
European Energy Transition 2030: The Big Picture

Ten Priorities for the next European
Commission to meet the EU's 2030
targets and accelerate towards 2050

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towards 2050

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Preface

Dear reader,

in 2018, the EU has decided upon an climate and energy framework up to 2030. The aim is to have a clean, affordable and reliable energy system in Europe. To that end, greenhouse gas emissions are to decline by at least 40 percent below 1990 levels, renewables are to deliver 32 percent of our energy and efficiency is to improve by even 32.5 percent. But what do these targets really mean? How will Europe's energy system look like in 2030? Which aspects of the transition are particularly important?

Against this background, we present you this report as a basis to understand where we are heading in Europe. For example, the overall renewables target translates into a Europe-wide 57 percent share of renewables in the power sector by 2030, implying that wind and solar will shape Europe's power system. And the greenhouse gas target implies that

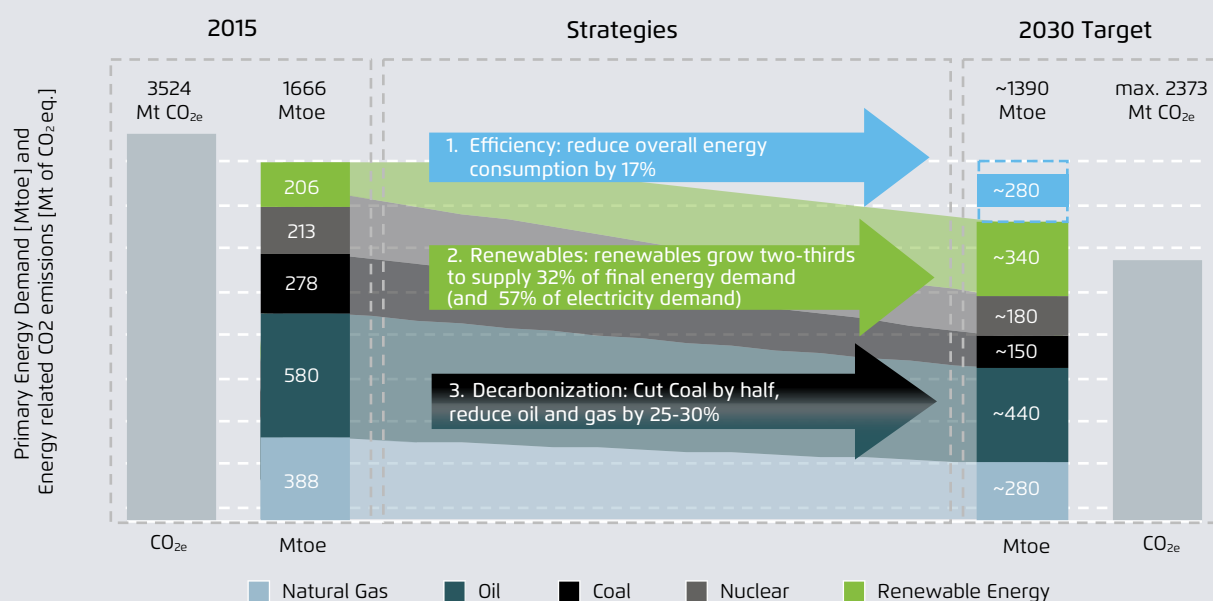
coal will need to be cut by half, gas to be reduced by 30 percent and oil by 25 percent – asking for socially just concepts for this transition.

The European Energy Transition 2030 is a political project that concerns us all. It will demand European politics to address key issues to make it happen. In this report we suggest ten priorities and four flagship initiatives. The report is complemented by a technical document that translates the recommendations into a concrete work plan for the new Parliament and the new Commission.

I hope you find this report inspiring and enjoy the read! Comments are very welcome.

Patrick Graichen,
Executive Director Agora Energiewende

Strategies for a cost-efficient transformation of the energy sectors by 2030



Own calculations based on Commission modelling for the Clean Energy Package and EU Long-term Strategy

Summary

1. The 10 megatrends shaping tomorrow's energy systems

1. Decarbonization challenge

As climate change accelerates, societal pressure to act increases

2. Deflation of fossil fuel prices

Coal, oil and gas prices will remain low, but become more volatile

3. Decrease in costs

Clean-energy technologies are becoming cheaper than conventional and fossil technologies

4. Digitalization

Energy and transport systems are becoming smarter and better networked

5. Electrification

The power, transport and heating sectors are increasingly interconnected

6. Dominance of fixed costs

Future energy systems will be dominated by investment costs

7. Influential cities

More people in cities means that urban decisions are becoming more important for enabling low-carbon lifestyles.

8. Demographic and economic change in rural areas

Many regions must cope with ageing and shrinking populations and face shifting economic opportunities

9. Decentralization

Small-scale solutions enable but also require proactive energy consumers

10. Interdependence

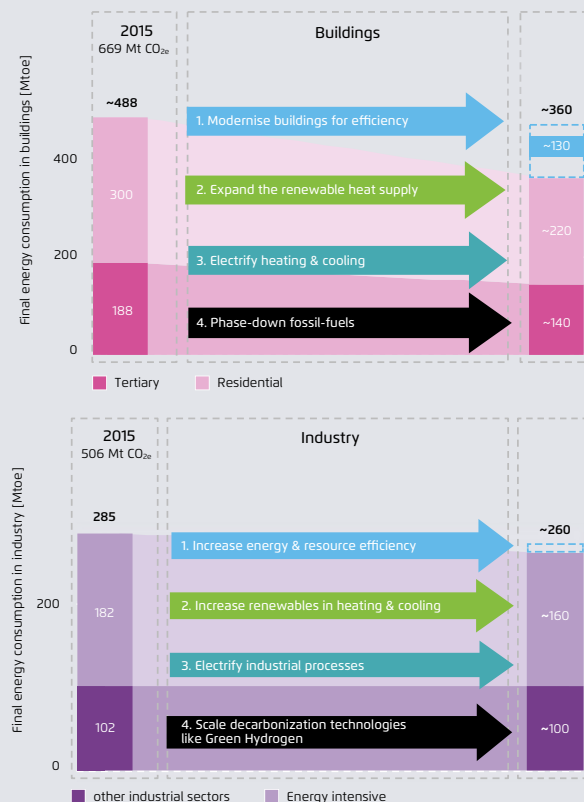
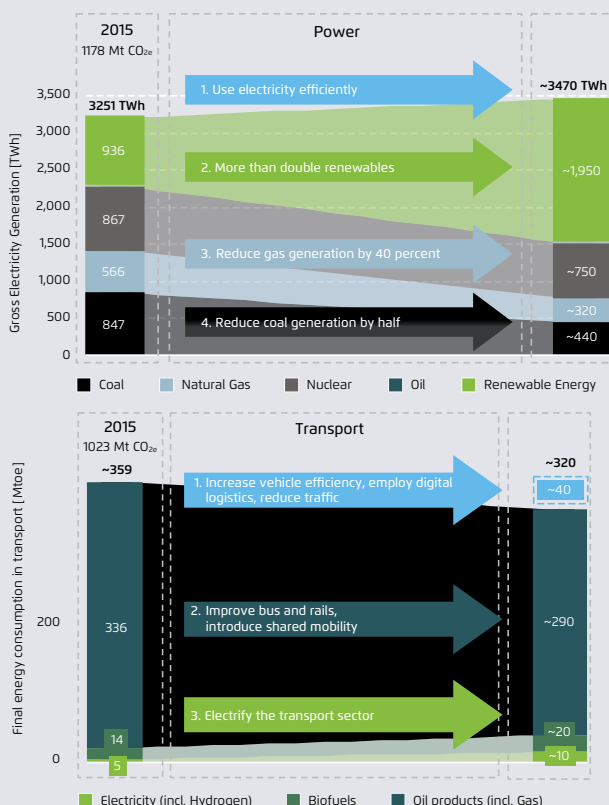
Progressive integration of European economies and energy systems is demanding more coordination between countries

2. A European clean-energy transition based on solidarity, security, competitiveness, and innovation

Advancing the European clean-energy transition is a task that primarily falls to national and regional governments. No national energy transition will be exactly alike. Irrespective of these differences, all Member States must find solutions for pursuing

the same set of objectives over the next decade. On the way, strong EU-level action will be needed to help resolve issues related to **solidarity**, to the **security** of energy supply and energy systems, to **competitiveness**, and to **innovation**.

3. Strategies for a cost-efficient energy transition by 2030



See section 3

4. The benefits of a just and clean European energy transition outweigh the costs if properly planned and managed. – Key Findings

1. The clean-energy transition will require considerable investment, but its costs will be comparable with those of the current energy system
2. The clean-energy transition will increase GDP and employment
3. The shift to renewables and energy efficiency increases energy security
4. Avoided health costs more than outweigh the additional costs of an energy transition
5. Meeting 2030 targets will not raise household expenses relative to the reference scenario
6. Overall industrial competitiveness is not at risk but energy- and trade-intensive branches need support

5. Ten Priorities for the next European Parliament and the next European Commission to deliver what is agreed and to accelerate where possible

Priority 1

A vibrant action framework for 2030: Kickstarting and supporting implementation at the national level

Priority 2

A state aid framework that enables and advances Europe's clean-energy transition

Priority 3

A shadow price on carbon emissions to guide infrastructure planning and investment decisions

Priority 4

Reducing emissions from individual mobility: An early and ambitious review of CO₂ standards for cars

Priority 5

Reducing emissions from heavy transport by raising ambition and increasing member state flexibility

Priority 6

Opening up a pathway to decarbonize aviation and shipping fuels

Priority 7

A strong, competitive, and sustainable battery industry in Europe

Priority 8

Establish the foundation for a scalable green hydrogen economy

Priority 9

"Buy Clean Europe": Create lead markets for zero-carbon cement and steel

Priority 10

Prioritize the energy transition in the new European budget for 2021–2027

6. Four Implementation Flagship Initiatives that address the social dimension of the energy transition and break through existing bottlenecks

Initiative 1

Renovate 1 million buildings by 2025 on an industrial scale

Initiative 2

Add 10 million solar roof-tops by 2025

Initiative 3

Support at least 100 cities in Europe to initiate the decarbonization of their heating and cooling networks by 2025

Initiative 4

Support a just transition in coal regions

7. Stepping up the EU's climate ambitions: The pathway to Net-Zero Europe

Europe should commit to a 50% reduction in greenhouse gases relative to 1990 levels, with up to 4% through international cooperation under Article 6 of the Paris Agreement.

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Introduction

In December 2015 at the Paris Climate Conference, the EU was part of the "high ambition coalition" that successfully pushed for the adoption of a global, legally binding target for stabilising climate change "well below 2 °C above pre-industrial levels" as well as for "efforts to limit the temperature increase to 1.5 °C above pre-industrial levels." The Intergovernmental Panel on Climate Change released a special scientific report end of 2018 that determines that net zero emissions by 2050 are necessary for stabilising rising temperature-levels at below 2 degrees Celsius, thereby avoiding the worst and dangerous impacts of a changing climate system.

Over the course of 2014-2018, the governments of Europe and representatives of the European Parliament adopted a comprehensive set of EU laws setting new, legally binding targets for climate and energy policy in Europe in a 2030 perspective. By 2030, the Member States of the European Union will: 1) reduce their greenhouse gas emissions by 40 percent compared to 1990 levels; 2) increase the energy efficiency of their economies by 32.5 percent compared to a 2007 baseline; and 3) increase the share of renewable energies in final energy consumption from roughly 20 percent today, to 32 percent in 2030. Furthermore, in November 2018 the European Commission presented the analytical foundation for the development of an EU Long Term Strategy for climate and energy policy and a political vision for achieving a Net Zero economy by 2050.

Simply put, these headline commitments for 2030, the aspirational goals for 2050 and the new legal framework mean that Europe as a continent has embarked on a clean energy transition based on an efficient use of energy and a progressive decarbonization of the energy supply. This report describes the "big picture" that emerges when looking at where we stand today, where we need to be in 2030, and what we need to do to get there.

Chapter 2 describes the mega-trends which drive the energy system, such as digitisation, automation or falling costs of clean energy technologies. They will shape the context in which the energy transition takes place.

Chapter 3 makes the case for a strong European Union to help citizens and governments to cope with concrete issues that will arise in implementation and devise innovative solutions for new issues that will arise on the way.

Chapter 4 and **Chapter 5** describes comprehensively how today's energy system (power, buildings, transport as well as the industry sector) will change to be consistent with the 2030 climate and energy targets, as well as what it will mean in terms of investments, costs and benefits for industry, households and the EU economy as a whole.

Chapter 6 gives an overview on the EU's 2030 climate and energy framework adopted over the course of 2016 to 2019 and highlights the main implementation challenges at the national level and the EU level.

Chapter 7 presents ten EU-level initiatives (3 on implementation, 3 on transport, 3 on industry, 1 on the next EU budget) to decisively advance Europe's clean energy transition.

Finally, **Chapter 8** highlights the important role that early, strong and decisive domestic action for advancing a just and clean European Energy Transition will play in creating the political foundation for the EU committing to further raise its climate & energy ambition in 2020.

1 The 10 megatrends shaping tomorrow's energy system

Within the space of a few years, the energy transition has become a global phenomenon affecting energy supply structures and the way citizens and companies can contribute to rapid decarbonization. The power sector is leading the way through the transition as solar and wind power increasingly replace coal, natural gas, and nuclear energy as the world's main energy sources.¹

The energy transition is shaped, enabled, and constrained by overarching "megatrends". By this we mean physical, technological, societal, and economic factors that are largely outside the control of national decision-making. Governments or companies must decide how to respond to these trends. They may speed up change that results from these trends ("riding the wave") or seek to delay their impact on the status quo. No country or company is able to insulate itself from these megatrends; all must find ways and strategies to cope with them.

The existence of megatrends does not mean that each country in Europe is impacted in the same way at the same time. National energy systems differ quite significantly, depending on natural endowments, past energy policy choices, or specific regulatory traditions. However, understanding these megatrends is crucial for meeting specific energy policy goals in specific European, regional, national, and local contexts.

The following ten energy transition megatrends shape, enable and constrain policy choices on climate and energy in Europe:

1. Decarbonization challenge
2. Deflation of fossil fuel prices
3. Decrease in costs
4. Digitalization
5. Electrification
6. Dominance of fixed costs
7. Influential cities
8. Demographic and economic change in rural areas
9. Decentralization
10. Interdependence

1.1 Decarbonization challenge: As climate change accelerates, societal pressure to act increases

The planet is now 1 °C warmer than before industrialization.² At the 2015 UN Climate Conference in Paris, the global community agreed to limit the rise in the planet's surface temperature to "well below 2 °C" by reducing greenhouse gas emissions. So far, national pledges to reduce emissions cover only about one-third of the reductions needed to reach the Paris goal.³

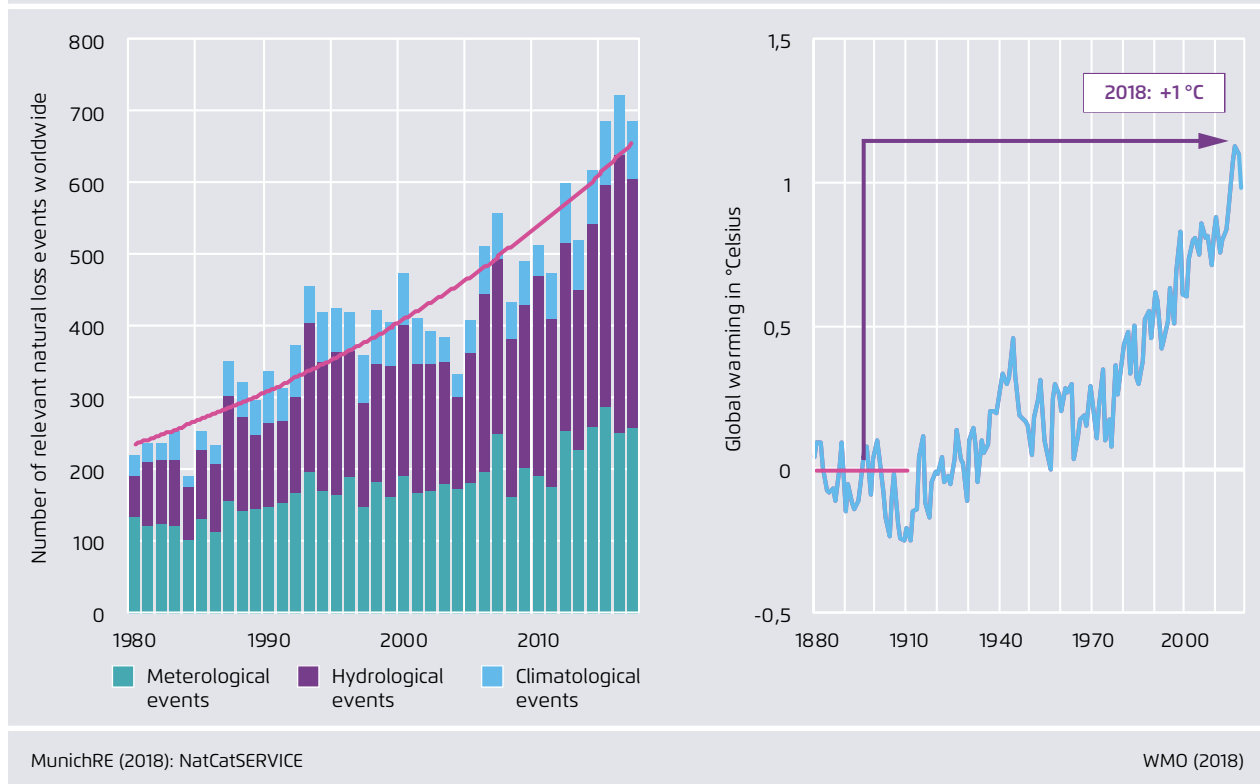
At the same time, across the globe, people have started to experience the impacts of climate change: rising sea levels, floods, droughts, the extinction of animal and plant species, and regional food shortages. The projected effects of a changing climate on the earth

system and on society differ dramatically whether temperature increase is limited to 1.5, to 2, or to 2.5 °C. Even every tenth of a degree makes a noticeable difference.

The already visible impacts of climate change together with growing awareness of the looming climate crisis have increased the pressure to act, regardless of the political system. Citizens as well as businesses and investors are demanding effective measures for the rapid decarbonization of today's energy systems. Often, such demands coincide with pressure to reduce air pollution from cars, coal power stations, and industrial facilities.

Climate change is real: since 1970 the rate of global warming has accelerated, and since 1980 extreme weather events have tripled

Figure 1



1.2 Deflation of fossil fuel prices: Coal, oil and gas prices will remain low, but become more volatile

For decades, it was assumed that the prices of fossil fuels would continuously rise as demand increased and global reserves progressively depleted. Since 2014, prices for coal, oil, and natural gas have moderated. There are three reasons to believe that this reflects a deeper structural shift, and that prices for coal, oil, and gas will remain relatively inexpensive over the next years and decades:

- Today, the de facto upper price limit for oil and natural gas is no longer set by expensive deep-sea drilling, but by the much lower costs of opening new reserves of shale oil and gas.
- The continuously decreasing costs of wind turbines and PV installations also create an upper price limit for coal and natural gas, as the operators of coal-

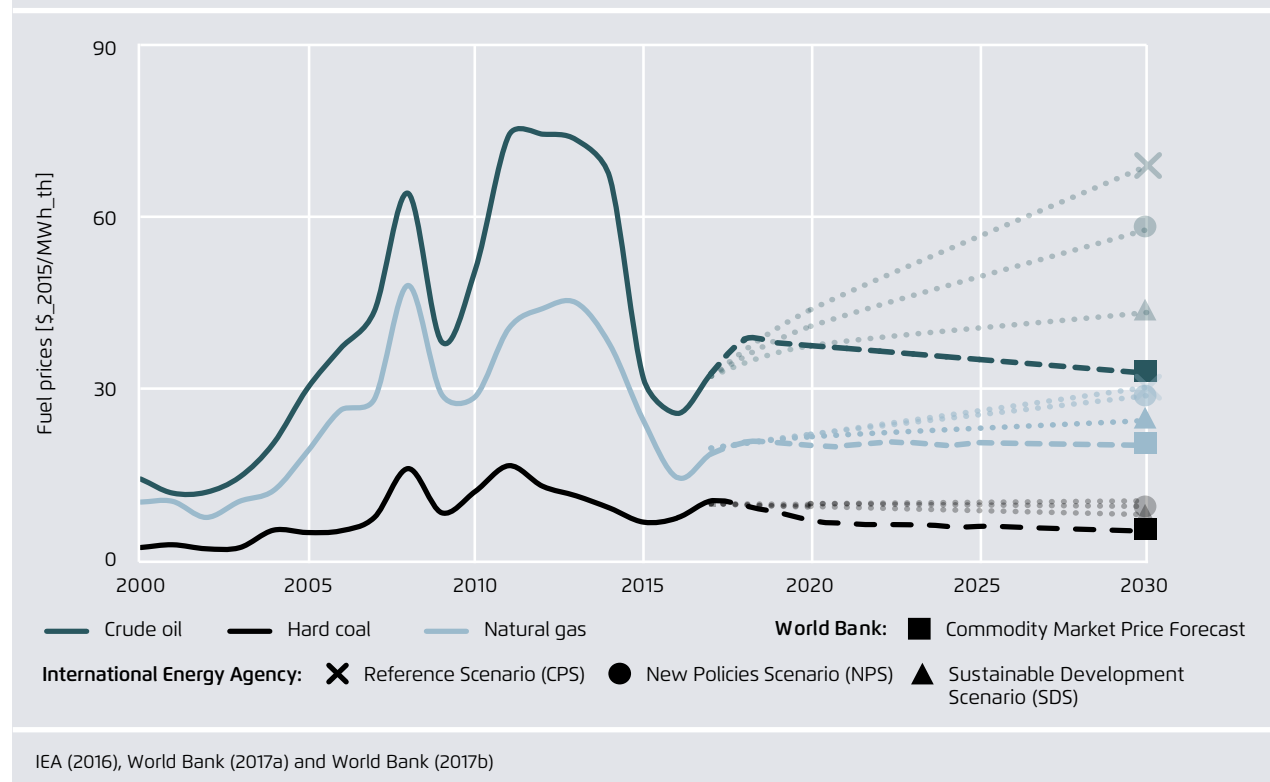
and gas-fired power plants need low commodity prices to compete with renewable energy.

- There is no shortage of fossil fuels. On the contrary, abundant quantities still exist. This is because large shares of the planet's remaining reserves of coal (80%), natural gas (50%) and oil (30%) will have to remain below the ground if the rise in global temperature is to stay under 2 °C or less.⁴

Clearly, market developments and political events may lead to spikes in fossil fuel prices. However, such spikes will be fairly short. Hence, we expect volatility to increase, but – like the World Bank – we believe that base-level pricing for coal, oil, and gas will remain at current levels.

Fossil fuel price projections forecast low to moderate price levels to 2030

Figure 2



1.3 Decrease in costs: Clean-energy technologies are becoming cheaper than conventional and fossil technologies

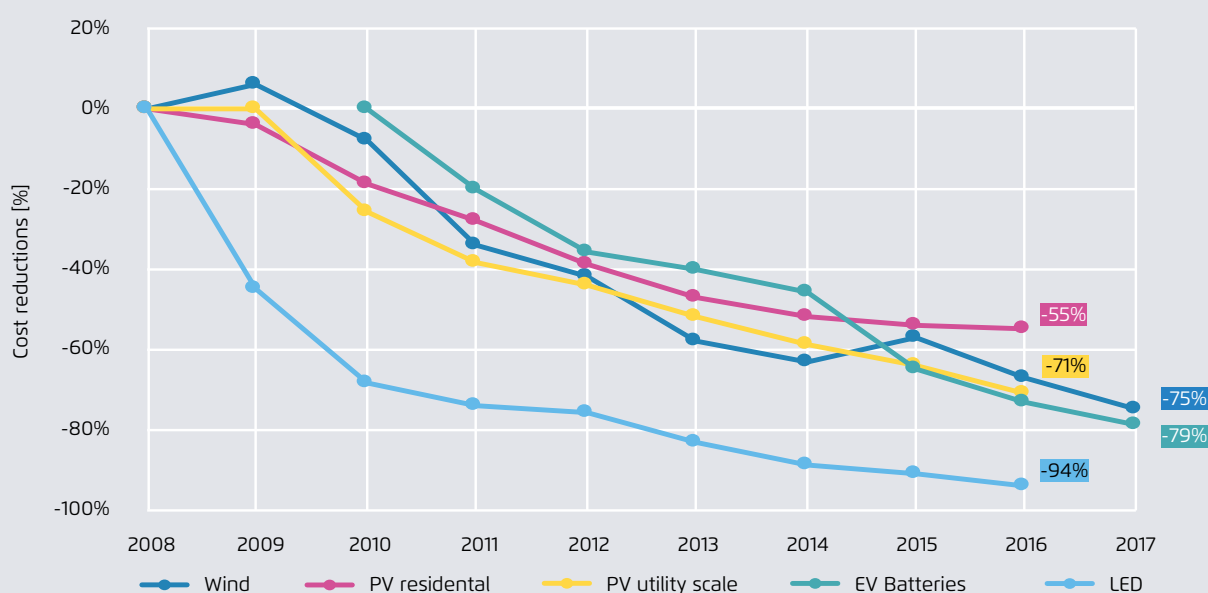
The cost of electricity generated by wind and solar power plants has drastically decreased in recent years. In more and more world regions, power from new wind and solar projects now costs less than power generated by new coal-fired, gas-fired, or nuclear power plants. In 2017, global average costs were 5 cents per kilowatt hour for new onshore wind projects and 8 cents per kilowatt hour for large-scale solar farms. The outcomes of competitive tenders for projects to be realized over the next years show that costs will fall further. Global solar and wind tenders have resulted in prices of under 3 cents per kilowatt hour,⁵ and various EU Member States have seen bids below 5 cents. Soon building new wind and solar projects in the EU will become cheaper than operating existing fossil fuel plants, signalling a key economic tipping point.⁶

A similar drop in costs has occurred for batteries. In the past seven years, the costs of lithium-ion units have fallen by over 70% to around 200 euros per kilowatt hour. As a result, electric vehicles are now taking off in the mass market. Within the next years, the end-consumer price of a fully electric mid-size car is projected to fall below the end-consumer price of internal combustion cars, which represents another economic tipping point.⁷ What is more, wind and solar power projects combined with storage are becoming competitive.

All projections suggest that these key energy transition technologies will continue to become cheaper in the future. An affordable energy-system based on clean-energy technologies is within reach.

Cost reductions in major clean-energy technologies from 2008–2017

Figure 3



NRDC (2018) Revolution now

1.4 Digitalization: Energy and transport systems are becoming smarter and better networked

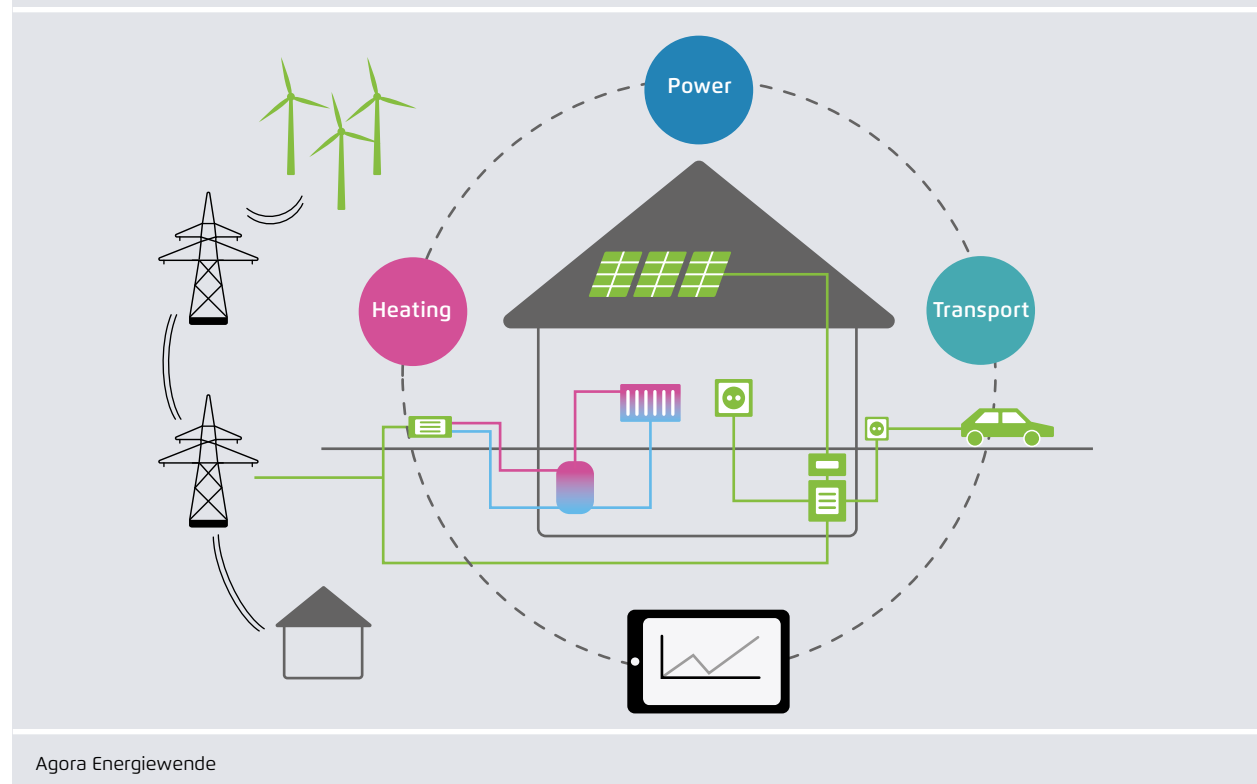
Modern information and communication technologies and new business models building on digital technology are revolutionizing the energy and transport industries. Digitalization is indeed a key enabler of the energy transition because it allows the co-ordination of supply and demand in real time. The sharing economy enables consumers to use cars and bikes with unprecedented convenience. Smart home systems optimize the use of rooftop solar installations, heating systems, battery storage, and electric vehicle charging and thereby help integrate renewables into the power grid. Value creation in the energy and transport sectors no longer comes from the sale of kilowatt hours, fuel or automobiles alone, but increasingly also from data-driven energy services.⁸

In the future, self-driving cars, peer-to-peer trading and AI-based grid monitoring will become part of the picture.

