PINC, under Article 40 of the Euratom Treaty. The 2017 PINC for the first time covers also an in-depth analysis of the end of the nuclear fuel cycle, including the decommissioning of nuclear power plants and fuel cycle facilities. In this field, the EU nuclear policy focuses on the adequacy, availability and transparent management of decommissioning and waste management funds – in line with the Directive 2011/70/Euratom. The European Commission addresses these issues with the support of the Decommissioning Funding Group (DFG). Based on the 2017 PINC, the European Commission performed further topical studies into the European decommissioning market, the risk profile of funds for back-end activities, and scenarios for nuclear energy under different LTO decisions.

To foster a dialogue on the role of nuclear energy in Europe, including opportunities, risks and transparency issues, the European Nuclear Energy Forum (ENEF) was established in 2007, hosted by the Czech Republic and Slovakia. After a very active period with dedicated working groups reporting to a plenary session twice a year, ENEF activities and membership is limited to an annual high-level gathering.

The role of nuclear beyond power generation

The role of nuclear for the decarbonisation of the EU energy system is set out in the 2050 Long-Term Energy Strategy of 2018. All scenarios expect the role of nuclear to be around 15% in power generation in 2050 (Figure 10.6). Considering that electrification will have substantially increased by that time, this corresponds to a nuclear capacity of the order of 100 GW.

Figure 10.6 Scenarios underlying the 2050 Long-Term Strategy



Renewables and nuclear energy are the backbones of the low-carbon energy mix in the EU's Long-Term Strategy in 2050.

* Non-energy use of fossil fuels.

Note: Mtoe = million tonnes of oil equivalent.

Source: EC (2018), 2050 Long-Term Strategy.

However, beyond electricity, nuclear may also have an increased role to play in other sectors.

- Nuclear power plants can deliver district heating. Operational experience exists in the Czech Republic, Hungary, Slovak Republic and Switzerland. Feasibility studies have been performed in Finland and Poland; the United Kingdom has also examined nuclear district heating.
- Studies are being performed in several EU countries to couple a nuclear reactor with industrial processes that require high-temperature steam supply. A project to build a demo plant is ongoing in Poland, with a number of international partners.
- Nuclear energy can be used to produce hydrogen through (high-temperature) steam electrolysis or through thermo-chemical cycles.
- Many of the advanced reactor systems under development are looking at co-generation[42], or operation in a hybrid energy system, together with renewables. In such systems, baseload nuclear generation can be used to produce either electricity or hydrogen, depending on market conditions, thereby also facilitating the integration of variable renewables in the electricity system.

Nuclear power can therefore contribute to easing the technical difficulties of integrating variable renewables and lowering the cost of transforming the electricity system by offering the necessary flexibility. EU countries, notably France, also have experience with load-following nuclear, but these options are largely limited when the nuclear fleet reaches a certain age, due to maintenance shutdowns needed for LTO/LTEs.

42 *Co-generation* refers to the combined production of heat and power.

Financing of nuclear energy

As outlined in Chapter 9, the EU has been supporting nuclear research for decades, including the ITER project. A number of nuclear research facilities which were built in the 1950s and 1960s are reaching the end of their life and will soon be closed.

Investments in new nuclear plants have been supported through national specific financing arrangements and guarantee schemes such as the Mankala[43] model in Finland, contracts for difference or the regulated asset base model under development in the United Kingdom, and long-term power purchase agreements. In the EU, these arrangements need to comply with relevant competition and state-aid regulation. Recent approvals of such arrangements for Hinckley Point C (United Kingdom) and Paks II (Hungary) used the Euratom Treaty as the legal base.

In 2020, the MFF (the EU Budget) for the period 2021-27 is under discussion. In parallel, a range of new financing instruments aiming at fostering investment in low-carbon infrastructures will be coming forward in the coming years. Some are already developed, but investments in nuclear projects are not always eligible (e.g. InvestEU, Modernisation, Innovation Fund, Structural and Regional Funds, European Investment Bank [EIB] Energy Lending tools), as nuclear activities at the EU level are covered by the Euratom Treaty, distinct from the Treaty on the Functioning of the European Union (TFEU), the basis for the above-mentioned funds.

The Sustainable Finance Taxonomy will provide for an investment label of green financing.

At the European Council of December 2019, several countries (Bulgaria, the Czech Republic, France, Hungary, Poland, Romania, the Slovak Republic, Slovenia and the United Kingdom) supported the critical role of nuclear for decarbonisation and its inclusion under sustainable financing.

A technical expert group (TEG) evaluated the contribution of nuclear energy to a decarbonised future and advised the Commission for the implementing rules and criteria used as benchmark for EU funding and private funding. The TEG was unable to recognize nuclear energy as sustainable / non-sustainable, but classified it as a so-called transitional or enabling activity.

The Taxonomy Regulation was adopted by the European Parliament on 18 June 2020. The Commission will regularly update the technical screening criteria for transition and enabling activities. By 31 December 2021, it should review them and define criteria to identify activities that have a significant negative impact. The EU is aiming to apply the taxonomy for climate change mitigation and adaptation by the end of 2021 and, for the other objectives, by the end of 2022.

43 The Mankala model is used in Finland, which allows investment risks to be shared by the utility co-owners, which include industry companies and regional and local power companies (municipalities). It can be seen as an effective way to address the challenge of financing the large capital investment costs that characterise nuclear new build. Utilities invest in and operate the production of electricity at cost for their shareholders. The company operates as a zero-profit-making co-operative for the benefit of its shareholders. The costs are distributed in proportion to each shareholder's stake in the company, and ownership gives each shareholder a proportional share of the electricity produced.

Assessment

Nuclear energy accounts for 25% of electricity generation in the EU, and 50% of its low-carbon electricity. There are 126 nuclear power reactors in operation in 14 EU member states, besides a number of front- and back-end fuel cycle facilities, which results in a good security of supply of nuclear fuel, combined with a diversified uranium supply. The need for further increasing diversification in the supply of nuclear fuel has been highlighted in the Energy Security Strategy issued by the European Commission in May 2014.

Europe's nuclear reactor fleet is ageing, approaching a lifetime of 40 years on average – which corresponds to their initial license lifetime. More than 90 reactors have been closed, but only 3 have been fully decommissioned. In the coming five years, some plants are planned to go out of service, and others will extend their operation, all depending mainly on national policies. There are five reactors under construction and some more planned.

The IEA (2019b) report *Nuclear Power in a Clean Energy System* analyses the role of nuclear power in advanced economies. Without action, nuclear power in advanced economies could fall by two-thirds by 2040, including in the EU, as shown also in the European Commission's PINC (EC, 2017). The implications of such a Nuclear Fade Case are analysed by the IEA in terms of the costs, emissions and electricity supply security impacts. The report concludes that electricity from nuclear power plants with LTE results in cheaper electricity than from new builds of any generation source.

According to the European Commission's scenarios in the Long-Term Strategy 2050, renewables (80%) and nuclear (15%) will constitute the backbone of the decarbonised electricity production in 2050. The 15% share of nuclear corresponds to the same level of installed nuclear capacity of today, as electrification will increase. As most of the plants in operation today will be taken out of service by 2050, this capacity would essentially be new-built plants. The estimated costs of building the new fleet is around EUR 400 billion (EC, 2017).

To keep open the option for nuclear energy by 2030, the EU needs to maintain its competence, technology, and ability to build new facilities, along with the associated supply chain.

Globally, the Intergovernmental Panel on Climate Change estimates a necessary increase of the worldwide nuclear capacity by a factor of 2 to 5 depending on the different decarbonisation scenarios (IPCC, 2018).

To reap the benefits of nuclear energy as a low-carbon electricity source, it is important that nuclear be treated on equal footing with other low-carbon technologies, and that there is coherence between the policies based on EU scenarios. This is particularly true for the financing and investment tools developed at EU level, in part to support the decarbonisation of energy supply (e.g. InvestEU, Modernisation, Innovation Fund, Structural and Regional Funds, EIB Energy Lending tools), of which some already exclude nuclear. In this regard, the implementing criteria of the Sustainable Financing Taxonomy are highly critical, since they will guide also EU financial instruments, and other international financing institutions, the private banking sector and investors at large.

Nuclear energy may play a role beyond electricity supply. Advanced and small modular reactors, including for co-generation or direct heat supply applications, could be promoted with research and demonstration. Such reactors may also contribute to flexibility requirements at the system level, to integrate nuclear with variable renewables, through, for example, hybrid systems as developed in the United States, or the production of hydrogen. The Euratom Research Framework Programme should take these options into account. More synergies and cross-cutting projects should also be developed under the non-nuclear parts of Horizon Europe (e.g. on material science, digitalisation and advanced manufacturing).

Progress towards standardisation and harmonisation will be an enabler for cost reductions. This includes industrial standards and licensing processes. All nuclear stakeholders, industry, regulatory authorities and waste agencies need to engage proactively in this process.

Important secondary European legislation under the Euratom Treaty is in place with regard to safety, decommissioning and waste management. The updated Safety Directive of 2014, following the Fukushima accident, contains an ambitious nuclear safety objective to prevent or mitigate accidents and requires regular peer reviews of safety-related topics. The first topical peer review in 2018 focused on the ageing management of nuclear reactors, showing the importance of the issue. The Waste Directive of 2011 requested member states to adopt national programmes on the management of spent fuel and radioactive waste, and to provide regular information to the Commission, which then issues consolidated reports. The second report was published on 17 December 2019. The DFG reviews the national funding mechanisms for the decommissioning of closed power nuclear plants, to ensure funds are available at the time the decommissioning starts.

Finland is in the final stages of building its deep geological repository for used nuclear fuel and high-level radioactive waste, to be commissioned in 2025. Sweden and France are close to the same stage in this process. This demonstrates that management of used nuclear fuel and high-level radioactive waste is reaching industrial maturity after decades of research and demonstration phases and can meet safety requirements.

It is critical to ensure continued availability and access to nuclear research facilities. International co-operation can be instrumental for the EU to maintain a leading position in nuclear science and education. For this, financial means at the EU level would have to be made available. Tools such as the European Strategy Forum on Research Infrastructures can help define priorities for further access to European research and innovation funding mechanisms (InvestEU via Horizon Europe).

In the long term, beyond 2050, nuclear fusion could contribute to the decarbonised energy supply. Continued support for ITER is required, noting the leading role that Euratom has taken in this project. It is therefore necessary to ensure proper EU as well as international participation in the next phase of the project. At a time when other major countries or regions in the world are maintaining, developing or rebuilding their competence in nuclear energy, the EU has to properly evaluate the consequences of not pursuing nuclear energy programmes. At a minimum, setting an adequately conducive environment by ensuring equal treatment of all low-carbon technologies would provide the right signal, fostering the nuclear community to engage.

Recommendations

The European Union should:

- ☐ Support the role that nuclear energy can play in the transition towards decarbonisation and sustainability, where this is the choice of a member state. Concerned member states should keep the nuclear option open by supporting the lifetime extension of existing nuclear power plants as well as new plants, based on a technology-neutral and consistent approach in EU strategies, legislation and financing mechanisms.
- ☐ Support a broader spectrum of research, development and demonstration on advanced concepts and small modular reactors, including for heat production for industrial uses and co-generation, integrating flexible nuclear and renewable sources and progressing towards harmonisation and standardisation, as well as the development of common approaches for licensing.
- ☐ Promote better synergies between the research programmes under Euratom and the TFEU, in particular on cross-cutting topics, to increase the effectiveness and impact of the funds. Ensure that financing mechanisms for innovation are open for nuclear-related demonstration projects.
- ☐ Work with EU member states on the proactive development of plans for the final repository of high-level nuclear waste, notably at regional level, as permitted under the Waste Directive of 2011, to accelerate their implementation in a cost-effective way.
- ☐ Foster international co-operation with non-EU countries and entities, where appropriate, in particular for the use or construction of scarce large nuclear research infrastructure, including fusion research.

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11. Natural gas

Key data (2017)

Production: 132 bcm, -39% since 2007

Net imports: 355.9 bcm, +16% since 2007

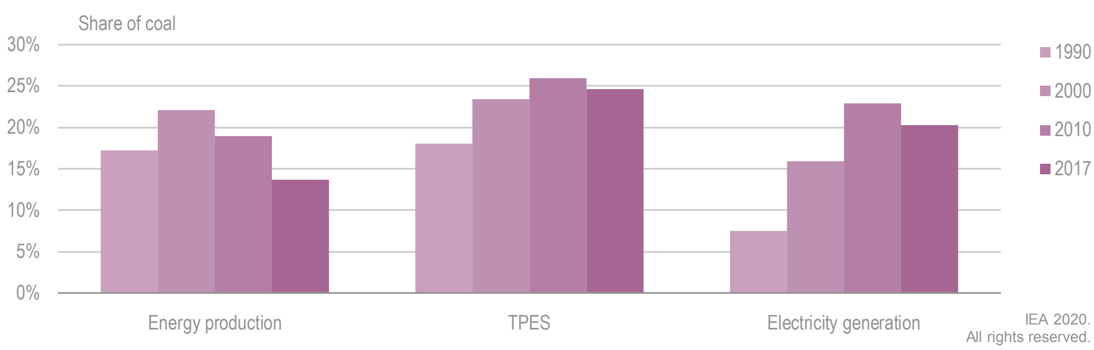
Share of natural gas: TPES: 24.6%, electricity generation: 20.3%, TFC: 21.8%

Gas consumption by sector: 486.6 bcm (heat and power generation 31.4%, residential 26.0%, industry 24.7%, commercial and public services 11.3%, others 6.6%)

Overview

The European Union (EU) is the largest gas-importing market in the world. Gas demand in the EU has decreased by 1.6% per year since its peak in 2010. Declining production in the main gas-producing countries (the Netherlands, the United Kingdom) has led to increased reliance on imports. Natural gas is still the second-largest energy source after oil in both total primary energy supply (TPES) and total final consumption (TFC). In 2017, natural gas accounted for 25% of TPES, 22% of TFC and 20% of electricity generation (Figure 11.1).

Figure 11.1 The role of natural gas in EU energy system, 1990-2017



Natural gas has a stable position in the EU's energy system, accounting for around a quarter of TPES, TFC and electricity generation, but its share in total energy production is falling rapidly.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/

Amid rising imports, the EU has strengthened security of supply by supporting more integrated gas markets, bidirectional gas flows and new pipeline interconnections. The EU has increased diversification thanks to increasing liquefied natural gas (LNG) regasification capacity and more import options. Internal market rules and procedures apply now also to pipelines to and from third countries (up to the border of the member state's territory and territorial sea).

A European framework for natural gas is under preparation for 2020. The framework should ensure that natural gas is able to continue to play a role in the energy transition. Europe’s gas infrastructure can provide opportunities for increased use of renewable and decarbonised gases in the future. The regulatory framework/market design needs to evolve to support the accommodation of low-carbon/decarbonised gases into the grids, such as biomethane, hydrogen and CO_2 for reuse or storage. The EU is in the process of adopting rules for sustainable financing in 2019, which will impact future EU funding instruments, including funding by the European Investment Bank (EIB) and Connecting Europe Facility (CEF). The EU will need to develop a consistent and clear taxonomy of renewable, decarbonised and low-carbon gases.

Natural gas will continue to play a role in the EU’s power sector as a source of flexibility, notably in the short to medium term, as coal and nuclear retire. The gas and electricity sectors are likely to interact more in future. Given their increasing interdependence, gas security strongly impacts on security of electricity supply.

Supply and demand

Natural gas consumption

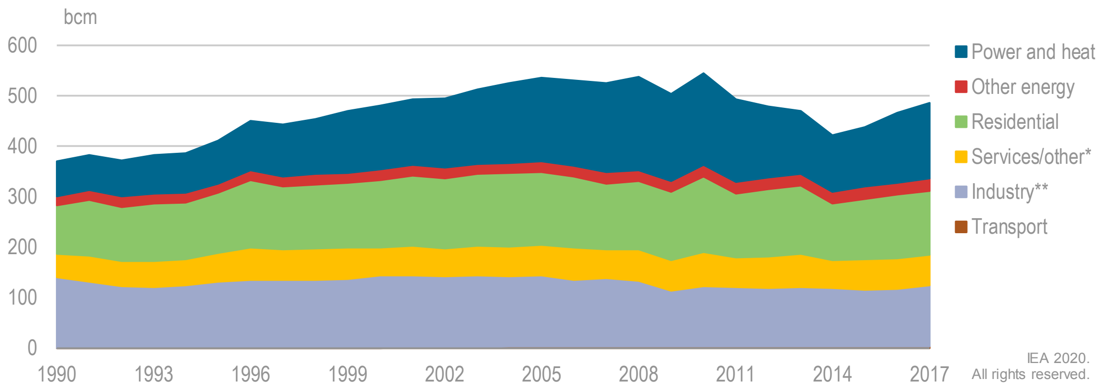
Natural gas is a significant pillar of the EU’s energy mix, providing power and heat to both buildings and industrial processes. Heating and cooling accounts for 50% of the EU’s total final energy consumption, significantly covered by natural gas. Natural gas is the second-largest energy source in the industry sector after oil, and the largest energy source in the residential sector. In 2017, natural gas was also the third-largest source of electricity generation in the EU, and its importance in the power sector is likely to increase amid the phase-outs of nuclear and coal power and the growth in variable renewable energy.

In 2017, total gas consumption in the EU countries was 487 billion cubic metres (bcm). This represented a 7% decline from a decade earlier, but a 15% increase from 2014 (Figure 11.2). Around a third of the gas is used for power and heat generation, and gas consumption in the power sector varies significantly, mainly due to price variations for other fuels, such as hard coal and lignite, and carbon pricing. Growth in renewable electricity and decreasing coal prices compared with gas prices resulted in a drop in gas power generation during 2012-15. However, in the past three years, gas use has come back again.

The residential and service sectors together accounted for 39% of total gas consumption in 2017, used mainly for heating in buildings, and the demand fluctuates with temperature variations. The role of gas in buildings varies widely across the EU countries. Natural gas accounts for 61% of residential energy consumption in the Netherlands and 64% in the United Kingdom, but less than 1% in Cyprus,[44] Finland, Malta and Sweden.

The industry sector accounted for 25% of gas demand in 2017. Demand has been stable from the gas-consuming industries, including chemicals and petrochemicals, which use gas as a feedstock for non-energy purposes in their processes. The chemical and petrochemical industry accounted for 35% of total industrial gas demand, followed by the food and tobacco industry at 15% and other non-metallic manufacturing at 14%.

Figure 11.2 Natural gas consumption by sector in the EU, 1990-2017



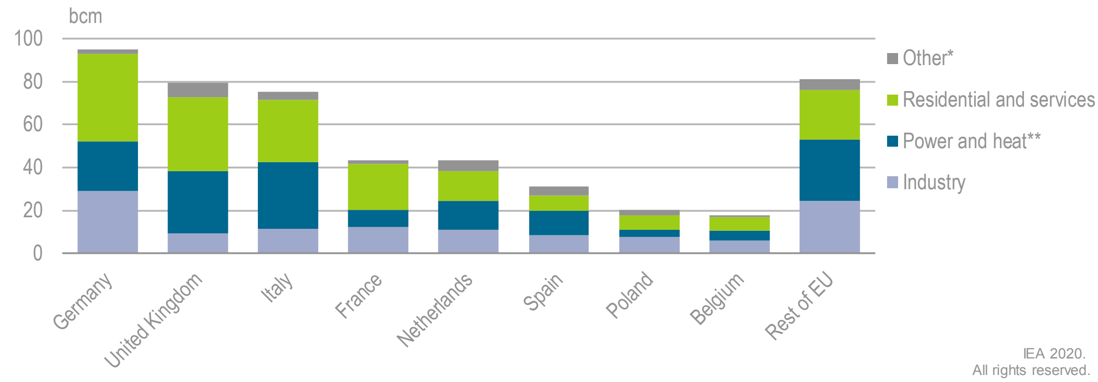
The power sector is the largest gas consumer in the EU and its demand fluctuates with changes in the electricity market, while other gas consumption is more stable.

**Services/other* includes commercial and public services, agriculture, forestry and fishing.
***Industry* includes chemicals and petrochemicals, food and tobacco, and non-metallic manufacturing.
Source: IEA (2019b), *Natural Gas Information 2019*, www.iea.org/statistics.

The six largest gas-consuming countries are responsible for some 75% of total EU demand for natural gas (Figure 11.3). Germany is the largest consumer in the EU, followed by the United Kingdom and Italy. The share of natural gas in TPES varies from around 40% in the Netherlands, Italy and the United Kingdom, down to well below 2% in Sweden. The breakdown by sector also varies by country, with final use in buildings and industry dominating gas demand in Germany, while power generation is the largest gas consumer in Italy.

[44] Two footnotes: 1. Footnote by Turkey: The information in this document with reference to “Cyprus” relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of United Nations, Turkey shall preserve its position concerning the “Cyprus issue”. 2. Footnote by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

Figure 11.3 Natural gas consumption by sector in different EU member states, 2017



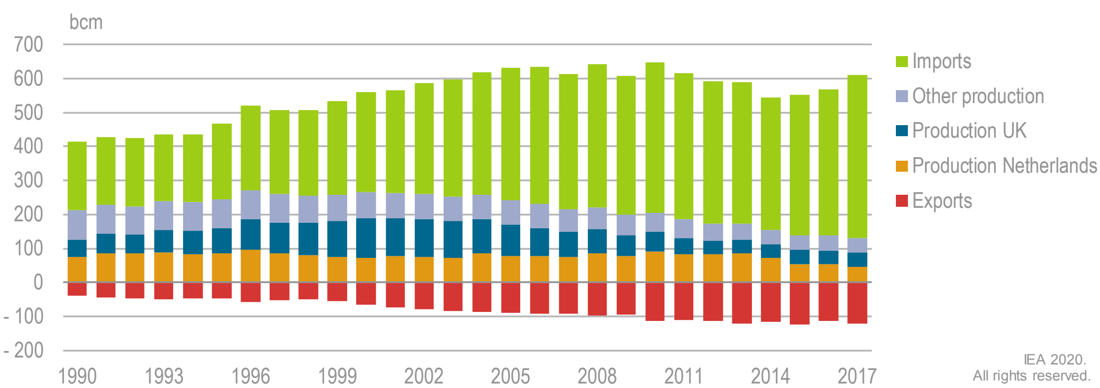
Germany, the United Kingdom and Italy are the largest natural gas markets in the EU and account for half of total gas demand, used across industry, power generation and buildings.

**Other* includes energy sector, distribution losses, transport, agriculture, forestry, fishing and non-specified.
***Power and heat* includes small shares of other transformation
Source: IEA (2019b), *Natural Gas Information 2019*, www.iea.org/statistics.

Production and imports

The Netherlands and the United Kingdom have been the largest gas producers in the EU, accounting for one-third of total production each. In 2017, the United Kingdom overtook the Netherlands to become the largest gas producer in Europe. Both these major producers have seen a significant decline in gas production in the last decade. In 2017, total gas production was 132 bcm, a 39% decrease since 2007. This production covered only 22% of total gas demand in 2017, and the rest was imported (Figure 11.4).

Figure 11.4 Natural gas supply by source, 1990-2017



With declining gas production in the EU, notably in the Netherlands and the United Kingdom, imports are covering an increasing share of the gas supply, with 73% of total supply in 2017.

Source: IEA (2019b), *Natural Gas Information 2019*, www.iea.org/statistics.

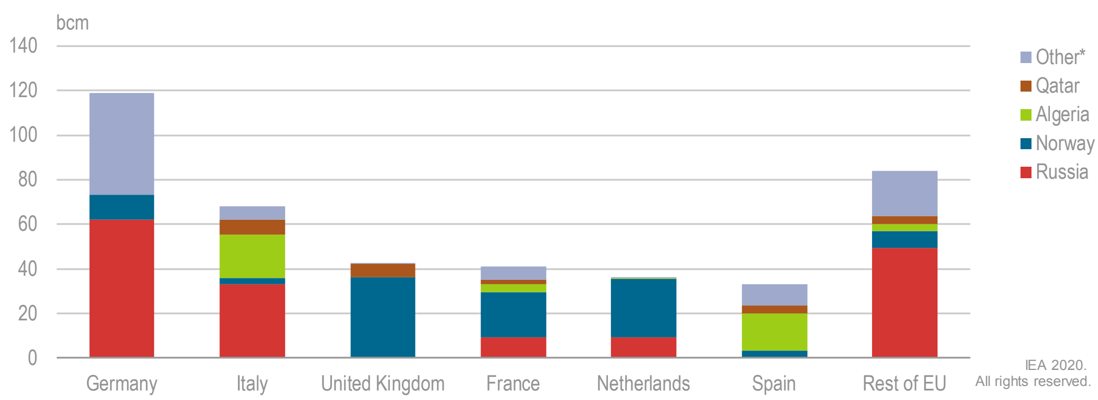
With declining production, the EU is becoming more dependent on gas imports. (As of 2018, Denmark is the only net exporter of gas among EU countries, but gas exports are down due to the shutdown of the Tyra field until redevelopment in 2022.) In 2017, 38% of all gas imports to EU countries (from countries outside the EU) came from the Russian Federation ("Russia"), mainly by pipeline (Figure 11.5). Norway was the second-largest source of gas imports, with 25% of the total gas imports, mainly to Germany, the United Kingdom, Belgium, and some to France.

EU domestic gas production has been falling faster than expected. Production from the North Sea in the United Kingdom, which had increased in recent years, is expected to fall by around 6 bcm from 2018-23 and 5 bcm from 2019-23. The Netherlands' giant Groningen gas field is set to end production by 2022, reducing swing capacity for the region of low-calorific (L-gas) users in the Netherlands and parts of Belgium, France and Germany. As the L-gas market is rather small, the impact on the region is largely confined to household and commercial users with specific appliances made for these low-gas specifications.

The decline has been compensated by increasing LNG imports and Norwegian production, and large-scale conversion of high-calorific gas to L-gas. Programmes to encourage consumers to use heat pumps or electric heating in the Netherlands and the United Kingdom are expected to limit the expansion of, and eventually reduce, natural gas consumption in the residential sector, thus leading to declining gas demand in the region. The regional impacts of declining North Sea production will change the gas mix and gas flows and price trends at both Title Transfer Facility (TTF) and National Balancing Point (NBP) gas hubs, which are today the heart of the North West gas market in the EU.

New gas and shale gas production is not envisaged. In 2019, the United Kingdom joined the countries that had already put in place bans or moratoria on shale gas extraction, including Bulgaria, the Czech Republic, France, the Netherlands and Spain as well as some regions of Germany.

Figure 11.5 Natural gas imports by country, 2017



Russia is the largest source of natural gas imported by EU countries with 38% of all imports (excluding between EU countries), followed by Norway (25%), Algeria (10%) and Qatar (5%).

**Other* includes imports from other countries than Russia, Norway, Algeria and Qatar, excluding other EU countries.
Note: The chart shows all imports from countries outside the EU. Exports are not included.
Source: IEA (2019b), *Natural Gas Information 2019*, www.iea.org/statistics.

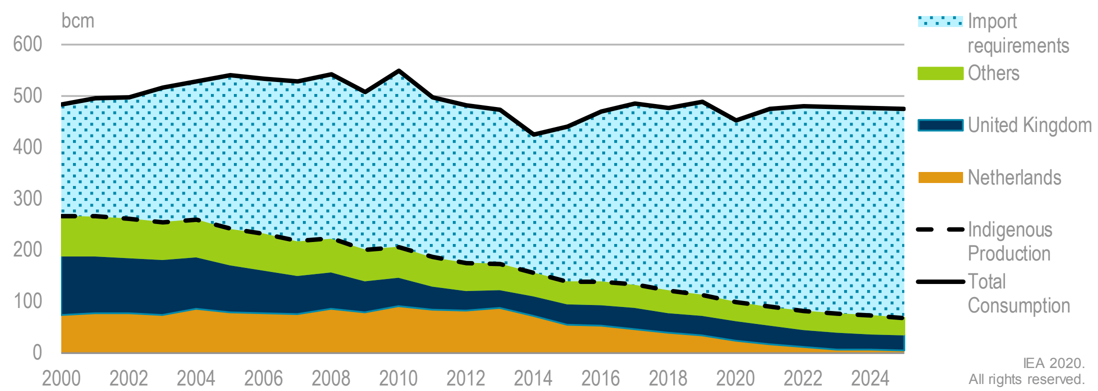
Natural gas is also shipped to the EU as LNG, which enables supply from a large variety of sources, such as Qatar and the United States. LNG imports to the EU are now increasing rapidly after a decade of slow progress, due to lower gas demand during 2010-14. LNG imports into Europe had decreased from almost 80 bcm in 2010 to 42 bcm in 2014, and then picked up in 2017 to reach 51.6 bcm and 57 bcm in 2018 and a record of 115 bcm in 2019.

The major LNG exporters to Europe are Qatar, accounting for 29%, Russia (18%), Algeria (14%), Nigeria (13%) and United States (12%). In 2017, Spain was the largest importer of LNG with 16.6 bcm, followed by France with 15.3 bcm and the United Kingdom with 7.0 bcm. By the end of 2019, imports have increased substantially in all countries, to reach 18 bcm in the United Kingdom.

Medium- to long-term outlook for natural gas in the EU

Total gas demand in the EU is projected to remain stable in the next five years up to 2024, according to the International Energy Agency (IEA). Total gas demand in the EU is expected to gradually recover through the next five years following a drop of over 7% in 2020. Gas use is expected to see growth in power generation but a decrease in heating in buildings towards 2030 (IEA, 2019d). As domestic production continues to decline, the EU needs to cover an ever-higher share of domestic demand through additional imports by 2025 (Figure 11.6).

Figure 11.6 EU natural gas supply by source, 2000-25



As production continues to drop fast, the EU gas import requirements are on a fast rise.

Source: IEA (2020), *Gas 2020.*

Following a record of 115 bcm of LNG imports in 2019, IEA expects Europe to continue to play a key role in balancing the global gas market by providing access to its spare regasification capacity, ample storage space and liquid pricing hubs. LNG imports are expected to oscillate in a range of 90-110 bcm/y through the medium term.

Gas is a major element in the European Union's energy mix, and is particularly important for the provision of power and heat to both buildings and industrial processes. Currently, gas infrastructure in the European Union delivers 50-100% more energy on average to end consumers than electricity grids. Gas grids also provide a major source of flexibility;

EU gas storage capacity today is 1 000 terawatt-hours (TWh), which is more than 50 000 times current global electric battery storage capacity.

Over at least the next decade, many of the European Union's climate and environmental policies are likely to induce increased gas consumption: for example, reforms to the Emissions Trading System have increased the price of carbon emissions, thereby encouraging fuel switching from coal to gas. Other EU policies encouraged gas competition and gas security of supply. In the longer term, however, the pathway for gas consumption is unclear in the face of EU policies that support energy efficiency and renewable energy, as well as longer-term policy ambitions to reach climate neutrality by 2050. The EU expects the share of natural gas to go down below 10% (3-4% or 7-9%, depending on the scenario) under a net-zero pathway, according to the European Commission's Long-Term Strategy (EC, 2018).

The IEA *World Energy Outlook* (*WEO*) *2019* expects the role of natural gas in the EU energy system to decline in the period to 2040 in the Sustainable Development Scenario (SDS), a path fully aligned with the Paris Agreement aim of holding the rise in global temperatures to well below 2°C and pursuing efforts to limit it to 1.5°C (IEA, 2019d). Gas use for power generation and heat plants declines in absolute terms from 146 bcm in 2018 to 96 bcm in 2040. Its share in total electricity generation falls from 19% to 10%. However, with much lower contributions from coal and nuclear, natural gas-fired power generation capacity increases in the SDS to bridge the gap, while operating in a more flexible manner, to balance the variability of renewable sources of electricity generation. Natural gas use in buildings sees the steepest drop, falling to 40% of today's level.

A net-zero pathway also leaves open the question of what role natural gas infrastructure might play in a low-carbon scenario. The *WEO 2019* has examined the prospects for midstream gas transportation infrastructure – including regasification terminals, transmission and distribution pipelines, and storage – to accommodate the uptake of low-carbon gases in the European Union. Low-carbon hydrogen is one such option, and could help deliver deep emissions reductions across a wide range of hard-to-abate sectors, including steel production, chemicals manufacturing, high-temperature industrial heat, shipping, long-distance and long-haul road transport, and buildings. Injecting hydrogen into gas pipeline networks has been identified as one of four key opportunities for hydrogen over the next decade (IEA, 2019e). However, there are several commercial and technical uncertainties, such as the tolerance of appliances and transmission and distribution infrastructure to different rates of hydrogen blending, the possibility of converting end-user equipment, and the overall costs and optimal production pathways for delivering low-carbon hydrogen at scale.

Another alternative to pipeline natural gas is biomethane. Unlike hydrogen, biomethane, a near-pure source of methane, is largely indistinguishable from natural gas and so can be used without the need for any changes in transmission and distribution infrastructure or end-user equipment. Most of the biomethane produced today in the EU (around 2 bcm) comes from the upgrading of biogas. The key issue is to produce biomethane from a sustainable feedstock, i.e. which can be processed with existing technologies, does not compete with food for agricultural land and does not have any other adverse sustainability impacts (e.g. reducing biodiversity). The IEA *WEO 2019* conducted a first-of-a-kind assessment of the sustainable technical potential and costs of biomethane supply globally and found that in the EU, over 100 bcm of such potential exists today. However, production costs are significantly higher than conventional natural gas; these average around USD 25 per million British thermal units (MBtu), compared with a five-year average wholesale natural gas price in the EU of around USD 7/MBtu (until 2019).

Legislation to support the roll-out of fuelling infrastructure compatible with biomethane is already in place in the EU. The European Commission presented guidelines on quantifying savings from blending renewable gases under the Renewable Energy Directive (2018/2001, EU). A number of European countries have developed biomethane registries to track the injection and extraction of biomethane from natural gas networks, as well as a pan-European registry that aims to facilitate international trade. Hydrogen is likewise enjoying policy support in several EU member states. However, there is currently no common regulatory framework for accounting, certification and verification of the levels and types of low-carbon gases injected into the grid. Such measures become essential if suppliers and operators are to be paid a premium for delivering low-carbon gases to European end users.

In the *WEO* Stated Policies Scenario, biomethane injected into gas grids by 2040 reaches almost 13 bcm. This number is three times higher in the SDS, and reaches nearly 15% of total gas demand. Relatively small quantities of hydrogen are also injected into gas grids in this Scenario, but a significant uptake is likely to take place beyond the 2040 modelling horizon.

Natural gas infrastructure

Gas pipelines

In 2019, the EU had a total pipeline import capacity of 5.401 TWh per year, according to ENTSOG. The gas transmission pipeline network was around 225 000 kilometres (km) in the EU, with the largest networks in Germany (38 128 km), France (37 548 km) and Italy (34 880 km). In the EU, there are 46 gas transmission system operators (TSOs).

Imports of Norwegian gas arrive to Belgium, France, Germany and the United Kingdom. Algeria delivers natural gas by pipeline to Portugal and Spain directly (Medgaz) as well as through Morocco (Maghreb-Europe pipeline). Morocco also delivers gas to Italy through Tunisia (Transmed). Gas from Libya is imported by Italy (Green Stream). Russian gas is mainly imported and transported via long distances in pipelines through:

- Ukraine to Poland, the Slovak Republic, Hungary and Romania, and then to the Czech Republic and other Western European markets.
- Belarus (Northern Lights, Yamal) to Poland and Lithuania.
- The Trans-Balkan pipeline system (Ukraine, Moldova, Romania, Bulgaria and Greece).
- Germany (Nord Stream) and onwards to the Czech Republic.
- Directly to Finland, Estonia and Latvia.

Four new large gas import pipelines are expected to come online in the short to medium term, which will supply the EU: Nord Stream 2, Turk Stream, the Southern Gas Corridor (and related Trans-Adriatic Pipeline [TAP]) and the Baltic Pipe.

Nord Stream 2 consists of two strings, each with a capacity of 27.5 bcm per year, following the route of Nord Stream 1. The construction is ongoing and when completed, Nord Stream 2 is to be connected to the EUGAL pipeline in Germany. EUGAL string 1 (30.9 bcm per year) has been completed with flows of over 50 million cubic metres (mcm) per day, allowing Nord Stream to run at a maximum, despite the reimposed cap on Nord Stream 1 evacuation on the OPAL pipeline (12 bcm per year). Nord Stream 2 is set to start commercial operations by the end of 2020 or the first quarter of 2021 at the latest, according to Russian government announcements in February 2020. Germany implemented the amended EU Gas Directive in October 2019, which will be applicable to Nord Stream 2 (for the part located in the last 12 nautical miles of the pipeline crossing German territorial waters), requiring the project company to offer parts of the capacity to the market and be unbundled. In December 2019, the United States Congress imposed sanctions on Nord Stream 2. The Nord Stream 2 project company began arbitration proceedings to obtain cancellation of the application of new EU gas unbundling rules to Nord Stream 2 under the Energy Charter Treaty. In May 2020, the German regulator rejected the request by Nord Stream 2 to waive the application of the EU Gas Directive, which means the project has to comply with all unbundling, third-party access and tariff transparency rules. On 20 May, the General Court of the European Union dismissed the complaint against the EU Gas Directive which has been transposed at national level. The Court ruled that Nord Stream 2 project company can request an exemption or derogation from the German regulator BNetzA, and if necessary, challenge that decision before a German court which can request a preliminary ruling by the European Court of Justice.

Gazprom's Turk Stream will deliver gas from Russia to Turkey across the Black Sea (two pipeline strings) and then on to South and South East European markets in Bulgaria, Serbia and Hungary (western string), with a total combined capacity of 31.5 bcm per year. On 8 January 2020, Turk Stream (eastern string) started operations, as the offshore pipeline to Turkey and the connection to the Turkish gas system has been completed (15.75 bcm per year). Turk Stream (eastern string) will be diverting 13 bcm away from transit through Ukraine. The Western string of Turk Stream (15.75 bcm per year) remains to be fully completed. However, an exit point has been created at the Turkey-Bulgaria border (Strandja 2-Malkoclar) for the eastern string, which links up with the existing section of the Bulgaria part of the Trans-Balkan pipeline and has enabled flows to reach South East European gas markets since January 2020. Recent upgrades allow physical reverse flows on the Trans-Balkan Pipeline from Greece up to Ukraine and Moldova. Bulgaria and Serbia conducted open seasons in 2019. Europe's South East region, the Western Balkans and Hungary, Romania and Bulgaria, remain dependent on Russian gas imports. Given the changing gas supplies in the region in the coming years, it is concerning that the countries cannot access 40% of the EU LNG regasification capacity (IEA, 2018b).

The opening of the Southern Gas Corridor will link gas production of Azerbaijan to the EU through TAP, which runs through Greece, Albania and Italy. The Southern Gas Corridor project, which was promoted by the European Commission, involves projects of USD 40 billion and runs with 3 500 km of pipeline across seven countries and involving more than a dozen major energy companies based on the following elements:

- The development of Shah Deniz 2 field and gas offshore in the Caspian Sea.
- Expansion of the natural gas processing plant at the Sangachal Terminal on the Caspian Sea coast in Azerbaijan.
- Three pipeline projects: South Caucasus Pipeline – Azerbaijan, Georgia; Trans-Anatolian Pipeline (TANAP) – Turkey; TAP – Greece, Albania, Italy.
- Expansion of the Italian gas transmission network.

- Connection to gas networks in South Eastern, Central and Western Europe.
- TANAP started operations in June 2018.
- In November 2019, TAP AG started to introduce the first natural gas into a 2 km section of the pipeline in Greece. TAP is expected to start operations by the end of 2020.
- The Baltic Pipe is planned to bring Norwegian gas to the region through a new, bidirectional offshore gas interconnection between Poland and Denmark. In 2018, design works for the Baltic Pipe started, in order to obtain the required permits for construction and operation of the offshore part of the pipeline. The pipeline is planned to be fully operational in October 2022. In the Baltic region, a regional gas market is in the making, which will link Estonia, Latvia and Lithuania to Finland and Poland. The Klaipeda LNG terminal in Lithuania improves the energy security level for the Baltic States, by providing an opportunity to have an alternative gas supply source, and creates conditions for a regional natural gas market. The terminal can cover the entire needs of the Baltic States (which had a total of 4.3 bcm of gas consumption in 2018). The Gas Interconnection Poland-Lithuania (GIPL) between Lithuania and Poland is expected to be commissioned in 2021, as part of a regional gas market that will become more integrated with the Balticconnector. The Balticconnector project includes upgrades to the interconnection between Latvia and Estonia (at Karksi expanding its capacity from 7 mcm per day to 10 mcm per day, bidirectional), which was completed in December 2019, and a connection between Estonia and Finland, which will be completed in 2020.

Underground gas storage

The total capacity of underground gas storage (UGS) facilities in the European Union is 1 100 TWh with the biggest capacities available in Germany, Italy, the Netherlands and France (Table 11.1). The storage capacities are very different across Europe. Twenty EU member states have underground gas storage capacity, while eight have none. Gas storages are largely depleted fields (Italy, the Netherlands and Austria). Germany is the EU country with the largest capacity, 50% from depleted fields and 50% from salt caverns (taking into consideration UGS located in Austria but serving the German market), while 70% of the capacity in aquifers is located in France. Salt caverns are usually fast-cycling and more reactive to short-term fluctuations while depleted fields/aquifers are used for seasonal storage.

Table 11.1 Working capacities of UGS in selected European countries, 2020 (TWh)

Country	Working capacity
Austria	94.53
Belgium	9
Bulgaria	6.27
Czech Republic	35.66
Croatia	5.21
Denmark	10.82
France	128.81
Germany	227.37
Hungary	69.63
Italy	196.88
Latvia	21.52

Country	Working capacity
Netherlands	139.78
Poland	35.55
Portugal	3.69
Romania	32.99
Slovak Republic	42.54
Spain	34.25
Sweden	0.08
United Kingdom	12.02

Source: GIE (2020a), AGSI, https://agsi.gie.eu/.

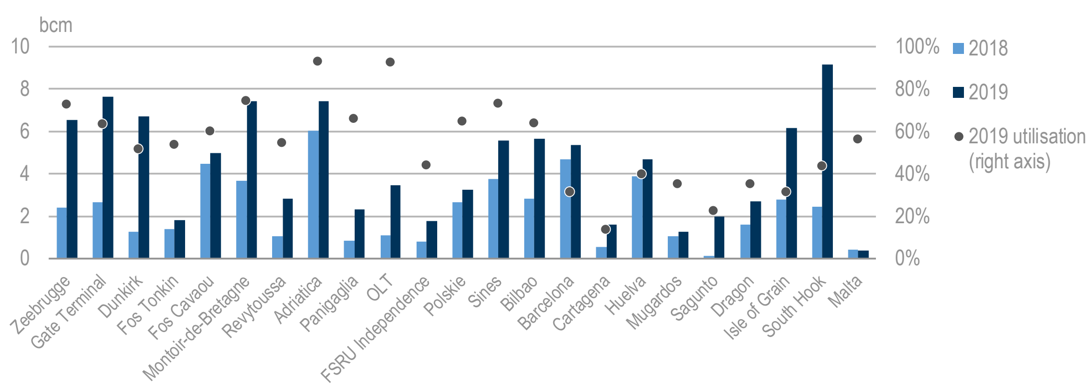
Italy is considerably expanding its gas storage capacity, with an additional 33 TWh under construction and 41 TWh more in the planning stage; if all these new sites become operational, the country's capacity will increase by 22%. The United Kingdom has plans to maintain its capacity, following the closure of its main storage site at Rough. Romania plans to add 12.5 TWh, i.e. more than a third of its current capacity, while Bulgaria plans to triple its capacity to 18 TWh.

The EU total gas storage capacity dropped 4% between 2016 and 2018, with the closure of several large UGS facilities, notably the Rough gas storage in the United Kingdom (3.4 bcm), 2.2 bcm in Germany, 0.8 bcm in France and 0.2 bcm in Austria. Together with the shut-in of production in the Netherlands, the flexibility in the North West gas market area has been reduced. Hence, the utilisation of non-seasonal gas storages was at a higher level in 2018 compared with 2011.

Liquefied natural gas

In 2019, the EU had 29 LNG import facilities in 11 EU member states with around 210 bcm per year of regasification capacity and 10 mcm of LNG storage capacity, equal to around 6 bcm (GIE, 2019). Spain (seven terminals), the United Kingdom (three) and France (four) account for the lion's share of EU LNG import capacity. Most of the LNG terminals are onshore plants, with the exception of several offshore facilities at Delimara (Malta), Klaipeda (Lithuania), and Porto Levante and Toscana (OLT, Italy).

Figure 11.7 EU LNG terminals – 2018-19 volumes and 2019 utilisation rates

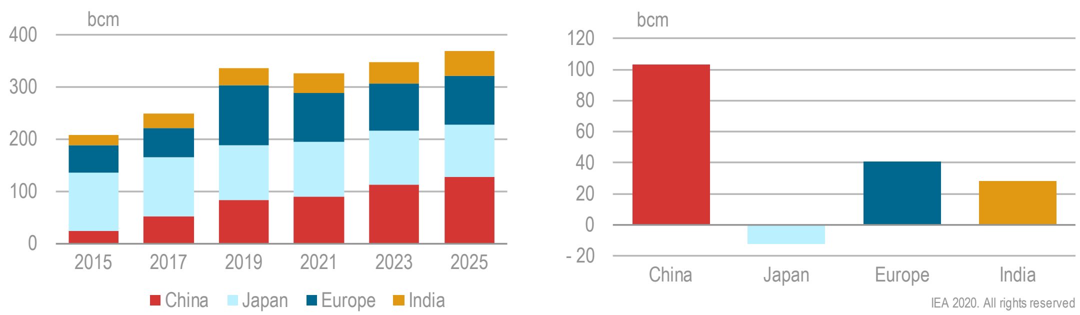


Source: GIE (2020b), ALSI, https://alsi.gie.eu/#/.

The LNG utilisation rate across the EU LNG terminals has been increasing from on average 21% in 2016 to 27% in 2018, but with large differences: 50% in Poland, 32.5% in France, and 13% in the United Kingdom. In 2018, many LNG terminals had still ample spare regasification capacity for LNG imports (Figure 11.7). The EU LNG imports reached record volumes during 2019; the utilisation rates of regasification terminals rose significantly, reducing spare capacity.

Europe was the second main source of LNG trade growth in 2019 with a total of 115 bcm imported. LNG imports are expected to oscillate in a range of 90-110 bcm/y through the medium term up to 2025 (IEA, 2020).

Figure 11.8. Global LNG imports by region, 2014-24



Source: IEA (2020), Gas 2020.

LNG flows to Europe continue to remain high, amid lower Asian demand and global LNG oversupply, leading to smaller spot price spreads between Europe and Asia. New long-term LNG contracts were signed between the EU and LNG producers at the end of 2018. LNG imports grow driven by a combination of decreasing domestic production in North West Europe and the ambition to increase the diversity of supply compared with traditional pipeline suppliers.

About 55.2 bcm per year of additional regasification capacity is in the planning, including capacity extensions to existing terminals but also new projects in countries that do not have an LNG terminal yet (Table 11.2). Croatia took a final investment decision for its first LNG terminal in Krk, and the terminal is expected to become operational by the end of 2020/early 2021. Several European countries are considering the LNG option, including Germany with four projects proposed. The German government, which is promoting the development of at least two projects, announced in March 2019 a plan to incentivise investment by lowering the cost of connection to the transport network by 90%.

Table 11.2 Planned new LNG import terminals in Europe

Country	Terminal	Developer	Initial capacity (bcm per year)	Possible start-up year
Albania	Eagle LNG FSRU	Gruppo Falcone	8	-
Croatia	Krk Island FSRU	LNG Croatia	2	2020/21
Cyprus*	Vassiliko FSRU	OceanFinance	-	2019
Estonia	Padalski LNG	Balti Gas	2.5	2020
Estonia	Muuga (Tallinn) LNG	Vopak	4	2019

Country	Terminal	Developer	Initial capacity (bcm per year)	Possible start-up year
Germany	Brunsbüttel LNG	German LNG Terminal (Oiltanking, Vopak, Gasunie)	8	2022
Germany	Stade LNG	Dow Chemical, Macquarie Group, China Harbour Eng.	5	-
Germany	Wilhelmshaven LNG FSRU	Uniper, Mol, ExxonMobile	10	2022
Germany	Rostock	Fluxys, Novatek	0.4	
Ireland	Shannon LNG	Shannon LNG	2.7	
Ireland	Cork LNG Terminal	NextDecade	-	-
Latvia	Riga LNG Terminal	AS Skulte LNG Terminal	5	2019
Romania	Constanta LNG	AGRI LNG	8	2025
Poland	Expansion of Świnoujście	Polskie LNG	7.5	2022
Poland	Gdańsk FSRU		4	2024/25
Total			**55.2**	

Note: FSRU = floating storage regasification unit.

* Two footnotes: 1. Footnote by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of United Nations, Turkey shall preserve its position concerning the "Cyprus issue". 2. Footnote by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

Source: GIE (2020b), ALSI, https://alsi.gie.eu/#/.

EU regulatory framework

EU internal gas market design

For more than ten years, the European gas market has undergone significant changes in terms of market design and regulations with new EU rules on third-party access, data transparency, unbundling and entry-exit regimes. The liberalisation has increased market effectiveness, liquidity and cross-border trade.

For gas, the relevant EU directives and regulations are:

- Directive 2009/73/EC concerning rules for the internal market in natural gas and amendments adopted in April 2019.
- Regulation 713/2009 establishing an Agency for the Cooperation of Energy Regulators (ACER).
- Regulation 715/2009 on conditions for access to the natural gas transmission networks.
- Regulation 1227/2011 on wholesale energy market integrity and transparency.
- Regulation 2017/1938 concerning measures to safeguard security of gas supply.

- Decision (EU) 2017/684 of the European Parliament and of the Council on establishing an information exchange mechanism with regard to intergovernmental agreements and non-binding instruments between member states and third countries in the field of energy.
- Regulation (EU) No 347/2013 on guidelines for trans-European energy infrastructure.

Since 2009, the EU has implemented the third energy package (see above directives and regulations), but not by all member states. The third package moved regulation of gas transmission pipelines on cross-border issues into an EU framework which builds on the independence and the EU-wide co-operation of the TSOs and the national regulatory authorities. The third energy package set the legal basis to establish detailed rules (the network codes) governing the day-to-day technical operation of TSOs and set the rules regarding their rights and obligations in relation to network users. During the last five years the following network codes have been adopted:

- The network code on interoperability and data exchange rules (Commission Regulation (EU) 2015/703 of 30 April 2015) co-ordinates the complex technical procedures used by network operators within the EU and network operators in the Energy Community and other countries neighbouring the EU.
- The network code on gas balancing of transmission networks (Commission Regulation (EU) No 312/2014 of 26 March 2014) sets out gas balancing rules, including the responsibilities of TSOs and users.
- The network code on capacity allocation mechanisms in gas transmission systems (Commission Regulation (EU) 2017/459 of 16 March 2017) requires gas grid operators to use harmonised auctions when selling access to pipelines. These auctions sell the same product at the same time and according to the same rules across the EU.
- The European Commission rules on congestion management procedures (Commission Decision 2012/490/EU of 24 August 2012) aim to reduce congestion in gas pipelines. Companies are required to make use of their reserved capacity or risk losing it, while unused capacity should be placed back on the market.
- The network code on harmonised transmission tariff structures for gas (Commission Regulation (EU) 2017/460 of 16 March 2017) enhances tariff transparency and coherence by harmonising basic principles and definitions used in tariff calculation, and it includes a mandatory comparison of national tariff-setting methodologies against a benchmark methodology. It also stipulates publication requirements for information on tariffs and revenues of TSOs.

Underground gas storage

Under the EU Gas Directive (2009/73/EC, amended to 2019/692), EU member states determine whether third-party access to a certain storage facility is technically and economically necessary in order to have access to the gas system for the supply of customers. If so, the gas facility will fall under regulation, and a legally and functionally unbundled storage operator will need operate the facility. The directive allows member states to choose either regulated third-party access to storage or negotiated third-party access. Based on the choice, the storage system operator is to apply the regime to its storage.