Digitalization creates opportunities but also challenges. Regulators must adapt laws to a fast-changing technological environment. They have to protect consumers' personal data and make sure the future energy system is resilient to cyber-attacks. It is also important to avoid unintended rebound effects. For example, autonomous electric cars significantly reduce carbon emissions and air pollution. But lower transport costs could also lead to increased road transport activity and increased congestion.⁹

Digital technology will enable the integration of the power, heating and transport sectors

Figure 4



1.5 Electrification: The power, transport, and heating sectors are increasingly interconnected

For the most part, power, transport, and heating have traditionally relied on separate infrastructures and different fuels. As a result, separate regulations and taxation regimes govern each energy use. Electrification is tearing down these sectoral barriers.

Electrification is often the most cost-effective approach for decarbonizing the transport and heating sectors. Leading examples are the increased use of electric vehicles in transport and of electric heat pumps in buildings. Indirect electrification, based on green electrofuels, is an important option in areas where direct electrification runs into technical difficulties, such as for heavy duty road freight, shipping, aviation and some industrial processes.

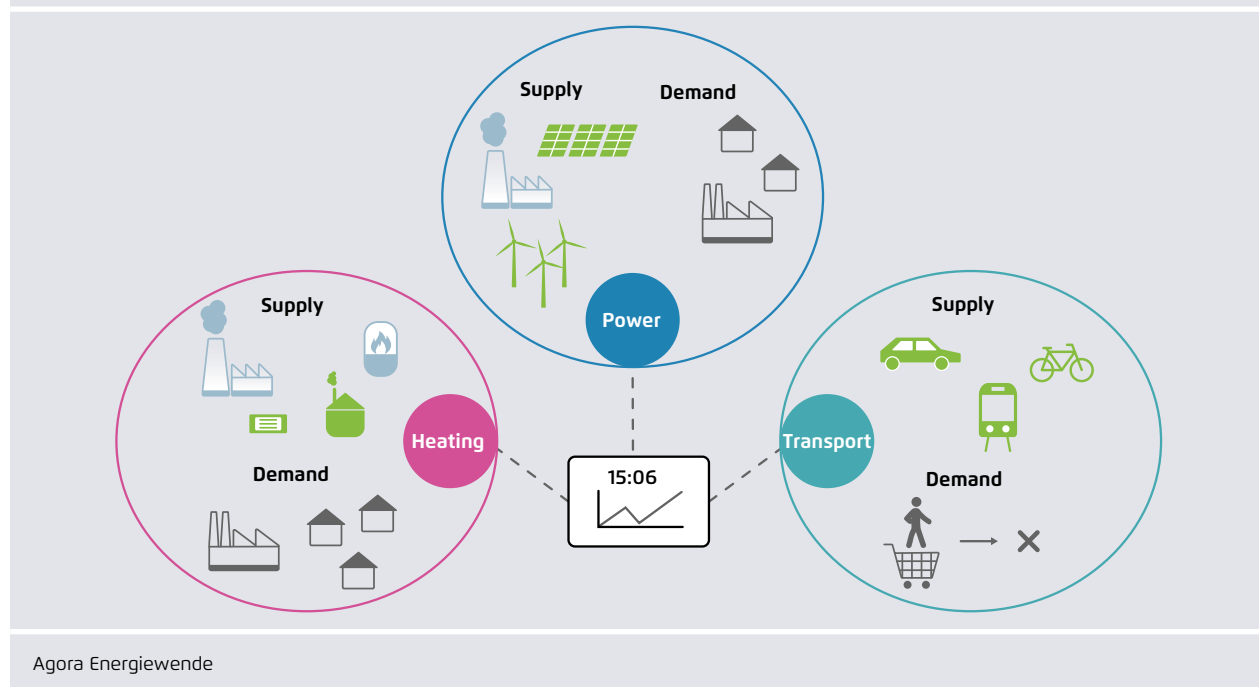
Combined with digitalization, electrification is opening many new opportunities for reliably linking power generation in the electricity system to energy demand

in transport, buildings, and industry. This helps with the energy system integration of variable renewable electricity. For example, power-to-heat can take in excess power on days with lots of wind and sun, while electric vehicle batteries can feed electricity back to the grid in hours of scarcity. The gas grid could become another key element in system integration, enabling the long-term storage of electrofuels (provided that their costs can be reduced).¹⁰

At the same time, electrification creates new challenges for power system planning, which must factor in the effects of electrification on the dimensioning of the power system and for ensuring supply security. As electromobility, heat pumps and electrolyzers for green hydrogen production become more widely used, they can push up overall electricity consumption and peak demand, reinforcing the need for efficient power use and increasing the urgency of expanding renewables.

Electrification is the key driver of a stronger coupling of power, heat and transport systems

Figure 5



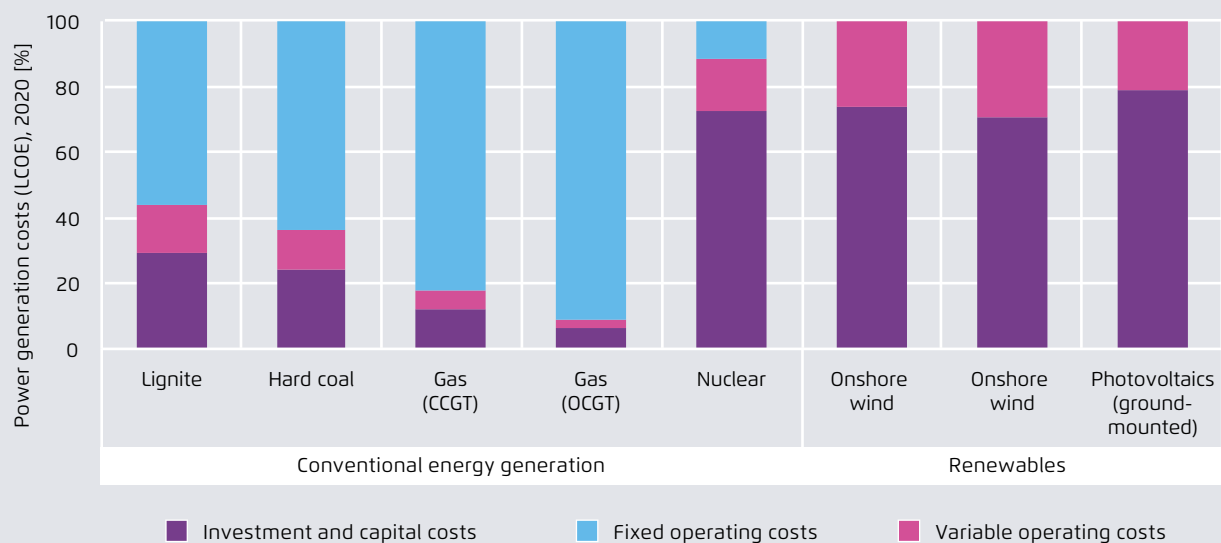
1.6 Dominance of fixed costs: Future energy systems will be dominated by investment costs

The energy transition rests on technologies characterized by high shares of up-front investment costs and low shares of operating costs. This goes for renewable power installations like wind, solar PV, and hydro, but also for batteries, electric vehicles, charging infrastructures, power grids and energy efficiency investments. The dominance of fixed costs fundamentally changes the financing structure of the energy system. Hence, to keep financing costs low requires measures that reduce the economic risk of changes in domestic political, administrative or market conditions. At the same time, clean-energy alternatives have much lower and less volatile operating costs than the current energy system that is dominated by fossil fuels. A clean-energy system is therefore much less vulnerable to external pressure, be it from changes in international fuel markets or from international political events.

The dominance of fixed costs presents a challenge to established markets and business models. For example, traditional electricity markets were designed to minimize the costs of conventional power: in any single hour, the least expensive set of power plants is chosen based on operating costs. The plant with the highest operating cost sets the price for all. In the past, this ensured that fuel costs were minimized and power plants could recover their investment costs. Today, power prices are increasingly determined by solar and wind with close to zero operational costs. This lowers wholesale prices, but may require a new power market design in the future. High up-front costs may also pose social challenges as poorer groups of society may not have sufficient savings to invest in new electric cars or in energy efficiency measures for their homes.

Renewables feature high fixed costs compared to conventional technologies, with the exception of nuclear

Figure 6



Calculations by Agora, based on IEA/NEA (2015)

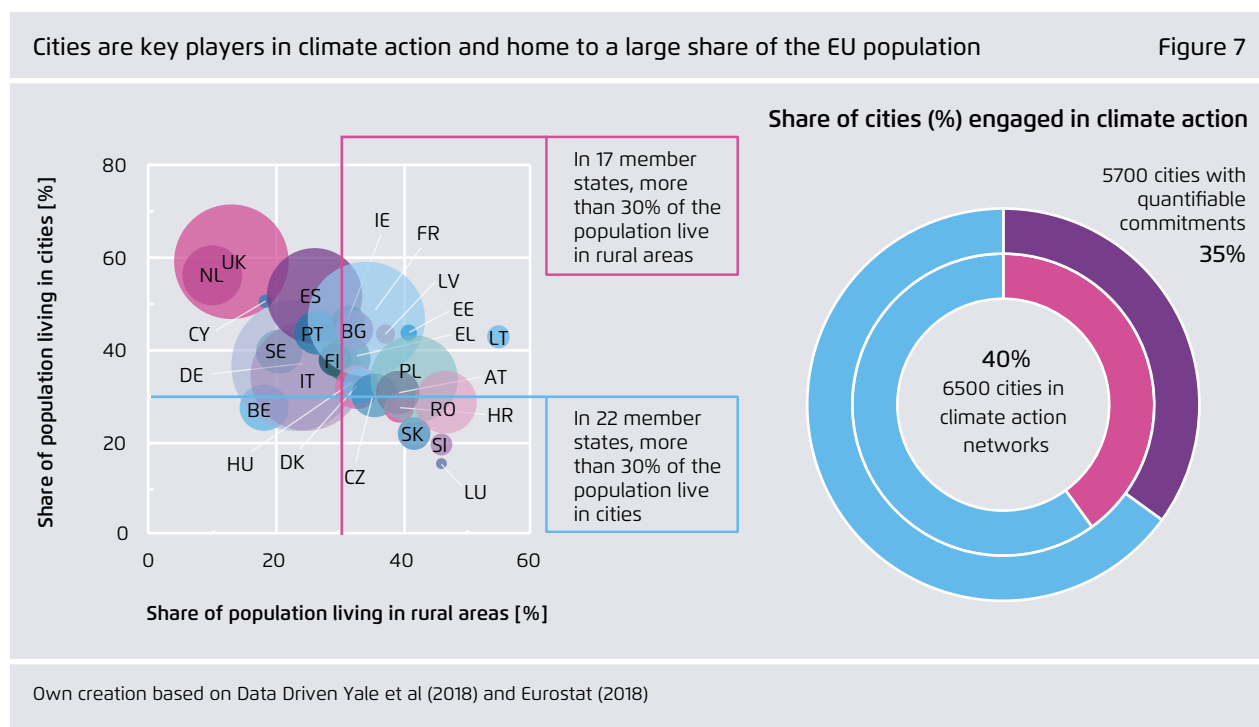
1.7 Influential cities: More people in big cities means that urban decisions are becoming more important for enabling low-carbon lifestyles.

Almost three-quarters of the EU's total population already lives in urban areas and population growth in cities and suburbs is outpacing the national average. Large metropolitan areas that offer most economic opportunities are growing particularly fast.¹¹ The resulting increase in traffic, industrial activity and infrastructure amplify environmental challenges.

Yet, in tackling these challenges, cities are becoming laboratories for low-carbon lifestyles and for electrification. Novel mobility solutions such as car, bike or ride sharing or cargo bike deliveries are easiest to implement in cities where shorter distances allow for life without private car ownership. Cities are also key markets for electric vehicles. These concepts are increasingly part of urban planning, as they increase quality of life by freeing up public space, reduc-

ing noise, pollution, and accidents. The proximity of industrial facilities and buildings also allows for distributing waste heat from factories through district heating networks. Smaller heat networks fuelled by renewables, heat pumps, and cogeneration enable the creation of new, zero-carbon neighbourhoods.

Increasingly, city governments are also asserting their growing relevance with decisions that influence policy-making at the national level. Examples include Paris' ban on diesel cars in the city centre by 2030, Oslo's comprehensive measures to support electric vehicles and New York City's decision to divest its fossil fuel-linked investments.



1.8 Demographic and economic change in rural areas: Energy transition chances and challenges

Ageing and shrinking populations are distressing the social fabric of many rural areas in Europe. Yet with the spread of wind and solar power generation and the production of renewable gases, the energy transition will offer new economic opportunities for rural areas, especially those whose solar and wind potentials are high. At the same time, the energy transition will also exacerbate existing rural challenges such as the downsizing of coal-fired power production and the loss of well-paid jobs in the coal-mining industry. Additionally, new wind onshore installations in some parts of Europe face local opposition due to concerns about landscape disfigurement.

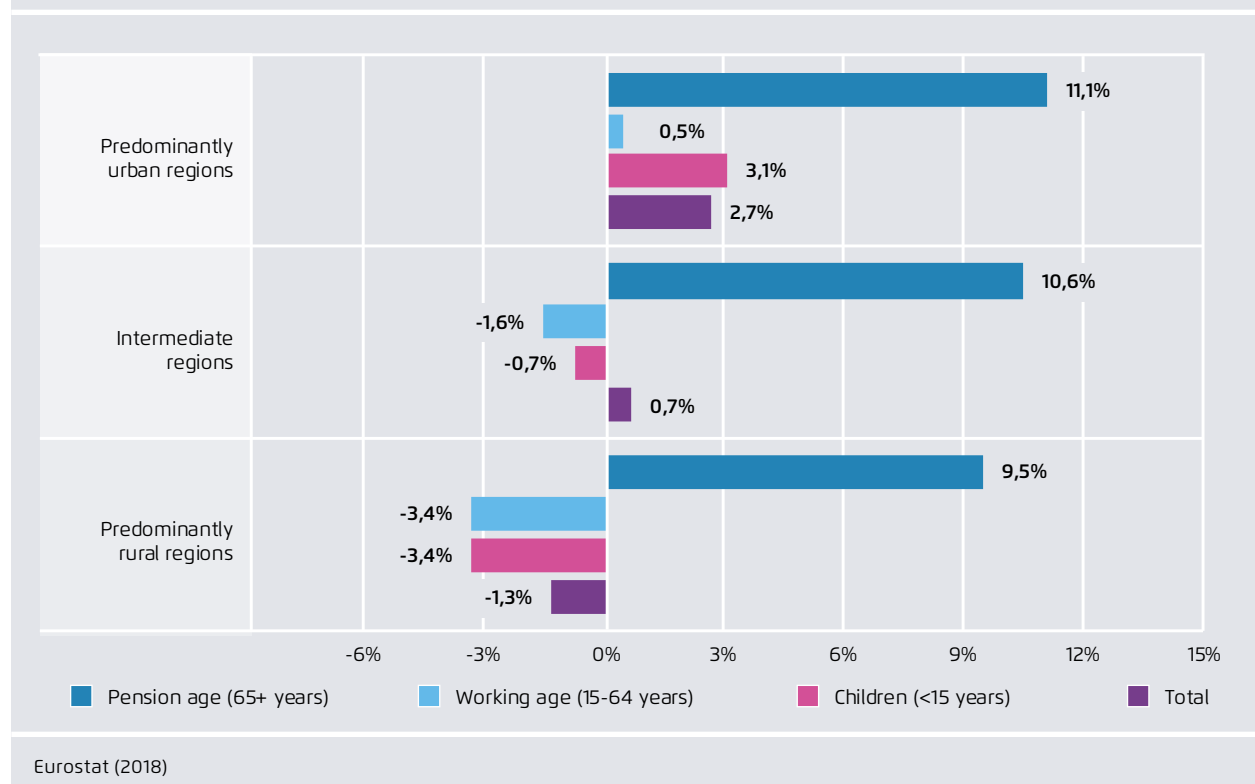
If the transition to clean-energy is to win broad-based social acceptance, strategies must be developed that

anticipate and, where necessary, mitigate its impact on rural populations. The *gilet jaune* movement that erupted at the end of 2018 in France has shown that the political neglect of distributional effects – in this case, of a planned fuel tax – can undermine the public acceptance of a policy instrument long called for by climate and energy experts. By contrast, Spain's successful coal phase-out agreement shows that proper planning and intense dialogue with rural stakeholders can help regional representatives and trade union officials embrace effective climate protection strategies.

Rural areas will therefore play a pivotal role in the social acceptance of the energy transition. Only if populations in rural areas see benefits instead of merely higher costs will the energy transition succeed.

Demographic change in the EU between 2011 and 2016: % change in urban and rural areas

Figure 8



1.9 Decentralization: Small-scale solutions enable but also require proactive energy consumers

In the traditional business model, a small number of companies organized as monopolies plan the electricity system from the top down and transport electricity from their own power plants via their own grids to end-consumers. Heating and gas networks also still largely rely on a small number of centralized producers.

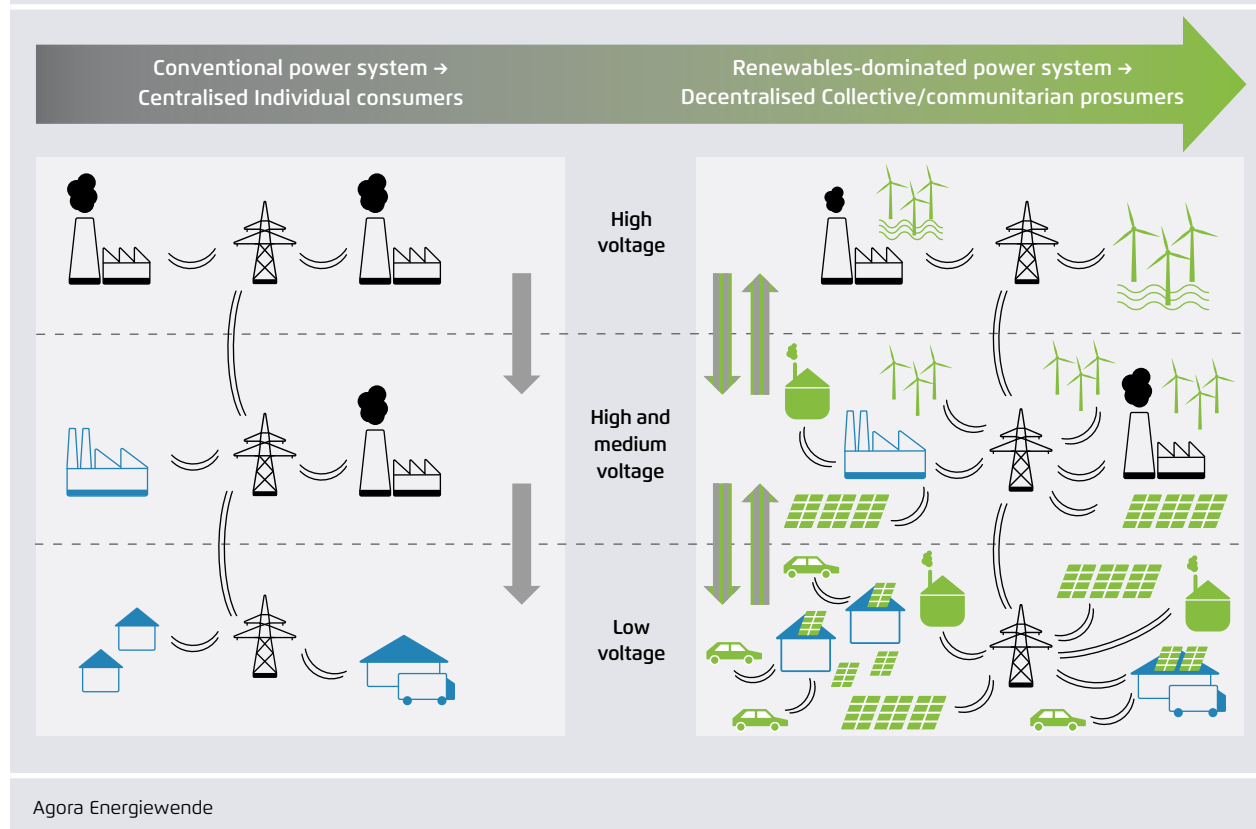
The liberalization of electricity markets in Europe and the introduction of millions of renewable energy plants has upended this system. The model of the future is decentralized. In it, producers both large and small generate electricity or heat at every level of the grid. So-called prosumers directly consume the energy they produce. And thanks to digitalization,

distributed electricity demand applications such as electric cars or heat pumps can be used as resources to integrate variable and decentralized wind and solar electricity production.

In this system, consumers are active agents of the energy transition. Its success will depend on their investment decisions, their willingness to adopt new technologies and mobility services, and their acceptance of energy infrastructure. If citizens and communities are to become the active agents we need, they must have a say in planning while seeing the benefits of the energy transition for themselves.

The power system's "one-way street" is replaced by a decentralised, networked structure

Figure 9



1.10 Interdependence: Progressive integration of European economies and energy systems is demanding more coordination between countries

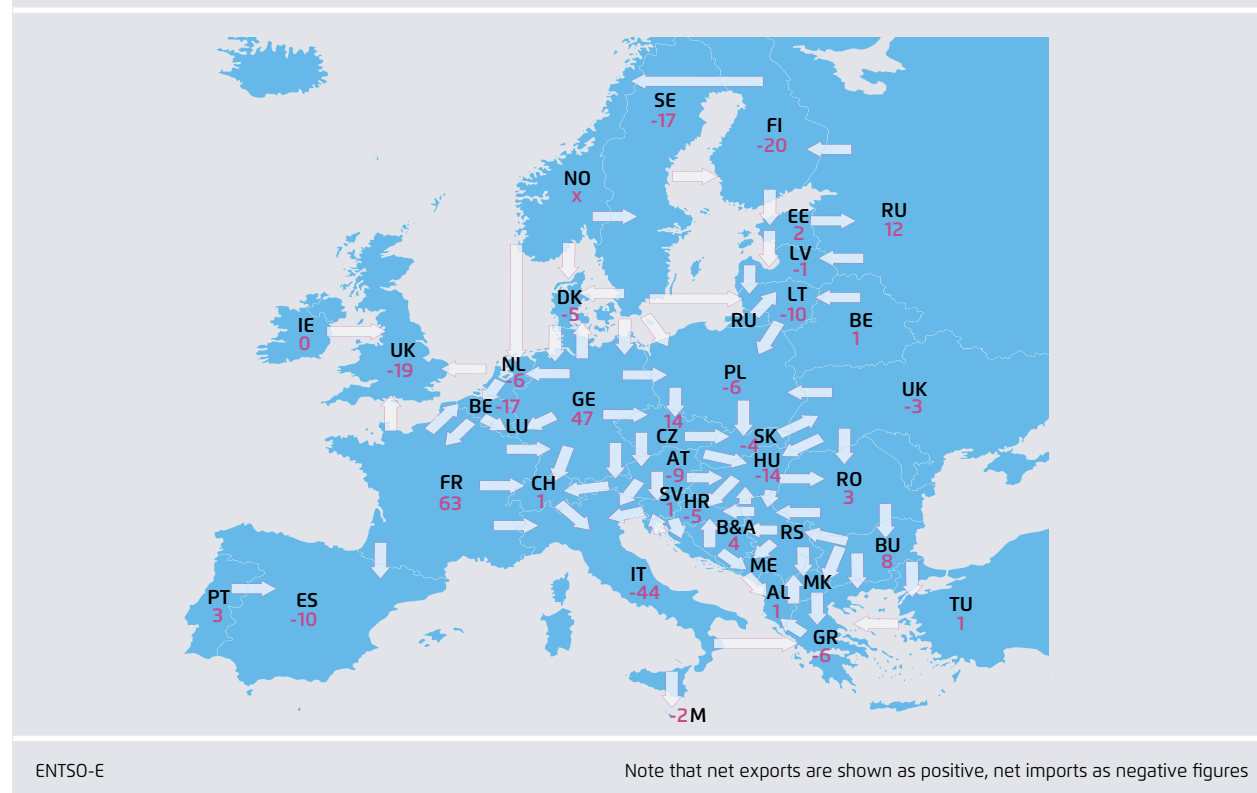
The single market lies at the heart of the European project and supports the free movement of people, goods, services, and capital. The single market has continuously deepened economic integration between Member States, including trade in energy. Although some regional fragmentation remains, energy market integration in the EU has made impressive progress: Nearly all Member States now have access to at least two sources of gas and 17 Member States have installed electricity inter-connectors with a capacity equal to at least 10% of the country's total power generation capacity.¹² Cross-border links enable power market coupling and the convergence of wholesale power prices. Further

integration will improve the EU's resilience to electricity and gas supply shocks, support the use of variable wind and solar power, and provide a better deal for consumers through increased competition.

But greater integration also requires the proper management of the many interdependencies that result. Increasingly, national energy policies affect neighbouring countries – such as the coal and nuclear phase-outs under discussion in Germany and France¹³ or state taxes on cars – and can have distributional effects. That is why enhanced co-ordination of national energy policies will be a key factor in making Europe's energy transition a success.

Net physical electricity flows between countries (TWh) in 2018

Figure 10



2 A European energy transition based on solidarity, security, competitiveness, and innovation

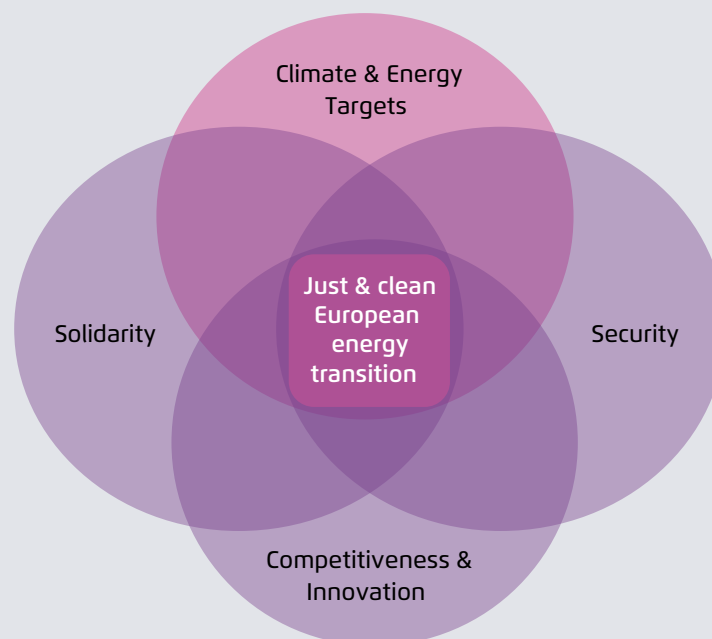
The EU's 2030 climate and energy targets seek a European energy transition based on greater energy efficiency and the gradual phase-out of fossil fuels in favour of low emission and carbon-neutral energy sources (Chapter 3 describes the phase-out in more detail). Advancing the European energy transition is a task that primarily falls to the Member States, and no national energy transition will be exactly alike. Each starts with different conditions regarding, say, energy mix make-up, renewable energy potential, and building stock. But irrespective of these differences, all

Member States must find solutions for pursuing the same set of objectives over the next decade.

Achieving these objectives will not be easy, and challenges will arise. Strong EU-level action will be needed to help resolve issues related to **solidarity**, to the **security** of energy supply and energy systems, to **competitiveness**, and to **innovation**. While meeting its climate protection targets Europe must not lose sight of these public policy concerns. (See Figure 11.)

Overlapping priorities and effective policies for a just and clean European energy transition

Figure 11



Authors' own illustration

Solidarity

Energy transition policies are one driver of social and economic change. But as the recent protests by the *gilet jaune* movement in France have shown, decision-makers must also address the social and distributional impacts of clean-energy policies, particularly their effect on the less affluent. Moreover, it is important that officials explain and emphasize the concrete benefits of the energy transition (e.g., new jobs, cleaner air). These steps will increase the legitimacy and public acceptance of the energy transition.