Some EU countries have also adopted gas storage obligations or obligations to store alternative fuels, including a government stockholding agency in Hungary and strategic gas stockholding obligations in Denmark, Italy, Poland, Portugal, the Slovak Republic and Spain. France abandoned the stockholding obligation in 2018 and replaced it with a minimum seasonal storage level, defined by the administration, for operators to recover their operating expenses (in the light of the deteriorating economics of natural gas storage). Under the new regulatory regime, gas injections in 2018 rose by almost two-thirds year-on-year, to their highest level at least since 2013.

LNG terminals

Most terminals in the EU have regulated third-party access (rTPA), with the regulator approving the tariffs, but five terminals have an exemption under Article 36 of the EU Gas Directive and negotiate the access regime with their users (negotiated third-party access [nTPA]): Gate, Dunkirk, Dragon, Grain and South Hook. Porto Levante was granted a hybrid regime with 20% rTPA and 80% nTPA.

With new market developments and the global LNG market taking off, terminal operators have developed new services, including truck loading or ship loading and trans-shipments, as described above. The regulatory framework has evolved in step, in many instances in response to new market developments, low utilisation rates, or new business models and services. The Council of European Energy Regulators (CEER) reviewed LNG regulations and access regimes in 2019 and concluded that market evolution has forced regulators to adopt drastic changes in the regulatory regime in recent years (CEER, 2019).

For instance, Spain is introducing a new model – it merges LNG plants under a virtual LNG hub model with storage and regasification capacity, providing the choice to users for downloading/loading LNG at any of the six different locations, while reducing the number of contracts and nominations to one. Italy has introduced auctions for the capacity allocation in its LNG terminals. Zeebrugge has adapted its regulated model to new services. Lithuania's Klaipeda terminal uses a security of supply regulated model with a variable and fixed part of the tariff charged by the designated supplier, besides the transmission network charges. Krk LNG terminal in Croatia (under construction) envisages a security of supply fee to be charged to all gas grid users.

Transmission network development

The European Commission has supported the strengthening of Europe's gas infrastructure by identifying some of the missing links across the EU through gas infrastructure planning, providing funding and encouraging regional co-operation.

The Energy Infrastructure Regulation 347/2013 created a regional process to identify projects of common interest (PCIs) along four gas priority corridors:

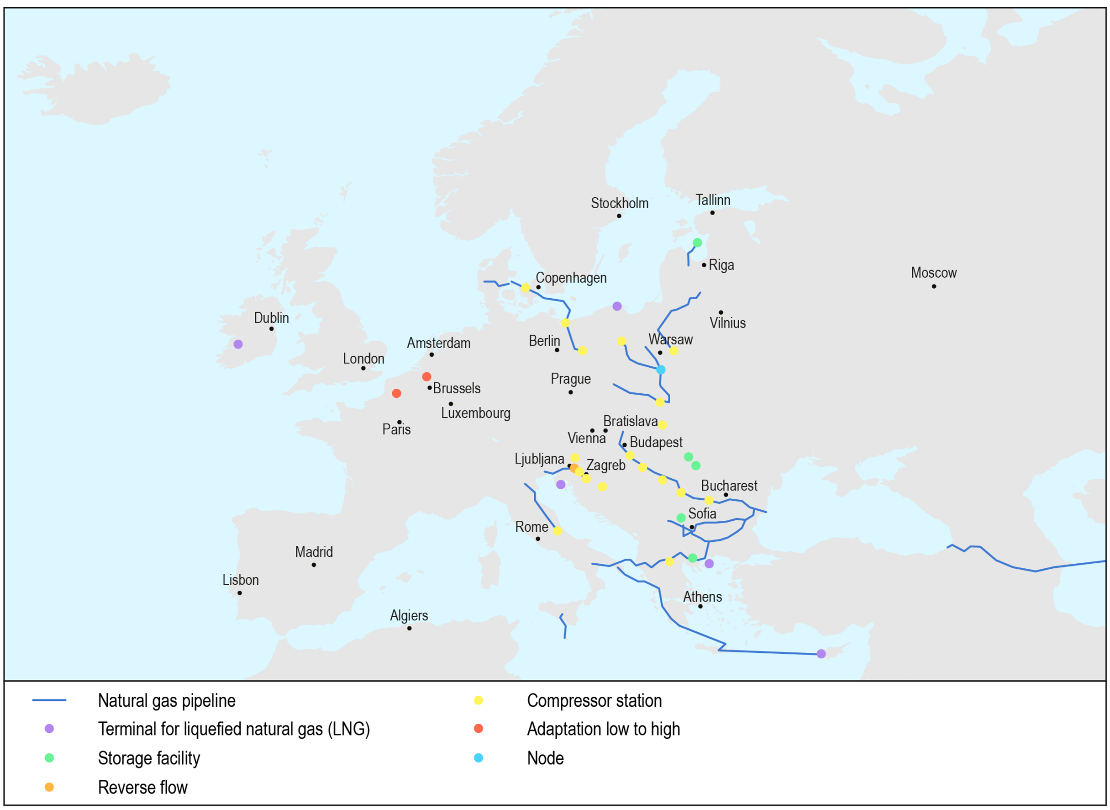
- North-south gas interconnections in Western Europe (NSI West Gas): infrastructure for north-south gas flows in Western Europe to further diversify routes of supply and for increasing short-term gas deliverability.
- North-south gas interconnections in central eastern and South Eastern Europe (NSI East Gas): gas infrastructure for regional connections between and within the Baltic Sea region, Adriatic and Aegean Seas, eastern Mediterranean Sea and Black Sea, and for enhancing diversification and security of gas supply.

- Southern Gas Corridor (SGC): infrastructure for the transmission of gas from the Caspian Basin, Central Asia, Middle East and eastern Mediterranean Basin to the EU to enhance diversification of gas supply
- Baltic Energy Market Interconnection Plan in gas (BEMIP Gas): gas infrastructure to end the isolation of the three Baltic States and Finland and their dependency on a single supplier, to reinforce internal grid infrastructures, and to increase diversification and security of supplies in the Baltic Sea region.

To support the gas infrastructure development, PCI implementation and gas market reforms, high-level regional groups have been established covering some of the corridors.

Together, the European gas system operators carry out a non-binding EU-wide gas transmission network and gas infrastructure planning through the biannual gas Ten-Year Network Development Plan (TYNDP), in line with EU Regulation 715/2009. The TYNDPs are developed by the European Network of Transmission System Operators for Gas (ENTSOG). ACER monitors the TYNDPs and issues a formal opinion on a TYNDP before it is finalised. Projects in the TYNDP may become PCIs under Regulation 347/2013, based on a cost-benefit analysis methodology performed by ENTSOG and approved by the European Commission.

Figure 11.10 PCI projects for natural gas – ongoing



This map is without prejudice to the status of or sovereignty over any territory, to the destination of international frontiers and boundaries and to the name of any territory, city or area.

Source: EC (2019), DG Energy: PCI interactive map, https://ec.europa.eu/energy/infrastructure/transparency_platform/map-viewer/main.html.

The EU CEF has provided financial support to many PCIs, notably reverse-flow projects and interconnectors. The latest 2019 list of 151 PCIs includes 32 gas projects, which may benefit from accelerated and streamlined permitting and regulatory conditions, as well as the right to apply for funding from the CEF. EU funding under the CEF provides financial support to energy projects (including electricity, gas and CO_2) with a budget of up to EUR 5.85 billion for the period from 2014 to 2020. In the draft EU budget 2021-27, the European Commission has proposed to renew the CEF, allocating EUR 8.7 billion for energy. Other EU funds have also supported natural gas infrastructure.

There has been good progress in the development of gas infrastructure across the EU, though in Central Eastern and South East Europe it has been slower than expected. The critical Bulgaria-Romania interconnector has been completed and many other projects are expected to become operational in 2020-21, including the TAP, the GIPL, the Poland-Slovakia interconnector, the Croatian LNG terminal at Krk, the Romania-Hungary reverse flow, and the Bulgaria-Greece gas interconnector (Figure 11.9).

The EIB approved a EUR 1.73 billion loan for TAP and a EUR 1.08 billion loan for TANAP, the largest set of loans contracted for a single project in the EU's bank history. The European Bank for Reconstruction and Development also provided a loan to the SGC with a total of EUR 1.7 billion. In October 2019, the EIB adopted its new lending policy, which rules out financing of fossil fuel infrastructure projects. This means that new natural gas projects will not be supported anymore after the end of 2021, while infrastructure for low-carbon gases will remain eligible.

Internal market rules for third countries

In 2019, the EU Gas Directive was amended (Directive (EU) 2019/692). EU gas market rules (including ownership unbundling, third-party access, non-discriminatory tariffs and transparency requirements) are now also applicable to natural gas pipelines connecting EU member states to a third country – up to the border of the member state's territory and territorial sea. The new regulatory framework is applicable retrospectively. But exemptions can be granted to natural gas pipelines that started commercial operations prior to the entry into force of the amended Gas Directive. Moreover, the EU requires transparency of intergovernmental agreements between member states and third countries in the field of energy (gas and oil)[45] that are subject to a mandatory ex-ante assessment by the Commission regarding their compatibility with EU law.

Wholesale gas markets

Since the EU Gas Regulation (715/2009), the EU gas market has transitioned from the previous point-to-point model to entry-exit regimes. An entry-exit model allows gas traders to book capacity rights independently from specific entry and exit points, and this model enables flexibility for network users, system transparency and cost-reflective network tariffs. Users do not need to book capacity along a specific route, and it is up to the TSO

[45] Decision (EU) 2017/684 of the European Parliament and of the Council of 5 April 2017 on establishing an information exchange mechanism with regard to intergovernmental agreements and non-binding instruments between member states and third countries in the field of energy, and repealing Decision No 994/2012/EU. Electricity is not covered under the ex-ante screening but could be in the future.

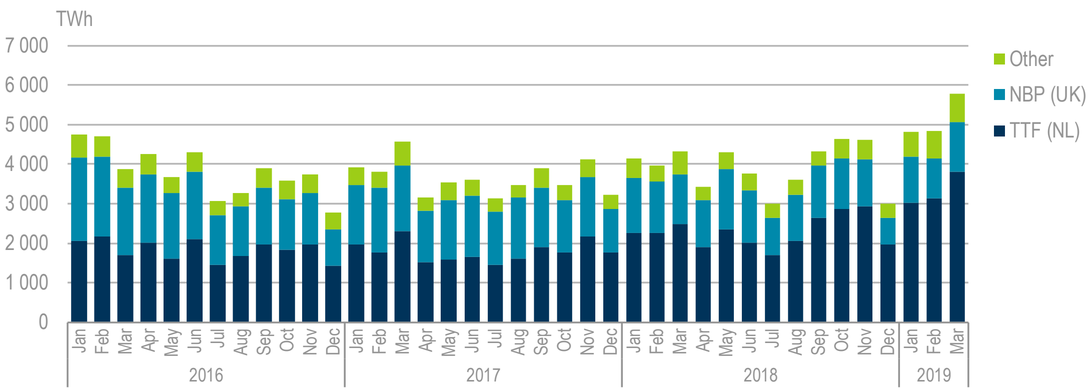
to balance the nominations on exit/entry capacity within their gas system, optimising the balance of flows within the network.

Two major gas hubs exist in Europe: the NBP in the United Kingdom and the TTF in the Netherlands. The Balgzand-Bacton Line (BBL) connecting the United Kingdom and the Netherlands is now bidirectional and will support liquidity between the NBP and TTF in the coming years, alongside the Interconnector (United Kingdom, Bacton to Belgium, Zeebrugge). This is the case during the summer when excess capacity in the United Kingdom can be channelled to Dutch or German gas storage and make up for reduced swing capacity from declining Dutch gas production in the winter to meet peak demand.

Market mergers are a bottom-up initiative with the objective to increase competition and liquidity by pooling supply and demand, changing the cross-border points and harmonising the market rules. Some countries have merged their domestic balancing zones; for instance, Germany has now two market areas (down from 19 in 2006), Gaspool and NetConnect Germany (NCG), which leads to different smaller virtual trading points and different gas price indexes. Germany decided to merge the two areas into one on 1 October 2021. A new single market, the Trading Region France (TRF) was created in November 2018 to replace two zones in France. In Eastern Europe, the creation of trading points has been slow to date compared with Western Europe. The Belgium and Luxembourg gas markets have been merged in the BeLux market area operated by the joint balancing operator Balansys. Other cross-border market mergers are being implemented in the Baltic countries and Finland, or are under consideration and further analysis for the Iberian market (Spain and Portugal) and the Austrian and Italian market. A cross-border balancing zone was established in April 2019 between Denmark and Sweden.

EU gas hubs have increased their liquidity in the past decade, supporting gas market integration with new products, including for trade across borders and with global LNG. The European gas trading platform PEGAS launched an LNG futures contract as European utilities are increasingly relying on global LNG imports to meet local demand and need to hedge their risk-to-price volatility in global LNG markets. The EU gas hubs are increasingly offering forward capacity products, leading to more depth of the market.

Figure 11.11 Traded gas volumes on the main European hubs, 2016-Q1 2019



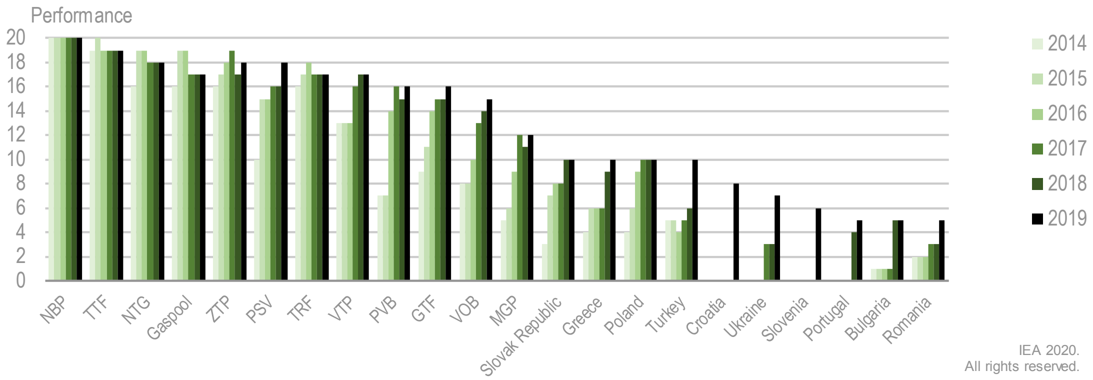
Notes: *Other* includes the following trading hubs: NCG and Gaspool for Germany, TRF in France, Punto do Scambio Virtuale in Italy, Zeebrugge beach in Belgium. 1 bcm is equivalent to 10.580 TWh.

Source: EC (2019a), "Quarterly report on European gas markets".

The liquidity of the main European gas hubs and traded volumes increased in 2019: total traded volumes amounted to around 15 619 TWh (equivalent to around 1 476 bcm), dominated by gas trading in North West Europe. The share of the Dutch TTF hub in the total EU trade rose to 64%, which was almost three times the traded volume of the NBP hub in the United Kingdom. A significant increase in the TTF hub trading volumes reinforced the leading role of the TTF in Europe, taking over from NBP since 2016 (Figure 11.11). The TTF benefits from its good connection to various supply sources. Low gas spot prices, availability of LNG and high levels of storage have also contributed to high trading volumes on the European market.

The European Federation of Energy Traders compares the performance of EU gas hubs through a benchmarking exercise, examining the structure of the hubs according to their entry-exit model and the strength of the price marker, among others. The 2019 study rated the NBP among the most developed hubs in Europe, followed by TTF, NGC, Gaspool and Zeebrugge (Figure 11.12, Figure 11.13).

Figure 11.12 Performance of European gas hubs, 2016-Q1 2019



Notes: NCG = Net Connect Germany; Gaspool, Germany; ZTP = Zeeburgge Trading Point, Belgium; PSV = Punto di Scambio Virtuale, Italy; TRF = Trading Region France; VTP = Virtual trading point, Austria; PVB = Punto Virtual de Balance, Spain; GTF = Gas Transfer Facility, Denmark; VOB = Czech virtual trading point; MGP = Hungarian virtual trading point.

Source: EFET (2019), EFET Gas Hub Development Study, https://efet.org/energy-markets/gas-market/european-gas-hub-study/.

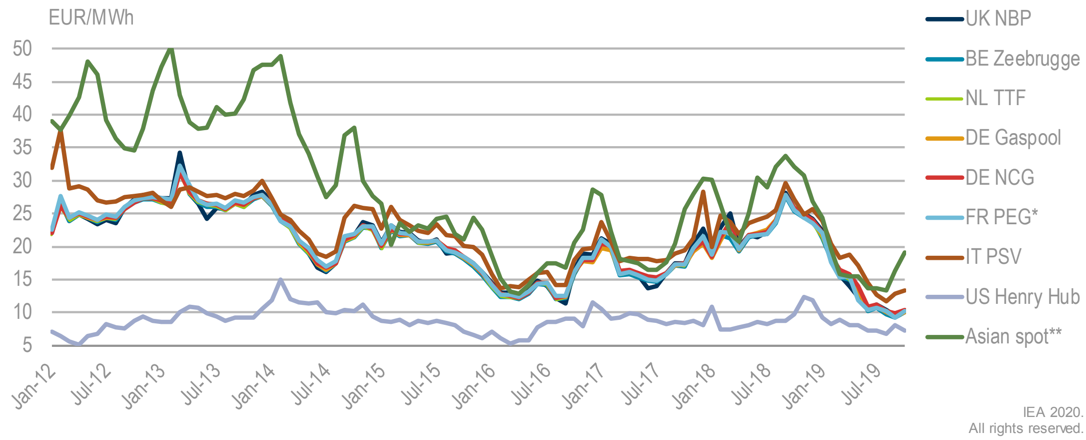
Wholesale gas prices

Unbundling of transmission from supply activities has in many markets supported more liquid gas trading, capacity allocation and price convergence. The convergence of gas supply sourcing costs is stabilising across the EU. European gas hub prices have strongly converged over the past years, a process that has been enabled thanks to greater market integration. Spot prices continued their decrease in 2019, mainly impacted by the mild weather and abundant LNG supply.

Given that more and more gas is imported, the terms of trade are increasingly important. EU gas markets are moving away from oil-indexed pricing, as key importers demanded less rigid pricing mechanisms and key exporters have increasingly linked their pricing to the EU gas hubs and sell more of their gas on the spot market/auctions. Also, competition inquiries by the European authorities put pressure on removing destination clauses and adhere to third-party access rules.

ENERGY SECURITY

Figure 11.13 Evolution of EU and international gas spot prices, 2011-19



*Prior to 1 November 2018 refers to PEG Nord prices.

** Refers to month-ahead prices.

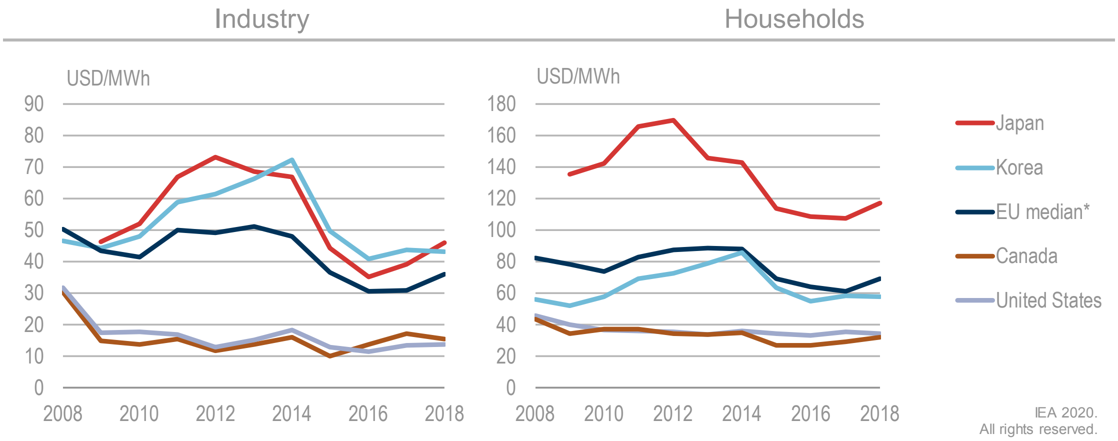
Note: MWh = megawatt-hours.

Source: IEA based on ICIS [other info] (Asian spot) and Bloomberg Finance LP [other info] (NBP etc...) ICIS LNG Edge, www.icis.com/energy/liquefied-natural-gas/lng-edge; NBP, Zeebrugge, TTF, Gaspool, NCG, PEG, PSV, Henry Hub: Bloomberg Finance LP (2019).

Natural gas retail markets – prices and competition

During 2014-18, EU retail gas prices declined, in step with the global decrease in wholesale gas prices. However, since 2018, household gas and industry prices started to increase again (ACER/CEER, 2018). By international comparison, the median EU natural gas price is typically lower than in LNG-dependent Japan and Korea, but higher than in Canada and the United States, which have access to cheap shale gas (Figure 11.14).

Figure 11.14 Natural gas prices for households and industry in EU member countries and selected IEA member countries, 2008-18



The median EU natural gas price is typically lower than in Japan and Korea but higher than in the Canada and United States.

*Median among EU countries with data availability.

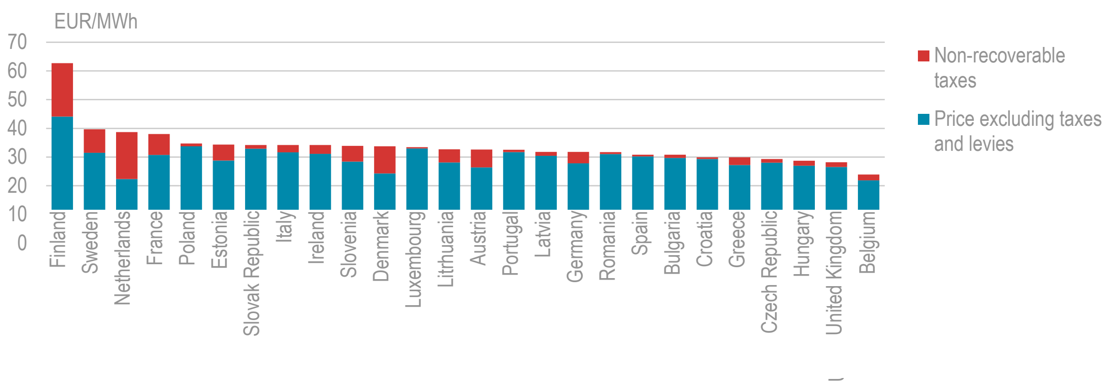
Source: IEA (2019g) *World Energy Prices 2019,* www.iea.org/statistics.

Natural gas prices for industry in EU member states were between around EUR 24/MWh and EUR 63/MWh in the first half of 2019 (Figure 11.15). Finland had the highest price among the EU countries and the highest share of tax, accounting for 30% of the total price. Belgium had the lowest price at EUR 24/MWh, of which 8% was taxes. Except for those countries, most have prices in the range of EUR 30/MWh to EUR 40/MWh.

For households, price differences between countries were more pronounced (Figure 11.16). Sweden had the highest price among EU countries at just above EUR 120/MWh in 2018 due to the highest taxes and the second-highest network charges. Portugal, Denmark and the Netherlands were other high-price countries, with prices above EUR 80/MWh. Romania, Hungary and Croatia had the lowest household prices, below EUR 40/MWh. Retail gas prices for both household and industrial customers showed a significant increase in the first quarter of 2019 compared with the same period in 2018. Household prices increased by 17% and industry prices 14% in the EU on average (Eurostat, 2019b, 2019a), implying that recent decreases in wholesale gas prices did not yet filter in the retail prices. The increase in the final retail prices might also have been driven by non-market elements, such as network costs and taxes.

Several countries have very active household customers: France, Germany, Ireland, the Netherlands, Portugal, Spain and the United Kingdom had switching rates at or above 10% with very active consumers in 2017, the year of the latest available data collected by CEER (2018). A large number of countries maintain regulated gas prices for more than 50% of consumers (Bulgaria, Croatia, France, Greece, Hungary, Lithuania, Latvia, Poland, Romania, the Slovak Republic), while Denmark, France, Portugal, Spain and decreased the share of customers under price regulation during 2008-16. Ireland phased out the regulation completely (EC, 2019b). The member states that in 2016 intervened in gas prices for non-household customers were Bulgaria, Greece, Hungary, Latvia and Poland.

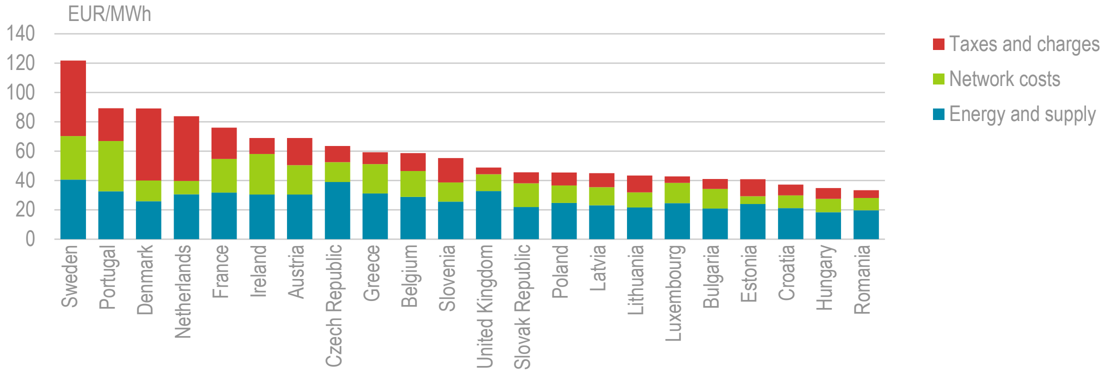
Figure 11.15 Natural gas prices for industry in EU member countries, 2019



Notes: Gas prices for non-household consumers in the consumption band 10 000 gigajoules (GJ) to 100 000 GJ.