EU-level measures are important for ensuring that the costs of the European energy transition are distributed fairly and that its benefits accrue equally to everyone. Some examples:

- A key priority for reducing carbon emissions in the buildings sector is **energy efficiency retrofitting** and the replacement of fossil fuel-based home heating systems with low-carbon alternatives (see Chapter 3.3). Due to the high up-front costs of retrofits, many homeowners will need public financial incentives or aid to undertake them. This is particularly true for lower income households that do not have sufficient savings. For Member States with lower levels of per capita GDP, EU funds make up a significant share of public investment – more than two-thirds in some cases. These countries will seek to make financial incentives for homeowners using EU funding. Without dedicated support from the EU, it will be hard to accelerate the rate of residential building renovations throughout all of Europe.
- By 2030, there will need to be at least 40 million electric vehicles on the road in Europe and at least 4 million publicly accessible recharging points. Achieving this will require annual investments totaling 2.7 to 3.8 billion euros per year from 2021¹⁴ (see Chapter 3.6). Judging from the current plans of Member States, the **roll-out of electric cars** will likely happen in three distinct waves: the first will occur in western Europe and Scandinavian

countries in the early 2020s, followed by southern Europe (Spain, Portugal, Italy, and Slovenia) in the mid-2020s and central and eastern Europe by the end of the decade (with the emergence of a second-hand market for electric vehicles). It is important the EU supports the creation of a public charging infrastructure throughout Europe, lest electric car owners be left stranded in countries and regions where electrification still lags behind and privately funded infrastructure is not yet a viable business model.

- **By 2030, Europe will need to halve its use of coal** in the power sector (see Chapter 3.2). Currently, 41 regions in 12 Member States rely heavily on economic revenues from coal mining and coal use. The industry directly employs around 185,000 people across the EU. In December 2017, the European Commission launched the Coal Regions in Transition Platform to foster dialogue between governments and stakeholders in affected regions and to facilitate the modernization of the structural and economic changes that will result from a coal phase-out.

Security

Maintaining a high level of energy security is a fundamental objective of all energy policy. Energy security has two dimensions: energy supply security, i.e. the reliable access to energy, and power system security, i.e. the reliable operation of the power system. As Europe's energy market becomes more integrated, maintaining energy security will increasingly have to occur at the regional or EU-wide level. Some examples:

- As its domestic fossil fuel production has declined, the **EU has become more dependent on fossil fuel imports**. This makes Europe vulnerable to increasingly volatile market prices for fossil fuels – see megatrend 1.2 – and puts it at risk for supply shortages. This is particularly true of natural gas. For example, Russia provides 42% of EU gas imports and is the sole supplier to nine Member States.¹⁵ The 2014 gas crisis between Russia and

the Ukraine affected gas imports to some countries in Eastern Europe. In response, the EU allocated significant funds to a number of infrastructure projects. These created at least two entry points for pipeline gas in every Member State, strengthened the EU's internal gas network, enabled the reverse flow of gas from west to east, and constructed additional terminals for importing liquified natural gas. They also required Gazprom to sell its gas freely in the EU's single market. In the medium to long term, the European energy transition will shift production to renewable energy sources and reduce energy consumption. Together, these factors lower the EU's dependence on fossil fuel imports and reduce its economic vulnerability to volatile fossil fuel prices and its political vulnerability to gas supply disruptions.

- **Increasingly interconnected power markets in Europe will provide electricity supply security at a lower cost** to taxpayers and consumers. EU laws have established the "software" for electricity trading across borders and for the integration of intermittent renewable electricity from wind and solar PV. But EU laws and financial support have also been instrumental for upgrading the power system "hardware." They established concrete targets for interconnection capacity between Member States and expedited the construction of transmission lines needed to operate an integrated trans-European power network. The recently adopted Clean Energy for All Europeans package defines additional important steps. These include the use of a European resource adequacy assessment for determining whether Member States have enough collective generating capacity to ensure reliable power supply in times of high electricity demand and avoid outages. Furthermore, it requires Member States to work together to devise regional risk preparedness plans and obliges transmission system operators to strengthen regional power grid coordination.
- **Digitalization** enables the **evolution of more integrated and smarter energy systems**. (See megatrend 1.4.) But it also increases the risk of

cyberattacks and the theft of private personal data. The **EU's General Data Protection Regulation** entered into force in May of 2018 and is widely regarded as one of the most comprehensive and advanced **privacy protection** systems in the world. It allows all EU citizens to determine who accesses their personal data and how it is used. These fundamental rights also apply to the increasingly "smart" energy world and must be respected by companies throughout Europe, including tech giants such as Google, Facebook, and Amazon. As for **cybersecurity**, EU laws already establish a common framework for ensuring that Member States and other actors cooperate across borders in preventing cyberattacks.¹⁶ The European Cyber Security Agency provides independent expertise for the support of Member States. Moreover, a new European framework for certifying products and services as "cybersecure" will ensure that citizens throughout Europe benefit from the same advanced cybersecurity standards.

Competitiveness and Innovation

The economic and political success of the European energy transition will closely depend on the ability of European companies to be leading innovators at home and abroad. In some areas of the energy transition (e.g. the power system integration of wind and solar) Europe is among the leading regions worldwide, providing many export opportunities for new technologies and services. Europe is also home to powerful industries (cars, chemicals, etc.) that will need to invest in low-carbon technologies in the coming years to ensure their competitiveness in a net-zero economy. Political decision-makers will need to support the political and economic conditions that facilitate and foster these changes. The EU-level framework is critical in this context. Some examples:

- The EU has the largest market in the world with 500 million consumers. Furthermore, European institutions have worked to **create and standardize a level playing field** for companies active in

Europe. A European energy transition will create **leading markets** for related products, services, and skills. European standards ensure that all companies active in the EU single market comply with the same basic requirements. Early standardization in Europe (for smart meters, cybersecurity design, charging stations, wind blade design, etc.) will make the EU the main reference point for companies overseas that plan to do business in Europe.¹⁷ Complementing the strong push-and-pull effect of the EU's single market is the decision of countries in Europe to speak and act with a **single, unified voice in their international economic relations**.¹⁸ This is particularly important when dealing with major competitors such as China or the United States of America.

→ European treaties give the European Commission a powerful mandate to regulate the EU's single market. This is particularly important for companies that incur significant additional costs through energy transition policies while facing stiff international competition. For example, energy-intensive companies are frequently exempted from levies that finance renewable energy infrastructure. The direct economic benefits that result from such exemptions count as state aid. Under **EU State Aid rules** these exemptions must, therefore, first be approved by the European Commission. EU State Aid and **EU competition laws** frequently come into play when seeking to scale nascent markets for energy transition products and services such as green hydrogen (see measures 6.2 and 6.6–6.9 below).

→ The **EU's multiannual budget** is important for **advancing innovation** that enables and accelerates the European energy transition. The EU research budget for the 2014–2020 period (Horizon 2020) stands at 77 billion euros¹⁹. The proposed new EU research budget for the 2021–2027 period (Horizon Europe) will likely be significantly larger, at around 100 billion euros. Furthermore, it will

(i) earmark a larger share of research grants for climate protection and energy transition,

- (ii) include dedicated “research missions” to focus EU funding around specific global challenges (including climate change), and
- (iii) broaden the scope of funding beyond academic research by means of a new financing instrument that reduces the risks of companies that move highly innovative products from an advanced development stage to the market (i.e., bridging the so-called valley of death).

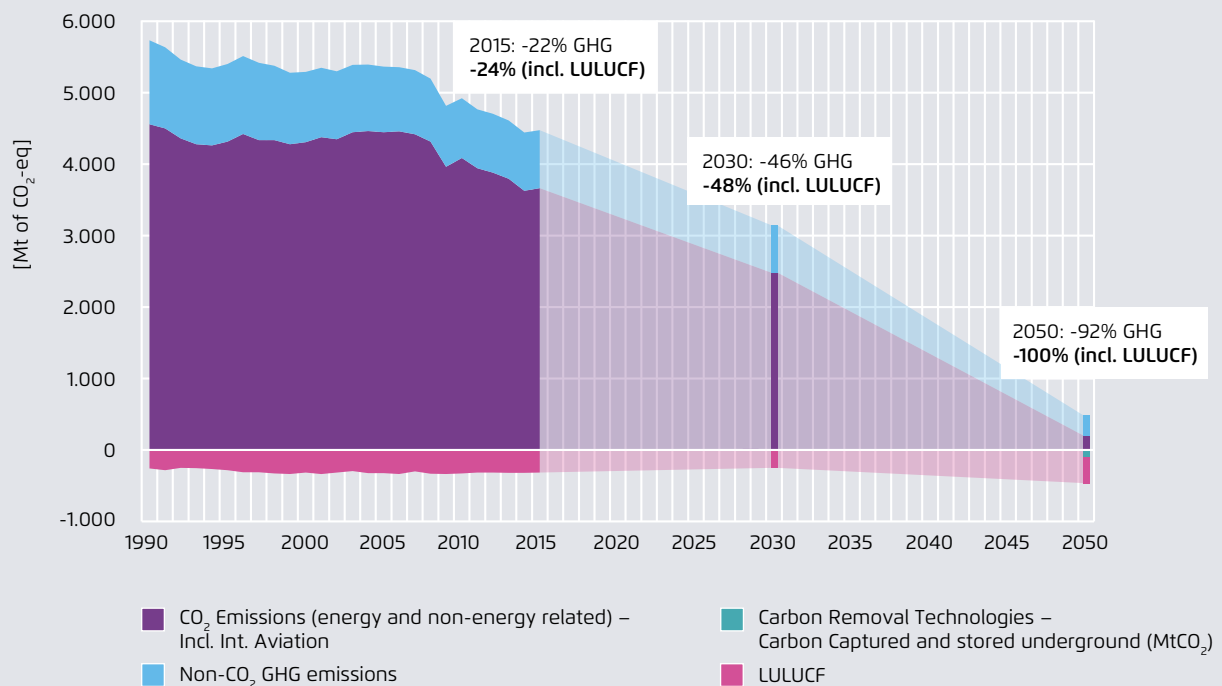
3 The European energy transition in 2030: a snapshot

The Paris Agreement calls for an early peak in emissions, followed by a decline to net-zero emissions in the second half of the century. In November 2018, the European Commission released a Communication on an EU Long Term Strategy for decarbonizing the European economy, which explores strategies to achieve "carbon neutrality" in Europe by 2050. The long-term pathways assessed by the Commission would result in emissions reductions ranging from 80% (from 1990 levels) up to net zero emissions by 2050.²⁰ This will require a sweeping transformation of the energy system, involving nothing less than a complete redesign of the power, buildings, transport and industry sectors.

2030 is an important milestone in the European energy transition, which ultimately aims to achieve a carbon neutral economy. The analysis accompanying the EU Long Term Strategy shows that the respective energy efficiency and renewables targets of 32.5% and 32% in the EU's 2030 framework would lead to greenhouse gas emissions reductions of 46% below 1990 levels by 2030 – significantly beyond the officially agreed reductions target of 40%.²¹ On the basis of the latest scenarios, the following sections show what the 2030 targets actually mean: how our electricity demand will be met, how we will provide heating & cooling, and how we will move around."

Greenhouse gas emissions from 1990-2015 and in 2030 and 2050 target scenarios

Figure 12



Own analysis based on EEA (2018) and EU Long Term Strategy

3.1 Strategies for the cost-effective transformation of the different energy sectors by 2030

Energy consumption has remained stable since 1990. While coal consumption has nearly halved, consumption of renewables has tripled, and gas and nuclear consumption has also increased. Where renewables are concerned, hydropower has remained stable, biomass consumption has tripled, and wind and solar have gone from being marginal energy sources to key elements of the power system.

In 2015, the EU consumed roughly 1,630 Mtoe of energy, 94% of which was accounted for by energy production and the remaining 6% by non-energy-related uses (such as the chemicals sector). Fossil fuels supplied roughly three quarters of the total energy consumed.²² The remainder was provided in almost equal parts by nuclear (14%) and renewable energy sources (13%). Coal accounts for around a quarter of the EU's electricity and heat generation, but for nearly three quarters of its CO₂ emissions. Oil makes up 94% of final energy consumption in the transport sector and nearly all transport-related emissions. Gas accounts for one third of final energy consumption in buildings, but for nearly two thirds of emissions. At the point of combustion, bioenergy emits the equivalent of 14% of the EU's energy-related CO₂ emissions. These emissions are not included in the overall account, however, in order to reflect the plants' absorption of CO₂ during growth.

There are significant transformation and production losses among fossil fuels and nuclear. Two thirds of primary nuclear energy, for example, is lost. On account of these conversion losses, only 72% of all primary energy can be used by end consumers. Around half of all final energy is used for heating, while a third is used for transport fuels, and a fifth for electricity.

A four-pronged approach: increase efficiency, expand renewables, electrify end-uses, and initiate a coal and oil phase-out

How can we cost-effectively meet the EU's 2030 climate & energy targets and set out on a path toward deep decarbonisation by 2050? The Commission's analyses for the EU Long Term Strategy and numerous other studies identify the following strategies as indispensable building blocks:

1. Increase energy efficiency

Energy efficiency is the key to successfully decarbonizing the power, heating, and transport sectors. Attempting to reach the EU's climate and energy targets without it would not only be more expensive, but could also encounter public resistance given the additional clean energy supply that would be required. In comparison with 2015, the EU will need to cut its energy consumption by around 17% by 2030 (or around 26% against 2005 levels).²³ The buildings sector will play a particularly important role here. After 2030, energy efficiency will need to continue to increase at a significant rate. Consumption will need to fall by at least a third and may even need to be halved by 2050 to achieve deep decarbonisation.²⁴

2. Scale up the deployment of renewables

The second pillar of the energy transition consists in the massive deployment of renewable energy. By 2030, the proportion of the EU's gross inland energy consumption accounted for by renewables needs to almost double to 25% (in 2015, renewables accounted for 12.4% of consumption).²⁵ Wind and solar both need to triple, and will then account for just over half of the increase in renewables production. In the Commission's scenarios, biomass will grow by less than 50% in relative terms, but will see the greatest increases in absolute terms. Hydro and geothermal will grow slightly.

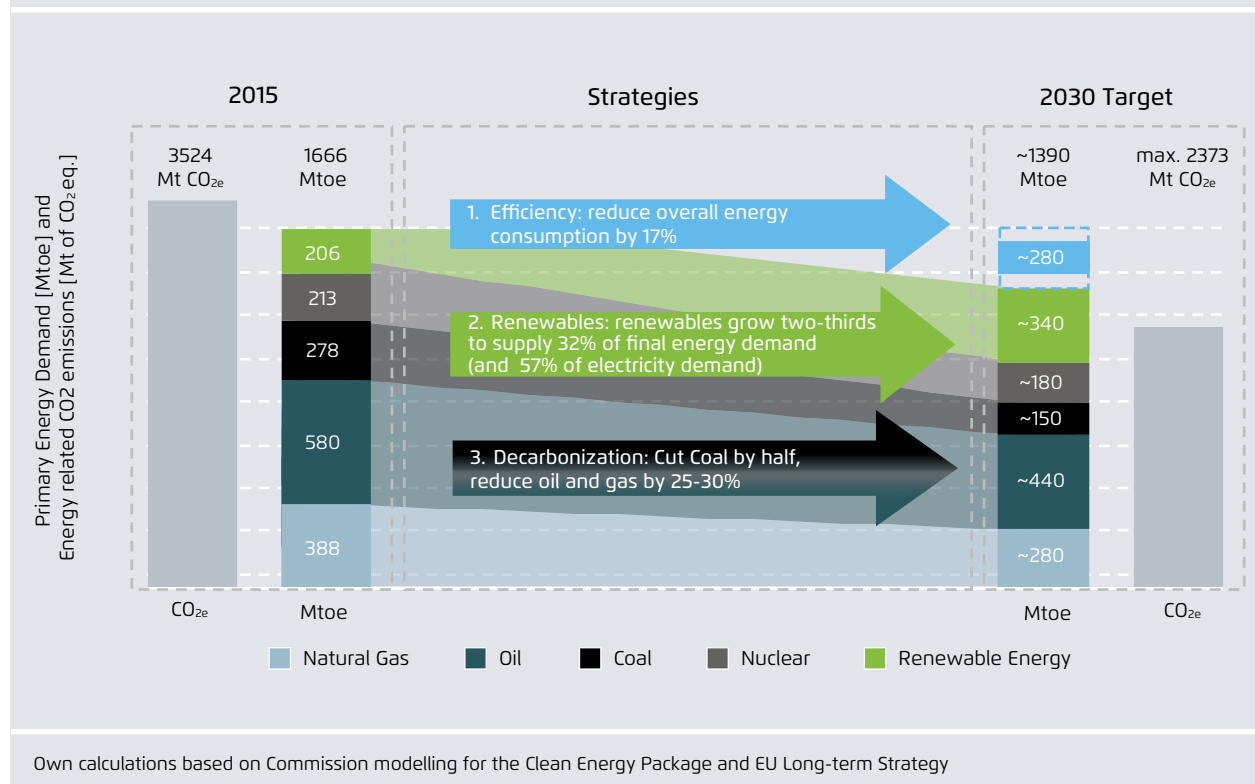
Renewables will play a particularly dominant role in the power sector, but will also be increasingly used in heating & cooling and transport. Deep decarbonisation will not only be facilitated via the direct electrification of buildings, transport, and industry with renewable power, but also by the direct use of renewables such as solar thermal, geothermal, and biomass in heating & cooling and advanced biofuels in transport (primarily for aviation and shipping purposes). Penetration levels for biomass-based renewables are nonetheless limited by their economic and production potential, the constraints involved in sustainably supplying them, and competing uses in non-energy-related, industrial applications (such as wood and bio-feedstock). Instead, renewable gaseous fuels, i.e. biogas, biomethane and green electrofuels generated from renewable electricity, could play an increasingly important role across sectors. After 2030 in particular, they will have a key role in enabling a carbon neutral Europe by 2050.

3. Maximize electricity usage and electrify nearly everything

As electricity increasingly becomes a cheap zero-carbon energy carrier, the transformation of the power sector provides a major opportunity to decarbonize other sectors as well. The electrification of these areas can either take place through the direct use of electricity (in heat pumps, power-to-heat, electric vehicles, and electrified rail) or indirectly through the production of electrofuels, particularly green hydrogen. In this way, the large-scale deployment of renewables will lead to the increasing electrification of our economy. As a share of final energy demand, electricity will grow from 21% in 2015 to 28% in 2030, and will at least double by 2050.²⁶ It will also facilitate the growing integration of the power, buildings, transport, and industrial sectors, so that the lines between them first fade and eventually disappear.

Strategies for a cost-efficient transformation of the energy sectors by 2030

Figure 13



4. Phase out fossil fuels

The fourth strategy is to reduce the use of fossil fuels in each of the energy sectors, since this will contribute most to cutting CO₂ emissions. In the EU's Long Term Strategy, coal usage in the EU nearly halves by 2030 against 2015 levels and virtually disappears by 2050. Oil usage will need to be cut by a quarter by 2030²⁷ and will likewise be almost completely phased out in the long-term. Finally, natural gas usage will need to fall by almost a third by 2030, and will increasingly be replaced by renewable and low-carbon gaseous fuels in the run-up to 2050.²⁸

All of the above and more are needed to ensure carbon neutrality by 2050

In order to achieve a net zero economy by 2050, these four mitigation strategies will all need to be implemented as fully as possible, but they will not suffice by themselves. In the agricultural sector, for example, some emissions will always remain (i.e. non-CO₂ emissions from livestock and fertilizer usage) and the aforementioned strategies do not address the many of the emissions in the industrial sector and parts of the transport sector (heavy-duty vehicles, aviation, waterborne transport). Reducing these emissions will require additional measures, including a significant research and innovation drive and, most importantly, the deployment of new technologies. Only through such deployment can the necessary technology and related infrastructure become commercially viable.²⁹ Furthermore, in order to achieve net zero GHG emissions, the remaining emissions will need to be offset by greater absorption into **natural sinks** (requiring afforestation and improved soil management) and the deployment of **negative emissions technologies** (such as bioenergy combined with carbon capture and storage). CCS is also necessary for carbon reduction in certain industries, and particularly for cutting process emissions (in cement production, for example).

3.2 Transforming the power sector for 2030

In 2015, power and centralized heating plants were responsible for 24% of total greenhouse gas emissions and 29% of CO₂ emissions in the EU28. Together, they constituted the EU's largest CO₂ emissions sector. Emissions nonetheless varied significantly between the various member states due to their different consumption levels and energy mixes. On account of its high carbon content, coal makes up a disproportionately high share of emissions in the sector, accounting for around 25% of EU electricity and centralized heat generation and for 72% of CO₂ emissions. Over the past 25 years, the EU generation mix has already changed significantly, which has had the effect of pushing down the power sector's CO₂ emissions by a quarter between 1990 and 2015, despite an increase in electricity generation by roughly a quarter.³⁰ During this period, the share of coal in the generation

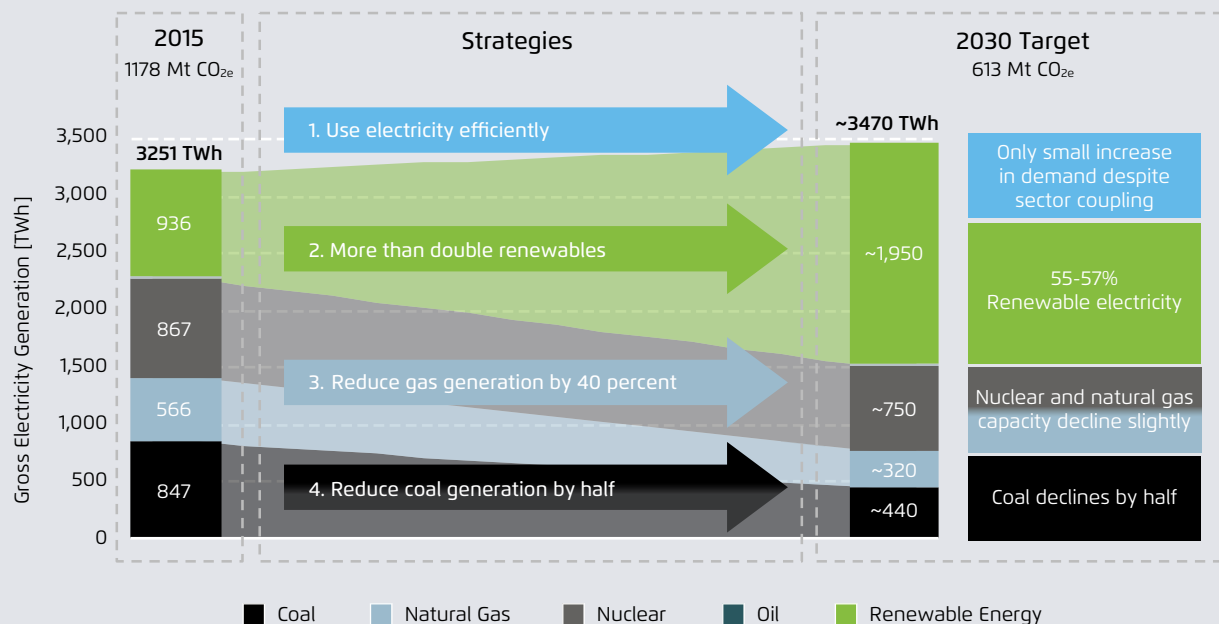
mix fell from 39% to 24%, while the level of renewable generation more than doubled from 13% to 30%. Most of the growth in renewables was due to wind, solar PV and biomass while hydro remained stable. Nearly two-thirds of current electricity consumption is accounted for by buildings and more than one-third by industry. Transport and agriculture each only represented roughly 2% of electricity demand in 2015.

The power sector challenge: a third of electricity comes from renewables, but coal emissions remain high

The power system has the greatest potential for cost-effective decarbonisation in the economy as a whole. The sector will therefore need to halve its emissions between 2015 and 2030 and become

Transforming the power sector for 2030

Figure 14



Own calculations based on Commission modelling for the Clean Energy Package and EU Long-term Strategy

almost fully decarbonized by 2050. The carbon intensity of electricity production can be reduced by increasing the proportion of **low carbon electricity sources** (i.e. renewables and nuclear energy) from 55% to 76% by 2030,³¹ while reducing fossil fuel (and particularly coal) generation by an equivalent amount. Onshore wind, offshore wind, and solar power have won the race to drive down technology costs and will constitute the leading technologies in the power sector by 2030. This will involve significant growth in rooftop PV systems, which will become standard not only for single-family homes but for any building with a suitable roof. Sectoral integration and energy efficiency will create further opportunities for energy companies and energy service providers, which will add value to the EU economy. Flexible power markets and intelligent networks that digitally integrate renewable energy installations, demand side management, and energy storage will ensure that security of supply remains as high in 2030 as it is today. These new technologies will nonetheless require new safeguards against cyber-attacks. Moreover, additional electric vehicles and heat pumps have the potential to significantly increase overall power consumption and demand variability, particularly on the low-voltage grid. These changes pose a challenge for the power system, since they may complicate grid operation and significantly increase the need for investment in new generation and grid reinforcement to meet higher peak demand. The scale of these changes will make it necessary to ensure that the adequacy of the single electricity market design remains high on the agenda in the coming decade in order to ensure cost-effective, zero-carbon power generation while avoiding stranded assets and maintaining public support.

Three strategies for 2030

1. Efficiency first: maintain a stable electricity demand despite closer sectoral integration

Energy efficiency is a key strategy in ensuring the cost-effective decarbonisation of the energy system. This is because investment in electrification and sectoral integration can only be limited by reducing overall energy demand in the buildings, industrial, and transport sectors, and by increasing the efficiency of end-use appliances. In the Commission's modelling, final electricity demand and gross electricity generation only rise slightly (by 8.5% and 6.9%, respectively) between 2015 and 2030 on the back of efficiency measures in these sectors.³² In the deep decarbonisation scenarios, direct electricity consumption increases by 50%, while overall electricity generation increases more than twofold (relative to 2015) due to indirect electrification (such as green hydrogen).

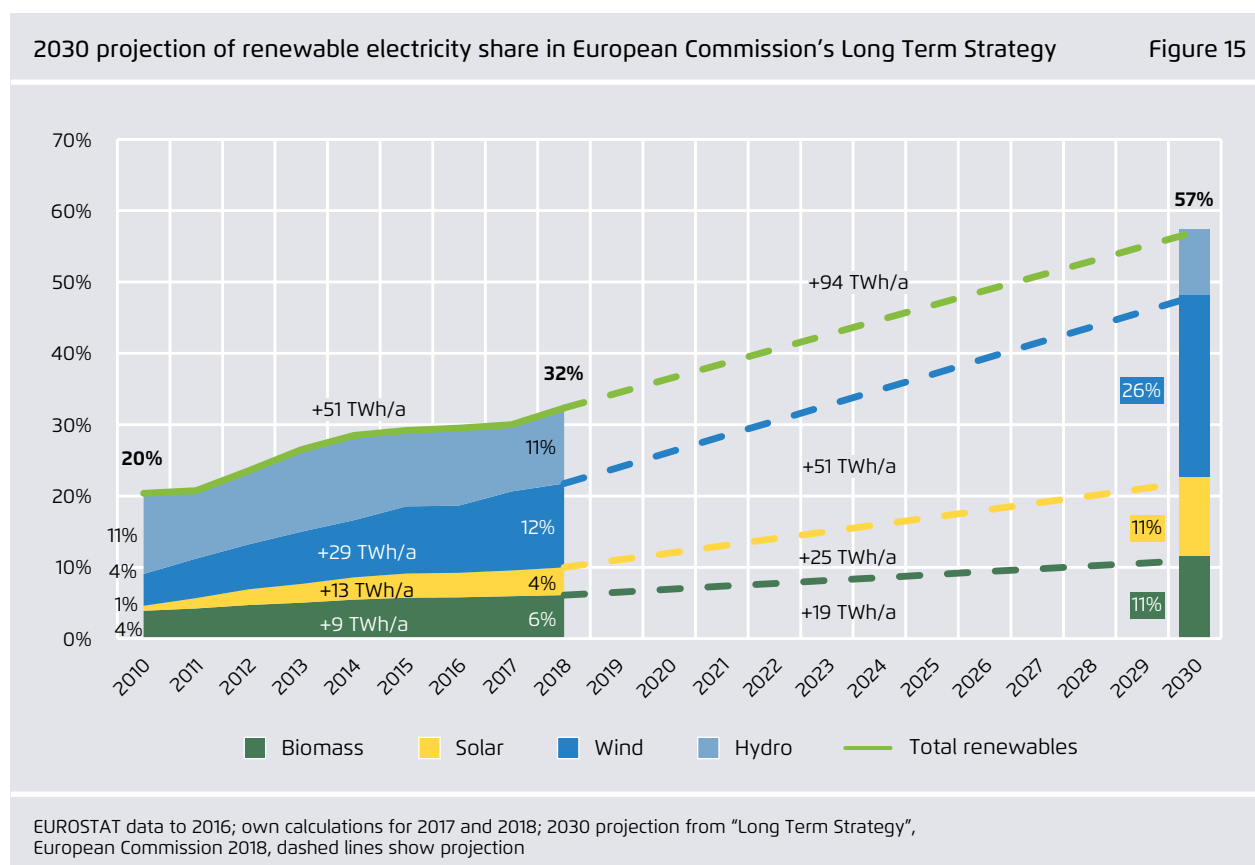
2. Reduce fossil fuel generation, coal by half

Significant reductions in coal capacity will be needed to facilitate the growth of renewables and ensure cost-effective decarbonisation. Given the high carbon intensity of coal, Europe needs to cut coal-fired generation and capacity by around 50% between 2015 and 2030 if it is to halve its energy-related CO₂ emissions.³³ In order to guarantee continued security of supply, wind, solar, and other low-carbon resources (such as biomass, biogas and hydropower plants, along with nuclear, demand response, and storage and interconnection) will need to fill the gap left by these capacity reductions. Limited new build projects and efficient use of the existing gas-fired capacity will help to cover peak demand. Member states and TSOs will need to better co-ordinate and improve long-term planning to minimize stranded assets and guarantee cost-effective solutions. Towards 2050, coal capacity will fall even further as the power sector becomes almost completely decarbonized in nearly all of the scenarios included in the EU Long Term Strategy.