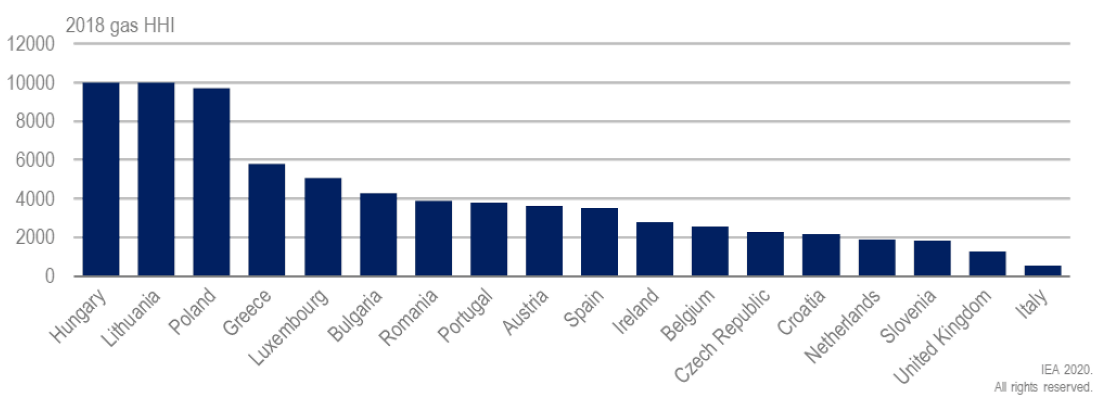
Source: Eurostat (2019a), Gas prices for non-household consumers – bi-annual data (from 2007 onwards), https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_203&lang=en.

Figure 11.16 Natural gas prices for households in EU member countries, 2018



Note: Missing data for countries not shown.
Source: Eurostat (2019b), Gas prices components for household consumers – annual data, https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_202_c&lang=en.

Figure 11.17 Concentration in natural gas retail markets, 2018



Source: CEER (2019), *Monitoring Report on the Performance of European Retail Markets in 2018*, CEER Report, https://www.ceer.eu/documents/104400/-/-/5c492f87-c88f-6c78-5852-43f1f13c89e4

Gas retail markets in the EU showed a rather high concentration in 2018, measured by the Herfindahl-Hirschman Index (HHI). According to the latest data by CEER, the HHI index was above 2 000 in 14 member states and above 5 000 in 4 countries in 2018 (Figure 11.16). Compared to electricity markets, gas markets have on average higher levels of competition. The low level of competition in some markets means that developments at the wholesale level, notably price decreases, have not been reflected necessarily in the EU retail prices.

In gas, there has been only one joint venture of TSOs across the border. In 2017, Fluxys Belgium and Creos established the joint venture Balansys for the management of the market-based balancing activities of the integrated Belux zone.

Future gas market reforms

As part of the European Green Deal, the European Commission pointed out the need for decarbonising the gas sector in the coming decades.

While gas market integration in the EU has increased, there are concerns that domestic and foreign gas suppliers still dominate the infrastructure ownership, as unbundling has been incomplete. The majority of gas TSOs are still part of a vertically integrated company and have not opted for ownership unbundling but functional unbundling. As the EU needs to ensure that different sources of gas (biomethane and hydrogen) have access to the gas infrastructure, greater enforcement of third-party access and of competition will be critical, notably in southern European and isolated gas markets, to ensure a level playing field for companies in a changing energy and gas market. Like the production of natural gas, the production of decarbonised, renewable or low-carbon sources of gas could be a competitive activity. The transportation of these new gases may require regulatory oversight (feed-in rules, third-party access rules) and tariffs to create a level playing field.

With the emergence of new technologies, notably energy storage, such as hydrogen, the monopoly of TSOs and distribution system operators (DSOs) on the identification of system needs may be problematic. Infrastructure planning should be carefully revisited to allow also for sector coupling and ensure TSO/DSO network planning and investment decision-making is not foreclosing investment by other new market players in the area of decarbonised gas production and transportation. The revision of the energy market rules may include the classification of decarbonised gases (life-cycle emissions, certification and review of the Gas Quality Directive). The Commission should create an enabling framework that allows the integration of low-carbon gases into the gas infrastructure, including hydrogen, in step with the evolving hydrogen market. The rules under the Sustainable Finance Taxonomy need to facilitate this, too.

The European Commission has announced it will review its policy for Trans-European Networks. The future network policy may need to ensure the identification and support of projects of common interest based on criteria adapted to new sources of gas. ACER/CEER ran a consultation during autumn 2019 and concluded on the future EU gas framework (ACER/CEER, 2019).

As the EU aims to align to a net-zero emissions pathway to 2050, the contribution from methane reductions is considered to be critical. The IEA methane tracker estimates that the global oil and gas sector methane abatement potential can be on the order of 75% (IEA, 2019f). The EU's domestic methane emissions from oil/gas sector account for only 3% of the global total, but the methane emissions footprint of gas imports is not accounted for. Within the EU, the main fugitive methane emissions stem from downstream gas activities and onshore conventional gas (IEA, 2019d; EDF, 2019). The Oil and Gas Climate Initiative and the Methane Guiding Principles provide for some global industry standards.

Security of gas supply

This section examines the legal framework for gas security in the EU and assesses the lessons learned from recent EU gas supply disruptions.

EU framework for gas security and emergency response

EU gas security has been strengthened in the aftermaths of the 2006 and 2009 disruptions of Russian gas supplies to the EU through Ukraine.

The emergency preparedness is strong in the EU, based on the EU gas security of supply regulation and its response mechanisms (Regulation (EU) 2017/1938 concerning measures to safeguard the security of gas supply and repealing Regulation (EU) 994/2010).

At the EU level, ENTSOG carries out a summer and winter outlook to assess the gas supply adequacy. The EU Gas Coordination Group (GCG) in which member states and companies are represented, has become the trusted group to discuss EU-wide gas supply disruptions (Ukraine, Russia, Algeria and LNG) and national gas crises that can affect neighbouring member countries. The GCG meets regularly also to review and discuss the risk assessments, notably the regional aspects of them. The EU has not had a major gas supply disruption in the past years. Some smaller technical incidents have “stress tested” the gas infrastructure in the EU, as explained in the section below.

In 2017, the EU revised the EU security of gas supply regulation. The 2009 regulation built on the robustness of both the gas infrastructure and gas supply to protected customers, and reinforced the national preparedness with regard to disruptions of gas supply based on the robustness of the gas infrastructure (N-1 standard), the gas supply standard (covering the gas supply to protected consumers for a certain number of days), and national preventive action plans and emergency plans.

The revised regulation allows member states to evaluate and address regional or common risks and increase regional resilience, and acknowledges the close interactions of the gas markets and systems in Europe. EU Regulation 2017/1938 expanded the risk assessment to a more regional dimension, through the creation of regional risk groups and EU-wide simulation of gas supply disruption scenarios. ENTSOG has been tasked to perform an EU-wide gas supply and infrastructure disruption simulation in order to provide a high-level overview of the major supply risks for the EU. The national preventive action plans and the emergency plans shall contain a regional chapter, or several regional chapters in cases a member state is a member of different risk groups, with agreed joint preventive and emergency measures. The Commission has also provided guidance on the technical, legal and financial elements for such bilateral solidarity arrangements (Recommendation (EU) 2018/177).

The regulation also includes precise rules for safeguarding the solidarity among EU member states (Article 13). EU countries must help one another to always guarantee gas supply to the most vulnerable consumers even in severe gas crisis situations. The regulation also fosters access to LNG and the stringent use of reverse flows on all interconnections and makes a more explicit link with the electricity sector (as a demand-side response), something that was missing from the previous regulation.

Recent gas supply crises

During recent winters, several episodes of cold spells combined with unplanned supply reductions occurred in Europe. These impacted several member states that used the crisis management measures as implemented by the 2017 security of gas supply regulation. These events showed the strong resilience of the integrated European gas system, highlighting the importance of implementing co-ordination policies and the role of network co-operation and integration. At the same time, most supply incidents have also pointed to the increasing interlinkages between gas and electricity security.

Technical incidents during winter 2017

Following an explosion and fire, Austria's Baumgarten facility suspended operations on 12 December 2017, and gas flows through the Trans Austria Gas (TAG) pipeline – connecting Baumgarten to Italy – stopped entirely for several hours (IEA, 2018a). Parts of northern Italy were on red alert after a weekend of freezing rain and snow. As the TAG pipeline flows represented almost half of Italian imports in 2017, Italy declared emergency level, which is the highest level after early warning and alert under the EU regulation, to ensure supply to priority users such as residential customers, and enable it to use different extraordinary measures such as allowing coal and oil power plants to operate at maximum capacity. The reactivity of gas storage in Italy and Austria was key to maintaining the supply of gas volumes required by the market. Withdrawals from storage sites doubled almost immediately after the accident. Operation at the Baumgarten hub was restored, and flows to Italy, Germany and Hungary almost returned to normal on the same day. Italy lifted its emergency on 15 December.

Cold wave in February/March 2018

In March 2018, the United Kingdom and Ireland suffered a cold wave named the "Beast from the East", responsible for unseasonably low temperatures and heavy snowfall. According to National Grid, 1 March was the seventh-coldest day in its 58-year weather record history and triggered the highest gas demand in seven years. Demand from the distribution network (serving primarily households and commercial entities) rose the most significantly. Meeting rapidly climbing gas demand was challenged by the fact that the severe weather conditions caused outages on key regional gas supply infrastructures: 1) Norway's Kollsnes gas processing plant shut in due to process problems caused by cold weather; 2) weather conditions and outages in the North Sea resulted in a decrease of gas flows to the St Fergus terminal (receiving both domestic offshore production as well as Norwegian imports), reducing the availability of gas in the United Kingdom; and 3) the South Hook terminal had an unplanned outage on 1 March. National Grid issued a gas deficit warning. As a result of the tight market situation, gas prices in the United Kingdom soared on 1 March to a 20-year high to GBP 127/MWh. The market reacted by optimising both the demand and supply sides.

Interlinkages of the gas and electricity systems

During the "Beast from the East", significant wind and coal-fired generation was able to support high heating and power demand. This favourable outcome in 2018 may not be replicated in the future. If a cold snap were to happen on a day with less wind, planned coal and nuclear closures could diminish the support from the power system to overcome a gas supply event. The question arises as to the level of gas price and power system flexibility (interconnections and batteries) that will be needed to balance both systems. With low wind levels, gas prices would need to rise higher to attract them for additional power generation. However, very high gas prices create an incentive for gas users, which includes power generators, to offer gas on the intraday commodity market, rather than generating electricity, which could further exacerbate a power system crunch; electricity prices would need to soar to counter such behaviour. As natural gas accounts for around

40% of the power generation in the Netherlands and the United Kingdom, the closer co-ordination of emergency measures, notably demand response across the sectors, is required.

Assessment

Natural gas has maintained a strong position in the EU energy mix since the last IEA in-depth review (IDR) in 2014, and the EU remains the largest natural gas importer in the world. Natural gas will remain important for the provision of power and heat to both buildings and industrial processes (accounting for 20% of electricity and 37% of heat). Use of gas has increased in the recent past, in particular in power generation, where recent low gas prices and higher carbon prices have made gas competitive against coal in power. Substitution of coal with gas has rendered large and rapid reductions in CO_2 emissions.

Indigenous gas production has continued to decline faster than expected. This seems to be an irreversible trend, due to lack of gas resources and different regulatory and political factors in member states as well as lack of public acceptance of shale gas fracking in many EU countries. With faster-than-expected production cutbacks at the Groningen gas field and its planned phase-out by 2022, the market has lost a source of flexible local supply. Groningen serviced only L-gas consumers, which have a small regional market outside the Netherlands. Required supply flexibility now primarily comes from contract flexibility of Russian and Norwegian swing production, LNG and storage.

Securing access to the EU's ample gas storage and LNG capacity across the internal gas market was a key element of IEA recommendations under the EU IDR 2014. The 2016 EU strategy for LNG and gas storage aimed to pave the way for the EU to tap into the emerging global LNG market. Much progress has happened in removing regulatory barriers and addressing infrastructure bottlenecks However, with increasing LNG coming to Europe, the transparency and access regime in Europe's LNG terminals will become more important than in the past to ensure a maximum level of flexibility and capacity available to the market.

The import of gas has grown steadily, in particular piped gas from Russia and LNG from various sources: in 2018, Qatar accounting for 29%, Russia 18%, Algeria 14%, Nigeria 13% and United States 12%. In 2019, LNG imports to the EU reached around 100 bcm. With large regasification capacity and a flexible gas market, the EU is in a favourable position to attract growing supplies of LNG from the world market. Spain is the largest importer, followed by France and the United Kingdom. The increased inflow of LNG has strengthened competition among suppliers in the market and is the primary cause for removal of oil indexation in long-term contracts and the decline in wholesale prices seen in 2018-19 to the lowest levels in more than ten years. However, still 40% of the EU LNG regasification capacity cannot be accessed by countries in central and South West Europe (IEA, 2018b). There is a strong competition between LNG and pipeline gas in North West and South West Europe. For Europe to gain greater access to global LNG supplies, and thus encourage competition and diversification, it is essential that LNG supplies can reach all regions across the EU.

Although gas import dependency has increased, gas supply security has been strengthened in the past years. In 2017 the EU revised the regulation of security of gas supply, with provisions on solidarity, enhanced regional co-operation and reverse flow on many pipelines. EU countries now need to implement the rules and agree on regional or cross-border actions for prevention and emergency response in order to address risks of which the impact goes beyond their borders. They also need to help one another out in situations where the supply to households is in jeopardy by offering gas volumes to such customers even if those are outside of their own borders (solidarity mechanism). Further build-out of infrastructure has increased source and route diversification for a number of countries. Disruptions to gas supplies during the 2017/18 winter in North West Europe proved the strong resilience and overall high level of security of supply of the gas system. It also showed how gas and electricity systems are increasingly interlinked and therefore impacts are felt across the systems, requiring a closer co-ordination of gas and electricity security. Electricity and gas systems are increasingly interdependent, and this is going to increase in the future with sector coupling, the use of hydrogen and higher flexibility needs. Security of supply is going to be increasingly defined in both markets and infrastructures. Amid changing gas flows and infrastructure use in the EU core gas markets, the EU should monitor and discuss gas and electricity supply security in a more integrated way.

Rising gas imports and the increasing role of natural gas in the EU energy mix (amid coal phase-outs and nuclear retirements) will mean that gas security will remain a very important topic for the EU. There is an increasingly important link between gas and electricity supply security, which should be addressed by the European Commission in the forthcoming EU Gas Framework. Despite global LNG markets becoming more liquid and flexible and the EU's ample spare capacity to import LNG, actual LNG supplies are not always as flexible and additional cargoes take several days to arrive, while gas storage or gas pipeline supplies are usually more readily available. The future of Norwegian, Algerian and Russian supplies are therefore important.

Ukraine accounted for over 40% of Gazprom's exports into Europe in 2018: Gazprom exported 177 bcm of gas into the EU in 2018 and Ukraine transited 83.83 bcm (out of that, 10.8 bcm was transited to Turkey, plus some 3 bcm to the Balkans, so the EU imported 70 bcm). The Gazprom-Naftogaz contract for gas transiting Ukraine expired at the end of 2019 and was replaced by a new contract signed on 20 December 2019 with a minimum ship-or-pay of 65 bcm in 2020, and 40 bcm per year for the next four years, extendable by an additional ten-year period. Both parties also agreed on the settlement of the Stockholm arbitration procedure and the withdrawal of new pending legal claims. The unbundling of the Ukraine's TSO was completed with the final certification on 26 December 2019.

Natural gas from Russia to the EU now flows through three diverse routes – Ukraine, Turkey and Germany. The settlement of a post-2019 regime for the Ukrainian gas transit route was necessary, as Nord Stream 2 is not fully operational at the expiration of this contract and is expected to run full capacity only at the end of 2020. Russia needed to continue the transport of Russian gas after 2019/20 to serve markets also in South East Europe, as Turk Stream (string one) can only provide some gas to South East European customers at the Turkish landing point with Bulgaria. The expected increase in EU gas import needs in the coming years and the lack of interconnections and LNG terminals in Central and South East Europe mean that Ukraine transit remains important also in the medium term.

Well-functioning, effective gas markets are essential for energy security as well as for achieving decarbonisation targets. The EU gas markets have been moving in the right direction over the past years. New infrastructure has strengthened interconnectivity and market integration. Price convergence between hubs has improved and liquidity has increased. However, the performance of the hubs is uneven, with only North West European markets to have reached a desired level of maturity. A remaining challenge is the full implementation of the adopted network codes and the guidelines. At the retail level, prices are still regulated in a number of member states, which distorts competition in the market, and they should be phased out.

In the medium term, natural gas is going to remain an important source of flexibility for power generation in the EU, notably in an ambitious climate scenario, as most of the coal and nuclear capacity will retire in the coming decade and the share of variable renewables is going to rise fast. With much lower running hours than peaking plants, the impact from CO_2 emissions from coal- and gas-fired plants will be limited, assuming the economics are supported through price signals in the electricity markets.

Looking ahead, continued use of natural gas and the gas infrastructure is a valuable asset for a cost-effective energy transition to a low-carbon system. The phase-out of coal and much higher volumes of variable renewable sources call for a larger role for flexible energy sources such as natural gas. In difficult-to-decarbonise end uses, such as medium- and high-temperature heating and industrial processes, natural and other low-carbon gases will likely be needed. The announced decarbonisation ambitions under the European Green Deal and the new EIB lending policy send a signal to investors that natural gas has a limited transition role in the EU, unless it can support the integration of other low-carbon gases. The EU has to review its funding instruments, under the CEF and PCI policy in natural gas. The criteria for funding and policy support should balance sustainability, security and affordability/competitiveness goals. Public support for natural gas projects has already declined, and if commercial funds are not directed to natural gas investment, it will be necessary for the EU to review the energy infrastructure policy for the period after 2025.

The EU gas infrastructure can transport large volumes of gas over long distances at a low cost and provide seasonal storage capacities, a key flexibility need for the decarbonisation. Blended with other gases such as hydrogen, sustained use of gas networks can avert substantial investments in developing electricity networks. The EU needs to ensure that new rules for the gas market are set for the multiple uses of the gas network, for different sources of gas and its use in various end-use sectors by studying the costs, feasibility and options for regulatory measures.

Leakages and release of methane along the gas value chain increases the carbon footprint of the natural gas sector. The concentration of methane in the atmosphere is currently around two and half times greater than pre-industrial levels and increasing steadily. As a large consumer and importer of gas, the EU should be involved in activities that aim to limit methane emissions, including at international level by industry and environmental coalitions. IEA analysis has highlighted that global methane emissions from the oil and gas sectors could be reduced by nearly half at no net cost.

Recommendations

The European Union should:

- Promote the completion of the internal gas market, including by enforcing rules across the EU, finalising the remaining network codes, and fostering access to gas infrastructure and investment in infrastructure links across East and South East Europe. Ensure competition at gas retail level by phasing out price regulation.
- Clarify the role that natural gas infrastructure can play in the energy transition in the medium term, notably as a source of flexibility in power generation and as an enabler to accommodate higher amounts of decarbonised and renewable gases.
- Recognise the strategic value of the gas infrastructure, and promote its development to accommodate higher amounts of decarbonised and renewable gases. Prepare EU rules for the increased uptake of decarbonised and renewable gases.
- Ensure a best practice performance of the European gas infrastructure from a methane leakage point of view by putting in place a European measurement and monitoring system to limit emissions.

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12. Oil

Key data

(2017/18)

Crude oil production (2018): 71.6 Mt/73.6 Mtoe, -39% since 2007

Crude oil net imports: 548.2 Mt/555.7 Mtoe, -4% since 2007

Oil product production (refinery gross output): 640.7 Mt/651.9 Mtoe, -9% since 2007

Oil product net exports: 12.7 Mt/12.2 Mtoe (compared with 11.8 Mt net imports in 2007)

Share of oil (2017): 32.8% of TPES and 41.5% of TFC

Consumption by sector (share of TPES): 531 Mtoe (transport 57.4%, industry 25.1%, other energy 12%, commercial 3.8%, heat and power generation 1.4%, residential 0.2%)

Overview

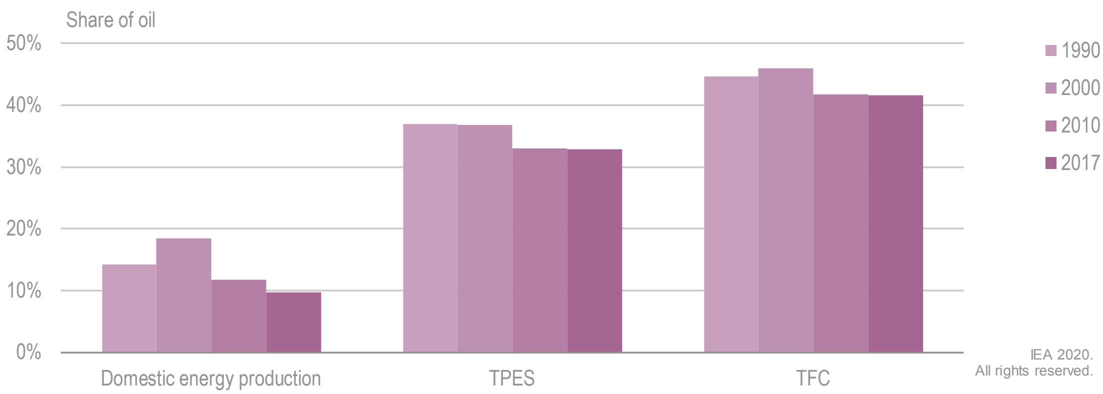
Oil is the largest energy source in the European Union (EU), accounting for 33% of total primary energy supply (TPES) and 42% of total final consumption (TFC) in 2017. Oil consumption in the European Union has been rather robust, declining by only 0.1 million barrels per day (mb/d) per year since 2000. Also, the share of oil in TPES and TFC declined only slightly (Figure 12.1). Transport oil demand, mainly for road transport, accounts for over half of oil in TPES. Crude oil production has fallen significantly in EU countries in the last two decades, and the EU depends on crude oil imports (mainly arriving by tanker) and is therefore exposed to the global oil market while it accounts for only 11.5% of global oil demand.

The EU is the largest diesel importer in the world. However, the dominance of diesel as road transport fuel in EU markets, compared with higher shares of gasoline in the People's Republic of China (hereafter, "China") or the United States (US), is set to change in the coming years as the transport sector and diesel consumption will be subject to stricter environmental standards and higher taxes.

Global oil markets entered a turmoil in 2020, with the double shock on supply and demand amid Covid-19 lockdowns. The EU oil market has witnessed a few unexpected trends. North Sea oil production had seen a revival with the United Kingdom (UK) stabilising recovery rates and Norway, the second-largest supplier to the EU, seeing an increase in oil production in the past years. However, in March 2020, Norway announced production cuts of 13%, and the North Sea is heading for a decline in investment.

The EU saw major refinery closures during 2008-14, as oil demand was shifting to Asia. Global oil product market changes had varied impacts in recent years, while the EU continued to export large amounts of gasoline. Despite Asia's large refinery capacity, EU exports were able to find markets in the United States (filling the gap left by lower US imports from Mexico and Venezuela) and Africa. With the global oil crisis in 2020, the EU refinery outlook becomes much more challenging.

Figure 12.1 Share of oil in EU's energy system, 1990-2017



Oil is the largest energy source in the EU, with stable shares of 33% of TPES and 42% of TFC in 2017, while the share of oil in total energy production is declining.

Source: IEA (2019a), *World Energy Balances, 2019*, www.iea.org/statistics/.

Supply and demand

Oil supply is split between crude oil, of which most is imported to the EU, and refined oil products, of which the EU is a net exporter. In 2017, total oil supply was 531 Mtoe in TPES plus an additional 95 Mtoe used in international marine and aviation bunkers. Around 74 Mtoe of the oil, equal to 14% of oil in TPES, was produced within the EU.

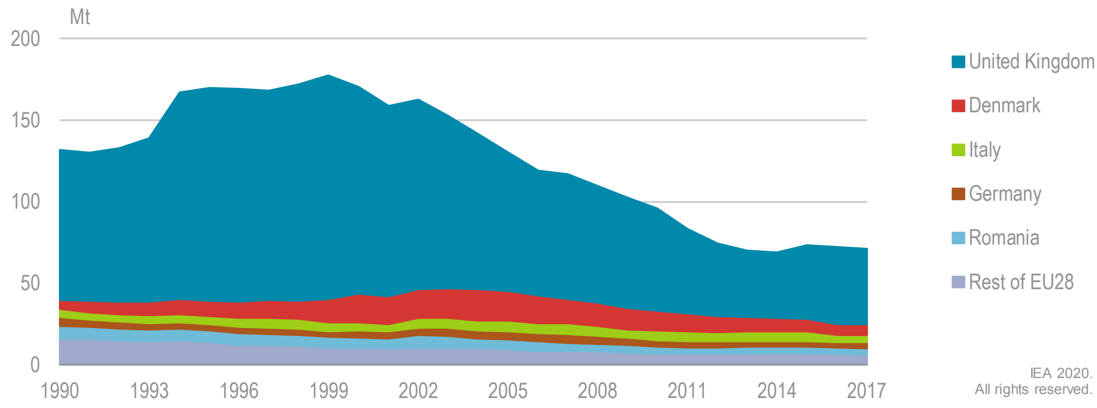
Crude oil production

Crude oil production has fallen significantly in the EU in the last two decades. Production peaked in 1999 at 178 Mt, and has since dropped to around 70 Mt per year in the last five years. In 2017, total production was 71.6 Mt, a 60% decline from the peak level.

The ten biggest producing companies in in the EU (Shell, Total, BP, Eni, Chrysaor, China National Offshore Oil Corporation [CNOOC], Apache, OMV, Suncor Energy and EnQuest) produced around 60% of the total crude oil production in the EU in 2018.

However, recently North Sea production saw robust growth in Norway, which is not a member of the EU but a large supplier to the European markets. Another producer in the North Sea, the United Kingdom (UK), was by far the largest crude oil producer in the EU (Figure 12.2), accounting for 65% of total production in 2017, followed by Denmark (9%), Italy (6%), Germany (5%) and Romania (5%). However, Danish and UK production have fallen rapidly over the last two decades, causing the overall drop in EU production. The United Kingdom's share of total EU production has declined from 77% at the peak in 1999 but recently saw a small growth, largely stabilising oil production. In the medium term out to 2025, the North Sea production will see a strong decline (Figure 12.3).

Figure 12.2 Crude oil production in the EU, 1990-2017

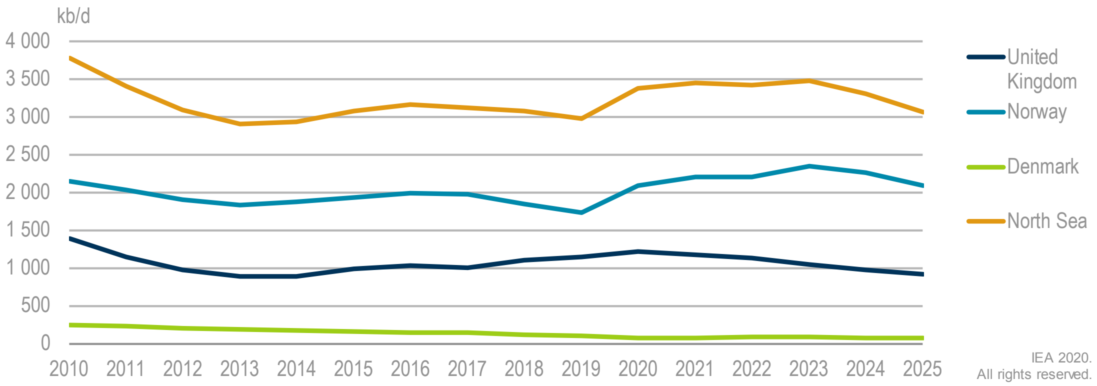


The United Kingdom was the largest crude oil producer with two-thirds of the EU total production, despite a significant decline over the last two decades.

Note: Mt = million tonnes.

Source: IEA (2019b), *Oil Information 2019*, www.iea.org/statistics/.

Figure 12.3. North Sea oil production outlook to 2025

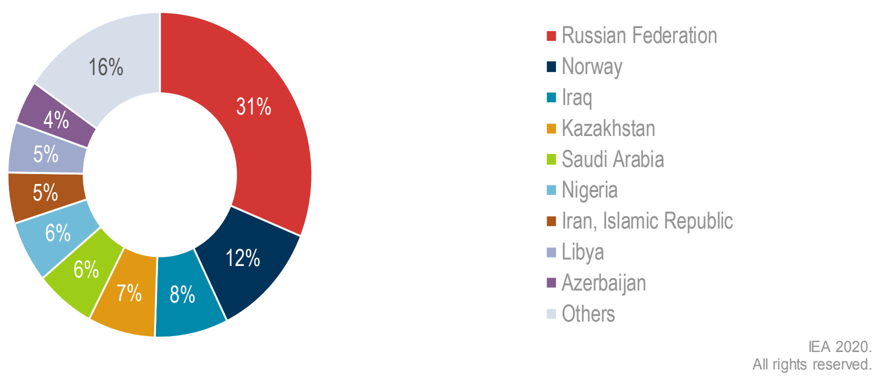


Note: kb/d = thousand barrels per day.

Source: IEA (2020), *Oil 2020*.

Crude oil imports have been more stable, varying between around 520 Mt and 620 Mt since 2000 (Eurostat, 2019a). In 2017, total crude imports were 566 Mt, of which over half came from the three largest suppliers: the Russian Federation (“Russia”) with 31% of total imports, Norway with 12% and Iraq with 8% (Figure 12.4). In 2018, crude oil imports from the United States started arriving to the EU.

Figure 12.4 Crude oil imports by source, 2017



Russia is the largest source of crude oil imports to the EU with nearly one-third of the total, followed by Norway and Iraq.

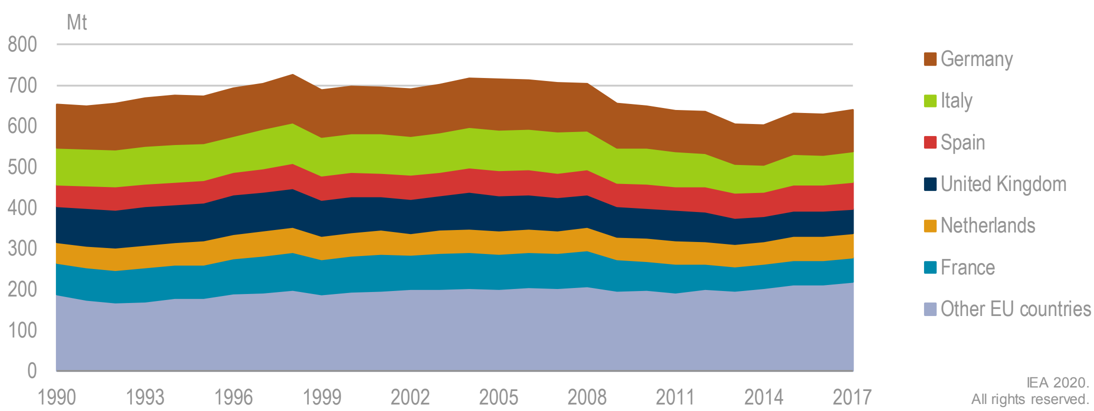
Note: Crude oil imports to the EU28 by country of origin.

Source: Eurostat (2019a), Oil and petroleum products – a statistical overview, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Oil_and_petroleum_products_-_a_statistical_overview&oldid=315177#Imports_of_crude_oil.

Oil products production and trade

The EU is a large producer of refined oil products, with refineries in 23 out of 28 member countries. In 2017, total gross output from EU refineries was 640.7 Mt, just above the ten-year average of 639 Mt. The EU is the world's largest diesel importer but a large gasoline exporter. The six largest producers of refined oil products in the EU account for around two-thirds of total production (Figure 12.5). Germany is the largest producer with 104 Mt in 2017, accounting for 16% of total EU production, followed by Italy (12%), Spain (10%), the United Kingdom (9%), the Netherlands (9%) and France (9%).

Figure 12.5 Oil product output by country in the EU, 1990-2017

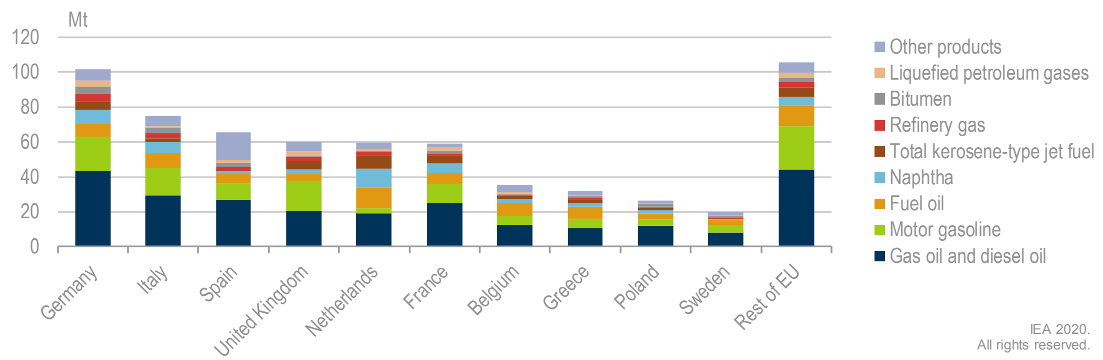


In contrast to crude oil production, refined oil products are produced in 23 out of 28 EU member states, and the six largest producers account for two-thirds of total production.

Source: IEA (2019b), *Oil Information 2019*, www.iea.org/statistics/.

Gasoil and diesel are the most common oil products from EU's refineries, reflecting the large share of diesel fuel in road transport. In 2017, gasoil/diesel accounted for 39% of total oil product output, with similar shares in most major producing countries (Figure 12.6). Motor gasoline is the second-largest oil product, accounting for 19% of total production in 2017, also used in road transport. The largest oil product used outside of road transport is fuel oil, mainly used in maritime shipping, with 12% of total production in 2017.

Figure 12.6 Oil product output by country, 2017

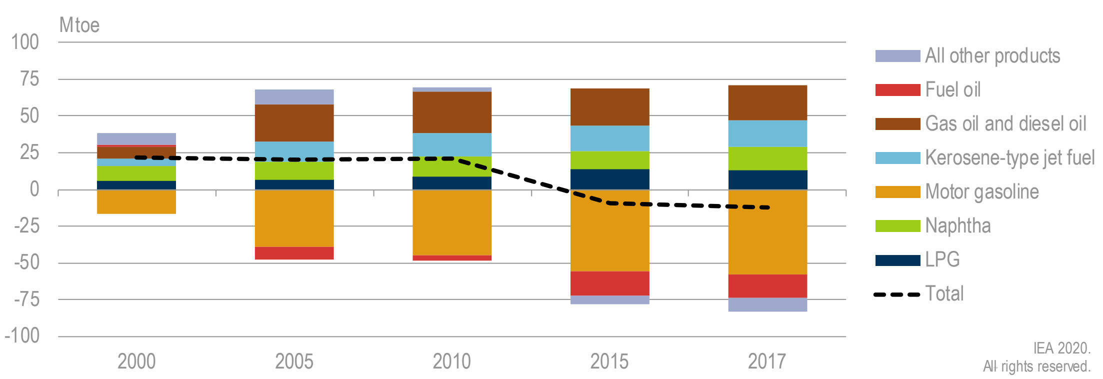


Diesel is the main oil product produced in the EU with around 40% of total production, followed by gasoline at around 20%, both used mainly in transport.

Note: Refinery gross output.

Source: IEA (2019b), *Oil Information 2019*, www.iea.org/statistics/.

Figure 12.7 Net imports of oil products by type, 2000-17



Gasoil/diesel accounted for the largest share of oil product imports, despite EU domestic production, while gasoline dominates exports.

Note: Mtoe – million tonnes of oil equivalent; LPG = liquefied petroleum gas.

Source: Eurostat (2019b), Net imports of selected petroleum products, EU-28, in selected years, 1990-2017, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Net_imports_of_selected_petroleum_products,_EU-28,_in_selected_years,_1990-2017.png.

Despite the large share of diesel production in EU refineries, diesel also accounts for the largest share of net imports. Motor gasoline, on the other hand, is the largest exported oil product (Figure 12.6). This is an indicator of the dominance of diesel as road transport fuel in European markets, compared with higher shares of gasoline in other markets. Total imports of oil products to EU countries were 351.6 Mt and total exports 364.3 Mt, making the EU as a whole a net exporter for the third consecutive year (Figure 12.7).

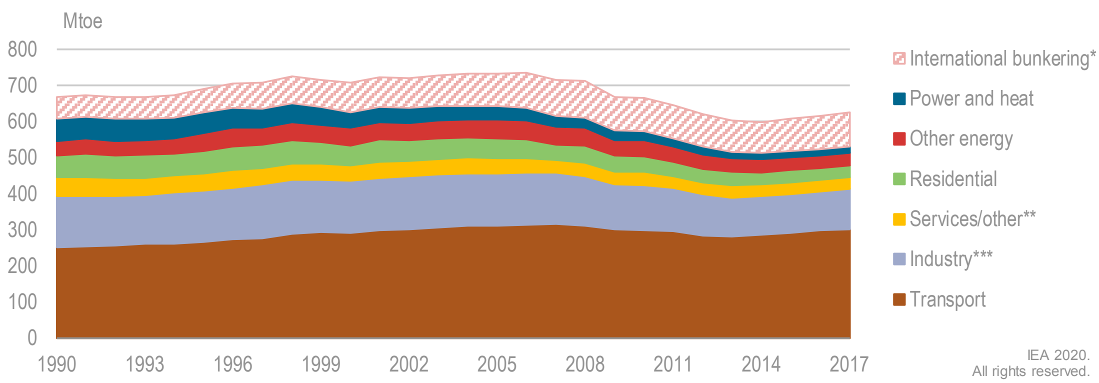
Oil consumption

The transport sector dominates oil consumption in EU countries (Figure 12.8). In 2017, total oil supply (in TPES) was 531 Mtoe, of which domestic transport accounted for 57%. This does not include bunker fuel for international shipping and aviation, which adds another 95 Mtoe to total oil demand. Road transport accounts for around 96% of total oil consumption in domestic transport, and the rest is used mainly in domestic shipping and aviation (this does not include transport between EU countries).

Industry accounted for 21% of total oil in TPES in 2017. Roughly 75% of this is used for non-energy purposes in mainly chemical industries and construction. The residential and services sectors (including agriculture) together account for 12% of total oil in TPES, used largely for heating in buildings. The remaining oil is consumed in energy transformation, in refineries and other energy sectors (7% of total oil in TPES), and for power and heat generation (3%).

Total oil consumption peaked in 2004 at 641 Mtoe, not including international bunkering. During the decade after the peak, oil consumption decreased across all sectors, with a total decline of 21% from 2004 to 2014. Consumption fell significantly in the energy sectors as well as in industry and in the residential and commercial sectors. The transport sector has fallen the least, and in the last three years, the trend has been reversed. From 2014 to 2017, transport oil consumption grew by 6%, leading to a total oil demand growth by 4%.

Figure 12.8 Oil demand by sector, 1990-2017



Oil demand declined by 21% between 2004 and 2014, but has since been increasing slowly, driven by a growth in the transport sector, which dominates total oil demand.

*Oil used as international bunker fuel was 95 Mtoe in 2017, equal to 18% of oil in TPES, but is not included in TPES.

***Services/other* includes commercial and public services, agriculture, forestry and fishing.

****Industry* includes non-energy consumption.

Notes: Oil in TPES by consuming sector plus international bunkering. The EU total is calculated as the sum of all member countries' consumption, i.e. transport includes only domestic transport within member states.

Source: IEA (2019a), *World Energy Balances, 2019*, www.iea.org/statistics/.

Medium- to long-term oil outlook

In 2018, the EU's oil demand was 11.1 mb/d, equivalent to around 11.4% of total global oil demand (96.9 mb/d) (Table 12.1). The EU's share in global oil demand is going to decline as global oil demand grows.

Oil consumption in the European Union has declined by 0.1 mb/d per year since 2000. The pace of decline accelerates in the projection period, with EU oil demand falling by 0.2 mb/d per year through to 2040. Most of this decline comes from passenger cars, as a result of strong efficiency improvements and rapid uptake of electric cars. Fuel economy for passenger cars is projected to reach 3.6 litres per 100 kilometres (L/100 km) by 2040, the lowest in the world, and 80 million electric cars are expected to be driving on the road in 2040 (25% of global electric car stock in that year). There is also a decrease in oil demand for buildings given stated policies to ban the installation of oil boilers in new houses and phase out existing equipment. Passenger cars and buildings together account for more than 60% of the decline in oil use between 2018 and 2040 (passenger cars 42%, buildings 19%). Despite some further new oilfield developments, domestic production declines at a much faster pace than increases from these new fields. Net import dependency therefore increases further to almost 90% by 2040.

In 2018, the EU was the world's largest diesel importer, but this consumption is going to change rapidly, which will impact the refinery outlook in the EU. In the medium term up to 2025, EU oil products demand is expected to decline in buildings, caused by the growing bans on fuel oil for heating, and in transport due to "dieselgate", fuel efficiency and stringent emissions performance standards and bans on the circulation of older cars in many EU countries and cities. As part of the European Green Deal (EGD), the EU plans to adopt more stringent air pollution standards, which will even further impact diesel demand in the EU and promote a switch to gasoline.

Table 12.1 Outlook for the EU's oil sector to 2040 (unit mb/d), STEPS

	2000	2018	2025	2040
Share in world oil demand	16.9%	11.5%	9.8%	5.9%
Domestic demand	13.1	11.1	10.1	6.3
Bunker demand	1.6	1.9	2.0	2.1
Total demand	14.7	13.0	12.2	8.4
Domestic production	3.6	1.7	1.5	0.7
Refinery processing gains	0.3	0.5	0.2	0.2
Total supply	3.9	2.2	1.6	1.0
Net trade balance	-10.8	-10.9	-10.5	-7.5
Net import dependency	74%	83%	87%	89%
Global oil demand	77.4	96.9	103.5	106.4

Note: STEPS = Stated Policies Scenario

Source: IEA (2019c), *World Energy Outlook 2019*, Paris.

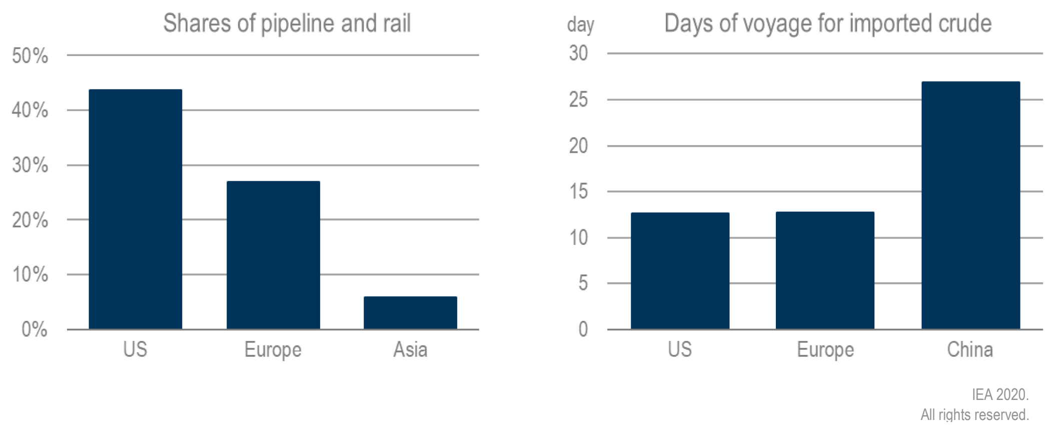
In the longer term, in the International Energy Agency (IEA) *World Energy Outlook 2019*, oil demand is expected to fall to 6.3 mb/d in 2040 (Stated Policies Scenario). In a pathway compatible with the Paris Agreement, the IEA Sustainable Development Scenario, EU oil demand is projected to decline to 7.3 mb/d in 2030 and 3.5 mb/d in 2040 (IEA, 2019c). This 70% decrease from today's levels is driven by road transport, most notably passenger cars. The number of electric cars on the road reaches 180 million by 2040 (more than twice the level in the Stated Policies Scenario and two-thirds of total passenger car stocks in that year). There will also be a considerable reduction in oil use for freight trucks, as the European Union is one of the few regions that have fuel economy standards for trucks.

The European Union expects oil demand to decrease across the economy. Under the EU Long-Term Strategy (LTS) the EU has evaluated different scenarios, with very different forecasts of the role of oil. For achieving 80% greenhouse gas (GHG) reductions, the share of oil (excluding non-energy use) in gross final consumption is expected to decline from 30% in 2015 to 25% in 2030 to, in 2050, between 12% and 8%, depending on the technology choices made and different scenarios of the LTS.

Oil infrastructure

The European Union has diverse supply routes and sources thanks to major ports and pipelines delivering oil to the EU. Crude oil imports to the EU arrive mainly by tanker, but also come by pipeline and rail (28%). In 2018, the average number of days on water for crude imports from the Middle East to Europe or the United States was 12 days, compared with 27 days for China (Figure 12.9).

Figure 12.9 Crude logistics for imports to Europe, 2018



Source: IEA (2019d), *Oil 2019*.

Ports

Norway plays a key role in securing oil supplies to the European Union, both via Norpipe from Ekofisk and to Teeside in the United Kingdom as well as to key EU ports.

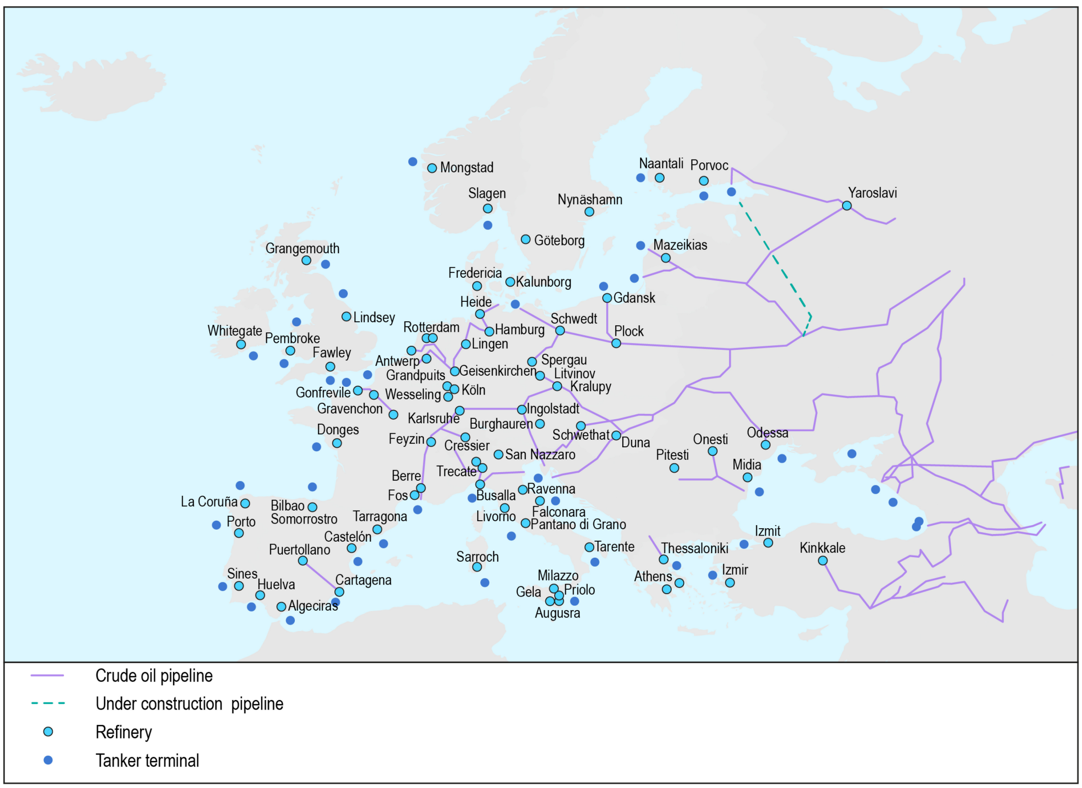
The majority (two-thirds) of Russian oil imports enters via European ports from the Russian ports in the Baltic Sea (Primorsk and Ust-Luga) and the Black Sea (Novorossiysk); around 30% of Russian crude oil arrives in Europe through the Druzhba pipeline system. An overview on the oil ports in Europe and oil infrastructure is given in Figure 12.10.

There are a few large oil pipelines which link major EU ports to inland refineries, namely the Rotterdam-Rhine Pipeline (RRP) from Rotterdam, the South European Pipeline (SPSE) from Marseille and the Transalpine Pipeline (TAL) from Trieste.

Refineries in Central and Eastern Europe (the Czech Republic, Germany, Hungary, Poland and the Slovak Republic) are supplied from Russia by the Druzhba pipeline.

Rotterdam, Marseille and Trieste are the major EU ports for importing crude oil, while the majority of oil products is imported/exported at the ports in London, Le Havre, Antwerp, Rotterdam and Amsterdam. The Dutch Amsterdam-Rotterdam-Antwerp port area (ARA) is the world's third-largest bunkering centre after Singapore and Fujairah.

Figure 12.10 Oil infrastructure in the EU

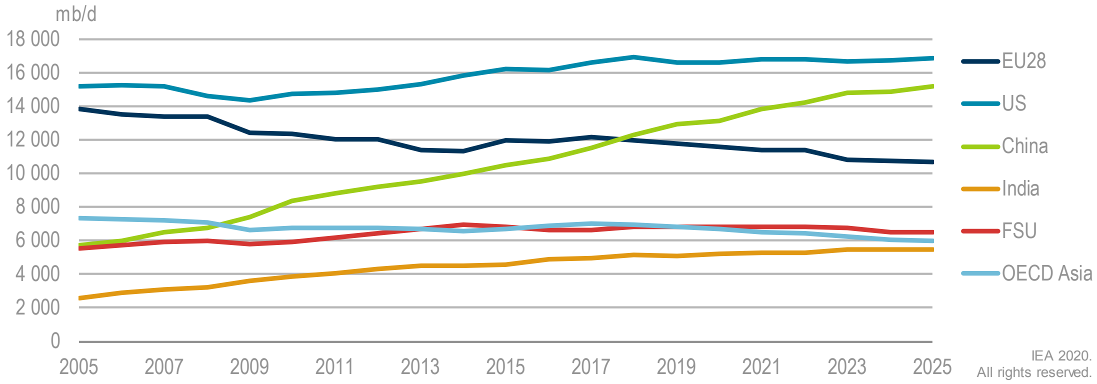


This map is without prejudice to the status of or sovereignty over any territory, to the destination of international frontiers and boundaries and to the name of any territory, city or area.

Refineries

Most refineries in the EU are located near the coasts, with inland plants in Austria, the Czech Republic, Germany, Hungary, Poland and the Slovak Republic (Figure 12.10). In 2018, China overtook the EU in terms of refining throughput. The EU is the world's third-largest producer of petroleum products with an oil refining capacity of 16% of the world total. By end of 2019, the refining capacity in the EU (including the United Kingdom) was 13 457 kb/d. IEA analysis shows EU refining throughput declining to 10.7 mb/d by 2025 (Figure 12.11).

Figure 12.11 Top refining regions by throughput (mb/d)



Note: FSU includes Russia and the other former Soviet Union countries; OECD = Organisation for Economic Co-operation and Development.
Source: IEA (2020), *Oil 2020*.

Retail market

Prices

Oil product prices vary between EU member states, mainly due to differences in tax levels (Figure 12.12). For diesel, fuel prices in 2018 varied from EUR 1.1/litre (L) in Luxembourg to EUR 1.5/L in Sweden. The tax level varied from 45% of the total price in Luxembourg to around 60% in Italy and the United Kingdom. For motor gasoline, the prices varied from EUR 1.1/L in Bulgaria to EUR 1.6/L in the Netherlands, with taxes from 49% to 66% of the total price. For fuel oil, the price difference was even larger. The lowest prices were again found in Luxembourg, at EUR 0.6/L, of which only 14% was in taxes. Denmark had the highest price at EUR 1.3/L, more than twice the price in Luxembourg. The Netherlands had the highest tax levels at over 60%.