3. More than double renewables

The overall share of renewables will increase from 30% in 2015 to 57% in 2030, with wind and solar roughly tripling from 12% in 2015 to 37% in 2030. While the level of solar will grow from 3% to 11% in the Commission scenarios, onshore and offshore wind clearly remain the dominant technologies, and are set to become the largest individual source of electricity by 2030, when they will account for 26% of generation. Hydro will remain stable, while bio-mass generation will increase by roughly 50%. Wind and solar combined will account for 53% of total net installed capacity by 2030, due in part to the need to add additional renewables to meet new power demand in other sectors with low carbon power. By 2050, Europe's **power sector** will need to achieve far higher levels of renewables in the range of 81 to 85%.³⁴

However, the Commission also expects a significant increase in bioenergy consumption after 2030,³⁵ which raises serious sustainability concerns.



3.3 Transforming the buildings sector for 2030

Buildings (and the people living in and using them) account for more than 40% of all natural gas consumption in the EU. Roughly 60% of final electricity consumption and nearly two thirds of overall heating & cooling demand comes from residential and service sector buildings. As a result, buildings currently account for the largest share of final energy consumption in the EU – around 40% of total consumption in 2015. Between 1990 and 2015, building-related emissions fell by roughly 25%, while energy consumption grew by 11%. Energy consumption in buildings is still far from efficient. Three quarters of buildings in the EU were built when energy efficiency requirements for buildings and equipment were limited or non-existent, and due to low renovation rates (which currently stand between 0.4% and 1.2% per year) most of these will still be energy inefficient in 2050.³⁶ Moreover, almost 50% of buildings in the EU are equipped with inefficient, fossil fuel-based boilers, many of which have exceeded their technical lifetime. More than two thirds of energy in buildings is used for space heating alone (71% in 2012).³⁷ In 2015, 34% of the total energy supply to buildings was provided by natural gas, with a further 15% coming from petroleum and 13% from electricity. Hard coal only provided a marginal 8% of supply. Direct renewable heating & cooling made up the remaining share and was largely supplied using solid biomass. In 2012, district heating satisfied 9% of overall EU heating demand for buildings and industry, the bulk of which was generated using natural gas, coal and biomass.³⁸

Buildings: the sector with the most durable capital stocks

In 2030, the buildings sector will be cleaner and far more efficient than it is today: energy consumption is predicted to fall by a fifth and CO₂ emissions by more than a third relative to 2015. These improvements will be seen despite a growing population, increased

commercial activity and greater average household incomes, which are all traditional drivers of energy consumption.³⁹ Almost half of all buildings will either be new or will have been modernized to meet today's high energy standards for greater efficiency and comfort. A vast increase in the diffusion of energy efficient appliances and "smart" energy management systems will help to further moderate energy demand and ensure energy is used more wisely. The dirtiest heating systems, fuelled by oil and coal, will be replaced by low-emissions systems such as heat pumps and efficient district heating, which will increasingly be sourced from renewables (including solar thermal, geothermal, and biomass), large-scale heat pumps, and waste heat. In a transitional period, gas will continue to be used, but will increasingly be burned in hybrid heating systems that combine heat pumps with hydrogen or gas-fired boilers as part of an initial step toward decarbonizing less efficient buildings. In the run-up to 2050, the remaining building stock will need to be fully decarbonized by at least doubling the historical renovation rate and converting all remaining buildings to use renewable heating & cooling.

Four strategies for 2030

1. Modernize buildings to improve efficiency

In order to transform the buildings sector in a cost-effective way, final energy demand will need to be reduced by 25% by 2030. This will be achieved for the most part by improving the thermal integrity of building shells and upgrading heating appliances to more energy efficient units. To achieve the necessary reductions in energy consumption, renovation rates will need to be at least doubled and all new buildings will henceforth need to be nearly zero energy buildings.⁴⁰ This transition to efficient building stocks will also enable a far more significant shift toward renewable heating and cooling fuels in both the medium and long term.

2. Expand the renewable heating supply

Where the transition from fossil fuels to carbon-neutral sources is concerned, the optimal supply option will be determined by the specific local circumstances, including renewable energy potential, the feasibility of district heating & cooling, the local building stock, and heating needs. There are many sources of renewable heat for buildings and district heating networks, including solar thermal, geothermal energy, ambient energy via heat pumps, woody biomass from waste & residues, and waste heat from industrial processes. These need to be rapidly scaled up so that the level of renewables in heating and cooling energy increases from 19% in 2015 to 32% in 2030 and to 55–80% in 2050⁴¹. In a 2030 perspective, this increase will largely be accounted for by ambient energy generated by renewable electricity-driven heat pumps. By contrast, direct renewable energy supply will remain stable or even contract slightly, with biomass satisfying 9% of total heating and cooling demand in 2030

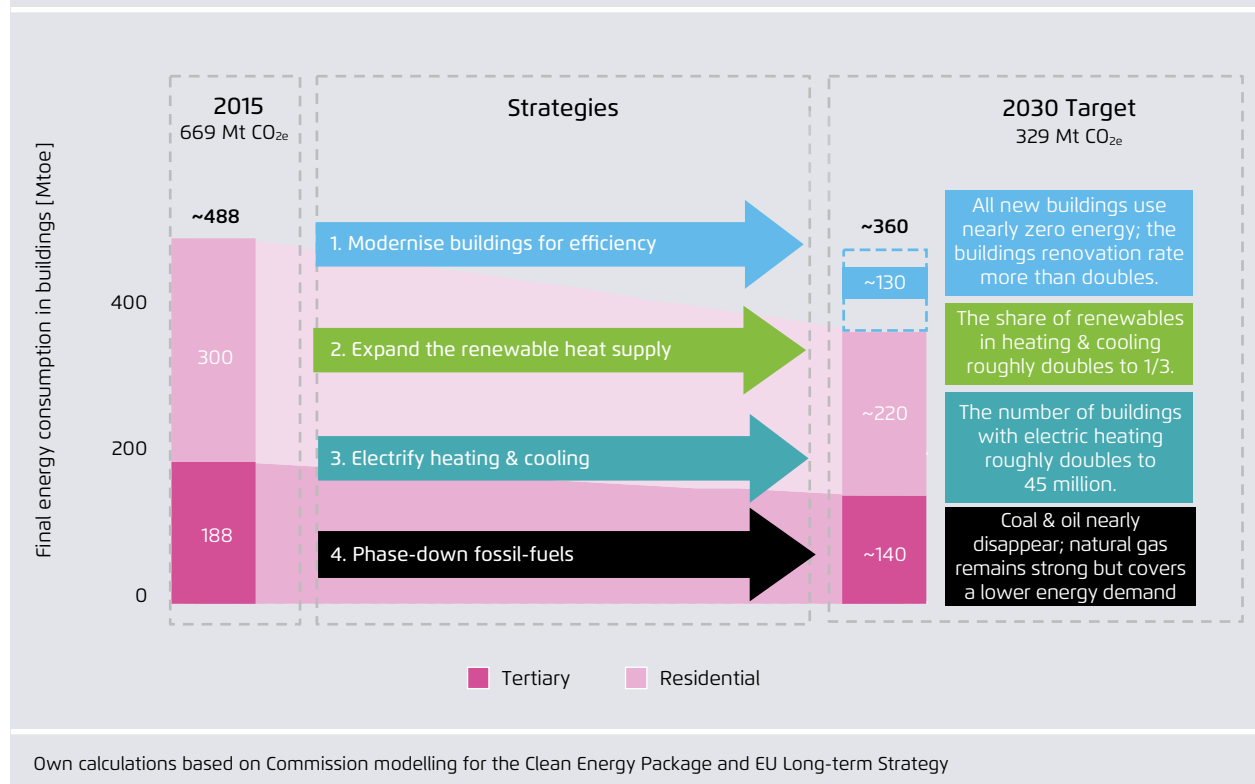
and solar thermal and geothermal heat satisfying only a marginal share. Distributed heat has the potential to satisfy up to 50% of heat demand by 2050, at which point 25–30% of heat could be supplied using large-scale electric heat pumps. This would make it necessary to reconfigure district heating networks for low-temperature operation.

3. Electrify heating using renewable power

Wind and solar power for power-to-heat and heat pumps represent the most efficient and cost-effective forms of decarbonized energy supply for the heating sector. Heat pumps can turn one unit of decarbonized electricity or gas into 3 or more units of heating or cooling, while power-to-heat can help integrate renewable power that would otherwise be curtailed. As a result, the number of central and direct gas heating units are set to plateau in the 2030s, before falling in the 2040s on the back of the electrification of space heating (through heat pumps in particular).

Transforming the buildings sector for 2030

Figure 16



By 2030, more than 45 million households will have electric heating, up from roughly 20 million in 2015. This number will roughly triple by 2050.⁴² This transition will also involve replacing existing, inefficient electric night storage heating systems, which will help to limit added power demand.⁴³ If these strategies are not successful, considerable quantities of gaseous electrofuels will be needed to ensure an equivalent level of decarbonisation.

4. Cut coal and oil usage in half

Coal and oil are the most carbon-intensive fossil fuels and their usage needs to be dramatically reduced by 2030 if the emissions targets are to be met. Greater penetration of electricity and renewables, combined with an overall decrease in demand will result in a fall in consumption of other fuels. Coal and oil will be almost absent from building-related energy consumption by 2030. Alongside electricity and direct renewables, gaseous fuels (i.e. renewable, low-carbon and fossil) will account for the bulk of the remaining consumption, though their share will drop from roughly 40% today to 31% by 2030. For economic and efficiency-related reasons, electrofuels are not likely to play a significant role in the buildings sector in 2030 unless they receive additional financial support. In the medium to long term, however, they will need to play a role in their decarbonized forms where other more efficient forms of renewable heating & cooling are not yet feasible or cost-effective.

3.4 Transforming the transport sector for 2030

Transport is a key challenge in decarbonizing Europe's energy consumption, since it is both the largest individual sector in terms of overall EU greenhouse gas emissions and the only sector with rising emissions.⁴⁴ In 2015, transport accounted for around a third of all final energy consumption in the EU. It also accounted for two-thirds of overall oil consumption, since all of the dominant transport technologies rely on oil-based fuels. Transport emissions are dominated by road transport, which in 2015 was responsible for 73% of overall transport emissions. Limited decarbonisation has been achieved by decarbonizing transport fuels using biofuels (which made up 4% of all transport fuels in 2015). Alternative powertrains (such as electric vehicles) currently only make up a small proportion of all road transport. As a result, electricity also plays a minor role in the sector (constituting 1.5% of all transport fuels in 2015), and is almost exclusively concentrated in rail transport.

Transport: the only sector with rising CO₂ Emissions

In order to make a fair contribution to cost-effective decarbonisation, the transport sector will need to decrease its emissions by 16% or more between 2015 and 2030. These emissions reductions are expected to take place against the backdrop of a 16% increase in passenger transport and a 29% rise in freight transport activity between 2015 and 2030. More than half of the increase in passenger transport activity and two thirds of the increase in freight transport activity is set to come from road transport. Further significant increases are expected in rail transport (36%), domestic and international air transport (43%), and EU marine shipping (21%).⁴⁵ Despite these developments, energy consumption in the transport sector will fall by 10%, which will help to drive a reduction in overall oil consumption of roughly 25% (final energy demand). These reductions in energy consumption are expected to be delivered almost entirely by pri-

vate cars and motorcycles (which will account for 23.1% of the decrease). Transport electrification will be a key driver of these reductions; by 2030, there are expected to be 40 million electric vehicles on the road, which will make up a significant share of the total stock of cars. Biofuels will also grow slightly from 4.6% to 8.1%.

Four strategies for 2030:

1. Increase vehicle & transport system efficiency

In the transport sector, the most cost-effective means of mitigating climate change are reducing distances travelled, transitioning towards more efficient modes of transport (such as rail and shipping), and improving overall system efficiency. Better urban planning, for example, can help to maintain individual mobility while reducing the distance between the home and work. Digital technology can also be used to organize transport more efficiently and better integrate private and public forms of transport. Road charging, collaborative intelligent transport systems, and other such mechanisms, meanwhile, can help increase the overall efficiency of the transport system. Furthermore, important energy efficiency gains can still be made through technological progress and a radical rethink of vehicle and vessel design (including light-weighting vehicles). This will ensure that new conventional and electric vehicles are truly more fuel and CO₂-efficient than previous models.⁴⁶ Significant improvements are also needed in the energy intensity of air transport, EU inland navigation, and international shipping. These will be driven by technical and operational measures. Together, these will reduce energy demand in the transport sector by around 10% by 2030 and by 31-50% by 2050 in comparison with 2005.

2. A modal shift and a mobility transition: transitioning to rail, public transport, and shared mobility / fostering a mobility transition & alternatives to fossil-based lifestyles.

Alongside changes *within* modes of transport (such as a transition from petrol to electric cars), what is also needed is a shift to different modes of transport altogether (such as from trucks & planes to rail & ships), as well as a mobility transition towards public transport, shared mobility, and cycling and walking. This will allow rail and public transport systems to absorb a significant share of the goods and passenger transport increases projected by 2030. Where the modal shift is concerned, passenger rail transport usage will need to grow much faster than road transport activity in order to shift some road and air travel to electrified rail. With respect to freight transport, a significant modal shift towards rail and inland navigation will also need to take place, with rail freight activity growing faster than passenger rail activity.

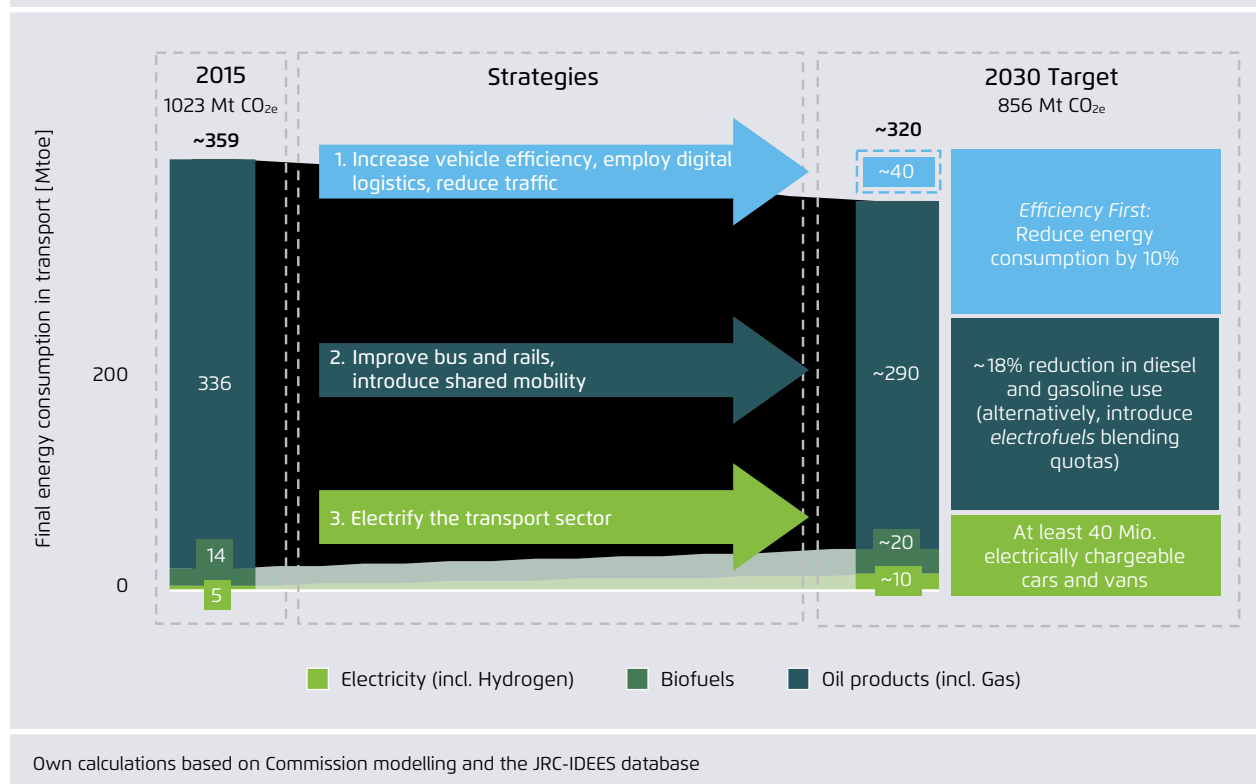
The mobility transition will take place in cities, where it will be enabled by their population densities and public infrastructure. It will accordingly be driven forward by planning processes and infrastructural investment.

3. Electrify transport

Direct electrification with green electricity from wind and solar is key to the transport transformation, since it is far more efficient than electrofuels and helps to improve air quality. One of the key technological developments that will facilitate the electrification of transport is a rapid decline in battery costs, which have fallen by 80% between 2010 and 2017. Electricity will therefore need to satisfy at least 4% of transport energy demand by 2030 and 15–26% by 2050.⁴⁷ This increase in electrification will be driven by a greater uptake of electric vehicles⁴⁸ and an increase in electrified rail services. In order to further reduce pollution, overhead electric catenary

Transforming the transport sector for 2030

Figure 17



lines placed along Europe's central motorways could be used to provide hybrid trucks with power on long-haul routes.

4. Decarbonize transport fuels

Some modes of transport are difficult to electrify directly due to the limited energy density of electric batteries. These include aviation and shipping, and to some extent heavy duty transport and long-haul coaches. These technical constraints make it much harder to cut emissions in these areas. Where it remains unfeasible to deploy zero emission vehicles, carbon neutral fuels (such as advanced biofuels and electrofuels) can instead be deployed for use in conventional vehicle engines, in the form of drop-in fuels. Green hydrogen and fuel cells could also help to enable a low-carbon road transport system, provided that the necessary hydrogen refuelling station infrastructure is established. There are nonetheless notable limits to this strategy. While CO₂ emissions for advanced biofuels and biomethane may be offset by initial biomass growth, their supply is limited by land and sustainability constraints. Significant quantities of electricity are also needed to produce electrofuels and hydrogen and capture CO₂. In the long term, these inherently constrained options will therefore have to be predominantly used in modes of transport such as air transport, road freight, and shipping, which can only be decarbonized to a limited extent or not at all.

3.5 Transforming industry for 2030

Industrial emissions accounted for 20% of all EU CO₂ emissions in 2015 and for a quarter of final energy consumption. Around 30% of industrial emissions consisted of non-energy-related process emissions (such as emissions from chemical reactions), which are more difficult to reduce. Energy-related industrial emissions fell by 42% between 1990 and 2015. The key factors behind the decline in energy consumption and emissions over this period include: 1) improvements in energy efficiency, 2) fuel switching to biomass, 3) capacity closures and structural shifts in the economy,⁴⁹ and 4) significant reductions in non-CO₂ GHG emissions. In 2012, 73% of industrial energy demand was for heating & cooling, and was mostly satisfied by gas and coal. Electricity was the most heavily consumed energy source in industry, while gas was the most heavily used fossil fuel. Each accounted for around a third of final energy consumption. Among renewables, biomass remains the dominant energy source for heating in industry (9%), since it is capable of replacing fossil fuels in many applications. All other renewable sources currently have a negligible share of <1%. Energy-intensive industry made up 65% of industrial final energy consumption, but accounted for 76% of industrial CO₂ emissions due to the CO₂-intensive nature of some of these industries.⁵⁰

Efficiency and fuel switches drive gradual progress in the industrial heat transition

Energy-related industrial CO₂ emissions reductions will need to fall by a third between 2015 and 2030, despite continued growth in industrial added value. Energy demand, meanwhile, is set to decrease by only 8%, with most reductions being achieved in energy intensive industries. Emissions reductions are expected to be largely driven by ongoing efficiency improvements, a transition to cleaner fuels and electricity, and broader developments in the EU economy. The relevant structural economic shifts will include

stronger relative economic growth in the less energy-intensive service sector. A transition to renewable heating & cooling fuels and renewable electrification is expected to take place at a slower rate than in the buildings sector, though natural gas, coal, and oil consumption is expected to be in continual decline by 2030 and will be nearly phased out by 2050. Accordingly, the importance of biomass, waste, and hydrogen will increase by 2050. In addition, F-gas emissions can be reduced by around two thirds (or 52 Mt CO₂e) by 2030, mainly through improvements in refrigeration & AC technologies. Process-related GHG emissions decline steadily in all scenarios, but their relative importance increases since the remaining mitigation potential becomes increasingly limited.⁵¹

Four strategies for 2030

1. Increase energy and resource efficiency

Between 2015 and 2030, industrial energy demand will need to be driven down despite a rise in added value. This will require old equipment to be replaced with newer, more energy efficient technologies (such as more efficient industrial boilers & CHP) and a structural shift towards higher value-added and less energy-intensive products. Additional energy use and process optimization measures will include reducing heat losses and recovering process-released heat for use in district heating systems, among other areas. Resource efficiency measures will also help reduce energy consumption.⁵² The use of recycled or scrap materials, for example, can help avoid the highly energy-intensive primary production of metals, glass and other materials,⁵³ while replacing cement with wood in the construction industry can help reduce unavoidable process emissions from cement production. These efficiency measures will help safeguard industrial competitiveness by mitigating the impact of increasing energy costs, but will often call for changes to product design or business models.

2. Increase the share of renewable fuels for heating & cooling

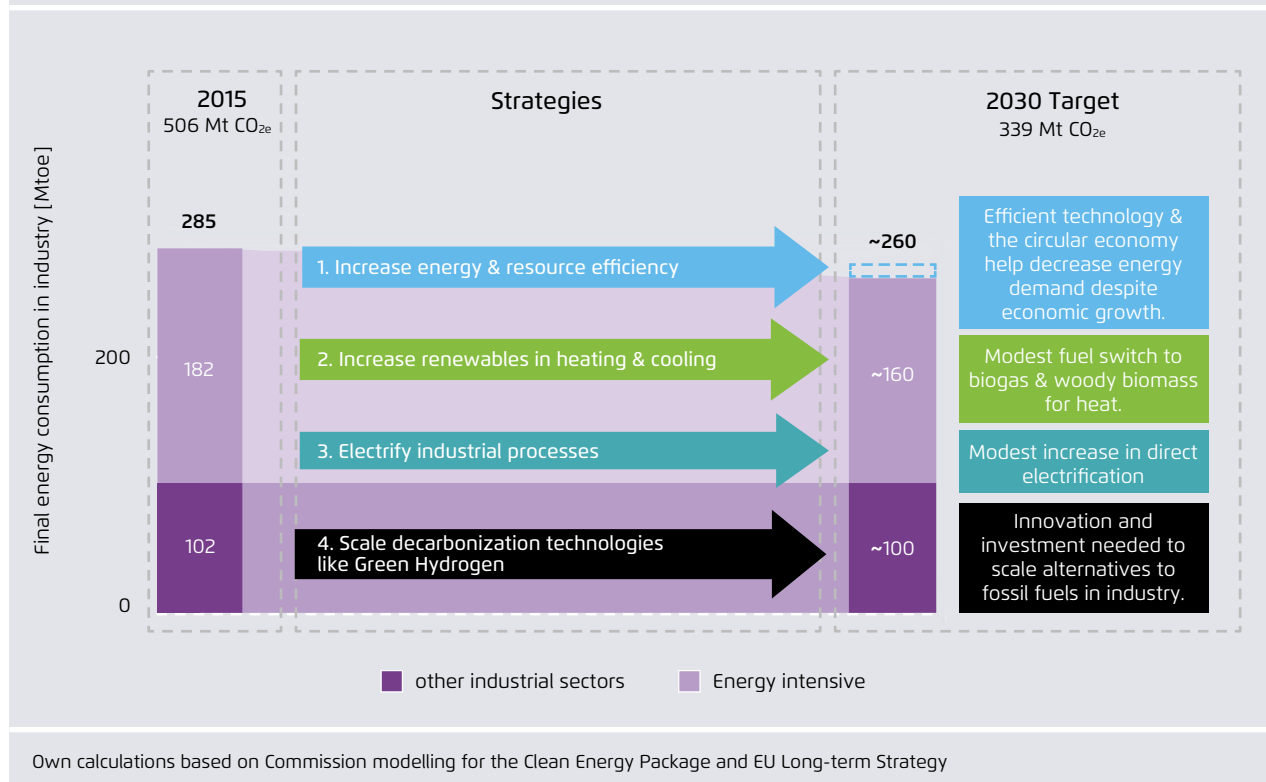
Industrial heating can be divided into low (below 200°C), medium (200°C to 500°C) and high (above 500°C) temperature levels. The relevant processes are sector and even subsector specific and require various temperatures that can exceed 2000°C. Temperature levels are an important variable, since current technical limits prevent some renewables from reaching temperatures above 200°C. The utilization of waste heat in industry nonetheless holds significant potential as for emissions reductions displacing fossil fuels by exploiting synergies with district heating & cooling. Also promising is a fuel switch to direct renewables (such as biomass, solar thermal, and geothermal) and heat pumps for low and medium temperature heat.

3. Electrify industrial processes

Electricity is already deployed in significant quantities for certain industrial processes, such as the production of aluminium and certain chemicals. Electricity consumption is not projected to increase significantly by 2030, whether in the form of direct electrification or that of indirect electrification using green hydrogen. There is nonetheless significant potential for the electrification of processes in certain industries, including chemicals and steel.⁵⁴ This potential will need to be exploited if net zero emissions are to be reached in the industrial sector by 2050. To this end, electricity will need to become the major energy carrier and industry will need to become the largest electricity consuming sector in the EU, with demand doubling or tripling between 2015 and 2050 to 2,162-2946 TWh (including 632-1407 TWh for hydrogen production). In order for this to be achieved, key low-carbon innovations (such as

Transforming the industry sector for 2030

Figure 18



the direct reduction of iron with green hydrogen) and technologies (such as electrolyzers), will need to be commercialized by 2030 to allow for timely scaling and deployment across the EU by 2050.

4. Cut coal & oil use

Coal accounts for only 13% of final energy consumption in the industrial sector, but produces 30% of energy-related industrial emissions. When non-energy-related uses of oil (such as chemical feedstocks) are taken into account, the industrial sector is responsible for around 20% of overall oil consumption, second only to the transport sector. In the run-up to 2050, all of the decarbonisation scenarios require fossil fuels to be almost completely phased out and for any remaining natural gas to be replaced by zero carbon gases as far as possible. In a 2030 perspective, these reductions will be facilitated by a combination of regulation, new equipment (such as industrial boilers), the EU Emissions Trading Sector, a fuel switch to less carbon-intensive fuels (particularly biomass and waste gases), a transition to alternative, low-carbon industrial processes, and increased electricity usage.

3.6 Transforming grid infrastructure for 2030

Grids are critical to the clean-energy system of the future. By 2030, significant investment will need to be made in grid infrastructure for power, gas, heating & cooling, and mobility. This strengthened and expanded grid infrastructure will: 1) enable electricity-led decarbonisation, 2) accommodate a transformed vehicle stock containing far greater numbers of fully electric vehicles, 3) facilitate a shift to a more decentralized power and heating energy system (see megatrend 1.9), and 4) enable decarbonisation in certain difficult to decarbonize industrial sectors and modes of transport via zero carbon fuels.

Expanding electricity grids to improve power system flexibility

The European energy transition requires both transmission and distribution grids to be expanded and restructured. Investing in enlarged, strengthened and smarter grids has two main benefits:

- 1) it ensures better use of areas with strong renewables potential and reduces the need to curtail wind and solar-generated power, since local weather patterns are balanced out over a larger geographical area;
- 2) it reduces the overall costs of the energy system by reducing the need for back-up generating capacity and other flexible resources, while providing the same security of supply.

New transmission lines nevertheless often face political resistance from (local) stakeholders, which can lead to bottlenecks for the energy transition. In order to resolve these tensions, grid developers need to engage in a genuine and committed way with stakeholders during grid planning processes, and in some cases need to make compensation payments, adjust the siting of lines, or change the technologies used in the project (by replacing overhead lines with underground cabling, for example). Where such issues cannot be resolved, additional transmission demand may

need to be met by expanding the capacity of existing power lines via regulatory changes or innovative uses of digital grid management technologies.⁵⁵ In order to ensure public support for investment in transmission, cost-sharing mechanisms can be used to fairly distribute the cost of infrastructural investment and network congestion management.