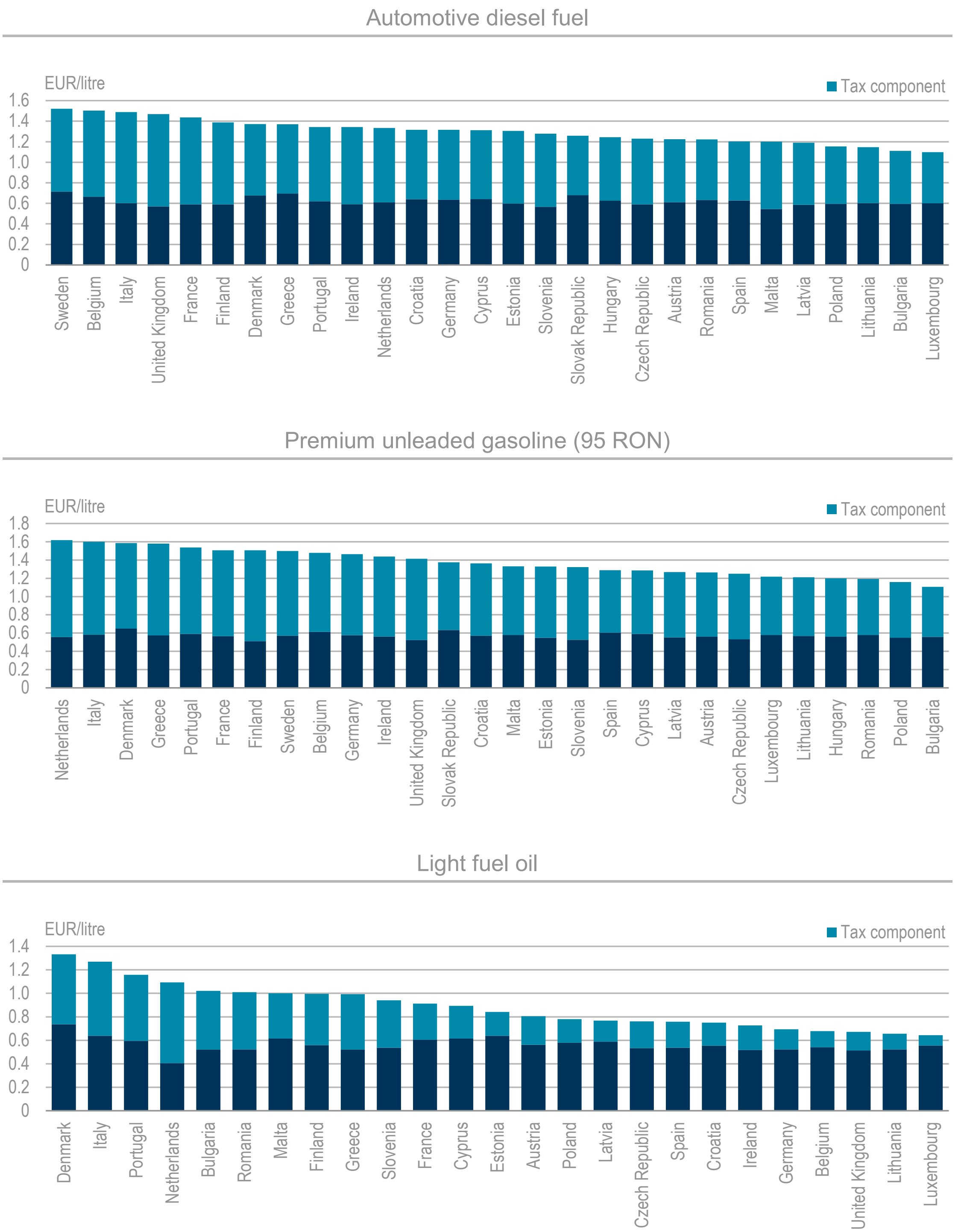
Energy taxation

Taxes on transport fuels, mainly the excise duty on petroleum products, are a major source of government revenue and also serve environmental purposes. For a long time, diesel was taxed substantially lower than petrol, encouraging production and consumption of diesel in the EU. In recent years, EU member states have started to increase excise duties for diesel to align them more with gasoline with a view to fight local air pollution and reduce the strong incentives for diesel use in the EU.

The directive on the taxation of energy products and electricity (Energy Taxation Directive [ETD] 2003/96/EC) sets minimum tax levels for electricity and for energy products used for heating or motor fuel. Member states are free to decide on the taxation above these minimum levels. In 2011, the European Commission proposed a revised ETD to bring it in line with environmental and climate change objectives by splitting the existing tax into two taxes depending on the carbon and on the energy content. However, the proposal was not supported by the Council. Under the EGD, the European Commission is proposing to amend the ETD alongside a proposal to change the voting procedure, requiring only qualified instead of unanimous support by the EU member states. The European Commission is reviewing the EU ETD, and its minimum tax rates, exemptions and procedures. With a view to align energy taxation with economic growth, climate, social and energy policy goals, the EU is looking at a comprehensive tax reform, examining the interplay of several instruments, including by reviewing the EU Emissions Trading System (ETS) (and the carbon leakage list) and the ETD and examining life-cycle and well-to-wheel approaches for products, and certificate schemes.

Energy taxation is an important instrument to achieve a cost-effective internalisation of environmental impacts, including pollution, notably in the sectors outside the EU ETS. In the absence of EU carbon pricing in the non-ETS sectors (transport), member states have started introducing carbon pricing or taxes in these sectors; for instance, the climate package in Germany adopted a tax of EUR 25 per tonne of CO_2 on transport and buildings while in France, the carbon component of the energy taxation (EUR 53 in 2019 and EUR 100 in 2022) was not implemented. At the same time, the energy system is changing, and fuel use and structure and taxation play a major role in incentivising the use of low-carbon fuels.

Figure 12.12 Oil fuel prices in EU member countries, 2018



Fuel prices vary significantly across the EU, mainly due to different taxes, with countries such as Denmark, Sweden and the Netherlands ranking high, and Luxembourg and Belgium low.

Note: Data are not available for fuel oil prices in Hungary, the Slovak Republic and Sweden.

Source: IEA (2019e), *Energy Prices and Taxes, second quarter 2019*, www.iea.org/statistics/.

Regulatory framework

The EU does not have many policies in place affecting the oil markets. EU policies focus mainly on the security of oil supplies and safety of offshore production. Stringent EU environmental rules do impact oil products demand and refinery operations.

Offshore oil and gas production safety

In the EU, member states have national sovereignty over their oil and gas resources, but must follow a set of common EU rules for licensing both onshore and offshore oil and gas operations. Safety in offshore oil and gas operations is a priority concern for the EU. Major accidents are likely to have devastating and irreversible consequences on the marine and coastal environment, as well as coastal economies, across borders.

EU Directive 2013/30/EU, and the Implementing Regulation (1112/2014), were developed to ensure the highest safety standards in EU offshore activities. Member states must follow a set of common EU rules for licensing both onshore and offshore oil and gas operations. The common rules require strong regulatory governance by setting up competent authorities, a comprehensive identification and assessment of risks, inspection and verification of critical elements, consultation with worker representatives, emergency response to incidents, data reporting, and others. The EU Offshore Authorities Group supports the implementation and further development of these measures, together with regulators, experts and sector stakeholders.

In 2014, the European Commission issued non-binding recommendations to member states that underlined the need for public consultations and information of potential risks and impacts, use of operators' global best practices, and a comprehensive assessment of environmental impacts of the use of hydraulic fracturing on water and air quality (EC, 2014).

In 2019, the European Commission was reviewing the directive with a focus on themes, such as liability, compensation claims, financial security and decommissioning.

Environmental regulation

The Renewable Energy Directive 2009/28/EC requires a 10% share of renewable energy in transport by 2020. In 2017, the share reached 7.4%. Renewable electricity in transport grew significantly, but mainly in rail transport, while road transport represents only around 2% of the total.

As a result of both EU and member state measures, the average specific fuel consumption of the EU passenger car fleet decreased from around 7.4 L/100 km in 2005 to 6.9 L/100 km in 2015 (Odyssee-Mure). After a steady decline (almost 22 grammes of CO_2 per kilometre [gCO_2/km]) between 2010 and 2016, the average CO_2 emissions of a new car sold in the EU rose by 0.4 gCO_2/km in 2017 to 118.5 gCO_2/km. According to the European Environment Agency, the upward trend continued with an additional increase of 1.9 gCO_2/km to 120.4 gCO_2/km in 2018 (EEA, 2019). The main factors contributing to the increase of new passenger cars' emissions in 2018 include the growing share of petrol cars in new registrations, in particular in the sports utility vehicle segment. Moreover, the market penetration of zero- and low-emission vehicles, including battery- and fuel-cell electric cars, remained slow in 2018. Further improvements need to be achieved by manufacturers to reach the 2021 target of 95 gCO_2/km.

Europe has stringent fuel economy standards and the 2021 targets are the strictest in the world. In January 2019, the EU endorsed new rules stating that from 2030 new cars must emit on average 37.5% less CO_2 and new vans on average 31% less CO_2 compared with 2021 levels. To meet the 2030 target, the trajectory foresees that between 2025 and 2029, both cars and vans will be required to reduce CO_2 emissions by 15%.

Moreover, the EU is the world's only region to have adopted CO_2 emissions standards for trucks and other heavy-duty vehicles, which require manufacturers to cut CO_2 emissions from new trucks on average by 15% from 2025 and by 30% from 2030, compared with 2019 levels.

The EGD announced in December 2019 proposed the further strengthening of emissions standards.

The most interesting change in Europe is the expected further decline in diesel use, following "dieselgate". The European Automobile Manufacturers Association (ACEA) data showed a drop in sales in 2018; this disaffection for diesel cars could benefit both gasoline and electric cars.

The new International Maritime Organization (IMO) regulations on sulphur content in marine fuels (maximum of 0.5 % sulphur in fuels) will be applied from 1 January 2020. It is a large reduction from the current 3.5% limit. Marine gasoil will benefit from this new regulation with an initial demand increase, which might be later replaced by a new fuel (so-called very low sulphur fuel oil).

Other environmental regulations impacting the refining sector are: the Industrial Emissions Directive (Directive 2010/75/EU), the Fuel Quality Directive (Directive 98/70/EC) and the Environmental Impact Assessment Directive (Directive 2011/92/EU of the European Parliament and of the Council). To discuss regulatory proposals affecting oil refining, the European Commission organises the EU refining forum twice a year.

Security of supply

Emergency response policy

In the oil sector, emergency oil stocks remain the most important tool for guaranteeing security of supply.

The 2009 Oil Stocks Directive (2009/119/EC) requires EU member states to hold minimum emergency stocks of oil and/or petroleum products equivalent to 90 days of net imports or 61 days[46] of inland consumption, whichever is higher. Stocks must be readily available so that in the event of a crisis they can be allocated quickly to where they are most needed.

[46] Since the very first 1968 oil directive, the EU obligation for all member states corresponded to 90 days of average internal consumption of some categories of products. However, the part of internal consumption met with derivatives of petroleum produced indigenously by the member states concerned could be deducted up to a maximum of 25% of said consumption. The pre-existing 25% deduction was therefore kept and applied to the new obligation (90 days – 25% = 67.5, this figure being rounded up to 70 days in the Commission's proposal). In the course of the negotiations with the EU Council, it was agreed to deduct 10% from the initial figure considered: 67.5 – 6.75 = 60.75 which was rounded up to 61 days).

EU countries report to the European Commission a statistical summary of their stocks at the end of each month (see Eurostat [2019c]). This summary must state the number of days of net imports or consumption that the stocks represent. Contingency plans and the necessary measures and arrangements are in place at national level, to be activated in case of a major supply disruption or a local crisis.

Member states are obliged to have in place emergency measures for the release of these stocks during a major supply disruption. Other emergency measures include programmes for demand restraint (for instance in the transport sector, such as carpooling, driving bans or speed limits), possibilities for fuel switching (in transport or industry), temporary production increases and the allocation of oil products in case of a disruption to priority consumer groups. The Oil Coordination Group was established as the main body for EU member states to discuss and co-ordinate their actions on oil security. The IEA regularly participates in the meetings of the group. The directive also introduced the possibility to carry out regular reviews of emergency preparedness and stockholding of EU member states.

During a supply crisis, the European Commission is responsible for organising a consultation among EU countries. Stocks releases should not be made before this consultation, except in a very urgent situation.

EU countries have the option to create a so-called central stockholding entity (CSE) for the acquisition and management of the emergency stocks, or to delegate its stockholding obligations to other member states and their CSEs, or to certain other economic operators which have surplus stocks. Under specific conditions, economic operators can delegate their stockholding obligations to the national CSE, to one or more CSEs in other member states, or to other economic operators with surplus stocks. Member states have to hold at least one-third of their commitment in refined products; this is more stringent than IEA rules. In addition, they can hold "specific stocks" mirroring at least 30 days of inland consumption. Specific stocks shall be owned by the member state concerned or the CSE set up by it.

Collaboration and alignment with the IEA

One main objective of Directive 2009/119 was to align the methods with those of the IEA. However, in order to keep the same level of security of supply, the directive maintained the obligation for all member states (also for net exporters, contrary to IEA). Under the IEA obligations, EU member countries (that are also a member of the IEA) hold emergency oil stocks also with a view to release them in an IEA collective action, not only an EU or domestic supply disruption. Directive 2009/119 authorises those member states that are IEA members to use their emergency oil stocks to fulfil their IEA obligations, and in particular to release them in an IEA collective action.

The European Commission regularly participates in IEA emergency response exercises and associates with those EU member states that are not parties to IEA. The IEA Secretariat was involved in the medium-term review of the Oil Stocks Directive and regularly participates in the meetings of the Oil Coordination Group. The European Commission contributed to the discussions on the future of IEA's stockholding mechanism.

Recent oil disruptions affecting the EU

Low level of Rhine River – summer 2018

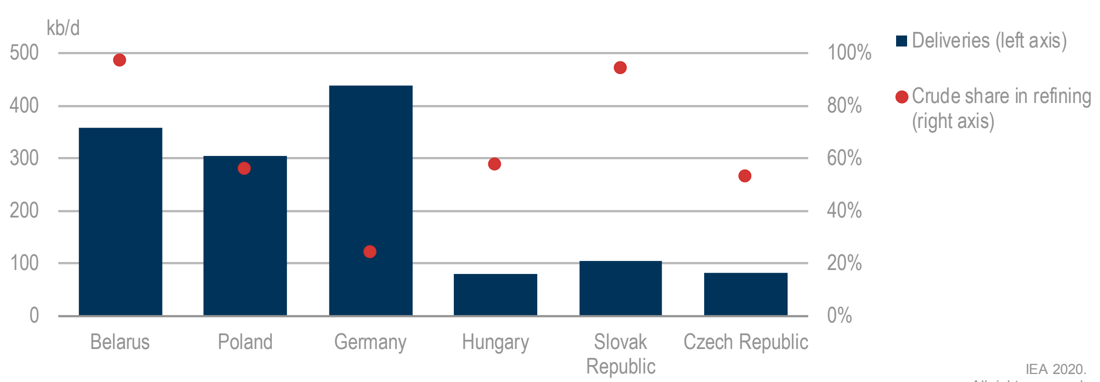
Austria, France, Germany, Luxembourg and Switzerland reported on their use of emergency stocks in 2018 due to low water levels of the Rhine and Danube. Germany's release of some 2 million barrels (mb) of gasoline and diesel was almost fully taken up by the market; the jet release of 0.53 mb was only about half taken. France also had to use emergency stocks, as industry's regional rebalancing was not enough to cover needs in the eastern region around Strasbourg.

This logistical constraint stemming from low water levels in rivers for the oil supply chain in France, Germany and Switzerland is chronic, and might happen again in the future with dry summers expected. The minimum fairway depth of the Rhine is usually 2.60 metres, which does not allow for the passage of fully loaded barges. But during summer it can be down to 30 centimetres in some parts, which makes it impossible for large barges transporting energy commodities (coal, oil or biomass) to continue supplies, impacting all the petrochemical and other manufacturing industries located along the Rhine river. Almost 80% of Germany's trade is transported along the Rhine river. Coal, oil and gas or chemical products are transported with a much higher intensity (10-30%). The Rhine river saw a 27% drop in transport performance in mid-2018, compared with the same period in the previous year, because of low water levels (Central Commission for the Navigation of the Rhine. By comparison, the Danube also saw its transport performance fall by 10%.

Druzhba incident – May to June 2019

Crude oil imports via the Druzhba pipeline are very significant for some Eastern European countries. Refineries in Central and Eastern Europe (the Czech Republic, Germany, Hungary, Poland and the Slovak Republic) are supplied from Russia by the Druzhba pipeline (Figure 12.13).

Figure 12.13 Crude oil deliveries (kb/d) and Druzhba crude share in refining (%), 2018



Source: IEA (2019f), Oil Monthly Market Report, May.

In April 2019, crude oil delivered by the Druzhba pipeline was contaminated by a high level of chlorides, and supply was stopped on the northern and southern branches of the Druzhba system. The incident directly impacted five IEA member states: the Czech

Republic, Germany, Hungary, Poland and the Slovak Republic. Three countries released some emergency stocks to keep their refineries running (Table 12.2).

Table 12.2 Recent oil disruptions affecting the EU and Switzerland

Country	Date	Occasion	Stock release details
Switzerland	Oct. 2015	Low water levels (Rhine river) and other logistical issues	An unplanned shutdown of Switzerland's only operating refinery, low water levels on the Rhine and railways being used at full capacity combined to disrupt domestic supply. In total, 1.5 mb (3% of the country's total emergency stocks) was released, although only 882 thousand barrels (kb) was used.
France	May-June 2016	Oil industry strike	The government released public stocks via swaps/loans and authorised industry to use their security stocks up to nine days. In total, around 1.7 mb were released.
Germany	Oct.-Dec. 2018	Low water levels (Rhine river)	German oil stockholding agency EBV released 518 kb of gasoline, 1.1 mb of diesel and 414 kb of jet fuel.
Switzerland	Oct.-Dec. 2018	Low water levels (Rhine river) and other logistical issues	The historically low level of the Rhine river as well as import capacity constraints (including the quota system applied on the product pipelines from France) led to a national shortage of oil imports. A total of 2.3 mb of oil products from the compulsory industry stocks were released in stages. About 1.6 mb was taken up by the market.
France	Jul.-Dec. 2018	Low water levels on the Rhine river	Due to low water levels, France faced oil product supply disruptions and resorted to the use of strategic stocks to ensure oil product supply in the east of France. Stocks released included 1.1 mb of diesel, 138 kb of heating oil and 54 kb of gasoline.
Luxembourg	November 2018	Low water levels on the Rhine river and the "yellow vests" protesters blocking oil depots in Belgium	In the second half of 2018, oil products supply chain faced major challenges due to the low water levels on the Rhine river and the "yellow vests" movement that made important oil depots in Belgium temporarily inaccessible. As a consequence, several individual decrees were issued to reduce the obligation of concerned importers for one to four days.
Czech Rep Germany Hungary Poland Slovak Rep	Apr.-May 2019	Contamination of oil in the Druzhba pipeline system	After crude coming from Russia via the Druzhba pipeline was found to be contaminated, flows were halted and supply shortages affected refineries in Eastern and Central Europe. The Czech Republic (2.95 mb), Hungary (2.6 mb) and Poland (8.1 mb) released emergency stocks at the end of April to maintain refinery operation. Germany and the Slovak Republic used commercial stocks for operation.

Source: IEA (2019g), *Energy security in ASEAN +6*.

Oil supply diversification

The EU attempts to diversify oil supply sources and routes for Central Eastern European countries, as their refineries heavily depend on Russian crude oil supplies. Six oil infrastructure projects have been identified by the EU in 2017 as projects of common interest to ensure more diversified oil supplies for the region (EC, 2017).

- Adamowo-Brody pipeline: pipeline connecting JSC Ukrtransnafta's handling site in Brody (Ukraine) and Adamowo tank farm (Poland)
- Bratislava-Schwechat-Pipeline: pipeline linking Schwechat (Austria) and Bratislava (the Slovak Republic)
- Litvinov (the Czech Republic)-Spergau (Germany) pipeline: the extension project of the Druzhba crude oil pipeline to the refinery Spergau
- expansion of the Pomeranian Pipeline: loopings and second line on the Pomeranian pipeline linking Plebanka tank farm (near Płock) and Gdańsk handling terminal and construction of an oil terminal in Gdańsk
- TAL Plus: capacity expansion of the TAL Pipeline between Trieste (Italy) and Ingolstadt (Germany).

Assessment

The global oil market turmoil in 2020, with a supply glut and a demand shock after the Covid-19 pandemic started, had an impact on the EU. Covid-19 lockdowns cancelled demand for mobility (road transport and aviation) across the EU and reduced global oil demand in March 2020 alone by around 11 mb/d compared with March 2019 and by 1 mb/d in Europe. The crisis is exacerbating the longer-term challenges and the grim outlook for EU oil production and refining. In North West Europe, refinery margins have seen negative levels in May 2020.

Until the end of 2019, oil consumption in the European Union was robust. Consumption declined by as little as 0.1 mb/d per year since 2000 and the share of oil in TPES and TFC remained stable. Despite stabilisation of the North Sea oil production in recent years, the declining trend of EU oil production is set to continue with a sharp decline after 2023, pushing up crude oil import needs. The EU has been the largest diesel importer in the world for decades, while it exports gasoline. This stable picture is going to change in the coming five to ten years.

As the EU aims to achieve a drastic reduction of GHG emissions by 2030 and 2050, declining fossil fuel demand is expected to play an important role in the EU 2050 long-term strategy. In the base case of this strategy, oil demand will decline by approximately 50% by 2050, and in the most ambitious decarbonisation scenario the share of oil in gross inland consumption might drop below 10%, compared with 30% in 2015, most of it replaced by renewables and biofuels.

Oil demand in the EU will decline as fuel efficiency standards increase, electric vehicles penetrate the market and biofuel blending mandates go up. The oil product demand is expected to shift to gasoline away from diesel. A major shift in oil product consumption is expected in the medium term: between 2019 and 2024, the IEA expects road diesel demand to decline due to improved fuel efficiency of cars, and as the share of diesel cars falls. Gasoline demand will continue to decline slightly with efficiency improvements offset by the expected switch from diesel to gasoline.

The oil industry, especially refineries and the petrochemical industry, will be faced with challenges in the short, medium and long terms, as EU policies aim to decarbonise energy supplies by implementing strict CO_2 reduction targets. This will require a reform of the industry, which will have to supply low-carbon liquid fuels and change feedstock from oil to less environmentally burdensome materials. In the medium term, this will require an assessment of the overall impact of this decarbonisation strategy on the EU oil security of supply, notably related to adequacy of oil stocks.

The EU policies on oil focus mainly on security of oil supplies and the safety of offshore production. For securing oil supply, the 2009 Oil Stocks Directive provides for emergency preparedness, along with the IEA emergency response mechanism. A positive aspect is that the EU has diversified its supply portfolio of imported oil, which works effectively in case of supply disruptions. The 2013 directive on the safety of offshore oil and gas infrastructure requires adequate licensing of operations, transparency and information sharing. Currently, a review of the directive is being carried out, focusing on themes such as liability, compensation claims, financial security and decommissioning.

There were two sizeable oil disruption incidents affecting European oil supplies in the last five years. Low water levels in the Rhine river in 2018 prevented fully loaded barges from going upstream and caused product supply shortages in France, Germany, Luxembourg and Switzerland. France, Germany and Switzerland released some emergency stocks to counter the logistical disruptions caused by the river's low water level. In 2019, the contamination of oil in the Druzhba crude pipeline coming from Russia disrupted crude oil supplies to the Czech Republic, Germany, Hungary, Poland and the Slovakia Republic. The Czech Republic, Hungary and Poland released emergency stocks in order to keep their refineries running.

Amid recurring water shortages on the Rhine and the increasing impacts of climate change on oil supply routes and infrastructure, the EU should increase its work on climate resilience, as outlined in Chapter 3 on Climate. Ensuring the preparedness of the EU for such very likely scenarios would foster the resilience of the EU to such intra-EU events. These incidents reinforce the need for maintaining adequate oil stockholding, emergency preparedness and response systems. The EU and IEA emergency response policies are closely interlinked, and given that not all EU countries are IEA members, notably in Eastern Europe, the EU should indeed continue the collaboration and close co-ordination with the IEA.

Recommendations

The European Union should:

- ☐ Review the impact of the decarbonisation policy on the oil industry from a security of supply perspective, taking into account the development of low-carbon liquid fuels.
- ☐ Continue close co-ordination between the EU and IEA emergency response mechanisms, notably for EU member states in Eastern Europe that are not members of the IEA.
- ☐ Address climate change impacts on oil security, including by regularly observing water levels of rivers that may cause restraints in logistics, examine alternative routes and the readiness of member states to release emergency stocks in case of disruptions.

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13. Coal

Key data
(2018)

Hard coal production: 73.8 Mt, -48% since 2008

Brown coal production: 369.1 Mt, -15% since 2008

Net imports of hard coal: 155.8 Mt (163.8 Mt imports, 8.0 Mt exports), -27% since 2008

Share of coal:* 14.1% of TPES and 21.2% of electricity generation

Consumption by sector:* 227.8 Mtoe (heat and power generation 72.8%, other energy** 11.8%, industry 10.4%, residential 4.1%, services/other 0.9%)

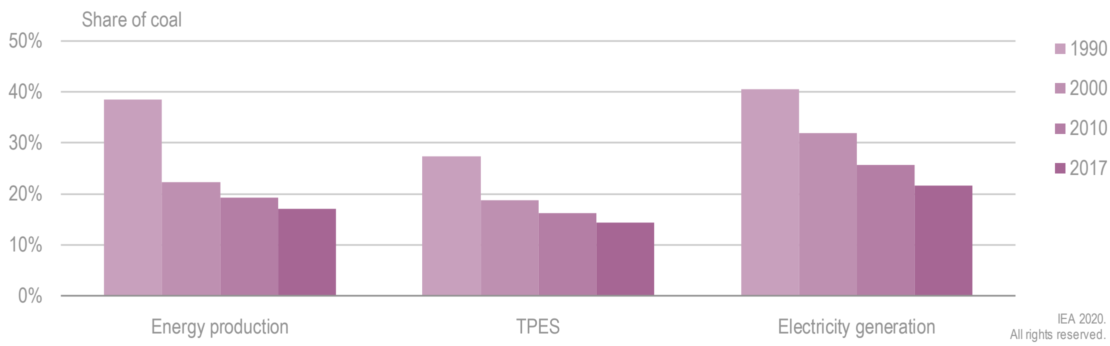
*2017 data and includes coal products and recovered gases.

**Mostly referring to coking coal used in steel industry.

Overview

The European Union (EU) was the tenth-largest hard coal producer in the world in 2018 and the largest lignite producer (IEA, 2019a). Once a dominating energy source in the EU, the coal sector is undergoing profound changes.

Figure 13.1 The role of coal in the EU energy system, 1990-2017



Production and consumption of coal in the EU is steadily declining, but it still accounted for over 20% of electricity generation in 2017.

Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics.

Back in 1990, coal accounted for nearly 40% of all energy production in the EU, over a quarter of total primary energy supply (TPES) and 40% of electricity generation. In 2017, these shares had fallen to around 14% of TPES and 21% of electricity generation

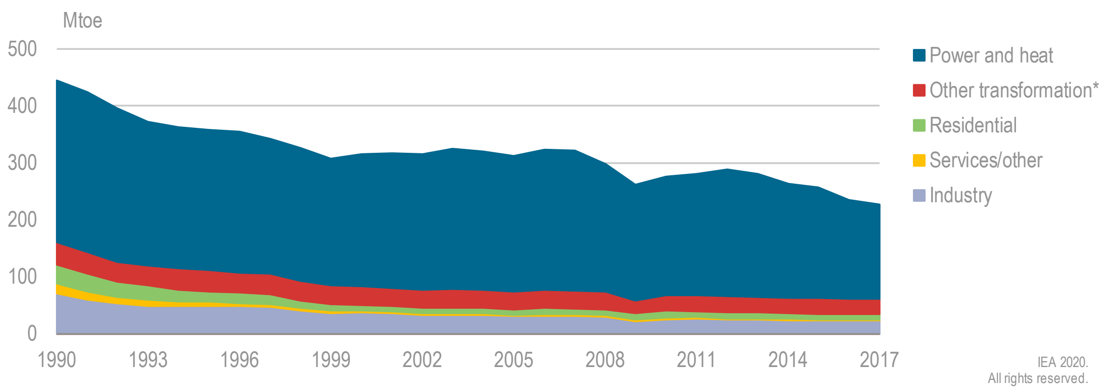
(Figure 13.1). In 2017, coal power still accounted for over 20% of total electricity generation in the EU, although the shares vary significantly between countries, with 73% of all coal consumed in heat and power generation.

Many EU countries plan to phase out coal-fired power generation, driven by political decisions to close coal-fired power plants but also increasing EU CO_2 pricing under the EU Emissions Trading System (ETS). However, coal still plays a significant role for security of supply and electricity baseload in several countries. Over half of coal consumed in the EU is produced within the EU, significantly higher than for oil or natural gas. There are environmental and social aspects of the coal phase-out, in particular in regions with large coal mining industries. A challenge for policy makers is to manage the coal phase-out while ensuring energy security as well as economic efficiency and social fairness of the transition. Around 180 000 people were employed in the coal industry in the EU in 2015 (EURACOAL, 2017).

In some industries, such as steel and cement production, replacing coal with alternative energy sources will not tackle the main process emissions and pollutants that are linked to the materials and not the heat production. To decarbonise such sectors, carbon capture, utilisation and storage (CCUS) technology is an important option. CCUS can also enable coal power generation with significantly lower emissions, but its business case compared with other low-carbon technologies remains low.

Supply and demand

Figure 13.2 Coal consumption by sector, 1990-2017



Coal used for heat and power generation accounted for 73% of the total in 2017 (in energy terms) but has declined fastest, while other coal consumption was relatively stable.

**Other transformation* includes coal used in coke ovens and blast furnaces mainly in steel industry, plus small use in briquettes plants, coal mining and other energy sector use.

Notes: Mtoe = million tonnes of oil equivalent. Coal and coal products (including recovered gases) in TPES by consuming sector.

Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics.

Coal consumption in the EU has nearly halved from 445 Mtoe in 1990 to 228 Mtoe in 2017 (Figure 13.2). The decrease in coal use has happened across all sectors, particularly in residential and service buildings, except in some member states that still use coal in residential heating, such as the Czech Republic, Germany, Poland and the United Kingdom (UK).

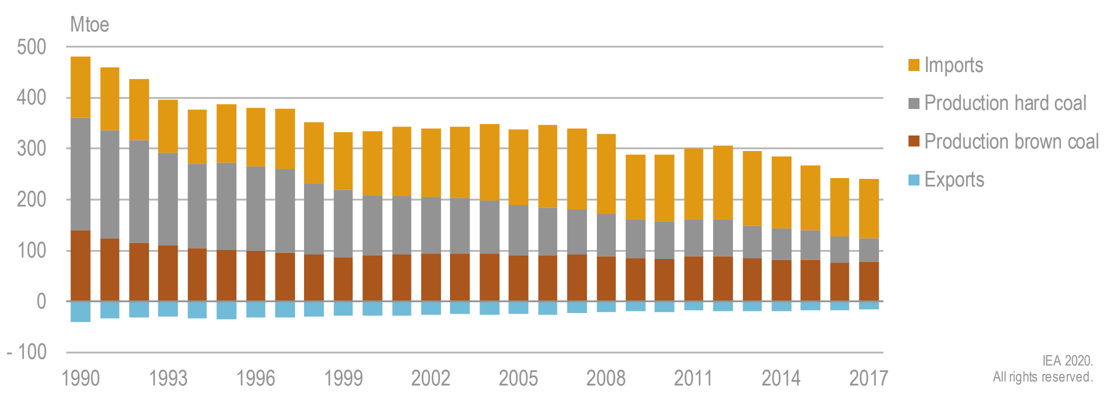
Most coal is used in power and heat generation. In 2017, the sector accounted for 73% of total coal consumption. However, the consumption was reduced by a third in the last decade, reflecting the ongoing phase-out of coal power in many EU countries. The rest of the coal was largely consumed in the steel industry, which is covered under “other transformation” (12% of total consumption in 2017, mainly coal use in coke ovens and blast furnaces) and industry (10% of total consumption, of which half is in iron and steel production), plus smaller shares in residential and service buildings (5%).

Coal supply from production and imports

In 2018, the EU produced 73.8 million tonnes (Mt) of hard coal and 369.1 Mt of brown coal (nearly all lignite). Globally, this ranked the EU as the tenth-largest hard coal producer and the second-largest brown coal producer after Indonesia, and the largest producer of lignite (IEA, 2019a). The EU is also the fourth-largest coal consumer in the world, after the People’s Republic of China (“China”), India and the United States (IEA, 2019b).

In energy terms, total coal production was 124.8 Mtoe in 2017; just below half of total coal supply to the EU (some 250 Mtoe) was produced by member countries, and the rest was imported from outside the EU (Figure 13.4). In energy terms, brown coal (mainly lignite) production accounted for 63% of total coal production in 2017 and hard coal for the other 37%. In 2018, Germany and Poland were the largest coal importers, followed by Italy, Spain and France (IEA, 2019a).

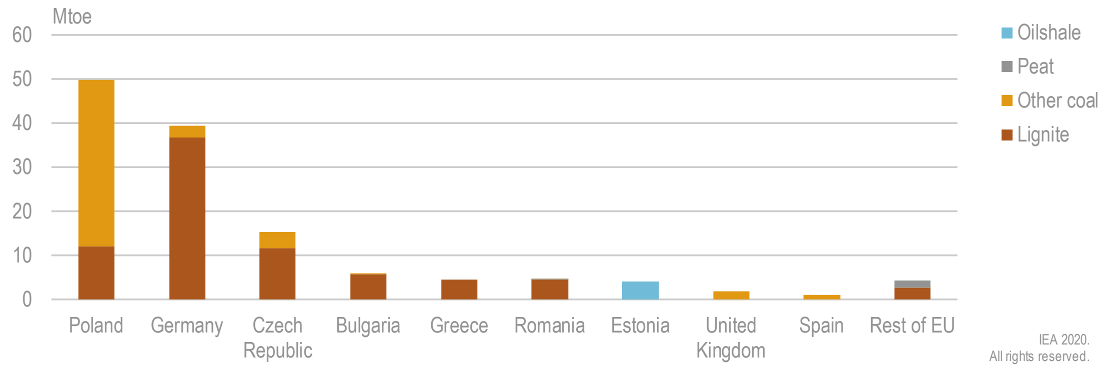
Figure 13.3 Coal supply by source, 2000-17



Half of total coal supply is produced within the EU, and both imports and production are decreasing, in particular hard coal production.

Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics.

Figure 13.4 Hard coal and lignite production in the EU, 2017



Poland is the largest coal producer in the EU with mostly hard coal production, followed by Germany, which mostly produces lignite.

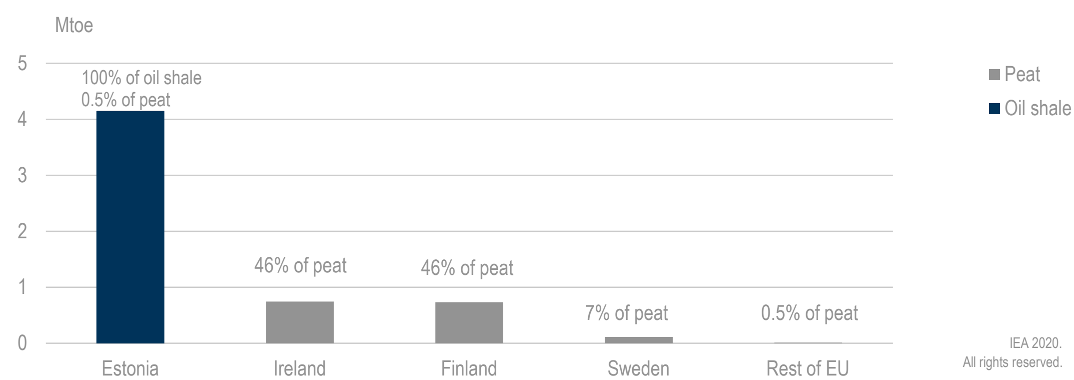
Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics.

Five EU member states still mine hard coal (the Czech Republic, Poland, Romania, Spain and the United Kingdom) – in 1990 there were 19 of the current member states. Germany is the dominant lignite producer in the EU besides Poland, the Czech Republic, Bulgaria, Greece and Romania (Figure 13.4). In 2017, Poland's lignite production accounted for 40% of the total in the EU and Germany's for 32%.

While lignite production has remained relatively stable, hard coal production has decreased rapidly, with a 48% drop in the decade from 2007 to 2017 (Figure 13.4). The reduced hard coal production has partly been replaced by imports from outside the EU. In 2017, net imports accounted for just over half of total coal supply in the EU, with the Russian Federation ("Russia") providing 30% of hard coal imports, followed by Colombia and the United States as the main exporters of hard coal to the EU.

In addition to coal production, some EU member states produce peat and oil shale (Figure 13.5). Estonia produces oil shale, which is also classified under coal in IEA energy statistics. In 2017, Estonia produced 4.1 Mtoe oil shale, equal to around 3% of coal production in the EU. The oil shale is used either directly for heat and power generation or liquefied and exported as so-called shale oil (Figure 13.5).

Figure 13.5 Oil shale and peat production in the EU, 2017



Source: IEA (2019b), *World Energy Balances 2019*, www.iea.org/statistics.

Coal power capacity

Despite the declining use, in 2018, coal remained the second-largest source of electricity generation, accounting for 20%, after nuclear (25%) and even before natural gas (19%).

The EU has over 600 coal power plants with total installed capacity of 164 gigawatts (GW). The nine EU member states most reliant on lignite for power generation are Bulgaria, the Czech Republic, Germany, Greece, Hungary, Poland, the Slovak Republic, Slovenia and Romania. Germany and Poland make up about half of the EU's installed coal capacity.

In several countries, new coal plants and mines were under development in 2019 (the Czech Republic, Germany and Poland). These countries also invested in the refurbishment and modernisation of their youngest plants to ensure compliance with emissions standards and pollution rules in the EU and prepare for application of carbon capture and storage (CCS).

According to the International Energy Agency (IEA) *World Energy Outlook (WEO) 2019*, over 90% of the existing fleet will be retired by 2040 under stated policies, reflective of ageing fleets and policy commitments. A total of 16 member states have endorsed or are considering the complete phase-out of coal-fired power plants that are not equipped with carbon capture; these countries have about 120 GW of coal capacity in operation today, representing over two-thirds of total EU coal capacity (IEA, 2019c).

Table 13.1 Coal power generating capacity by country in 2018 and WEO 2019 Stated Policies Scenario projections for 2030

	Installed capacity (GW)	
	2018	**STEPS – 2030**
Total European Union	**164.2**	**58.9**
Germany	47.8	16.8
Poland	32.9	24.4
Italy	11.9	-
United Kingdom	11.5	-
Czech Republic	9.8	5.6
Spain	10.3	2.5
Romania	6.8	4.0
Netherlands	5.3	-
Greece	5.1	-
Bulgaria	5.0	4.6
France	4.0	-
Finland	3.9	-
Denmark	2.5	-
Portugal	1.9	-
Slovak Republic	0.98	-

	Installed capacity (GW)	
Ireland	1.3	-
Hungary	1.3	-
Austria	1.2	-
Slovenia	0.7	0.7
Croatia	0.3	0.3
Sweden	0.2	-

Note: STEPS = Stated Policies Scenario.
Sources: IEA (2019c), *World Energy Outlook 2019*.

Coal-to-gas switching in the EU

Most of the switching from coal to gas took place during the 1980s-2000s,[47] notably in the residential sector; power generation will be the second large sector to move out of coal in the coming decade. Gas use has grown from 11% of the EU energy mix in 1980 to around a quarter today, thanks to large gas finds and production in the United Kingdom and the Netherlands, but also the EU ETS. The carbon price under the EU ETS increased from EUR 5 tonnes of CO_2-equivalent (tCO_2-eq) in 2008 to EUR 25 tCO_2-eq in 2019. The main increase in the EU ETS price happened during the period 2017-19, thanks to the ETS reforms. The EU introduced a higher annual cap on emissions allowances from 2021 onwards and reduced the surplus carbon allowances, including through the backloading of auctions planned in 2014-16 and their placement in a Market Stability Reserve which started in 2019.

Some countries have introduced additional carbon pricing instruments to fix the carbon price and avoid volatility, notably the United Kingdom carbon price support (fixing the price of carbon rather than the volume under the ETS). In 2019, the Dutch government decided to introduce a minimum carbon price of EUR 12.30 in 2020, increasing to EUR 31.90 in 2030. Under the climate package, Germany plans to introduce a carbon price of EUR 25 per tonne of CO_2 in non-ETS sectors, in transport and buildings. France also has a carbon component in its energy tax, which increases gradually every year.

While EU gas-fired capacity could fill the gap resulting from coal and nuclear phase-outs/closures, its investment case is not certain. Since 2010, high natural gas prices, strong renewables growth and low CO_2 prices ruled out significant coal-to-gas switching. The reform of the EU ETS has raised the generating costs for fossil fuel plants, particularly coal. Amid higher CO_2 prices in 2018, the economics of coal-to-gas switching have become more favourable. However, weak wholesale power prices in renewables-rich systems are not incentivising investments in new thermal capacity; over half of the revenue from a new combined-cycle gas turbine would need to come from sources other than wholesale power prices. As a result, gas plants may largely remain on standby and recover their costs by fulfilling balancing functions, rather than providing significant quantities of baseload power.

[47] The German reunification led to the shut-in of coal capacity in Eastern Germany.

Coal policies in the EU

State aid rules and subsidies

Domestic hard coal production in Europe is considered mostly uncompetitive against imported coal (Russia or the United States). State aid for the closure of uncompetitive mines has been approved by the EU for ten member states. Under the state aid rules (Council Decision 2010/787/EU), state aid for production losses in hard coal mining were phased out by 31 December 2018.

On the other hand, electricity production subsidies were allowed under EU law (Electricity Directive 2009/72/EC) for reasons of security of supply. EU member states may give preference (i.e. subsidies) to power plants that use domestic primary energy sources, but only up to 15% of the total primary energy use in electricity generation per year. This has been used in the Slovak Republic and Spain.

Building on the international Powering Past Coal Alliance,[48] 16 EU countries have set targets for phasing out coal use (France by 2025, Italy by 2025, Ireland by 2025, the Netherlands by 2029, Finland by 2029, Portugal by 2030, Denmark by 2030, Sweden by 2022, the United Kingdom by 2025, Austria by 2025 and Spain). Outside of the Alliance, coal might stay beyond 2030 in Germany (phase-out envisaged by 2038 at the latest), Greece and several countries in Central Eastern Europe (Bulgaria, the Czech Republic, Romania, Slovenia).

In order to respond to the socio-economic challenges associated with the phase-out of coal production in the EU, the European Commission launched a Coal Regions in Transition Initiative as part of the Clean Energy Package (CEP), which provides technical and financial support for the technological transition and economic diversification, as well as worker reskilling, in the areas affected by the transition away from coal (around 200 000 workers, which includes oil shale and peat). In 2019, the initiative covered 41 coal mining regions across 12 EU member states, with more tailored assistance being delivered to 18 coal regions in 8 member states.

Under the EGD, the European Commission proposed a Just Transition Mechanism, which would also include funding for the "just transition" in Europe's coal regions. This financial support was fundamental for EU countries to join efforts and agree on the climate neutrality target for 2050 for the EU as a whole.

Environmental rules

EU environmental rules limit the emissions of air pollutants from combustion in small, medium and large combustion plants.

The EU Industrial Emissions Directive (IED) (2010/75/EU) requires around 50 000 industrial installations to reduce harmful industrial emissions across the EU, in particular through application of best available technologies (BATs). Activities listed in Annex I of the IED are required to operate in accordance with a permit (granted by the

[48] As of 22 September 2019, a total of 91 members have joined the Powering Past Coal Alliance, comprising 32 national governments, 25 subnational governments, and 34 businesses or organisations.

authorities in the member states), which contains conditions set in accordance with the principles and provisions of the IED. The IED requires permits to take into account the entire plant, covering e.g. emissions to air (nitrogen oxides, sulphur oxides, CO, dust), water and land (mercury, hydrogen chloride); generation of waste; use of raw materials; energy efficiency; noise; prevention of accidents; and restoration of the site upon closure. To guide authorities in the EU, a reference document for large combustion plants was elaborated with BATs and associated emission levels. Chapter III of the IED on large combustion plants includes certain flexibility for member states (transitional national plan, and limited lifetime derogation, among others).

As part of the European Green Deal (EGD), the European Commission announced its intention to revise the industrial emissions rules in the coming years.

An increase in efficiency will also marginally reduce the air pollution levels. The European Union's coal-fired power plants are on average 36% efficient, with ultra-supercritical power plants in Germany reaching 47%.

EU rules also allow for the use of existing coal-fired power plants as reserve capacity and their remuneration. Flexible coal-fired power plants can contribute to security of supply, notably during hours of low wind and solar availability, which usually affects more than one country in the region (a situation that is referred to as *Dunkelflaute* by system operators in Europe).

The EU Electricity Regulation (2019/943) sets an emissions performance standard for capacity included under the capacity remuneration schemes in EU member states at the level of 550 grammes of CO_2 per kilowatt-hour. The new standard applies to new plants from 4 July 2019 (investment decision taken and construction started) and to existing ones as of 1 July 2025, which rules out new coal plants being constructed in the EU.

Assessment

The 2014 IEA in-depth review predicted that coal use would start to decline in the near future. Indeed, coal use has fallen for a number of reasons. Despite this decline, new coal-fired power plants were under construction in three member states in 2018 (the Czech Republic, Germany and Poland) but it is unlikely that additional coal power plant projects will be proposed, as new plants are no longer economically competitive in the EU and are not favoured politically.

A key reason for the decline in coal use has been the increase in CO_2 emissions allowance prices under the EU ETS, following the latest reforms, and the introduction of national carbon-pricing measures in some member states, including the UK carbon price support or the French and German carbon pricing in non-ETS sectors. At the same time, natural gas prices have declined thanks to a sharp increase in liquefied natural gas supply globally, initially led by Australia and later the United States. As a result of both developments, coal-to-gas switching took place in recent years.

Apart from rising CO_2 prices under the ETS, EU legislation on air pollution has framed the operation of coal-fired power plants and coal use in industry. These limits have become gradually stricter over time and this trend will continue with the revised conclusions on "best available technologies" which were adopted in July 2017.

Despite the political declarations to phase out coal, in 2018, the role of coal mining was still significant. Globally, the EU is the tenth-largest producer of hard coal and the largest producer of lignite. The EU is also the fourth-largest coal consumer in the world, after China, India and the United States. Five EU member states mine hard coal (the Czech Republic, Poland, Romania, Spain and the United Kingdom) – in 1990 there were 19 member states with hard coal mining activities.

In compliance with EU law, all subsidies for hard coal production in the EU ended on 31 December 2018. State aid can now be paid only to alleviate social and environmental impacts of coal mine closures. As a result, the last hard coal mines in Germany were closed at the end of 2018. The only significant hard coal producer remaining in the EU is Poland, which intends to continue to produce coal. Germany is the dominant lignite producer in the EU besides Poland and the Czech Republic, Greece, Bulgaria and Romania. Lignite is mostly burned for electricity close to the pit. Similarly, in Estonia, oil shale is used for power generation. Poland has plans to build three new hard coal-fired power plants as well as a new lignite-fired power plant.

Coal still provides around 21% of electricity supply in the European Union and heat energy for district heating. Coal is also used in the production of iron, steel and cement. But power generation is the main use for coal in the EU, accounting for almost four-fifths of total coal use. In many countries, coal-fired power generation is scheduled to be phased out. Under the Powering Past Coal Alliance, 16 member states have committed to phase out unabated coal power, i.e. coal-fired power generation without CCS. Germany is working on a phase-out of coal-fired power by 2038 at the latest, but most of its coal power plants will close much earlier.

Almost all EU countries have a policy to decarbonise their electricity and heat supply, and have large programmes to promote renewable electricity sources. One still widely used option is to use biomass instead of coal in previous coal-fired plants. However, this raises more and more sustainability questions, as some biomass sources compete with food production, while others have to be imported over long distances by oil-fuelled ships.

Integration of large shares of variable renewable electricity such as solar and wind come with challenges for security of electricity supply. In most countries, natural gas is seen as the transition fuel for dispatchable generation. Additional investments are likely needed to adapt plants to flexible use. A number of member states have introduced capacity remuneration schemes, which currently can also cover existing coal plants, although a new 550 gramme emissions limit in the CEP for existing power plants will apply from 2025. As such plants will run only occasionally, total emissions from coal-fired generation would continue to decline. For instance, during cloudy windless periods (*dunkelflaute*) existing coal-fired power plants can play a role in the short to medium term.

In 2019 the European Commission announced plans to increase the ambition for CO_2 reductions by 2030 from currently 40% to at least 50% and possibly 55% as part of the EGD. The decarbonisation of the power sector would have to speed up, as heating and transport are slower, and will have to contribute the lion's share of this increased ambition. Such a massive transition in such a short time frame will require new avenues, and large-scale deployment of CCUS on existing power plants may well be one of them. Also the energy security implications for electricity will have to be carefully considered, as this will have implications for dispatchable coal- and gas-fired power generation.

The European Commission's long-term strategic vision of carbon neutrality by 2050 not only impacts coal-fired power generation, but also the use of unabated coal in industry. New ways of making iron, steel and cement will have to be developed at commercial scale for these industries to remain economically viable in the EU. Commendably, the EU plans to fund large research, development and demonstration projects with this aim. CCUS can be applied to existing steel and cement facilities and provide for an opportunity for industry to export this technology. Even if the EU is able to secure its electricity supply without coal-fired power, in other regions of the world coal-fired power is to stay for several decades. This is a major challenge for the climate. Therefore, developing CCUS into a commercially viable, low-carbon technology, including for industrial applications, would definitely be an asset in other regions of the world, notably in Asia.

Finally, the social consequences of a shift away from coal should not be ignored, as there are still several regions across the EU that are heavily reliant on the coal industry. It is commendable that the European Commission underlined the concept of a "just transition", building on the initiative for coal regions in transition, part of the CEP. Attracting new investment into the coal regions should be a priority to create sustainable jobs, preferably jobs linked to the energy transition. This would likely enhance the willingness of energy consumers to contribute to the costs related to the energy transition. Early 2020, the European Commission proposed a Just Transition Mechanism to mobilise investment in the EU, which would include also funding for the just transition in Europe's coal regions. This financial support was fundamental for EU countries to join efforts and agree on the climate neutrality target for 2050 for the EU as a whole.

Recommendations

The European Union should:

- ☐ Ensure that the energy transition is guided by market principles enshrined in the EU ETS and capacity mechanisms where needed, which, together, can ensure a strong reduction of CO_2 and greenhouse gas emissions from coal use while retaining, for a period, the short- and longer-term security benefits of coal use.
- ☐ Explore, through support for new technologies, how industry currently using coal in their processes can either use CCUS on their installations or move away from coal.
- ☐ Assess the regional impacts of the coal phase-out plans and retirements on EU electricity and gas security.

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ANNEX A: Organisations visited

Review team and preparation of the report

This in-depth review was carried out in 2019-20 after the review team's visit to Brussels from 16-23 September 2019. In Brussels the team met with European Union institutions, officials and regulators, industry associations, non-governmental organisations, academia, and stakeholders in the public and private sectors as well as other organisations and interest groups, all of whom helped the team identify the key challenges facing energy policy makers in the European Union.