Expanding distribution networks generally does not provoke such local resistance, and like investment in transmission lines is often an effective way of limiting the need to curtail renewables. Nevertheless, the scale of the grid investment needed to cope with increased electrification will make it essential to distribute network costs fairly and transparently among consumers. It will also be essential to make more effective use of the existing grid and available distributed energy resources (such as batteries) using energy efficiency measures⁵⁶, digital tools, and new market arrangements.⁵⁷

Increased digitization makes energy systems smarter, facilitates a higher level of renewables penetration, and enables consumers to actively participate in the energy market. It nevertheless also increases the system's exposure to cyber-attacks, which jeopardize consumers' data privacy as well as security of supply. In the highly integrated European energy markets, cross-border cascading effects are another potential concern. These issues will become increasingly relevant in the coming years.

Modernizing heating & cooling networks to ensure a low-carbon energy supply

District heating & cooling networks are central aspects of climate action, particularly in the buildings & industry sectors. These networks:

- **Help to replace fossil fuels** where heat and cold from decentralized renewable energy sources (such as wind and solar PV via heat pumps, geothermal

and solar thermal energy, waste heat, and municipal waste) is fed into a district heating & cooling network.

- **Provide power system flexibility** by cheaply storing thermal energy in hot water tanks or underground, for example. This helps to balance the variable production of wind and solar PV and to reduce their curtailment.
- **Help diversify and boost the resilience of energy supply** when they are based on local resources rather than global markets.
- **Can improve air quality** when they replace coal-based domestic heating.

District heating & cooling systems have the potential to supply a significant share of the EU heating market, provided they are subject to ongoing decarbonisation and efficiency measures and are part of an integrated heating approach that also involves improving the existing building stock. Today, district heating & cooling already accounts for a large share of national residential heat consumption in those member states with colder climates – particularly Scandinavia and the Baltic states.⁵⁸ The bulk of district heat is nonetheless produced using natural gas, coal, and woody biomass, and networks are often geared towards transporting heat from central generation facilities to poorly insulated buildings. If the 2030 targets are to be met, the existing heating networks and their regulatory conditions will need to be reconfigured to take into account falling heat demand, lower temperature applications, and feed in from various decentralized, low-carbon heating & cooling sources. Identifying where this reconfiguration is a viable solution will require knowledge concerning local potential for carbon-free heat generation and the availability of heat sinks. It is therefore crucially important to develop municipal heating programmes by 2030 that map out the future contours of a carbon-neutral heat supply system and anticipate the infrastructural investment needed to implement it.

Smart electrification of all transport networks

The transport sector is far from being prepared for across-the-board electrification. Significant investment is needed here, and will need to focus on three areas:

→ **Accelerating the roll-out of smart charging and refuelling infrastructure for electric vehicles.**

By 2030, there are expected to be over 40 million electric vehicles on Europe's roads, and these will require smart charging infrastructure. The infrastructure will need to be installed alongside highways and roads, in cities and rural areas, and in commercial buildings across the whole of Europe. Enabling electric vehicles to be charged anywhere in Europe in a way that harmonizes with the grid system will allow the continent to remain fully connected and ensure that the benefits of a just and clean European energy transition are not restricted to wealthier member states.

→ **Expanding the electrified rail network and exploring the use of overhead lines on motorways.**

Thus far, only 54% of the EU railway network has been electrified.⁵⁹ By 2030, up to 80% of trains will need to be electric. In order to make significant progress in rail electrification, greater investment will be needed in rail vehicles and the railway infrastructure network, along with additional measures to connect European markets and infrastructure (particularly at border crossings). Electrified overhead catenary lines may provide another means of electrifying nationwide goods transport and could be installed along major highways. These would enable hybrid trucks to complete part of their journeys using electric power.

Though they require considerable investment,⁶⁰ the existing national plans drawn up in response to the Alternative Fuels Infrastructure Directive suggest that the number of public charging points for electric vehicles will keep pace with the anticipated growth in electric vehicles in the coming years – as long as the member states deliver on their plans.⁶¹ There will also be sufficient numbers of fast chargers along the

principal motorway routes, with at least one fast recharger every 40km. The introduction of minimum EU standards for physical plugs and payment systems means that interoperability between different infrastructure operators is also likely to be adequately implemented in the coming years.⁶² Yet while an estimated 95% of charging takes place at home and at work, private and workplace charging infrastructure still lags behind public infrastructure,⁶³ and the roll-out of smart meters that ensure smart charging is uneven across Europe.

Preparing gas networks for a decarbonized future

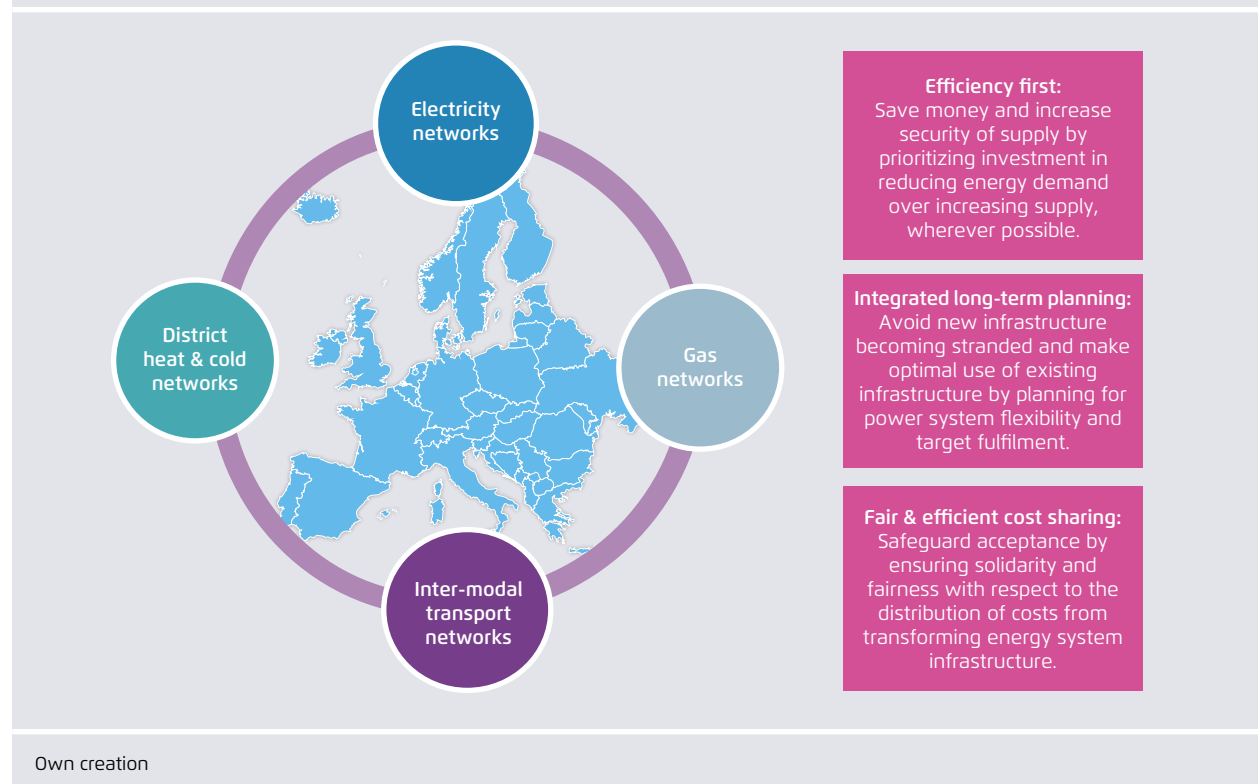
Gases will continue to play an important role as feedstocks and energy carriers in future. The decarbonisation of the energy system will require gas demand to be significantly reduced by means of electrification and energy efficiency measures, as well as the stepwise replacement of fossil methane by renewable

and low-carbon gaseous fuels especially after 2030.⁶⁴ Reductions in gas consumption are likely to make further investment in expanding import or transport grid capacity unnecessary. Continued investment will nonetheless be needed to maintain parts of the existing gas grid, and particularly to integrate carbon neutral gases into the system.⁶⁵ As a result, the costs associated with the gas grid are not expected to decline in line with consumption if the current grid is maintained. These changes could lead to a rise in grid tariffs for gas consumers and in the worst case to network assets becoming stranded. Accordingly, gas networks will likely need to be smaller in 2050 than they are today if they are to adapt to this changing cost structure.

Another key challenge for the gas networks of the future will be the integration of new sources of decarbonized gas supply. The sustainability of CO₂-based synthetic gases (such as electro-meth-

Transforming network infrastructure for 2030

Figure 19



ane) and biogas converted to biomethane is subject to significant economic and environmental constraints. The advantage of these gases, however, is that they can be transported through the gas grid without any major technical limitations. Green hydrogen produced via renewables-based electrolysis, by contrast, is more efficient and sustainable, but there are limits on the quantities of the gas that can be injected into the grid. Studies suggest that hydrogen could be blended with natural gas at up to 10 or 15% of the gas volume without any major adaptations to the gas transmission and distribution infrastructure or end-user appliances being required, while a blend containing over 15-20% hydrogen would require significant changes. There are currently no common European standards and rules in this area.

Three strategies for a robust, smooth, efficient, and fair grid transformation

1. "Efficiency First"

The 'efficiency first' principle prioritizes investment in customer-side efficiency resources (including end-use energy efficiency and demand response) wherever they would be less costly or deliver more value than investment in energy infrastructure, fuels, and supply alone (in line with the "save before you build" principle).⁶⁶ Applying the efficiency first principle in practice prevents unnecessary infrastructure from being built and thereby yields significant cost savings. It also helps to reduce congestion in electricity, gas, and transport systems by reducing demand in peak hours.

2. Integrated long-term planning:

The energy transition provides an opportunity for the timely and often cost-effective replacement of ageing infrastructure and assets with modern, highly efficient and carefully designed infrastructure that is compatible with the EU's decarbonisation objectives. Long-term integrated planning for such infrastructure can enhance system efficiency and reduce costs by minimizing the number of new investment projects that end up stranded as a result of decarbonisa-

tion, while making optimal use of existing infrastructure and assets in the long term.

3. Fair and efficient cost sharing:

New investment, just like renovating, retrofitting, and converting existing infrastructure, will require significant, capital-intensive changes that will largely need to be financed by household and industrial consumers. As a result of geographical shifts within the energy system (involving decentralization and regionalization), the distribution of the costs and benefits of operating the system are likely to change significantly, both between member states and within them (e.g. between cities and rural areas). This will likely require new approaches to cost sharing that ensure solidarity and fairness with respect to individual costs and the overall energy system.

4 The investments, costs, and benefits of the European energy transition

In earlier debates about the European energy transition, investments and costs were contentious issues. Some raised concerns about the potential effects on the competitiveness of European companies and the economy at large. Others argued that the energy transition would create new jobs and better livelihoods and enable European companies to maintain a competitive edge in the leading markets of the future.

Many of the sceptics have since come around. They now acknowledge the positive economic effects of clean-energy investments and the lasting benefits from decreased energy system costs, a reduced reliance on energy imports, and improved public health. The debate today focuses more on the distributional effects of concrete policy measures.

Assessing the costs and benefits of the European energy transition

Any methodologically sound effort to quantify the costs and benefits of the European energy transition must start with three key facts:

- First, the **energy transition is not the only transformative trend** that will affect the EU and the global economy over the coming decades. As highlighted earlier in the report, global megatrends such as ageing populations, digitalization, and automation will transform our economy regardless of the climate action we take.
- Second, **any energy system creates costs**. Even if Europe were to stop investing in the energy transition, houses will need to be heated, cars will be bought, ageing power plants will be replaced, and regular maintenance of the gas and electricity infrastructure will occur. Any quantitative assessment involves economic modelling and must compare the expected costs and benefits of the

European energy transition with a hypothetical scenario without clean-energy measures.

- Third, the continued **consumption of fossil fuels creates high costs for society**, most prominently through the impact of rising temperature levels. In Europe, extreme weather events (floods, draughts, heat waves) caused by the 1 °C rise in global temperatures that has already occurred has caused significant economic damage.⁶⁷ A global energy transition that keeps global warming to 2 °C would save 70 billion euros per year in climate change-related damages relative to a 3 °C rise.⁶⁸ The reason is that damages increase exponentially with each increased temperature scenario. Over the longer term, differences in the costs of climate change-related damages associated with different temperature scenarios are even more pronounced.⁶⁹ Nonetheless, most economic models used for comparing the costs and benefits of different climate and energy policy choices do not reflect the economic impact of rising temperature levels.⁷⁰

Current energy costs in Europe

Household and industry spending for energy products in Europe continues to depend primarily on **fossil fuel prices** rather than on energy sector transformation. As most fossil fuel is imported to Europe, prices are determined by global markets, which are highly volatile.⁷¹ Import prices for oil and natural gas fell by roughly 50% between 2012 and 2016, but returned to 2012 levels in 2017. Hard coal prices have seen a similar development.⁷² These price oscillations have had serious implications for households and businesses but also more broadly for the EU trade balance, economic performance, and its geopolitical situation.⁷³

Import prices do not represent the full prices paid by end-consumers, be they households or industries.

End-consumer prices are composed of wholesale prices plus the costs associated with supply, taxes, and levies. These prices vary between energy carriers, between Member States, within Member States, and between consumer types.

Overall spending on energy depends not only on prices but also on the quantity of energy consumed. Between 2008 and 2014, for example, increased end-consumer prices were partly compensated by reduced overall energy consumption. This reduction was due to decreased economic activity after the financial crisis and to energy efficiency improvements.

Average household energy-related expenses increased from 4.7% in 2000 to 7.3% in 2015 (+67%) relative to income, but have been relatively stable since 2008.⁷⁴ However, household energy expenditures vary strongly in absolute terms (ranging from €500 to €2,300 per household) as well as by income level and by Member State.⁷⁵ In 2015, 9.8% of the expenditures of the poorest 10% of households was spent on energy, while middle income households spent 6%, and higher income households spent less still.⁷⁶ Northern and western European households spent 4–8% and central and eastern Europeans spent 10–15%. Moreover, while energy is affordable for most Europeans, a certain percentage, mainly in southern and eastern Europe, is unable to keep their homes adequately warm. The reasons, though various, are mainly due to general income level, the availability of governmental support for lower income households, and the efficiency of buildings and heating systems.⁷⁷

For most **industries**, energy-related expenses are a minor cost factor and have remained relatively stable, at around 2% of overall production costs. International competitiveness depends more on factors such as market access, financing, research support, and the availability of skilled workers.⁷⁸ Energy price

increases over the 2008–2012 period were more than offset by reduced energy consumption on account of the economic downturn and of improvements in energy efficiency.

However, energy costs are an important factor for some industries, particularly those that are **energy intensive** and that must compete internationally (e.g., iron and steel, cement and glass). Member States typically provide direct or indirect subsidies in the form of exemptions to taxes, levies, and network charges for electricity and gas. Over the 2008–2015 period, energy costs fell for businesses in most sectors and declined 8% overall. The most significant decline was in energy intensive industries due to subsidies, lower wholesale energy prices, efficiency increases, and a shift to less energy-intensive products.⁷⁹

The **EU Emissions Trading Scheme** had only a minor effect on wholesale electricity prices in the 2012–2017 period because certificate prices remained below 10 euros per tonne of CO₂. In 2018, however, prices increased to more than 20 euros per tonne. Energy intensive industries in which carbon leakage is a risk benefit from the free allocation of emission certificates.

The costs and benefits of the energy transition in 2030

In preparation for the 2030 EU climate and energy framework and its recently launched long-term strategy for 2050, the European Commission commissioned an extensive set of studies using a standardized scenario framework. By comparing the costs of current policies with the costs of an energy transition that meets the 2030 climate and energy targets or that leads to decarbonization by 2050, these studies provide important information on the costs and benefits of the European energy transition over time. Six key conclusions can be drawn from these assessments:

1. The European energy transition will require considerable investment, but its costs will be comparable with those of the current energy system

Achieving the 2030 targets and replacing existing infrastructure will require investments of roughly 1,081 billion euros a year between 2021 and 2030. This is 37% higher than in 2015 and 20% higher than would be needed under current policies.⁸⁰ In terms of EU GDP, it would require increasing investment levels in the energy system from around 5% today to around 6%.⁸¹

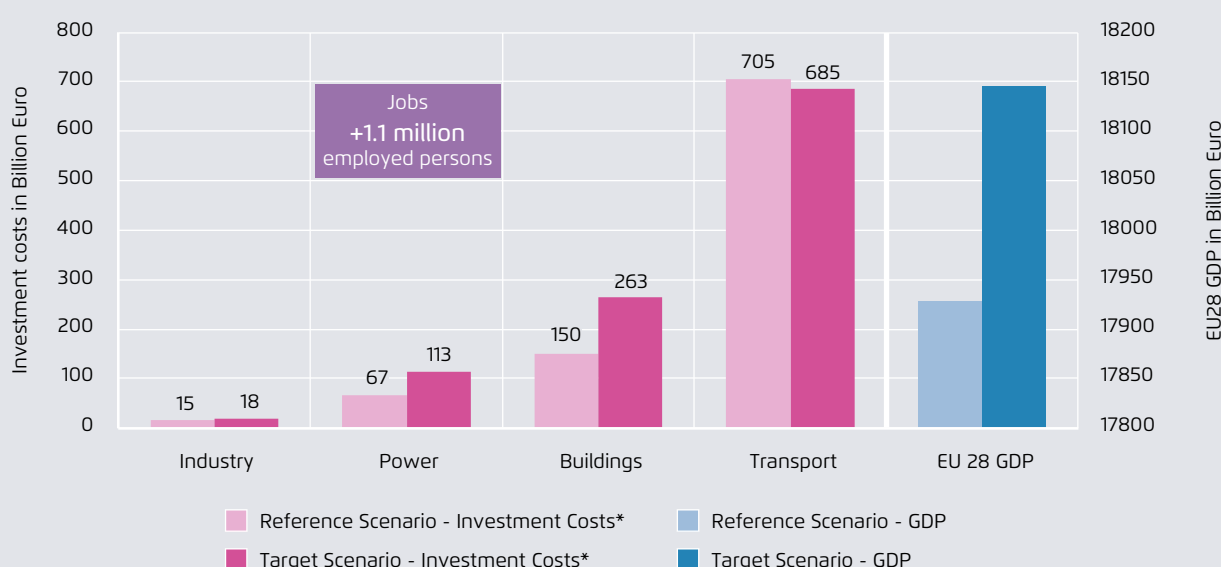
Most of the additional investment will take place in the buildings sector, followed by power and industry, and will largely need to come from individuals or private companies. Compared with current levels, the EIB estimates that between 2016 and 2030 annual investment in energy efficiency savings in buildings and industry will need to triple, while investment in

energy networks and power generation and in the transport sector must rise by a quarter.⁸²

Mobilizing this considerable shift from consumption to capital investment represents a challenge, but it is manageable from an economic and financial perspective. The architecture of the financial system will have to be reconfigured away from fossil fuels and towards low-carbon investments in order to avoid stranded assets. But the required investments represent less than a quarter of the capital market's annual increase. This means that capital availability need not be a bottleneck providing that a proper investment framework is provided.⁸³ Moreover, additional investments in renewables and energy efficiency will help reduce the role of operational costs (especially through lower fuel expenditures). As a result, total annual energy system costs (including annualised investments and energy purchasing costs) are only around 25% higher than 2015 levels in absolute terms,

Investment costs are higher in a target scenario vs a reference scenario, but so are growth and jobs

Figure 20



Own calculations based on the EU 2016 Reference Scenario and Commission modelling for the Clean Energy Package and the EU Long-term Strategy
 *Average annual investment expenditure (2021-2030) in Billion Euro (€'13)

and only minimally higher (3% or 70 billion euros) relative to the costs of current policies.

2. The European energy transition will increase GDP and employment

Reaching the 2030 targets is expected to increase GDP by 1% relative to the reference scenario (i.e. the continuation of current policies). GDP growth is likely to be even stronger under more ambitious targets for renewables and energy efficiency due to the additional investment and value they create. At the same time, shifting to renewables and energy efficiency will lower fuel imports, which results in greater domestic value creation.

The effect on jobs is also positive. If 2030 targets are reached, employment is expected to be 0.5% higher than in the reference scenario. In general, investment in renewables and energy efficiency is considered to be beneficial for employment relative to other energy investment alternatives because they are labour intensive and are difficult to relocate outside Europe. For example, compared with oil and gas sector investments, employment creation is expected to be 2.5 to 4 times larger for energy efficiency and 2.5 to 3 times larger for renewable energy.⁸⁴ At the same time, the overall composition of the labour market is likely to be affected in significant ways. For example, the mining and extraction sectors are expected to contract considerably in the medium and long terms due to decreased demand for fossil fuels. The transition will also change which skills are in demand, and may affect income distribution as well.

3. The shift to renewables and energy efficiency increases energy security

Over the past decade, as its indigenous fossil fuel production has shrunk, the EU has increased its dependence on energy imports. This high level of energy dependence makes the EU economy more vulnerable to volatile world market prices and supply shortages. This is most relevant for natural gas, where Russia provides 42% of EU imports and is the sole supplier to nine Member States.⁸⁵

Without additional action, this vulnerability is expected to increase due to rising fossil fuel prices and further declines in domestic oil and gas production.⁸⁶ A decarbonised energy system would help to address these threats by shifting production to domestic renewable sources and by reducing energy consumption.⁸⁷ The Commission estimates that if the 2030 targets are met the overall share of imports will decline from 55% in 2015 to 52%. In particular, the overall fossil fuel imports will fall by 19% (from 900 Mtoe to 730 Mtoe) and natural gas imports will decrease by 6% (from 254 bcm to 240 bcm).⁸⁸ Europe's energy import dependence would further decline by 2050 if a net zero carbon footprint is reached by 2050. This raises questions about the long-term use of import capacities, especially when it involves the construction of new ones.⁸⁹

4. Avoided health costs more than outweigh the additional costs of an energy transition

The burning of fossil fuels in power plants, industrial facilities, buildings, and vehicles affects local air quality. Poor air quality can result in reduced quality of life, illness (e.g. respiratory diseases), reduced crop yields, and building damage. In 2015, the main air pollutants – particulate matter, nitrogen dioxide, and ground-level ozone – caused almost half a million premature deaths in Europe. On average, one out of 1,000 city inhabitants loses 10 years of life because of these pollutants.⁹⁰ In 2010, the health-related costs amounted to 1 trillion euros.⁹¹ Direct economic damage totalled 23 billion euros mainly on account of lost working days, healthcare costs, crop yield losses, and building damage.⁹²

Meeting the 2030 targets would mean burning fewer fossil fuels, which would improve air quality and reduce the annual costs related to illness and premature death by more than 136 billion euros annually relative to the reference scenario. This would more than offset the additional annual energy systems costs for shifting to higher shares of renewables and better energy efficiency (roughly 70 billion euros).⁹³

5. Meeting 2030 targets will not raise household expenses relative to the reference scenario

In all scenarios, household electricity prices are projected to rise between 2015 and 2030 and to stabilize thereafter, irrespective of policy. The overall share of household expenditures for energy – including investments, efficiency improvements, and energy purchases – will increase by less than one percentage point if the 2030 targets are met.⁹⁴ At the same time, gains from energy efficiency investments are expected to reduce energy expenditures over several decades.⁹⁵ Average household income is also expected to increase across all household groups in most countries, with low income households benefiting most.⁹⁶

Nevertheless, end-consumers will face higher upfront costs, although costs for energy will fall due to greater energy efficiency. These types of investments can present a challenge to households, particularly low-income households with limited means to

invest in, say, more efficient appliances and vehicles or home renovations.

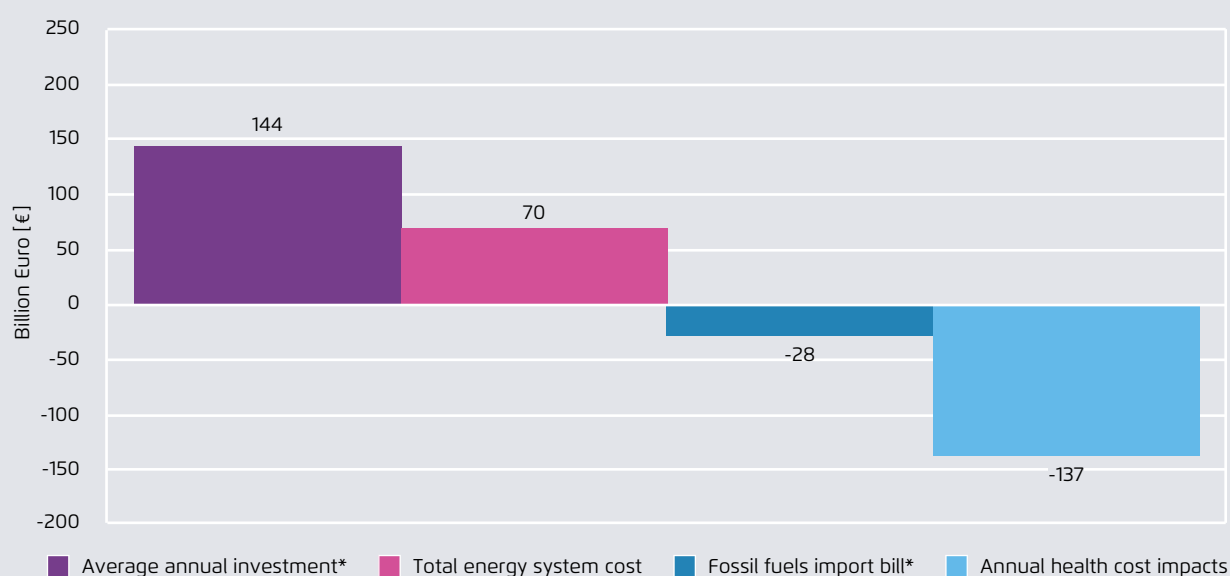
6. Overall industrial competitiveness is not at risk but energy- and trade-intensive branches need support

Meeting 2030 targets is expected to raise annual energy system costs for industry only slightly from 2015 levels. Remarkably, they are lower than those in the reference scenario.⁹⁷ This is mainly attributable to increasing energy efficiency, which reduces energy purchasing costs and offsets rising investments costs. In addition, the shift to renewables and energy efficiency will stabilize energy costs by reducing dependence on volatile oil and gas markets.

However, some industries, especially those in energy- and trade-intensive branches, will face competitive pressures from increased carbon and energy prices, and are thus likely to find it difficult to increase investment in more efficient capital stock.⁹⁸

Difference in investments, costs and benefits (in billion euro) in 2030 between the EU reference Scenario and a target scenario (excludes climate damages)

Figure 21



* (avg. Annual 2021-2030) in bn €'13

** Mortality & morbidity / cost savings NOx, SOx, PM10 and PM2.5 in 2030 in bn €

COM (2016, 2017, 2018)

Conclusion

The following five conclusions can be drawn from our analysis:

- **The EU energy transition will bring economic opportunities** because investment in renewables and energy efficiency will generate new jobs and regional economic value. Households will bear higher upfront costs, which is likely to be challenging for some. However, from an economic and financial perspective, the magnitude of investment is manageable. End-consumers stand to benefit as well: household incomes will increase and energy bills will fall; and most industrial consumers will be able to offset their upfront investment costs with reduced fuel expenditures.
- A full assessment of the costs and benefits of the energy transition must take into account how the transition will affect different groups in society. Low-income households in particular will need help making the required investments. Energy-intensive industry might face competitive disadvantages, and their ability to invest in advanced processes or new technologies may be limited. **Targeted social, labour, and industrial policies** are needed to ensure public acceptance for low carbon technologies and infrastructure. In particular, the EU and its Member States must support vulnerable consumers and workers who lose their jobs. The energy transition will also require improved measures for maintaining industrial competitiveness in energy-intensive sectors subject to international competition.
- **Innovation is needed to strengthen the EU's position in the growing market for renewables and energy efficiency:** Europe's strong innovation makes it well-placed to develop cost-effective technologies and services for the low-carbon energy and transport system. But in the face of strong competitors such as China, European businesses require a large domestic market to develop technologies early and strengthen their international position. This will also allow Europe to develop its own standards for a level playing field.
- The **energy transition will reduce the EU's reliance on energy imports, enhance energy supply security, and reduce vulnerability to the volatile prices of fossil fuels.** A EU that has achieved its renewable and energy efficiency targets will reduce its dependence on natural gas imports from Russia. The money saved on imports will remain in the EU for local value creation.
- **The energy transition will reduce air pollution and help limiting global warming to 2 °C or less, creating large economic benefits for human health, economic activity, and the environment.** These savings could more than offset the additional annual energy system costs that come with achieving the 2030 targets for renewables and energy efficiency.

5 The EU's 2030 Climate and Energy Framework: The main implementation priorities

In recent years, the EU has negotiated and adopted a large portfolio of laws and regulations to translate its climate policy ambitions into concrete action. Among other measures, the EU has enshrined its climate targets in a number of key laws and has determined the associated planning, monitoring, and enforcement procedures. Lawmakers have also finalized the Clean Energy for all Europeans package and crucial regulations concerning transport emissions. Here they have often revised existing legislation in order to reach the 2020 targets. Whether or not the EU can make meaningful progress towards decarbonisation will depend first and foremost on its commitment to fully implementing all of these measures.

Implementation has several dimensions. First, most legal acts require additional rulemaking in specific areas via delegated or implementing acts. While this rulemaking is sometimes concerned with technicalities and details, it may also have a substantial impact on the effectiveness of the legislation in practice. Second, member states need to transpose EU directives into national law. In many cases they have significant flexibility to determine policies that are suitable at the national level. While national policymaking processes provide an opportunity for policy innovation and local ownership, they may also result in the stringency of the relevant measures being watered down. Finally, and most importantly, both member states and the EU have to translate the various requirements contained in the legislation into action, while establishing monitoring and enforcement procedures to ensure that they achieve their intended objectives. This section highlights the key implementation priorities that EU and national policymakers will need to address in each sector of the energy transition.

The overarching framework for achieving the targets

The EU's overarching target of achieving a 40% reduction in greenhouse gas emissions compared to 1990 levels has been enshrined in law via the revised Emissions Trading System Directive⁹⁹ and the Climate Action Regulation¹⁰⁰ that sets a binding national emissions target for each member state. Emissions from land use and forestry (LULUCF) are addressed by a separate regulation.¹⁰¹ A new governance mechanism¹⁰² requires member states to strategically plan their future energy systems. These plans must also indicate the states' prospective national contributions toward the EU's 2030 energy renewables and energy efficiency targets.

At the EU level, the key implementation priorities in the field of target governance include:

- A thorough Commission review of the draft National Energy and Climate Plans (NECPs) that member states are required to draw up under the new Energy Union Governance Regulation, as well as intense engagement with member states to ensure that they have high-quality, actionable, and sufficiently ambitious NECPs in place that will ensure the EU climate and energy targets can be reached. Particular attention will be given to emissions from the transport and buildings sectors, where the latest projections show that a number of member states are not yet on track.¹⁰³
- Subsequent rigorous monitoring of the implementation of the final NECPs from 2021 on, in order to ensure the Union remains on track to meet its 2030 energy targets and can take corrective action where necessary (the so-called gap-filler mechanism).

- The establishment of an EU-level renewable energy financing mechanism. The Governance Regulation requires the European Commission to set up such a mechanism by 2021. It will be used for the EU-wide tendering of new renewable energy projects, in order to close any remaining gaps between the EU's 2030 target and member states' national contributions. It is also intended to facilitate the ambitious deployment of renewable energy within member states.¹⁰⁴ The mechanism could become the first Union-level financing instrument to support renewable energy.
- The submission of the Commission's long term EU strategy to the UNFCCC by 2020.
- The establishment of forest reference levels by the European Commission in order to facilitate implementation at the national level. The reference levels will determine how member states account for

greenhouse gas emissions related to forestry and agriculture (or land use, land use change, and forestry, LULUCF). This in turn will determine how many LULUCF credits a member state can potentially use in order to comply with its national targets under the Climate Action Regulation.¹⁰⁵

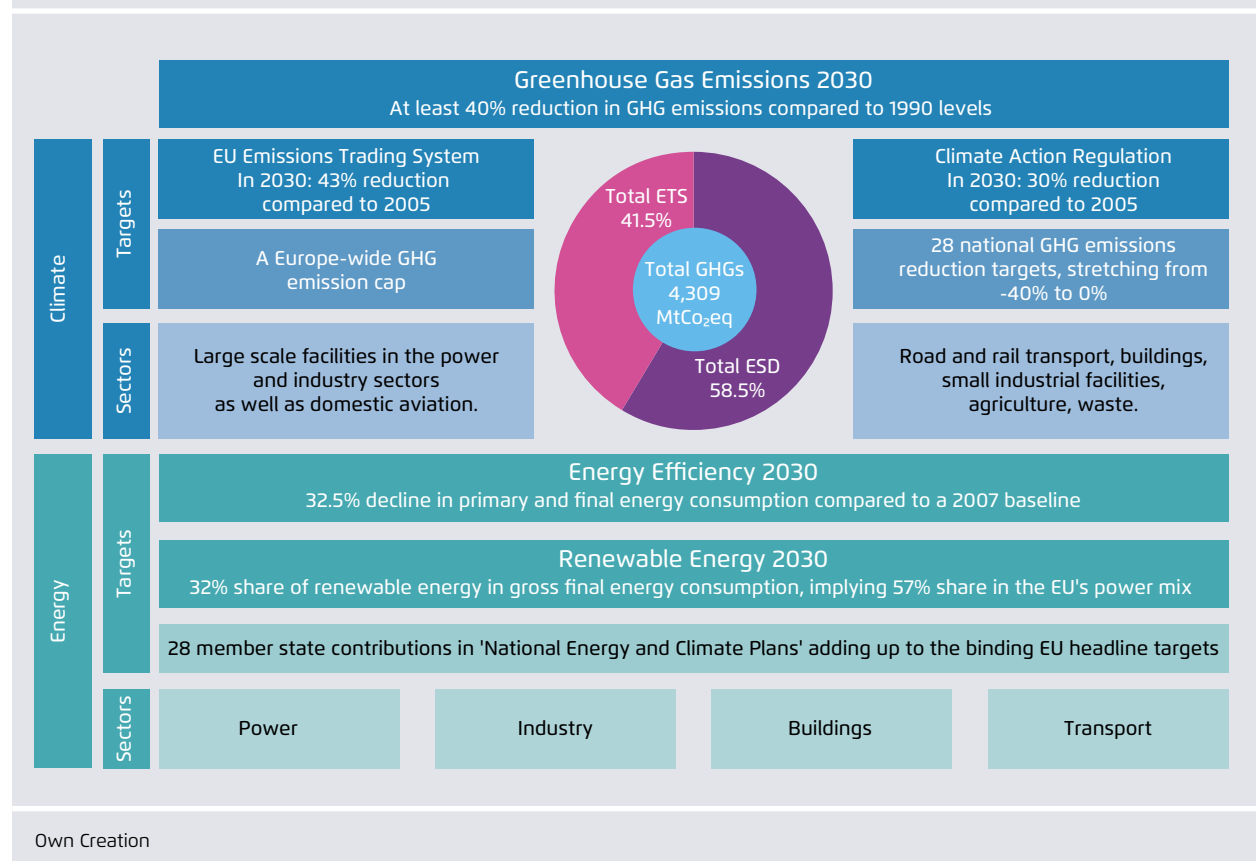
- Under the Governance Regulation, the Commission will also establish a template for the biennial national progress reports on NECP implementation.¹⁰⁶

At the national level, the implementation will require member states to:

- Draw up NECPs for 2030 and long-term strategies that make a sufficient contribution to meeting EU climate targets and are adopted via an inclusive process.

Overview of the EU's 2030 climate and energy target framework

Figure 22



- Put in place or continue obligatory energy efficiency schemes or alternative policies in order to achieve annual final energy savings of 0.8%, a certain proportion of which need to benefit lower income households.

Buildings

Given their significant share of energy consumption as a whole and the range of options for on-site energy production, buildings will play a key role in meeting the EU targets for energy efficiency and renewable energy. The main EU laws in this area are the Energy Efficiency Directive (EED),¹⁰⁷ the Energy Performance of Buildings Directive (EPBD),¹⁰⁸ the Renewable Energy Directive (RED),¹⁰⁹ and the Eco-Design Directive.¹¹⁰ These laws require a number of implementation actions. While the nearly zero-energy standard will be mandatory for new buildings across Europe from 2021 on, energy efficiency requirements for existing buildings only come in to force when major renovation work is undertaken. This underscores the importance of energy audits, information campaigns, and targeted financial support.

At the EU level, the implementation priorities include the following:

- In accordance with the revised EPBD, the Commission is tasked with establishing an EU-wide approach for two new voluntary tools: a building renovation passport that lays out a renovation roadmap for specific buildings, and a smart readiness indicator that can assess a building's capacity to adapt to the needs of its inhabitants and the grid while improving efficiency and flexibility.
- Where forest-based biomass is concerned, the European Commission must deliver implementation guidelines on how to demonstrate compliance with the new sustainable forest management criteria and the requirement to avoid negative LULUCF impacts.

The main implementation work will take place at the national level:

- When defining their national 2030 energy efficiency targets as part of their NECPs, all member states should specify the extent to which enhanced building efficiency will contribute to meeting the targets and which measures will be put in place to this end.
- Member states need to develop and implement long-term building renovation strategies, including milestones, to accelerate the renovation rate.
- In new-build projects, national governments will need to ensure that all public buildings are nearly zero-energy buildings (NZEBs) after 2019 and that all other new buildings are NZEBs from 2021 on by defining and enforcing NZEB standards in accordance with the EPBD.
- National governments will also need to specify the level of final energy for heating and cooling that will be provided by renewable sources by 2030, and will have to implement measures to ensure an annual indicative increase of 1.3 percentage points for renewables in heating and cooling between 2020 and 2030.
- Member states will need to update the 2015 assessments on the potential for high-efficiency cogeneration and efficient district heating networks.
- Governments should implement the EPBD pre-wiring requirements to enable home and workplace charging for electric vehicles in residential and commercial buildings as soon as possible and well ahead of 2025.
- The product-specific regulations set out in the Ecodesign and Energy Labelling Directives are directly applicable to member states, but these will need to carry out market surveillance to ensure proper compliance.

Transport

The last two years saw the publication of three Mobility Packages in May 2017, November 2017, and May 2018, respectively. The packages' most important legislative initiatives focus on improving vehicle efficiency, i.e. on "tank to wheel" emissions, while the RED's transport chapter focusses primarily on reducing "well to tank" emissions by promoting alternative fuels.

The regulation on mandatory CO₂ standards for passenger cars and vans¹¹¹ and the sister regulation on heavy-duty vehicles do not require national transposition. They directly require vehicle manufacturers to achieve efficiency improvements in their fleets and, on the basis of updated, specific targets, to significantly increase the number of electric vehicles, plug-in hybrids, and/or fuel-cell electric vehicles on the market. Nevertheless, a number of specific rules that may have a significant climate impact remain to be clarified.

At the EU level, the implementation priorities include the following:

→ The updated regulation on car and van emissions sets out the reductions that need to be achieved relative to a 2021 baseline level. This baseline will still need to be determined individually for each manufacturer in the years to come. At the same time, the EU has also adopted a new regime for measuring vehicle emissions – The Worldwide Harmonised Light Vehicle Test Procedure (WLTP) – and will start using fuel consumption meters from 2021 on to monitor the gap between official CO₂ emissions values and actual emissions under real-world conditions.¹¹² These measures to close the current gap between theoretical standards and real world emission levels should stimulate the deployment of fuel-efficient vehicles and cut emissions.

Where renewable energy used in transport is concerned, the EU needs to clarify the following issues by means of delegated acts:¹¹³

- By 2021, the European Commission will need to introduce a GHG reduction threshold and a GHG accounting method for recycled carbon fuels (such as those from plastic waste).
- Moreover, it will need to develop a system to ensure that renewable electricity used in transport is 'additional', meaning that it is not counted as part of the national baseline for renewable power generation. This will be crucially important in ensuring the closer integration of the various energy sectors.

Member states need to deliver on the following implementation priorities:

- The overarching challenge for all member states is to design a package of transport policies that makes it possible to reduce the transport sector's emissions in line with national targets under the Climate Action Regulation, despite the growth of the sector in recent years. In particular, it will be important to adopt taxation regimes that incentivize the uptake of ultra-low emission cars and reduce sales of high-consumption diesel and gasoline cars. This will mainly involve purchase and registration taxes and company car taxes. Member states will also need to implement measures to increase demand for zero-emissions vehicles, which may take the form of incentives, fiscal measures, or measures to accelerate the deployment of charging infrastructure.
- Member states also need to accelerate implementation of the current Alternative Fuels Infrastructure Directive in order to reduce barriers to the uptake of zero emissions vehicles and ensure a sufficiently dense, fully interoperable, and accessible recharging and fuelling network.
- At a more detailed level, member states will need to specify the planned level of renewable energy use in the transport sector in their national energy and climate plans, as well as the fuels and alter-

native technologies that will be used to reach this target. Since member states are free to cap the level of conventional biofuels from food and feed crops at 0, the national transport target can be as low as 7%, which may necessitate additional incentives to meet the collective EU target.¹¹⁴

The power sector

In its 2016 Clean Energy Package, the EU acknowledged the pivotal role of the power sector, in which renewable electricity penetration levels are now expected to reach over 55% by 2030. Accordingly, the package proposed a new set of rules governing the electricity market and renewables. The overarching aim of these is to make the electricity markets more flexible so that they can accommodate rising levels of variable wind and solar power, and new sources of demand (such as electric vehicles and heat pumps) while maintaining grid stability.

The implementation tasks at the EU and regional levels include:

- Advancing the Single Electricity Market by effectively applying existing implementation standards known as network codes (concerning, for example, the integration of intra-day markets), monitoring the use of interconnectors, conducting a bidding zone review, and supporting the regionalisation of system operation.
- Supporting, monitoring, and enforcing the new EU laws on the functioning of electricity markets. Particularly important areas here include market payments to certain market participants in return for their ready availability (known as capacity mechanisms), enhancing the role of demand side response, and further developing wholesale markets.
- Adequately implementing the methodology for the European resource adequacy assessments, which play a key role in establishing whether a national government is allowed to put in place a capacity mechanism.

- Reviewing the current environmental and energy state aid guidelines that will assume even greater importance as a result of the electricity-led decarbonisation of the transport and buildings sectors.

The implementation priorities for member states include the following:

- As part of their national energy and climate plans, national governments need to determine the level of final electricity demand that they plan to satisfy using renewable sources by 2030. The plans will need to include a trajectory showing the expected contribution of the various technologies over time, along with measures to increase the flexibility of the energy system with regard to renewable energy production.
- Member states will need to implement the detailed requirements of the revised Renewable Energy Directive, which aims to establish a favourable environment for renewable energy investment. These include provisions on reliable support schemes without retroactive changes and requirements for Member States to provide five years' visibility on renewable energy auctions (including timing, volumes, and budgets). The requirements also address streamlined administrative procedures (for repowering projects in particular), grid access, information and training, and the facilitation of self-generation and self-consumption (particularly with regard to roof-top photovoltaics), as well as joint investment by renewable energy communities, the development of sustainability standards for biomass-based energy use, and the obligation for member states to remove administrative barriers to corporate renewable power purchase agreements
- Compliance with air pollution standards will need to be ensured for large combustion plants under the EU Industrial Emissions Directive. Specific air pollution standards have been set out in technical documents detailing the best available technologies to reduce emissions of various pollutants. By mid-2021, public authorities will need to update oper-

ating permits and require plant operators to adhere to these standards. Member states will nonetheless retain a certain level of flexibility in setting the emissions limits. They may also choose to exceed the European minimum standards and insist on stricter national limits.

- Where electricity market reform is concerned, member states need to transpose a number of new EU rules into national law. These include the obligatory introduction of dynamic pricing schemes, rules on smart-meter roll-out and consumer data handling, a limit on CO₂ emissions per kWh for plants receiving capacity payments, and the phasing out of regulated electricity prices.

Industrial greenhouse gas emissions are regulated by the EU Emissions Trading System, the Industrial Emissions Directive (IED),¹¹⁵ the Ecodesign Directive,¹¹⁶ and by circular economy measures.

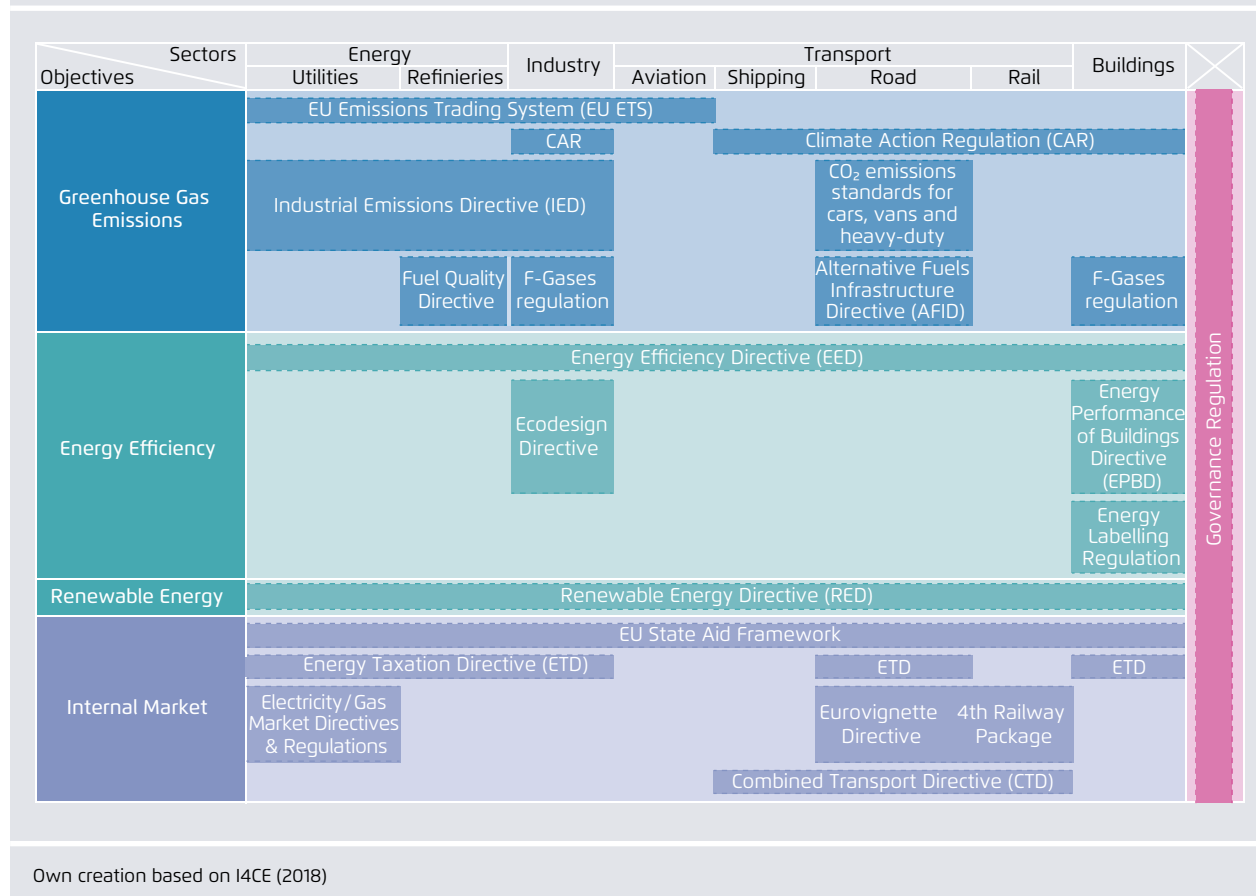
At the EU level, the implementation priorities include:

- Establishing revised benchmark values for the free allocation of CO₂ emissions allowances to industry.¹¹⁷ The Commission also needs to develop detailed rules on how to select demonstration projects involving innovative and breakthrough industrial technologies, so that these can receive funding derived from auction revenues under the EU Emissions Trading System (known as the innovation fund).

Industry

EU Legislative Map

Figure 23



- Determining how EU product standards could help to enhance resource efficiency rather than focussing purely on energy use. Through the EU Ecodesign Directive, the Commission has set itself the task of exploring new requirements related to durability, reparability, disassembly, information, ease of reuse, and recycling for each new or revised standard.¹¹⁸ This exploratory process has not yet been completed, but should be continued and accelerated.
- Implementing the Commission's 2018 Circular Economy Package, which presents a range of potential policy instruments to improve the economy's resource efficiency, and focusses particularly on plastics and critical materials. One important legislative measure in the policy field is the recently agreed directive banning a number of single-use plastic items.¹¹⁹

National governments will need to deliver on the following implementation task:

- Applying the air pollution standards set out in the Industrial Emissions Directive by 2021 (see above).

mance in each sector and, where necessary, propose timely course correction measures in the run up to 2030.

Another critical building block in Europe's energy transition is the next EU budget, which will cover the period between 2021 and 2027 (See measure 7.10). Investment in Europe's clean-energy infrastructure represents a major challenge, particularly for member states with lower income levels and thus a more limited tax base. EU co-funding and the use of EU money to accelerate and scale private investment is essential to expand the deployment of renewable energy generation capacity, renovate the existing building stock, and enhance and strengthen power, gas, transport and heat networks. The budget is currently being negotiated by the EU's member states and the European Parliament.

Conclusion

Over the last few years, the EU has adopted a range of legislative measures that provide for ambitious action on climate change in all energy-using sectors. Putting these measures into practice will require the EU to agree on a range of implementing and delegated acts to settle numerous specific questions. It will also require member states to transpose EU law into effective national legislation and then to follow through with appropriate implementation. Effective implementation will require intensified cooperation between member states and a pro-active and supportive European Commission. Most importantly, the European Commission has a key role to play in enforcing the new set of rules and ensuring that both EU and national targets are reached by means of an effective monitoring system. To this end, it should regularly review the EU's and member states' perfor-

6 Ten priorities for the next European Commission: Meeting the EU's 2030 targets and accelerating towards 2050

The transformation and progressive decarbonization of the European energy system is a long-term project. However, decisions taken during the next decade will determine whether Europe can meet long-term targets in the face of the dire threat posed by climate change.

Member States and the newly elected European Parliament will soon appoint a new political leadership for the European Commission to take up work in November 2019. The European Commission is mandated with overseeing the effective implementation of existing European laws and with guaranteeing the function of the EU's Single Market. The Commission also has the right and the responsibility to propose new European laws so that these can be debated and eventually adopted by the European Parliament and member states in the Council.

Over the next five years, the European Commission will have to apply all its competencies to advancing a just and clean energy transition in Europe. Only if the new EU climate and energy laws are fully implemented and if the transformative force of the EU's Single Market is employed in favour of the energy transition, will there be political space for accelerating further.

The following section lays out ten priorities on climate and energy that are primarily directed at the new European Commission, including concrete next steps for reaching and potentially overshooting the EU's 2030 climate and energy targets. The ten priorities were distilled from a much broader range of ideas developed over the course of 14 months, taking into account:

- The backdrop of energy transition megatrends in *Chapter 1*,
- The public policy objectives (solidarity, security, competitiveness and innovation) with particular scope for EU level action in *Chapter 2*,
- The core strategies for achieving the 2030 targets in *Chapter 3*,
- The investments, costs and benefits of energy transition assessed in *Chapter 4*,
- The key implementation challenges emerging from recently adopted legislation in *Chapter 5*, and
- Input received from decision-makers and experts during the numerous meetings held as part of this project.

The ten priorities are all EU-level measures with strong value-added for a just and clean European energy transition. Three priority measures tackle effective implementation, three address the transport sector, three the industrial sector, and a last measure highlights priorities for the next EU budget.

For each priority we describe where Europe stands on the specific issue, where Europe needs to be in 2030 and what should specifically be done now by the incoming European Commission to get us there.¹²⁰

Priority 1 A vibrant action framework for 2030: Kickstarting and supporting implementation at the national level

1) Putting the 2030 implementation framework into action

- The European Parliament that assembles after the May 2019 elections should establish a *Standing Committee on the European energy transition* to create a political space for dialogue between national energy transition stakeholders and EU-level decision-makers.
- In November 2019, the European Commission should launch an *Energy Transition Support Service* that provides member states and stakeholders with tailored support to resolve concrete implementation challenges, advance initiatives, and facilitate partnerships.
- Finally, the European Commission must also launch a series of *Implementation Flagship Initiatives* that address the social dimension of the energy transition and break through existing bottlenecks (see Box 1).

Where we are today

The EU's new framework for energy and climate policy requires member states to draw up two plans: (1) an integrated national energy and climate plan for 2030; and (2) a long-term plan for 2050.

The integration and long-range planning required by this framework offers many benefits, such as improved infrastructure planning and the avoidance of fuel lock-in and stranded assets.

The new framework includes tools to assess whether member states and the EU are on track to meeting their 2030 targets and to addressing deficiencies that arise on the way. This is particularly important for sectors outside the EU Emissions Trading System – buildings, transport, agriculture, and parts of industry. At present, only six member states expect to meet their national 2030 targets based on current policies.¹²¹ Key priorities at present are the elaboration of new policy measures, the effective implementation of existing commitments, and the early development of implementation partnerships between high-income and low-income member states.

Inclusive dialogue around the national energy and climate plans will help to identify the redistributive effects and social impacts of specific energy transition

measures as well as address concerns about international competitiveness.

Where we want to be in 2030

By 2030, Europe has an integrated, forward-looking approach to energy and climate policy. Its ambitious energy transition policies are aligned with other drivers of large-scale change (such as digitalization). Social and economic concerns are addressed as integral elements of the transition.

The EU climate and energy framework has become the institutional backbone for a vibrant dialogue between national governments, stakeholders, and EU decision-makers. Where needed, existing measures are adjusted and new ones adopted. The European Commission is a strong partner to governments, regions, and cities in resolving concrete energy transition challenges. Moreover, the European Union has increased its greenhouse gas reduction target for 2030, putting it on track to become net zero by 2050 (see Chapter 7). The vast majority of Europeans positively embrace the idea of a carbon-neutral future.

What to do at EU level to get there

The energy transition in Europe needs a permanent space for political dialogue so that the integration of

climate and energy policy does not become a merely bureaucratic exercise. The new European Parliament should therefore establish a *Standing Committee on the European Energy Transition* that holds regular hearings with regions, cities, and other stakeholders on concrete political challenges that arise in implementing the 2030 framework. This committee would complement the Commission's annual status updates on EU climate and energy policy and technical discussions between Commission and member states.¹²²

The information generated under the 2030 framework and the demands of member states for targeted feedback and support will overwhelm the European Commission in its current state, leaving a significant gap between what the Commission can do and what some member states expect from it. The Commis-

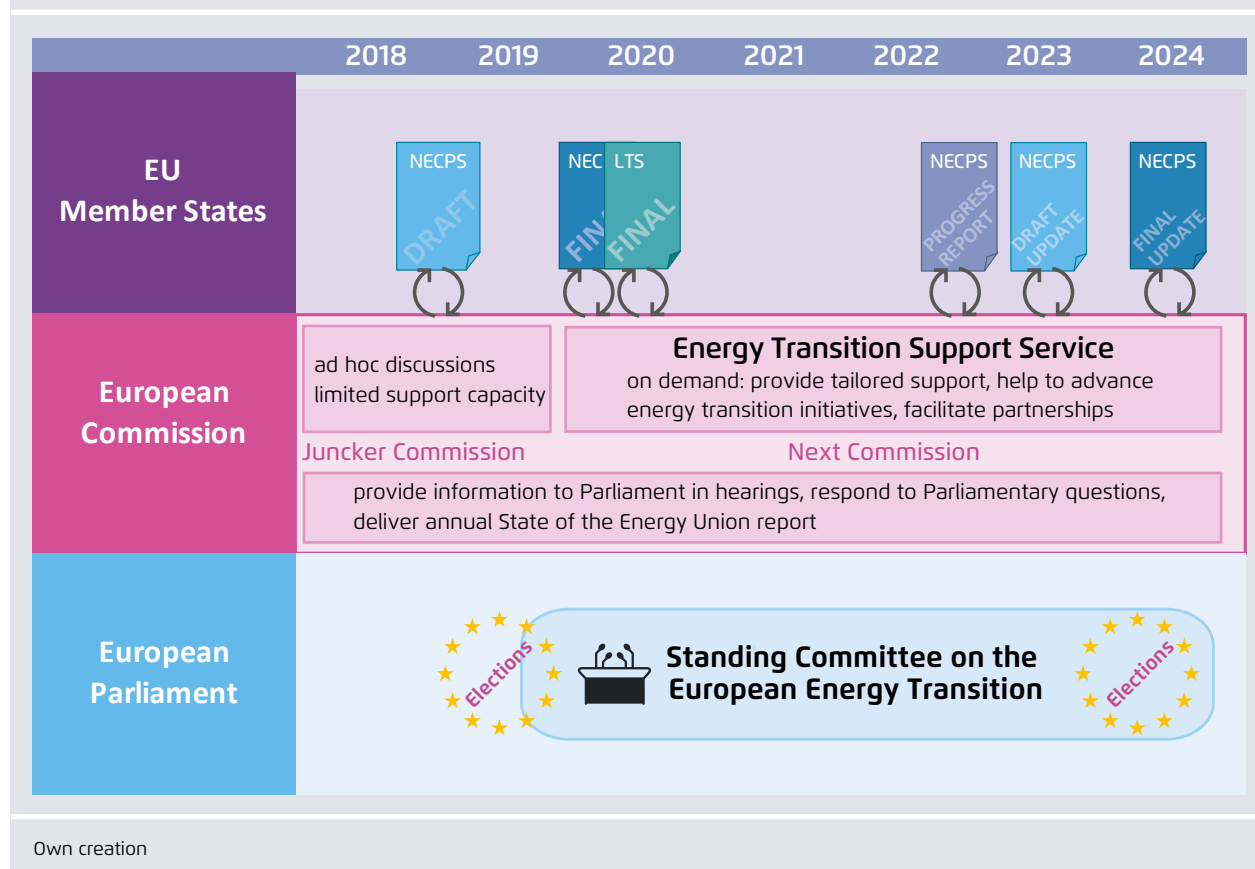
sion that assumes office in November 2019 should, therefore, establish a new *Energy Transition Support Service*. The service will respond to concrete requests and provide tailored support

- (i) to resolve concrete implementation challenges;
- (ii) to advance concrete energy transition initiatives; and
- (iii) to facilitate partnerships between member states.