The International Energy Agency (IEA) Secretariat and the review team are grateful for the hospitality, the high-quality presentations, the co-operation and the assistance of more than 100 people throughout the visit. Thanks to their engagement, openness and willingness to share information, the visit was informative, productive and enjoyable.

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The report was prepared under the guidance of the IEA Head of Energy Policy and Security Division, Mr Aad van Bohemen. The review was carried out by Ms Sylvia Beyer, who organised the review and the drafting of the report. The preparations of the EU review benefited from the excellent support by Ms Lilly Lee. Mr Marc Deffrennes, from the OECD/NEA, prepared the chapter on nuclear energy. Special thanks to IEA strategic initiatives office team, Mr Simon Bennett, Mr Simone Landolina and Mr Jean-Baptiste Le Marois who led the analysis and preparations of the chapter on energy technology and innovation. Mr Oskar Kvarnström and Mr Peter Journeay-Kaler led the work on the chapter on energy sector integration.

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Organisations visited

During its visit to Brussels, the review team met with the following organisations:

Council Secretariat Working Party on Energy

Finland European Union Presidency

European Commission DG Energy, DG Climate Action, DG Taxud, DG GROW, DG Research and Innovation Joint Research Centre (JRC), DG Environment, DG Competition

European Parliament – Committee on Industry, Transport, Research and Energy (ITRE), Committee on Internal Market and Consumer Protection (IMCO), Committee on Environment (ENVI)

European executive agencies (EACI, INEA)

European Investment Bank

Agency for the Cooperation of Energy Regulators (ACER)
Council of European Energy Regulators (CEER)
European Network of System Operators – Gas (ENTSOG)
European Network of System Operators – Electricity (ENTSO-E)
CORESO
Eurelectric
Eurogas
Gas Infrastructure Europe (GIE)
International Association of Oil and Gas Producers
European Federation of Energy Traders (EFET)
Europex
BusinessEurope
Euroheat & Power
COGEN

Hydrogen Europe

Cembureau
SolarPower Europe
Wind Europe
EDSO4SmartGrids
SmartEn
European Committee of Domestic Equipment Manufacturers (CECED)
European Chemical Industry Council (Cefic)
EURACOAL
Europia
Centre of European Policy Studies (CEPS)
FSR Think (Florence School of Regulation)
Institut français des relations internationales (ifri)
E3G
European Policy Centre
Regulatory Assistance Project
European Commission European Political Strategy Centre (EPSC)

Institut Jacques Delors

WWF
Greenpeace
Carbon Market Watch

ANNEX B: Energy balances and key statistical data

Energy balances and key statistical data

Unit: Mtoe

SUPPLY		1990	2000	2005	2010	2015	2016	2017
TOTAL PRODUCTION		**950.59**	**950.99**	**910.10**	**842.51**	**771.29**	**759.17**	**754.39**
Coal		365.20	212.23	192.89	161.90	143.53	131.19	129.00
Peat		3.75	2.36	3.33	3.16	1.77	1.56	1.60
Oil		134.65	175.47	134.49	98.71	75.47	74.68	73.56
Natural gas		163.99	209.79	190.52	159.29	107.34	107.32	103.09
Biofuels and waste[1]		47.18	66.59	88.93	125.23	143.69	148.07	151.40
Nuclear		207.28	246.30	260.12	238.95	223.41	218.89	216.30
Hydro		24.96	30.69	26.94	32.41	29.42	30.18	25.86
Wind		0.07	1.91	6.06	12.84	25.96	26.04	31.16
Geothermal		3.19	4.59	5.31	5.52	6.55	6.75	6.81
Solar/other[2]		0.34	1.07	1.52	4.50	14.16	14.49	15.60
TOTAL NET IMPORTS[3]		**691.56**	**745.39**	**893.40**	**865.71**	**818.39**	**819.42**	**853.13**
Coal	Exports	40.76	27.67	23.63	21.16	17.43	17.19	15.02
	Imports	120.59	125.67	148.86	130.89	127.70	115.31	115.28
	Net imports	79.82	98.00	125.24	109.73	110.27	98.12	100.27
Oil	Exports	267.68	337.18	357.00	357.28	401.23	413.66	423.47
	Imports	799.20	869.20	959.73	918.38	942.20	948.60	966.96
	Int'l marine and aviation bunkers	-59.52	-80.42	-91.63	-91.62	-87.41	-91.16	-94.71
	Net imports	472.00	451.60	511.10	469.48	453.57	443.78	448.78
Natural gas	Exports	28.29	48.93	69.68	87.25	97.37	87.84	96.03
	Imports	163.96	242.43	323.76	366.96	344.35	357.27	392.14
	Net imports	135.67	193.50	254.07	279.72	246.98	269.43	296.08
Electricity	Exports	15.89	20.90	27.47	25.03	34.06	31.31	32.20
	Imports	19.82	22.88	28.82	25.68	35.31	32.89	33.08
	Net imports	3.93	1.98	1.35	0.65	1.24	1.58	0.88
TOTAL STOCK CHANGES		**3.07**	**-1.82**	**-8.62**	**19.03**	**-0.33**	**20.69**	**11.52**
TOTAL SUPPLY (TPES)[4]		**1645.22**	**1694.57**	**1794.88**	**1727.25**	**1589.35**	**1599.28**	**1619.04**
Coal		450.92	318.53	315.32	279.57	261.21	239.92	232.00
Peat		3.06	2.63	2.82	3.48	2.35	2.30	2.19
Oil		606.98	623.96	639.86	570.30	517.13	521.73	531.13
Natural gas		297.00	396.00	445.13	447.60	357.90	382.74	398.38
Biofuels and waste[1]		47.52	66.92	90.48	131.42	150.02	154.65	158.72
Nuclear		207.28	246.30	260.12	238.95	223.41	218.89	216.30
Hydro		24.96	30.69	26.94	32.41	29.42	30.18	25.86
Wind		0.07	1.91	6.06	12.84	25.96	26.04	31.16
Geothermal		3.19	4.59	5.31	5.52	6.55	6.75	6.81
Solar/other[2]		0.34	1.06	1.52	4.49	14.16	14.49	15.60
Electricity trade[5]		3.93	1.98	1.35	0.65	1.24	1.58	0.88
Shares in TPES (%)								
Coal		*27.4*	*18.8*	*17.6*	*16.2*	*16.4*	*15.0*	*14.3*
Peat		*0.2*	*0.2*	*0.2*	*0.2*	*0.1*	*0.1*	*0.1*
Oil		*36.9*	*36.8*	*35.6*	*33.0*	*32.5*	*32.6*	*32.8*
Natural gas		*18.1*	*23.4*	*24.8*	*25.9*	*22.5*	*23.9*	*24.6*
Biofuels and waste[1]		*2.9*	*3.9*	*5.0*	*7.6*	*9.4*	*9.7*	*9.8*
Nuclear		*12.6*	*14.5*	*14.5*	*13.8*	*14.1*	*13.7*	*13.4*
Hydro		*1.5*	*1.8*	*1.5*	*1.9*	*1.9*	*1.9*	*1.6*
Wind		*-*	*0.1*	*0.3*	*0.7*	*1.6*	*1.6*	*1.9*
Geothermal		*0.2*	*0.3*	*0.3*	*0.3*	*0.4*	*0.4*	*0.4*
Solar/other[2]		*0.0*	*0.1*	*0.1*	*0.3*	*0.9*	*0.9*	*1.0*
Electricity trade[5]		*0.2*	*0.1*	*0.1*	*-*	*0.1*	*0.1*	*0.1*

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

Unit: Mtoe

DEMAND							
FINAL CONSUMPTION	**1990**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**
TFC	**1133.50**	**1178.17**	**1240.28**	**1204.72**	**1117.28**	**1137.78**	**1154.03**
Coal	119.04	50.73	43.28	40.15	34.92	34.63	35.04
Peat	1.26	0.66	0.57	0.60	0.46	0.45	0.43
Oil	505.73	542.01	556.29	503.08	465.03	470.61	479.40
Natural gas	226.72	272.04	287.28	278.44	243.68	252.07	254.39
Biofuels and waste[1]	39.29	49.32	59.70	83.46	87.81	90.01	92.84
Geothermal	0.41	0.44	0.45	0.44	0.50	0.54	0.57
Solar/other[2]	0.16	0.43	0.70	1.48	2.09	2.15	2.27
Electricity	185.79	217.22	239.41	244.02	236.52	239.20	240.59
Heat	55.10	45.33	52.60	53.05	46.27	48.13	48.53
Shares in TFC (%)							
Coal	*10.5*	*4.3*	*3.5*	*3.3*	*3.1*	*3.0*	*3.0*
Peat	*0.1*	*0.1*	*0.0*	*0.1*	*0.0*	*0.0*	*0.0*
Oil	*44.6*	*46.0*	*44.9*	*41.8*	*41.6*	*41.4*	*41.5*
Natural gas	*20.0*	*23.1*	*23.2*	*23.1*	*21.8*	*22.2*	*22.0*
Biofuels and waste [1]	*3.5*	*4.2*	*4.8*	*6.9*	*7.9*	*7.9*	*8.0*
Geothermal	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Solar/other [2]	*0.0*	*0.0*	*0.1*	*0.1*	*0.2*	*0.2*	*0.2*
Electricity	*16.4*	*18.4*	*19.3*	*20.3*	*21.2*	*21.0*	*20.8*
Heat	*4.9*	*3.8*	*4.2*	*4.4*	*4.1*	*4.2*	*4.2*
TOTAL INDUSTRY[6]	**444.08**	**420.32**	**424.56**	**376.83**	**352.00**	**354.52**	**365.80**
Coal	69.08	37.91	31.34	25.31	23.81	23.34	23.84
Peat	0.39	0.30	0.24	0.26	0.18	0.16	0.15
Oil	141.95	146.13	145.29	125.60	108.51	108.23	112.64
Natural gas	113.16	117.31	115.99	99.20	92.46	93.42	97.72
Biofuels and waste[1]	13.92	16.53	18.59	21.57	24.73	25.73	26.27
Geothermal	-	-	0.00	0.01	0.00	0.01	0.01
Solar/other[2]	-	-	0.00	0.01	0.01	0.02	0.02
Electricity	85.38	91.02	97.23	88.33	86.65	87.66	89.04
Heat	20.21	11.12	15.87	16.56	15.64	15.96	16.12
Shares in total industry (%)							
Coal	*15.6*	*9.0*	*7.4*	*6.7*	*6.8*	*6.6*	*6.5*
Peat	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	-	-
Oil	*32.0*	*34.8*	*34.2*	*33.3*	*30.8*	*30.5*	*30.8*
Natural gas	*25.5*	*27.9*	*27.3*	*26.3*	*26.3*	*26.4*	*26.7*
Biofuels and waste [1]	*3.1*	*3.9*	*4.4*	*5.7*	*7.0*	*7.3*	*7.2*
Geothermal	-	-	-	-	-	-	-
Solar/other [2]	-	-	-	-	-	-	-
Electricity	*19.2*	*21.7*	*22.9*	*23.4*	*24.6*	*24.7*	*24.3*
Heat	*4.6*	*2.6*	*3.7*	*4.4*	*4.4*	*4.5*	*4.4*
TRANSPORT[4]	**259.02**	**303.46**	**324.35**	**319.82**	**313.48**	**320.86**	**326.93**
OTHER[7]	**430.40**	**454.39**	**491.38**	**508.07**	**451.80**	**462.40**	**461.30**
Coal	49.75	12.81	11.93	14.83	11.10	11.27	11.18
Peat	0.87	0.36	0.34	0.35	0.28	0.28	0.28
Oil	110.66	99.97	98.07	78.70	65.61	64.22	63.97
Natural gas	113.22	153.92	168.67	176.59	148.07	155.37	153.28
Biofuels and waste[1]	25.35	32.08	37.86	48.70	49.04	50.35	51.38
Geothermal	0.41	0.44	0.44	0.44	0.49	0.53	0.57
Solar/other[2]	0.16	0.43	0.70	1.47	2.08	2.13	2.25
Electricity	95.08	120.17	136.63	150.51	144.51	146.07	145.99
Heat	34.89	34.22	36.73	36.48	30.63	32.17	32.41
Shares in other (%)							
Coal	*11.6*	*2.8*	*2.4*	*2.9*	*2.5*	*2.4*	*2.4*
Peat	*0.2*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
Oil	*25.7*	*22.0*	*20.0*	*15.5*	*14.5*	*13.9*	*13.9*
Natural gas	*26.3*	*33.9*	*34.3*	*34.8*	*32.8*	*33.6*	*33.2*
Biofuels and waste [1]	*5.9*	*7.1*	*7.7*	*9.6*	*10.9*	*10.9*	*11.1*
Geothermal	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*
Solar/other [2]	*0.0*	*0.1*	*0.1*	*0.3*	*0.5*	*0.5*	*0.5*
Electricity	*22.1*	*26.4*	*27.8*	*29.6*	*32.0*	*31.6*	*31.6*
Heat	*8.1*	*7.5*	*7.5*	*7.2*	*6.8*	*7.0*	*7.0*

Unit: Mtoe

DEMAND							
ENERGY TRANSFORMATION AND LOSSES	**1990**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**
ELECTRICITY GENERATION[8]							
Input (Mtoe)	645.16	683.09	745.73	725.09	670.15	665.28	665.81
Output (Mtoe)	221.58	258.49	283.00	286.85	276.42	278.36	281.11
Output (TWh)	2576.54	3005.76	3290.73	3335.50	3214.23	3236.69	3268.66
Output shares (%)							
Coal	*40.6*	*32.0*	*30.0*	*25.6*	*25.6*	*22.6*	*21.5*
Peat	*0.2*	*0.2*	*0.2*	*0.3*	*0.2*	*0.2*	*0.2*
Oil	*8.7*	*6.0*	*4.3*	*2.6*	*2.0*	*2.0*	*1.9*
Natural gas	*7.5*	*16.0*	*20.3*	*22.9*	*15.5*	*18.9*	*20.3*
Biofuels and waste [1]	*0.8*	*1.5*	*2.6*	*4.3*	*6.3*	*6.4*	*6.4*
Nuclear	*30.9*	*31.4*	*30.3*	*27.5*	*26.7*	*25.9*	*25.4*
Hydro	*11.3*	*11.9*	*9.5*	*11.3*	*10.6*	*10.8*	*9.2*
Wind	*-*	*0.7*	*2.1*	*4.5*	*9.4*	*9.4*	*11.1*
Geothermal	*0.1*	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*	*0.2*
Solar/other [2]	*-*	*0.1*	*0.4*	*0.8*	*3.5*	*3.6*	*3.8*
TOTAL LOSSES	**501.78**	**521.74**	**554.23**	**520.59**	**473.14**	**462.17**	**460.79**
of which:							
Electricity and heat generation[9]	361.36	373.40	401.86	375.01	338.49	329.41	327.16
Other transformation	32.02	32.90	31.97	28.35	26.30	26.28	25.97
Own use and transmission/distribution losses	108.40	115.45	120.40	117.24	108.35	106.48	107.67
Statistical differences	**9.95**	**-5.34**	**0.37**	**1.93**	**-1.07**	**-0.67**	**4.21**
INDICATORS	**1990**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**
GDP (billion 2010 USD)	11831.77	14777.98	16254.14	17009.61	18005.55	18370.48	18826.92
Population (millions)	477.98	487.17	494.96	503.70	509.74	511.30	512.39
TPES/GDP (toe/1000 USD)[10]	0.14	0.11	0.11	0.10	0.09	0.09	0.09
Energy production/TPES	0.58	0.56	0.51	0.49	0.49	0.47	0.47
Per capita TPES (toe/capita)	3.44	3.48	3.63	3.43	3.12	3.13	3.16
Oil supply/GDP (toe/1000 USD)[10]	0.05	0.04	0.04	0.03	0.03	0.03	0.03
TFC/GDP (toe/1000 USD)[10]	0.10	0.08	0.08	0.07	0.06	0.06	0.06
Per capita TFC (toe/capita)	2.37	2.42	2.51	2.39	2.19	2.23	2.25
CO_2 emissions from fuel combustion ($MtCO_2$)[11]	4024.2	3786.3	3922.8	3612.6	3216.1	3202.2	3209.3
CO_2 emissions from bunkers ($MtCO_2$)[11]	185.7	249.9	285.4	285.4	270.4	282.1	293.0
GROWTH RATES (% per year)	**90-00**	**00-05**	**05-10**	**10-14**	**14-15**	**15-16**	**16-17**
TPES	0.3	1.2	-0.8	-2.4	1.2	0.6	1.2
Coal	-3.4	-0.2	-2.4	-1.2	-2.1	-8.2	-3.3
Peat	-1.5	1.4	4.3	-8.5	-3.7	-2.1	-4.7
Oil	0.3	0.5	-2.3	-2.8	1.4	0.9	1.8
Natural gas	2.9	2.4	0.1	-6.4	4.2	6.9	4.1
Biofuels and waste[1]	3.5	6.2	7.8	2.4	3.7	3.1	2.6
Nuclear	1.7	1.1	-1.7	-1.1	-2.2	-2.0	-1.2
Hydro	2.1	-2.6	3.8	-0.1	-9.0	2.6	-14.3
Wind	39.8	26.0	16.2	14.1	19.3	0.3	19.7
Geothermal	3.7	3.0	0.8	3.1	5.1	3.1	0.9
Solar/other[2]	12.0	7.3	24.3	30.9	7.5	2.3	7.7
TFC	0.4	1.0	-0.6	-2.3	1.9	1.8	1.4
Electricity consumption	1.6	2.0	0.4	-1.1	1.5	1.1	0.6
Energy production	0.0	-0.9	-1.5	-1.9	-1.0	-1.6	-0.6
Net oil imports	-0.4	2.5	-1.7	-1.7	3.5	-2.2	1.1
GDP	2.2	1.9	0.9	0.8	2.3	2.0	2.5
TPES/GDP	-1.9	-0.8	-1.7	-3.2	-1.1	-1.4	-1.3
TFC/GDP	-1.8	-0.9	-1.5	-3.1	-0.3	-0.3	-1.0

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

Footnotes to energy balances and key statistical data

1. Biofuels and waste comprise solid biofuels, liquid biofuels, biogases, industrial waste and municipal waste. Data are often based on partial surveys and may not be comparable between countries.
2. Other includes tide, wave and ambient heat used in heat pumps.
3. In addition to coal, oil, natural gas and electricity, total net imports also include peat, biofuels and waste and trade of heat.
4. Excludes international marine bunkers and international aviation bunkers.
5. Total supply of electricity represents net trade. A negative number in the share of TPES indicates that exports are greater than imports.
6. Industry includes non-energy use.
7. Other includes residential, commercial and public services, agriculture/forestry, fishing and other non-specified.
8. Inputs to electricity generation include inputs to electricity, CHP and heat plants. Output refers only to electricity generation.
9. Losses arising in the production of electricity and heat at main activity producer utilities and autoproducers. For non-fossil-fuel electricity generation, theoretical losses are shown based on plant efficiencies of approximately 33% for nuclear and solar thermal, 10% for geothermal, if no country-specific information is reported, and 100% for hydro, wind and solar photovoltaic.
10. Toe per thousand US dollars at 2010 prices and exchange rates.
11. "CO_2 emissions from fuel combustion" have been estimated using the IPCC Tier I Sectoral Approach methodology from the *2006 IPCC Guidelines.* Emissions from international marine and aviation bunkers are not included in national totals.

ANNEX C: Acronyms, abbreviations and units of measure

In this report, abbreviations and acronyms are substituted for a number of terms that are frequently used in the International Energy Agency or in the Government of India. While these terms generally have been written out on first mention, this annex provides a quick and central reference for the abbreviations used.

Acronyms and abbreviations

ACER	Agency for the Cooperation of Energy Regulators
AGR	advanced gas-cooled reactor
APR	advanced pressurised reactor
bcm	billion cubic metres
b/d	barrels per day
BWR	boiling water reactor
CCS	carbon capture and storage
CDM	clean development mechanism (under the Kyoto Protocol)
CEER	Council of European Energy Regulators
CEF	Connecting Europe Facility
CER	certified emissions reduction
CHP	combined production of heat and power (or co-generation)
CPPNM	Convention on the Physical Protection of Nuclear Materials
DFG	Decommissioning Funding Group
DH	district heating
DSO	distribution system operator
EEA	European Economic Area
EEEF	European Energy Efficiency Fund
EEPR	European Energy Programme for Recovery
EIB	European Investment Bank
EIIs	European Industrial Initiatives
ENEF	European Nuclear Energy Forum
EPC	energy performance certificate
EPR	European pressurised water reactor
ERA	European Research Area
ERDF	European Regional Development Fund
ESCOs	energy services companies
EU-ETS	Emissions Trading Scheme (European Union)
ENTSO-E	European Network of Transmission System Operators (Electricity)
ENTSOG	European Network of Transmission System Operators (Gas)
GCR	gas-cooled graphite reactor
GHG	greenhouse gas

HDV	heavy-duty vehicle
IAs	implementing agreements (IEA projects)
IAEA	International Atomic Energy Agency (in Vienna)
IDSF	International Decommissioning Support Funds
IEE	Intelligent Europe Energy
IMO	International Maritime Organisation
IPs	interconnection points
IPCC	Intergovernmental Panel on Climate Change
ITER	international thermonuclear experimental reactor
JI	joint implementation (projects under the Kyoto Protocol)
JRC	Joint Research Centre
KIC	Knowledge and Innovation Communities
kb/d	thousand barrels per day
kWh	kilowatt hour
LNG	liquefied natural gas
LPG	liquefied petroleum gas
LULUCF	land use, land-use change, and forestry
LWGR	light water-moderated graphite reactor
mb	million barrels
MBtu	million British thermal units
mcm	million cubic metres
MEPS	minimum energy performance standards
Mt	million tonnes
$MtCO_2$-eq	million tonnes of carbon dioxide-equivalent
Mtoe	million tonnes of oil-equivalent
MW	megawatt
NPP	nuclear power plant
NRA	national regulatory authorities
NREAP	National Renewable Energy Action Plan
NECPs	National Energy and Climate Plans
NTC	net transfer capacity
ONR	Office of Nuclear Regulation
OU	ownership unbundling
PCI	project of common interest
PHWR	pressurised heavy water reactor
PPP	purchasing power parity: the rate of currency conversion that equalises the purchasing power of different currencies, i.e. PPP estimates the differences in price levels between countries
PV	photovoltaics
PWR	pressurised water reactor

RES	renewable energy sources
R&D	research and development
RSK	Reactor Safety Commission
SCC	small cities and communities
SET (Plan)	Strategic Energy Technology Plan
SMEs	small and medium-sized enterprises
STC	Scientific and Technical Committee
TEN	Trans-European Networks
TFC	total final consumption of energy
TFEU	Treaty on the Functioning of the European Union (the Lisbon Treaty)
toe	tonne of oil-equivalent
TPA	third-party access
TPES	total primary energy supply
TSO	transmission system operator
TTIP	Transatlantic Trade and Investment Partnership
TYNDP	Ten-Year Network Development Plan
UNFCCC	United Nations Framework Convention on Climate Change
VRE	variable renewable energy
VTP	virtual trading point
VVER	water-moderated, water-cooled power reactor

SME	small and medium-sized enterprise
SO_2	sulphur dioxide
SO_X	sulphur oxides
TCP	Technology Collaboration Programme
TFC	total final consumption-
TOD	time-of-day
TPES	total primary energy supply-
USD	US dollar
VAT	value-added tax
VRE	variable renewable energy

Units of measure

Bcm	billion cubic metres
EJ	exajoule
gCO_2/km	grammes of CO_2 per kilometre
gCO_2/kWh	grammes of CO_2 per kilowatt hour
Gt	gigatonne
Gt CO_2	gigatonnes of CO_2
Gt CO_2-eq	gigatonnes of CO_2 equivalent

GW	gigawatt
GWh	gigawatt hour
Hz	hertz
kb/d	thousand barrels per day
kcal/kg	kilocalories per kilogram
Kg	kilogramme
kg CO_2	kilogramme of CO_2
Km	kilometre
km^2	square kilometre
Kt	thousand tonnes
kV	kilovolt
kWh	kilowatt hour
Lge/100 km	litres of gasoline equivalent per 100 kilometres
Mb	million barrels
mb/d	million barrels per day
mcm/d	million cubic metres per day
Mg	milligramme
mg/Nm^3	milligrammes per normal cubic metre
Mt	million tonnes
Mt CO_2	million tonnes of CO_2
Mt CO_2-eq	million tonnes of CO_2 equivalent
Mtoe	million tonnes of oil equivalent
Mtpa	million tonnes per annum
MVA	megavolt ampere
MW	megawatt
MWh	megawatt hour
m^3	cubic metre
µg	microgramme
T	tonne
t CO_2	tonne of CO_2
Toe	tonne of oil equivalent
TWh	terawatt-hour

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Energy Policy Review

The International Energy Agency (IEA) regularly conducts in-depth peer reviews of the energy policies of its member countries. This process supports energy policy development and encourages the exchange of international best practices and experience. This report on the European Union (EU) discusses the energy challenges facing the continent and recommends possible solutions to help it achieve a secure and sustainable energy future.

The European Commission under President Ursula von der Leyen took office in late 2019 with an ambitious programme for the five years to come. The centrepiece initiative is the European Green Deal, which aims to prepare the EU for climate neutrality by 2050. The EU's impressive track record of decarbonising power systems through renewable energy technologies, notably offshore wind but also solar PV, offers an inspiring example for many economies around the world. It also provides a sound basis for the broader decarbonisation of Europe's economy in the longer term. To achieve climate neutrality, EU policy efforts need to focus on transport, industry and buildings, alongside policies that support energy system integration.

This policy review commends the progress made by the EU, such as the creation of an internal energy market and enhancement of energy security and climate policies. The IEA provides a range of recommendations for the successful implementation of the European Green Deal in the coming years. The report also outlines opportunities for boosting short- and long-term actions for a resilient, sustainable and just recovery of the European economy.