Experience with early implementation will benefit stakeholders throughout Europe. Hence, the new European Commission should launch a set of *Implementation Flagship Initiatives* in tandem with interested partners that address the social dimension of the energy transition and break through existing bottlenecks (see textbox 1).

Proposed EU-level framework to support member state implementation and raising ambition (2019-2024)

Figure 24



Box 1: Four Implementation Flagship Initiatives that address the social dimension of the energy transition and break through existing bottlenecks

The 2030 climate and energy framework will benefit from initiatives that address the social dimension of the energy transition and break through existing bottlenecks. It is crucial that experience be shared across Europe to inspire further action. The following *Implementation Flagship Initiatives* are suggestions for catalysing delivery of the 2030 climate and energy framework through concrete implementation “on the ground”.

Initiative 1: Renovate 1 million buildings by 2025 on an industrial scale

Energy efficiency renovation of buildings is progressing at a rate of only 1% per year. This is less than half of what is necessary to reach the EU’s climate and energy targets for 2030. A crucial bottleneck is today’s small-scale approach: for most renovation projects knowledge, service provider, materials and financing are organised from scratch. The Dutch *Energiesprong* model¹²³ demonstrates that an industrialized approach can be both feasible and affordable.

This *Implementation Flagship Initiative* seeks to industrialize the process of energy efficiency renovation of buildings so that 1 million new building renovations can be completed by 2025. The initiative should build on the *Energiesprong* model and scale it for the entire EU, focusing on low-income housing and office buildings.

As part of the initiative, the European Commission should launch and co-fund 5–10 pilot projects per member state in partnership with national agencies, cities, and industries. The purpose of the projects is to demonstrate the feasibility of industrialized renovation of existing buildings. The European Commission should also organize accompanying studies to identify barriers and costs. If useful for further scaling, the next European Commission should propose before the end of its mandate an EU-wide measure to harmonize market entry conditions for industrialized building renovations throughout Europe.

Initiative 2: Add 10 million solar roof-tops by 2025

In 2015, only 4.7 million households in Europe (of 219 million in total) produced power with rooftop PV, most of them concentrated in one-third of the member states¹²⁴. Contrast this number with Europe’s total potential, which amounts to at least 68 million households¹²⁵, and an estimated potential for 2030 of at least 25 million¹²⁶. Despite this sluggish development, the costs for solar PV have fallen dramatically, while rooftop PV can generate up to three times as many jobs and three times as much value creation as large-scale PV installations.

This *Implementation Flagship Initiative* would add 10 million solar roof-tops by 2025 prioritizing socially and economically disadvantaged households in member states with low residential solar PV uptake. As part of the initiative, the European Commission should partner with regional governments and agencies to develop custom packages that combine (i) a review of administrative and regulatory conditions for developing rooftop solar PV and identifying best practices for power system integration; (ii) the creation of a financing strategy with the use of EU funds; and (iii) the dedicated support of training programmes for new installers.

Initiative 3: Support at least 100 cities in Europe to initiate the decarbonization of their heating and cooling networks by 2025

The new EU Directives on Renewable Energy and on Energy Efficiency require that member states progressively achieve both (1) improved energy efficiency and (2) an increase in the share of renewable energy and waste heat and cold within their overall heating and cooling mix. District heating and cooling networks could contribute significantly to both of these objectives. Although decisions regarding heating and cooling infrastructure planning and investment are made at the local level, the Commission can play an important role in supporting and encouraging cities and regions, especially by fostering the development of long-term planning, the better integration of EU infrastructure, and the targeted use of EU funds.

This *Implementation Flagship Initiative* seeks to help at least 100 cities in Europe in developing and launching long-term strategies for the decarbonization of their heating and cooling networks by 2025. To that end, the Commission must ensure that the district heating and cooling industry contributes to EU-level discussions on the joint Ten-Year Network Development Plan between ENTSO-E and ENTSO-G. Furthermore, it must make sure that district heating & cooling projects are eligible to achieve the status of Projects of Common Interest (PCI).

Initiative 4: Support a just transition in coal regions

Currently, 41 regions in 12 member states rely on economic revenues from coal mining and coal use, which provide direct employment to about 185,000 people across the EU. If the EU is to achieve its 2030 greenhouse gas reduction targets cost-effectively, coal-based power generation will have to be halved (see Section 3.2). This will decrease economic revenues and eliminate a significant number of coal-related jobs in affected regions, three-quarters of which are located in Central and Eastern Europe.

It is possible to phase-out coal over the course of a decade. But such a transition must be planned well in advance and be embedded in broader regional strategies developed together with affected stakeholders. As a first step in this direction, the European Commission in December 2017 launched the Coal Regions in Transition Platform to support dialogue and the sharing of experience between regional governments and stakeholders.

The *Implementation Flagship Initiative* to support a just transition in coal regions must be underpinned by robust financing opportunities in the next EU budget (2021–2027). Regions that are committed to phasing-out coal mining and coal use need specific support measures to attract new employers (companies, universities, research organizations) for worker retraining and infrastructure upgrades. In some cases, it will be possible to combine the phase-out of coal-related jobs with the creation of new-energy jobs, whether in renewables or in the emerging green hydrogen economy.

Priority 2 A state aid framework that enables and advances Europe's energy transition

2) Ensuring that state aid decisions are consistent with the EU's climate and energy targets

- The incoming Commission commits itself to achieve consistency of its state aid decisions with the EU's 2030 climate and energy framework. To this end, it should conduct internal assessments of relevant draft state aid decisions with EU climate and energy objectives and train staff of DG Competition on energy system aspects of the transition, key climate action technologies and energy market dynamics.
- The new EU Energy and Environment State Aid Guidelines should enable governments to
 - (i) create lead markets for industrial transformation,
 - (ii) push for electricity-led decarbonization in the transport and buildings sectors,
 - (iii) provide revenue stabilization for investors in specific energy transition technologies, and
 - (iv) employ a shadow price for carbon emissions consistent with scientific studies (80-100 Euro/tonne CO₂).

Where we are today

Today's markets do not reflect the true costs of carbon emissions (80-100 Euro/tonne CO₂). For this reason, governments must introduce regulatory, financial, and other supplementary measures that favour zero- or low-emission products, services, and investments. For example, governments across the world actively stabilize the revenue flows of investors in capital-intensive renewables.

Government measures that change market dynamics to reflect the true cost of carbon often qualify as state aid. The EU treaties provide the European Commission with a powerful role in this regard by prohibiting state aid unless the Commission specifically approves it. Commission decisions on state aid thus play a pivotal role in the energy transition (see figure 24). In some areas (e.g., capacity mechanisms, renewable energy investments, industry exemptions) they are as critical as formal EU laws on climate and energy.

To date, little effort has been made to ensure that state aid decisions are consistent with the European energy transition. However, as electricity-led decarbonization becomes a major force in the transport, building, and industry sectors and as governments in Europe actively create lead markets for large-scale decarbonization, state aid decisions will become even more important than today.

Where we need to be in 2030

By 2030, state aid decisions are a powerful tool for an energy transition that relies on market forces to achieve its objectives. The Commission routinely assesses the impact of state aid decisions on the energy transition. State aid decisions taken in the 2020s must enable member states to create lead markets for zero-carbon industrial products. This must trigger new investment, accelerated technology learning curves, and achieved significant cost reductions, all of which have advanced the clean European energy transition and given European industries a competitive edge in international markets.

What to do at EU level to get there

The new Commission leadership that will assume office in November 2019 must commit to ensuring that its state aid decisions are consistent with the EU's 2030 climate and energy objectives. To this end, the Commission should establish an internal quality check of relevant state aid decisions. This system must include a thorough appraisal of the likely impact of state aid decisions on greenhouse gas emissions and on the energy transition. Moreover, staff members at the Commission's Directorate General on Competition should receive regular training with regard to climate science, the transition's energy system aspects, key technologies, and energy market dynamics. Other Commission

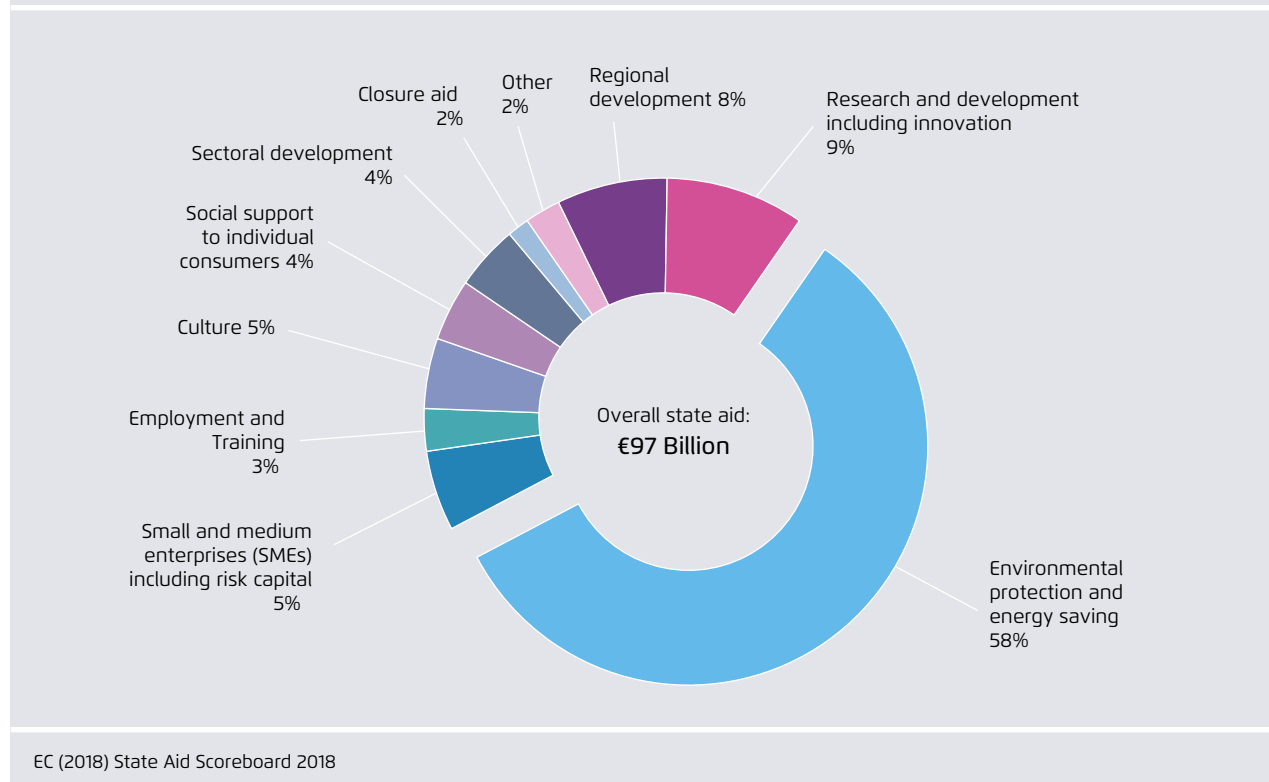
services should be routinely invited to validate basic assumptions about energy market dynamics, power system operation, technology costs, etc.

The Commission's updated Energy and Environment State Aid Guidelines should be crafted to enable a market-based energy transition. Specifically, the updated guidelines should:

- (i) include a dedicated section on industrial decarbonization that facilitates the creation of lead markets for zero-carbon products, processes, and services;
- (ii) support the electricity-led decarbonization of the transport and buildings sectors;
- (iii) introduce technology-specific revenue stabilization for investment in capital-intensive clean-energy technologies; and
- (iv) enable governments to employ a shadow price for carbon emissions in the range of 80-100 Euro/tonne CO₂.

Shares of overall state aid in the EU by category, 2018

Figure 25



Priority 3 A shadow price on carbon emissions to guide infrastructure planning and investment decisions

3) A shadow price on carbon emissions will align investment decisions with EU climate objectives, avoid stranded assets, and support the energy transition

- The new European Commission that takes office in November 2019 should prepare an ambitious proposal for an EU Regulation that sets an EU-wide minimum shadow price of €80–100 per tonne of CO₂ emissions and that determines how and for which specific decisions the shadow price will be applied at the EU and national levels.
- Shadow prices should be applied to legislative impact assessments, infrastructure planning, public procurement, EU project funding, and the setting of regulatory benchmarks for sustainable private-sector financing.

Where we are today

Shadow pricing is a method used in investment and decision analysis that seeks to more accurately consider the true cost of carbon emissions. Unlike a market price on carbon emissions, a shadow price does not change real world prices. Instead, it is used to better align investment decisions with climate objectives, by identifying the best investment case when markets are assumed to reflect the true costs of carbon emissions. It is a particularly helpful instrument when planning long-lived infrastructure (e.g. buildings, highways, and grids) or when making investment or procurement decisions. Carbon shadow prices are a useful complement to explicit carbon pricing instruments such as a carbon tax. One of their advantages is that their application can be determined very specifically through the underlying regulation.

Shadow prices on carbon emissions are already in use today. For example, German planners take shadow carbon prices into account within the framework of the Federal Transport Infrastructure Plan.¹²⁷ The Dutch Infrastructure Authority uses a shadow price to evaluate environmental impacts when ranking and selecting submitted offers.¹²⁸ And the World Bank and the European Investment Bank use shadow pricing to incentivize low-carbon investments.¹²⁹ Shadow prices are also used outside the public sector to guide

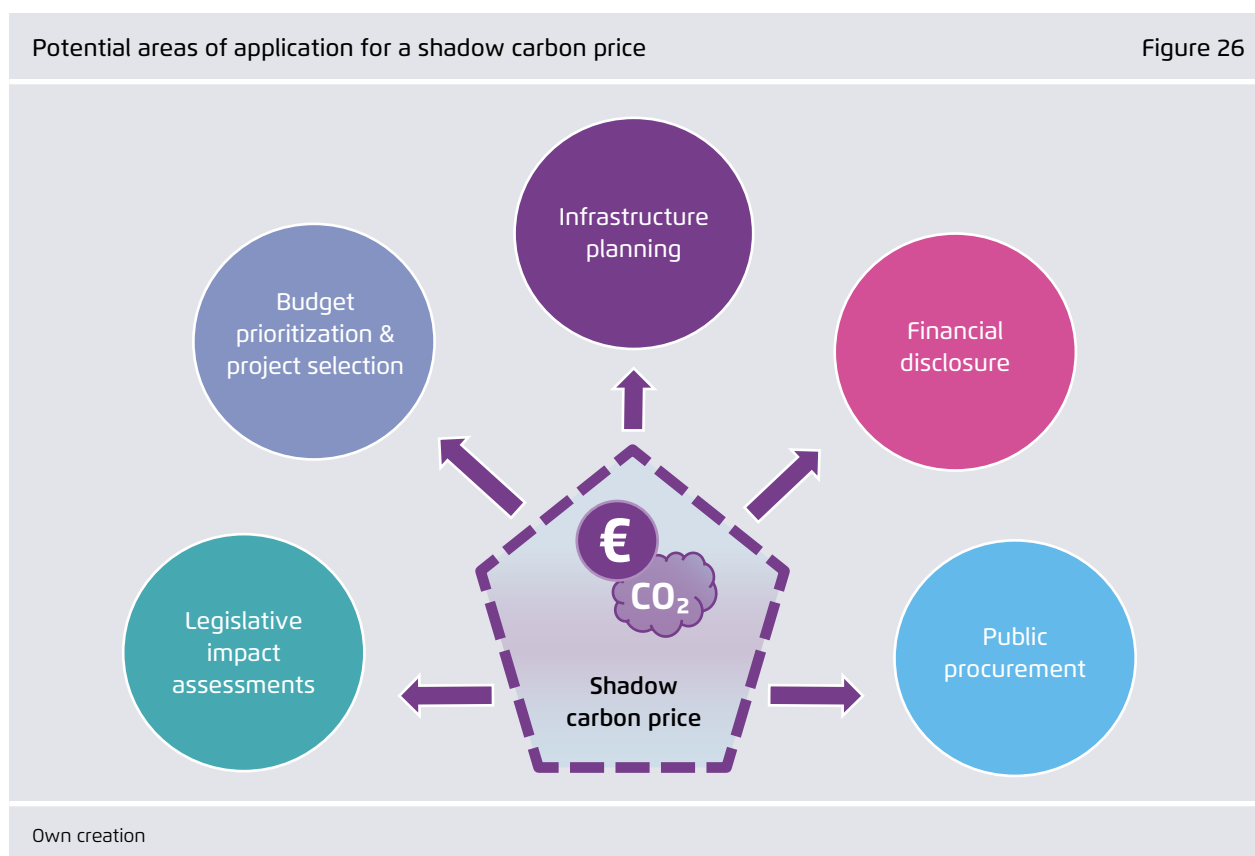
private investment decisions. Almost 1400 companies are already putting a price on carbon emissions or are planning to do so.¹³⁰ However, these efforts are mostly voluntary and the carbon price applied varies significantly between applications.

Where we want to be in 2030

By 2030, public authorities throughout Europe apply a carbon shadow price of €80–100 per tonne of CO₂ emissions to specified planning and purchasing activities, including public construction works.¹³¹ All legislative impact assessments prepared by the European Commission apply the shadow price when evaluating the costs and benefits of various policy options. Key EU legislation on infrastructure planning (e.g. the Ten-Year Network Development Plan for Electricity and Gas), on project selection for EU funding instruments (e.g. EU Projects of Common Interest), and on public procurement was updated to include a carbon shadow price. The European Investment Bank (EIB) uses shadow pricing for all infrastructure projects to align its investment decisions with the Paris Agreement on climate change.

What to do at EU level to get there

The new European Commission that takes office should pull together the best available knowledge on shadow pricing methods and on specific potential applications of carbon pricing in the EU framework. On this basis, the European Commission should propose an EU Regulation to set a shadow price of €80-100 per tonne of CO₂ emissions and to determine how and in which specific situations the shadow price will be applied at the EU and national levels. Shadow prices should be applied to all EU legislative impact assessments, public procurement, EU project funding, and the setting of regulatory benchmarks for sustainable private-sector financing.



Priority 4 Reducing emissions from individual mobility: An early and ambitious review of CO₂ standards for cars

4) Ensuring the right boundary conditions for the rapid adoption of electric cars

The European Commission that takes office in November 2019 should conduct an early and broad review of the effectiveness of the new CO₂ emission standards for cars. On that basis it should:

- propose by 2022 a further increase in ambition to ensure that by 2030 the majority of all new passenger cars are zero- and low-emission vehicles (ZLEVs);
- consider introducing binding ZLEV sales mandates;
- ensure that the method used to measure the energy consumption of electric vehicles and plug-in electric vehicles under the EU's type approval system is realistic;
- include ZLEVs in the EU Car Labelling Directive and
- propose EU legislation to safeguard and improve the energy efficiency of ZLEVs.

Where we are today

CO₂ emission standards for cars and vans are important for reducing CO₂ emissions and fuel consumption, as well as for driving the uptake of zero- and low-emission vehicles (ZLEVs). In December 2018 EU legislators reached a political agreement on an EU regulation that will establish emission standards for new passenger cars and vans for the years 2025 and 2030. This legislation requires a 15% reduction in CO₂ emissions from new passenger cars by 2025 and a 37.5% reduction by 2030 (compared to a 2021 baseline). In addition, it gives manufacturers some flexibility in meeting their targets if they produce certain shares of ZLEV. The Commission will review the effectiveness of the Regulation in 2023, while placing a special emphasis on the representativeness of measured CO₂ emissions.

This legislation is a step in the right direction. However, the new standards will not encourage the full exploitation of the technical potential and are projected to result in CO₂ emissions from road transport well above what is needed to decarbonise the transport sector in line with national emission targets under the EU's Climate Action Regulation. As a result, member states will need to implement supplementary and wide-ranging national measures to meet their

targets, particularly when they have comparatively high non-ETS targets under the Climate Action Regulation. Potential supplementary measures include raising fuel tax rates, reforming vehicle and company car taxation policies, and levying tolls on infrastructure use. However, all of these measures are controversial and difficult to adopt in practice.

Where we want to be in 2030

By 2030 the majority of all new passenger cars are zero- or low-emission vehicles. This brings the European Union on a path to zero emissions from transport by 2050. Legislation mandates further reductions in car emissions after 2030.

Zero- and low-emission vehicles sold in Europe are highly energy efficient in order to minimize the amount of electricity they consume, as they contribute to the amount of electricity generation that will need to be decarbonized. Realistic measurement methods are established for ZLEVs based on real-world conditions.

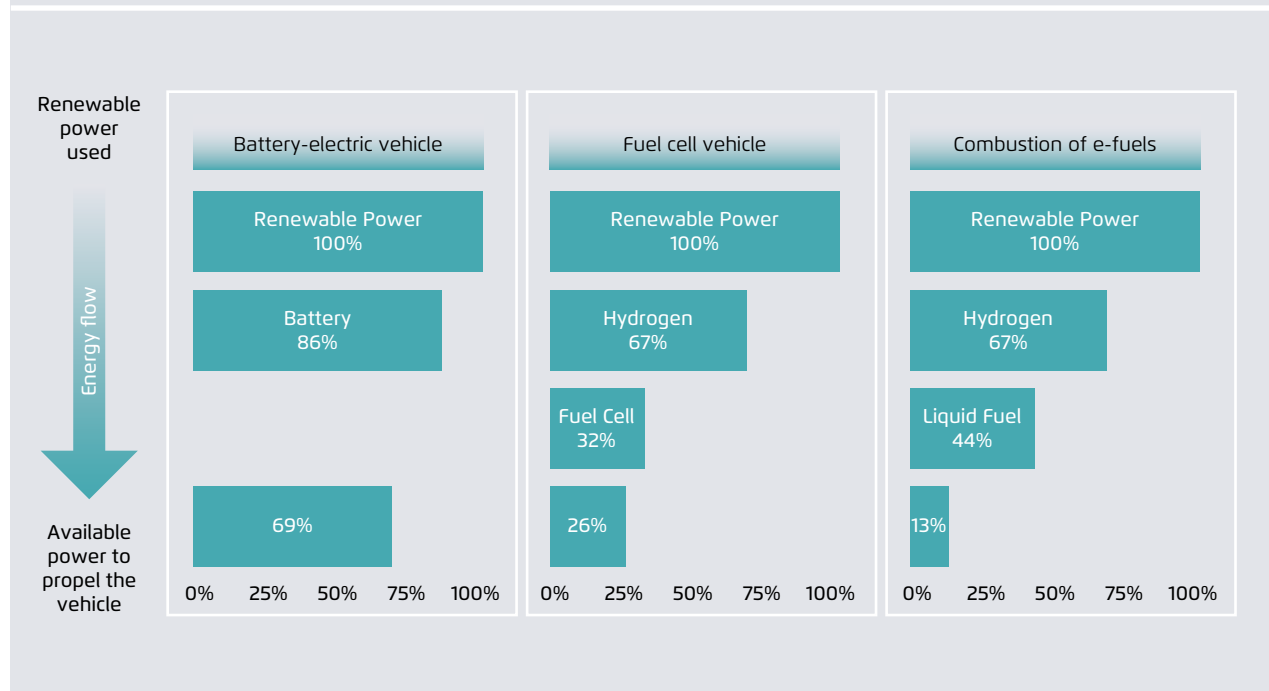
What to do at EU level to get there

The European Commission that takes office in November 2019 should undertake an early and broad review of the effectiveness of the new CO₂ emission standards for cars. On that basis it should:

- propose by 2022 a further increase in ambition to ensure that by 2030 the majority of all new passenger cars are zero- and low-emission vehicles (ZLEVs);
- consider introducing binding ZLEV sales mandates;
- ensure that the method used to measure the energy consumption of electric vehicles and plug-in electric vehicles under the EU type approval system is realistic in order to avoid a gap between tested and real energy consumption, as is the case for conventional vehicles;
- include ZLEV into the EU Car Labelling Directive¹³²; and
- propose EU legislation to safeguard and improve the energy efficiency of ZLEVs.

Individual and overall efficiencies for cars with different vehicle drive technologies, starting from renewable electricity

Figure 27



Authors' own illustration based on Agora Energiewende and Agora Verkehrswende (2018).

Priority 5 Reducing emissions from heavy transport by raising ambition and increasing member state flexibility

5) Adopt ambitious CO₂ standards for trucks and more flexibility for national road charging regimes

The European Commission that takes office in November 2019 should:

- propose by 2022 legislation that requires a -40% reduction in emissions from heavy-duty vehicles as well as a binding new sales quota for zero and low-emission vehicles (ZLEV) of at least 25% in 2030.
- further develop its proposal for a revision of the Eurovignette Directive on road charging to enable member states to include into national road charging regimes CO₂ costs of at least at €80–100 per tonne of CO₂ as well as the cost of key infrastructure investment for the European energy transition in transport.

Where we are today

Freight volumes have increased significantly since 1990 and will continue to grow in the years up to 2030. At the same time, the modal shares and competitive positions of road and rail freight transport remain substantially unchanged. Road freight transport dominates among inland modes (comprising 76% of freight volumes in 2016), while rail freight (with a share of 17.4% in 2016)¹³³ remains well below its potential for minimizing the environmental impacts of freight transport activity. Thus, the effective regulation of emissions from road freight is the most important lever available to the EU for reducing emissions from heavy transport.

In February 2019, provisional agreement was reached in the trilogue negotiations regarding the first ever EU-wide CO₂ emission standards for heavy duty vehicles (-15% CO₂ emissions by 2025 and -30% by 2030 relative to 2019 levels, in addition to an incentive system for zero- and low-emission vehicles). While this is a welcome step in the right direction, it falls well short of the technical potential for improving road freight efficiency (at least 40% compared to current levels¹⁸⁸).¹³⁴

As is the case of individual mobility (priority 4), governments in Europe with comparatively high national emission reduction targets under the EU

Climate Action Regulation will be obliged to put in place additional national measures to reduce freight transport emissions. In contrast to individual mobility, however, Member States are more constrained in their ability to take measures that will limit the free internal movement of goods in the EU's Single Market – for example, through fuel taxes or road charging. Furthermore, the proposed revision of the Eurovignette Directive on road charging will not be finalized before European elections.

Where we need to be in 2030

By 2030, Europe has electrified short-haul trucks (batteries, hydrogen) and realized the emissions reduction potential of long-haul trucks. The share of ZLEVs entering the market each year reaches at least one quarter of new vehicle registrations. The revised Eurovignette Directive permits member states to operate road pricing schemes that charge all vehicle types for their infrastructure use, support the financing of key infrastructure needed for the transformation of road freight, and fully internalize the external costs of road transport (including CO₂ emissions).

What to do at EU level to get there

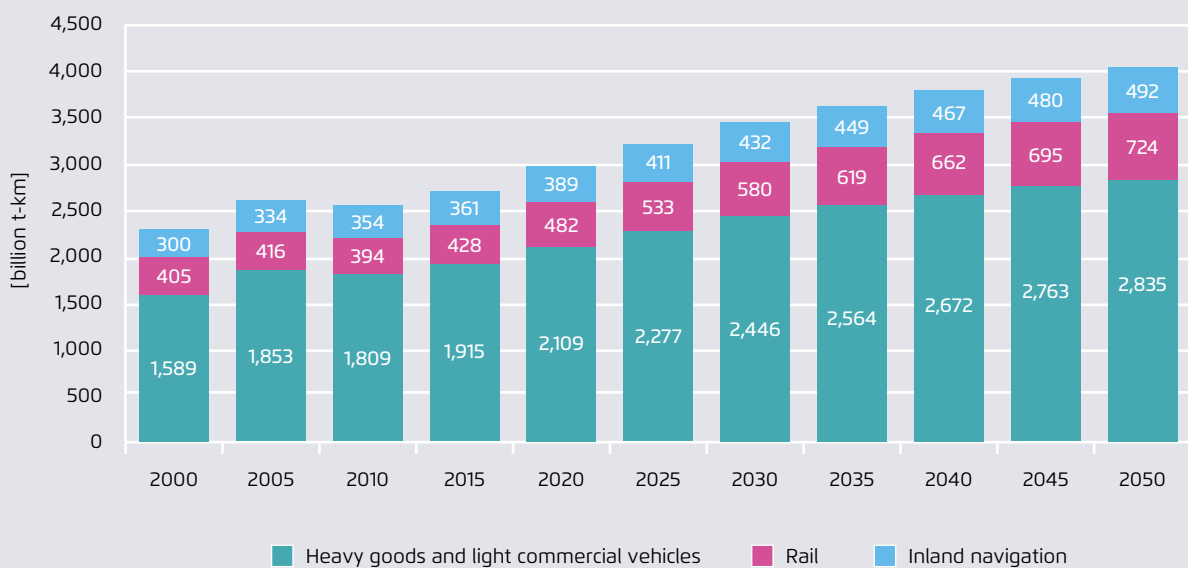
The European Commission that takes office in November 2019 needs to kick-start preparations for the 2022 review of the recently adopted CO₂ standards for heavy-duty vehicles. By 2022, it should propose legislation that requires a -40% reduction in CO₂ emissions from heavy-duty vehicles as well as a binding new sales quota for zero and low-emission vehicles (ZLEV) of at least 25% in 2030.

Furthermore, immediately after taking office, the new European Commission should modify its proposal for a revised Eurovignette Directive. The proposal should allow member states to apply road charges to all road vehicles, internalize the cost of climate pollution, and help finance the infrastructure investments needed for the transition to ZLEV. To this end, CO₂ costs should be added to chargeable external costs and set at 80–100 euros per tonne of CO₂, in line with the carbon shadow price (see Priority 6.3), and key

infrastructure investments for the energy transition in transport should be eligible for consideration as chargeable infrastructure costs (including catenary lines and inter-modal infrastructure).

Projected transport freight demand until 2050 for the EU28

Figure 28



EU Commission 2016 Reference Scenario

Priority 6 Opening up a pathway to decarbonize aviation and shipping fuels

6) Creating an enabling framework for the decarbonization of aviation and shipping fuels

- The new European Commission should propose a legislative package on the decarbonization of aviation and shipping fuels that includes concrete arrangements for the introduction of an alternative fuels quota in EU aviation and shipping, including measures to prevent avoidance strategies among operators.
- The package should also include robust additionality and sustainability safeguards for the sourcing of CO₂ for electrofuels production, as a complement to the sustainability framework developed for green hydrogen (see Priority 8).

Where we are today

Though aviation currently only accounts for 3% of the EU's greenhouse gas emissions, air travel is increasing significantly in the EU and globally. By 2030, this rise could wipe out around half of the reductions achieved in land transport emissions. While EU shipping emissions fell during the financial crisis, they are now rising in Europe and across the world. Existing mature technologies for the direct electrification of transport are either unsuitable here or are insufficiently energy-dense to power long-distance aviation and shipping routes. Decarbonizing such routes is therefore likely to require the use of advanced fuels (including electrofuels and advanced biofuels), as well as a significant increase in the efficiency of planes and ships. Each of these approaches will require large-scale investment in further research, innovation, and scaling if they are to become viable solutions. The Commission's 2016 European Strategy on Low Emission Mobility acknowledges the need to focus on such fuels in order to decarbonize sectors (such as aviation) that may remain at least partially dependent on liquid fuels.

The current fiscal and regulatory framework, however, is grossly inadequate for this task. Existing prices fail to incentivize the necessary transition. Although flights within the European Economic Area have been included in the EU's Emissions Trading System since 2012, a combination of low emission

allowance prices and tax exemptions (for aviation fuel and VAT on aeroplane tickets) has reduced incentives for decarbonization. Furthermore, all international flights are excluded from the EU's Emissions Trading System. The new EU Renewable Energy Directive requires member states to increase the levels of "new fuels", such as electrofuels and advanced biofuels, in the transport sector. The flexibility of the associated conditions nevertheless makes it highly unlikely that any member state will prioritize the decarbonization of aviation and shipping fuels.

Where we want to be in 2030

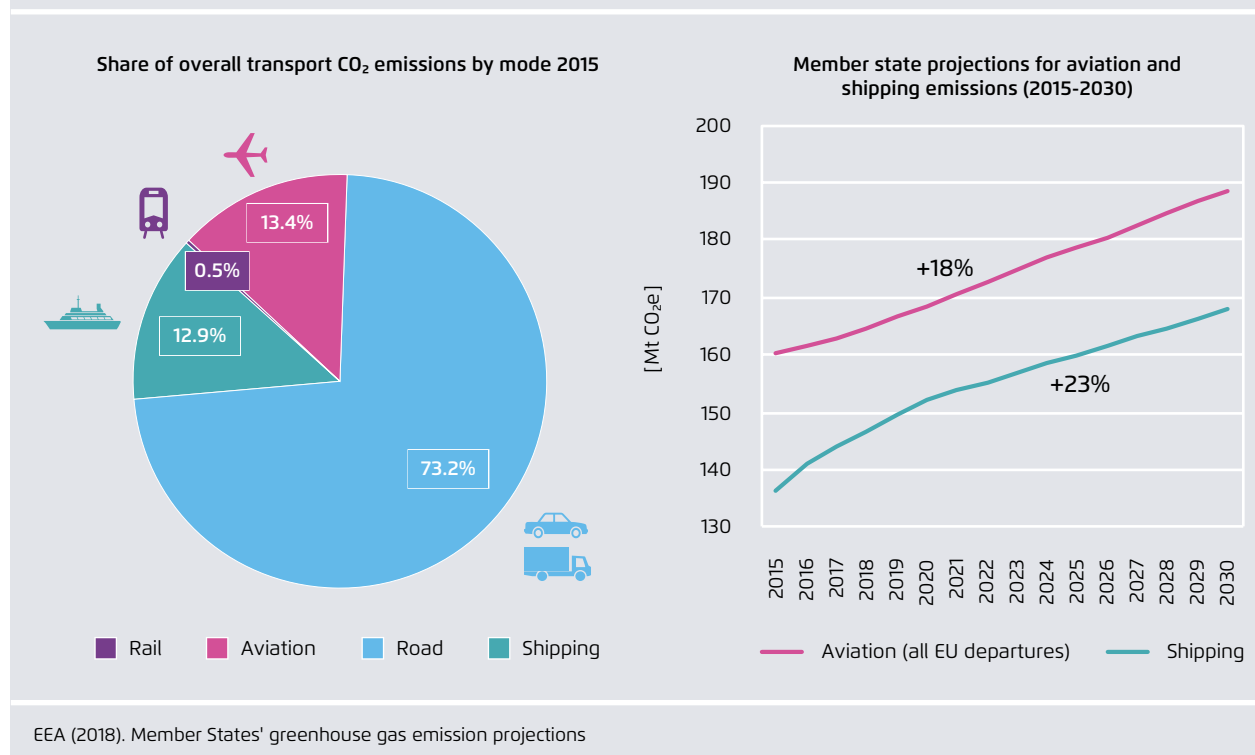
By 2030, active policy support for scaling up sustainably produced and efficiently used drop-in electrofuels and other alternative fuels such as ammonia has opened up a pathway toward a low-emissions future for aviation and shipping. Strict additionality and sustainability standards ensure that these changes in the composition of transport fuels result in real, quantifiable GHG reductions and that their production does not harm the environment. Complementary efforts by the International Maritime Organization and the International Civil Aviation Organization to increase efficiency standards for conventional ships and planes, as well as continued support for technological improvement, minimize the efficiency deficits of electrofuels.

What to do at EU level to get there

The European Commission needs to propose a legislative package on the decarbonization of aviation and shipping fuels that includes an EU electrofuels quota for aviation fuel supplied in the EU, as well as an EU quota for selected novel fuels in shipping fuel supplied in EU ports. This proposal should be designed in such a way as to ensure that the use of electrofuels in aviation and shipping is prioritized over their use in road transport. The EU quotas should be as ambitious as possible and should be incorporated into a strict additionality and sustainability framework that complements EU efforts on green hydrogen (see Priority 8). The sustainability framework should ensure that all of the CO₂ required for carbon-based electrofuels is derived exclusively from atmospheric sources or from sustainable biomass. Member States should be enabled to prevent tankering and other avoidance strategies such as moving aviation hubs overseas.

EU aviation and shipping transport emissions are projected to grow by 20% (2015-30), and far more globally

Figure 29



Priority 7 A strong, competitive, and sustainable battery industry in Europe

7) Establishing a comprehensive EU framework for a strong, competitive, and sustainable battery industry in Europe

- The new European Commission should launch a broad industrial strategy that combines regulation, financing, research, and international trade to promote a strong, competitive, and sustainable European battery industry.
- The Commission should propose:
 - EU legislation setting minimum environmental and sustainability requirements for batteries sold in Europe.
 - Ambitious recycling targets for strategically significant raw materials (particularly lithium and cobalt) as part of a reformed EU Battery Directive.
 - The inclusion of cobalt in the EU Regulation on Conflict Minerals.
- The Commission should establish a European clearing house for battery life cycle data to improve transparency on energy and raw materials consumption in battery manufacturing.

Where we are today

The electrification of road transport is picking up speed. A number of car manufacturers have recently made announcements concerning the purchase of battery materials, the introduction of electric vehicles, and the phasing out of internal combustion engines. Several countries in Europe have announced they will end registrations of internal combustion engine vehicles between 2030 and 2040.

Transport electrification will lead to a significant rise in demand for batteries. This raises a number of concerns. First, Europe risks replacing its current dependence on oil imports with a new dependence on imports of batteries and non-renewable materials such as lithium or cobalt, which are only mined in a limited number of countries. A further concern is the environmental footprint of current battery technologies, which is chiefly related to the emissions from the energy consumed in their production and the use of certain raw materials, particularly lithium, cobalt, nickel and graphite.

Against this backdrop, the European Commission launched the "European Battery Alliance" in October 2017 as a cooperative platform to help create a competitive manufacturing value chain for sustainable battery cells in Europe. In May 2018, the Commission

presented an "EU Strategic Action Plan for Batteries",¹³⁵ which aims in part to support the sustainability of EU battery cell manufacturing by encouraging the lowest possible environmental footprint. To this end, the Commission is now looking at design and use requirements for batteries sold on the EU market. It envisages the development of European standards for the production, (re-)use, and recycling of batteries, and is addressing the ethical sourcing of raw materials for the batteries industry.

Where we need to be in 2030

In 2030, Europe should be home to a strong, competitive, and sustainable battery industry. Automotive batteries sold in Europe should comply with environmental and sustainability standards that ensure transport electrification leads to real emissions reductions and is socially and environmentally sustainable. An effective recycling structure for lithium ion batteries should be in place across the EU and high domestic recycling rates for non-renewable battery materials should be complemented by international trade relations that enable such materials to be responsibly sourced. Decision-makers and stakeholders should have access to transparent information on energy and materials consumption in battery manufacturing.

What to do at EU level to get there

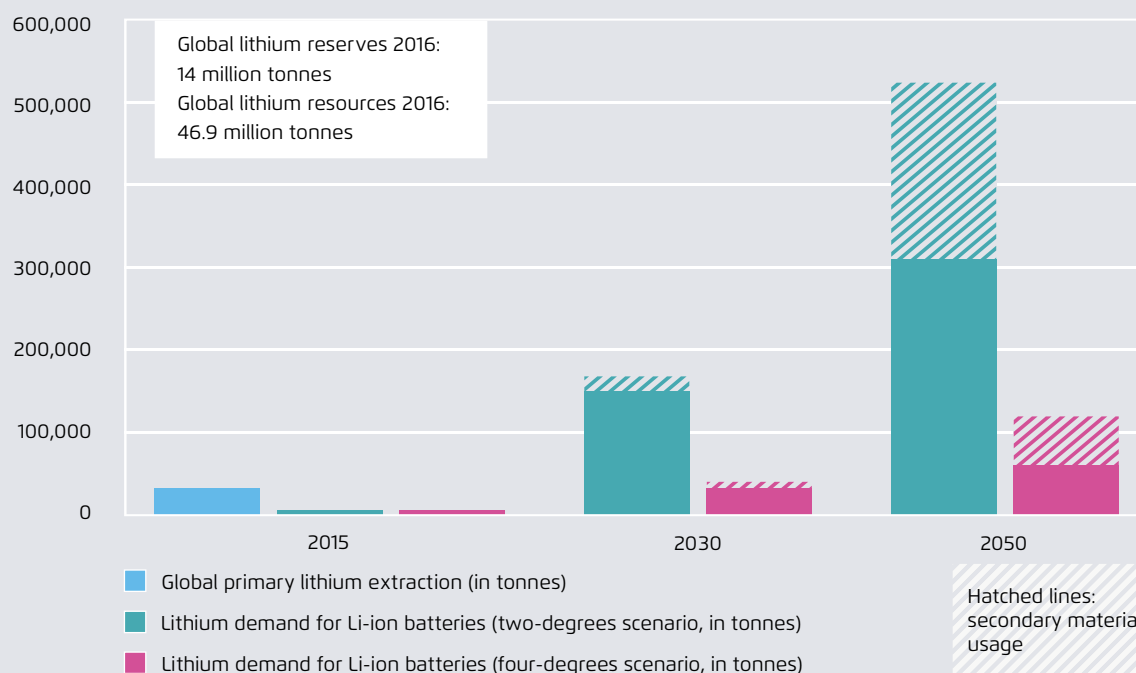
Building on the European Battery Alliance, the new European Commission should launch a broad industrial strategy to develop a strong, competitive, and sustainable battery industry in Europe. The strategy should combine the EU's power to standardize and shape sustainable battery markets with targeted finance for R&D and international trade instruments. In order to ensure battery sustainability in both design and use, the Commission should propose minimum environmental and sustainability requirements on the basis of a life cycle approach that addresses production-related greenhouse gas emissions for all batteries sold in Europe.

The Commission should use the upcoming reform of the EU Battery Directive to propose ambitious recycling targets for strategically significant raw materials used in batteries (particularly lithium and cobalt) and should recommend that cobalt be included in the EU Regulation on Conflict Minerals.

The Commission should create a European clearing house for anonymized battery life cycle data to improve knowledge on energy and raw materials consumption, while respecting competition.

Global lithium demand for lithium-ion electric vehicle batteries in 2015, 2030, and 2050 is much smaller than resource availability even in scenario consistent with 2°C temperature increase

Figure 30



USGS* 2017 for primary extraction levels and reserves and resources; authors' own calculations and visualisation

* Including secondary material usage

Priority 8 Establish the foundation for a scalable green hydrogen economy

8) Establish a robust framework that allows to scale up green hydrogen

- As part of its upcoming Gas Package, the Commission should propose a binding, gradually increasing EU-wide renewable gas quota for natural gas suppliers, rising from 2 percent of overall final gaseous fuels demand in 2022 to 10 percent in 2030. This is projected to equate to some 370 terawatt hours in 2030.
- A sub-quota should require at least one third of the annual renewable gas share to be supplied by green hydrogen. This will ensure that EU green hydrogen production and electrolyzer capacity grow to at least 120-125 terawatt hours and 30 gigawatt, respectively, by 2030.
- The Commission should include in its proposal a rigorous sustainability framework for green hydrogen and CO₂-based electrofuels to ensure the additionality of the renewable electricity used for its production.
- Finally, the Commission should work with stakeholders to harmonize technical rules for managing higher shares of hydrogen in existing gas grids.

Where we are today

Low-carbon technologies are still expensive in key areas of industry, such as steel and chemicals. The longevity and capital intensiveness of investment in these areas mean that most plants built in the next decade will still be in operation in 2050. If low-carbon technologies are to be deployed across the EU by 2050, they must be commercialized over the next decade. This is essential for carbon lock-in to be avoided.

Green hydrogen produced with electrolysis will play an important role in replacing fossil fuels in many industrial sectors. At present, however, green hydrogen is not competitive with fossil methane (natural gas) or with fossil-based, grey and blue' hydrogen. Driving down the cost of green hydrogen requires reducing the investment costs of electrolyzers by scaling up unit sizes and standardizing and commoditizing the underlying technology. At the same time, the pathways for green hydrogen and CO₂-based electrofuels (see figure 31) face significant uncertainties with regard to infrastructure, sustainability, and end-use prioritization. A rapid scale-up of investment in new large-scale electrolysis capacity will require the creation of a robust sustainability framework and the adoption of financial de-risking instruments. One such instrument could be a binding quota

or feed-in tariffs for injecting green hydrogen in the existing natural gas network so as to enable guaranteed off-take with long-term contracts.

Where we want to be in 2030

A European framework has been put in place that enables the scaling up of production and use of green hydrogen. Various industrial sectors consider green hydrogen as a medium- and long-term decarbonization option, and a robust sustainability framework for green hydrogen and electrofuels is in place to ensure further scalability. Harmonized EU-level rules allow a higher share of hydrogen in existing gas transmission and distribution grids – helping to displace fossil methane across the EU while maintaining the EU's single market.

What to do at EU level to get there

As part of its upcoming Gas Package, the Commission should propose a binding, gradually increasing EU-wide quota for renewable gases (biogas, biomethane, green hydrogen, synthetic methane). The quota would require suppliers of natural gas to include a gradually increasing share of renewable gas in their product, rising from 2 percent in 2022 to 10 percent of overall final gaseous fuels demand (measured in TWh) in 2030.

A sub-quota should require one-third of the share of renewable gases in each year to consist of green hydrogen. Green hydrogen that is supplied outside of the natural gas network (e.g. in separate hydrogen networks) may be counted towards the natural gas suppliers obligation.

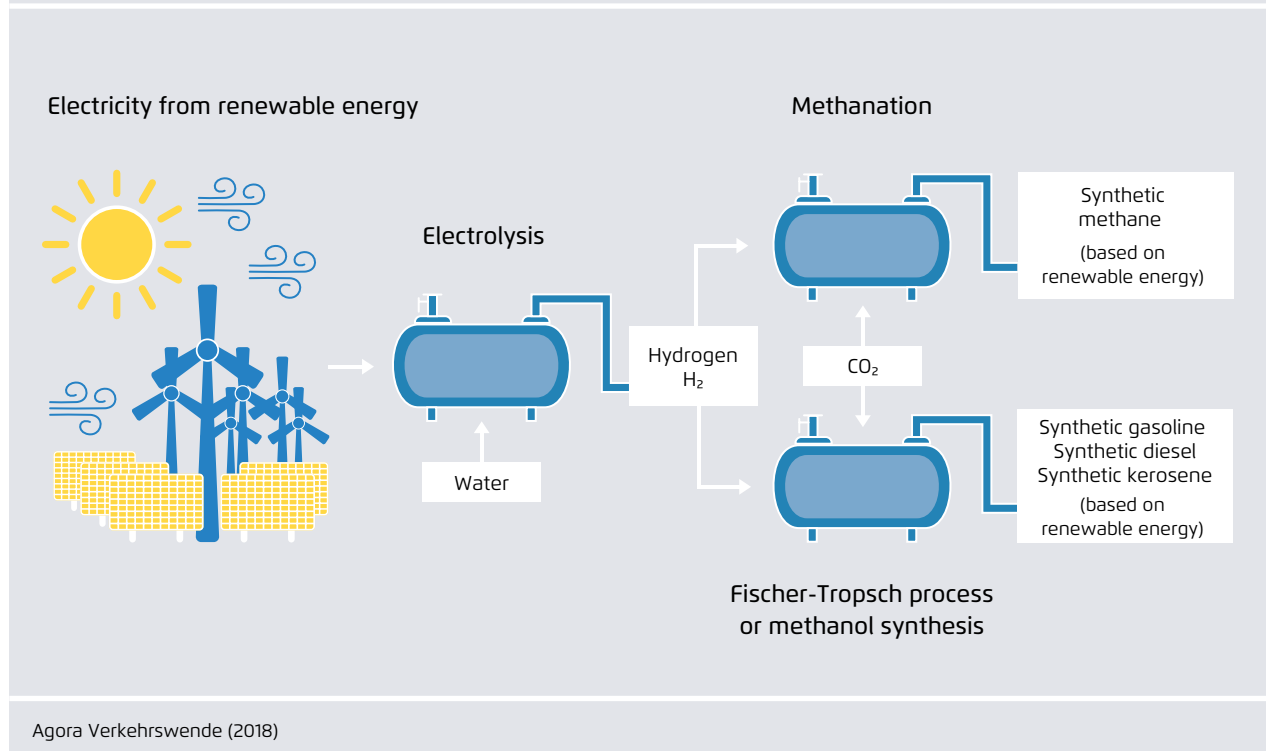
Projected demand for gaseous fuels in 2030 in the baseline scenario of the EU Long Term Strategy is 3720 terawatt hours. Hence, 10 percent of this amount would equate to some 370 terawatt hours of green gases in 2030, of which about 120–125 terawatt hours would stem from green hydrogen. The objective would ensure that the EU would increase its total electrolyzer capacity to at least 30 GW by 2030. This is needed in order to scale up green hydrogen and CO₂-based electrofuels after 2030 so as to fully decarbonize fuels by 2050.

For green hydrogen to reduce greenhouse gas emissions without adversely affecting the environment or social sustainability, the power that is used to produce green hydrogen must come solely from additional renewable power installations. The Commission should therefore include in its proposal a rigorous sustainability framework for green hydrogen and CO₂-based electrofuels.

Finally, the Commission should cooperate with relevant stakeholders to develop a new hydrogen network code that harmonizes technical rules on the content of hydrogen in gas grids with the aim of generally enabling a share of at least 15% hydrogen by volume across the EU.

Production process for electrofuels
(hydrogen, power-to-gas methane and power-to-liquid fuels) from sun and wind

Figure 31



Priority 9 “Buy Clean Europe”: Create lead markets for low-carbon cement and steel

9) Harnessing public-sector procurement to create lead markets for zero-carbon cement and steel

The new European Commission should launch a “Buy Clean Europe” initiative that includes:

- A proposal for an EU Directive that obliges public authorities to purchase low-carbon cement and zero-carbon steel in public infrastructure projects.
- A proposal for an amendment to the Clean Vehicles Directive that requires vehicles purchased by public authorities to contain a minimum share of green steel.

Where we are today

While new methods and technologies are enabling the greener production of key commodities such as cement and steel, price remains the decisive driver of commodity purchase decisions. In the absence of a global carbon price, commodity producers thus have little economic incentive to invest in green innovation, as this threatens to undermine their price competitiveness. This is a pressing problem, as the commercialization of industrial decarbonisation technologies is essential over the near-term if widespread adoption is to take place after 2030.

Public authorities are a major source of demand in many European markets. In 2015 public purchasing, excluding utilities and defence, accounted for more than 2 trillion euros, some 13% of EU GDP.¹³⁶ Current EU procurement laws *allow* but *do not oblige* purchasing authorities to include environmental performance criteria in public tenders. In real-world practice this option is rarely exercised.¹³⁷

Against this backdrop, in February 2019 the Council and Parliament found a political agreement on a revision of the EU Clean Vehicles Directive¹³⁸ that would oblige public authorities to meet minimum procurement targets for clean vehicles (light-duty vehicles, buses, trucks) in 2025 and 2030. If formally adopted, the negotiated agreement will send a strong signal that procurement activities must become a driver of the European energy transition. Notably, the EU does

not yet apply a similar approach to public infrastructure investments. This is surprising considering the importance of infrastructure for effective decarbonisation (see chapter 4.6). Furthermore, the purchase of low-carbon cement and low-carbon steel would only have a minor impact on end-consumer prices for buildings and vehicles (see figure 32).¹³⁹

California, the world’s fifth largest economy, recently adopted the “Buy Clean California Act”.¹⁴⁰ The law obliges purchasing authorities to take climate change into account in their planning and investment decisions and to employ full life-cycle cost accounting when evaluating and comparing infrastructure investments. It applies to construction materials such as steel and glass (including to mineral wool for insulation) whether these are domestically produced or imported. Due to its full life-cycle approach, the law addresses emissions embodied in products and thereby avoids the taxpayer financing of construction materials produced in countries with highly carbon intense energy systems.

Where we want to be in 2030

The “Buy Clean Europe” initiative has ensured that all public infrastructure projects progressively use low- and zero-carbon materials based on a full life-cycle approach and that vehicle companies progressively use green steel for cars, buses, and trucks. In this way, domestic demand provides innovative companies with the stability needed to invest in low- and

zero-carbon products. By extension, the EU steel and cement sectors are competitive and key exporters of low- and zero-carbon solutions in rapidly growing international markets.

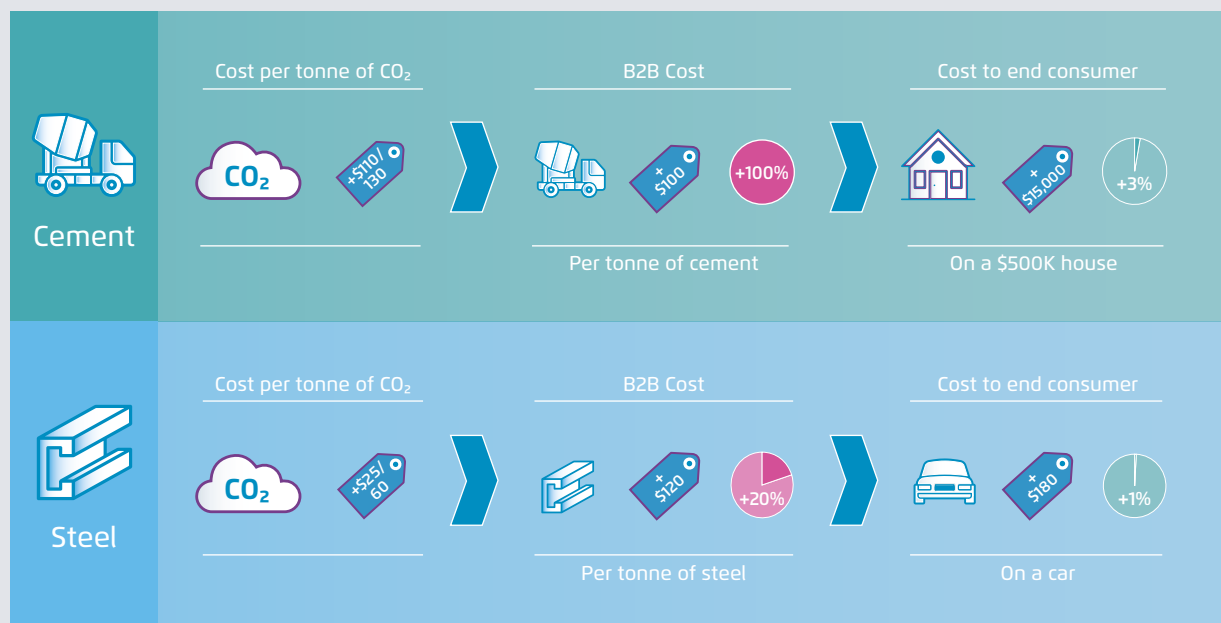
What to do at EU level to get there

The new European Commission should launch a “Buy Clean Europe” initiative that targets the cement and steel sectors, where innovation in low- and zero-carbon products is urgently needed before 2030. To provide the sector with a reliable investment and innovation framework, the European Commission should:

- Propose an EU Directive that obliges public authorities to step-by-step increase the purchasing of low-carbon cement and zero-carbon steel in all public infrastructure projects.
- Propose an amendment to the Clean Vehicles Directive that requires vehicles purchased by public authorities to contain a minimum share of green steel.

Maximum decarbonization costs for cement and steel

Figure 32



Based on Energy Transition Commission (2018)

Priority 10 Prioritize energy transition in the new European budget for 2021-2027

10) Set EU budget priorities to support decarbonization and the European energy transition

- The next EU budget should make at least 25% of non-climate-related funding under the Cohesion and Structural Funds conditional on the fulfillment of certain basic criteria related to the European energy transition.
- The new EU budget should explicitly ban funding for fossil fuels and establish a shadow carbon price of €80–100/t CO₂ for the prioritization of funding for infrastructure projects.
- The European Commission should insist that operational programmes negotiated with member states reflect key budget priorities in support of the European energy transition (see Box 2) and enable the European Energy Transition Support Service to support flagship initiatives (see priority 1).

Where we are today

Reaching the EU's climate and energy targets for 2030 will require additional investments of around 144 billion euros per relative to current policies euros per year, mostly from private sources. However, public funding will play an important role as a driver of investment activity. By financing critical infrastructure such as electric vehicle charging networks, public authorities can pave the way for increased private-sector investment and consumer demand. Public funding will also be important when market participants do not have an incentive to act. The construction of interconnectors between national power systems, for example, requires government initiative. Public spending can also augment the impact of private investment when used to support specific activities. Public and private partnerships are particularly important for the development of energy technologies with high upfront costs and associated financing risks.

Comprising just 1% of EU GDP, the EU budget is small compared to the national outlays of member states. However, in certain areas, the EU budget fulfills crucial functions. In many Eastern and Southeastern Europe, for example, government investment in public infrastructure is reliant to a significant extent on EU funding. Furthermore, EU research funding is one of the most important sources of funding for universities and research centres in Europe.

National budgets normally follow annual cycles. The European Union, by contrast, uses multi-annual budgets that are normally seven years in duration. The next EU budget is for the period 2021–2027. These will be decisive years for the European energy transition and for entering a pathway to net-zero emissions by mid-century.

The Commission proposed a new EU budget in the summer of 2018,¹⁴¹ which is slated for adoption in 2020. The proposed budget foresees a general earmark for "climate action". However, little effort has been made to strategically channel EU funding to the most pressing investment priorities in the European energy transition. Moreover, the proposed budget does not rule out EU funding for investment into new fossil fuel infrastructure.¹⁴²

Where do we need to be in 2030

By 2030, EU funds have triggered substantial spending on clean-energy infrastructure, both by national governments and the private sector. EU research and innovation funding plays a crucial role in developing and scaling up the transformational technologies needed to achieve a net zero economy. EU funding is used to assist regions transitioning away from coal mining and use. Well before 2030, fossil fuel assets do not anymore receive EU funds, with the limited exception of investment to upgrade existing gas and

heating infrastructure to accommodate a decarbonized energy supply.

What to do at EU level to get there

At least 25% of funding not related to climate action under Cohesion and Structural Funds should be made conditional on member state fulfillment of the following criteria:

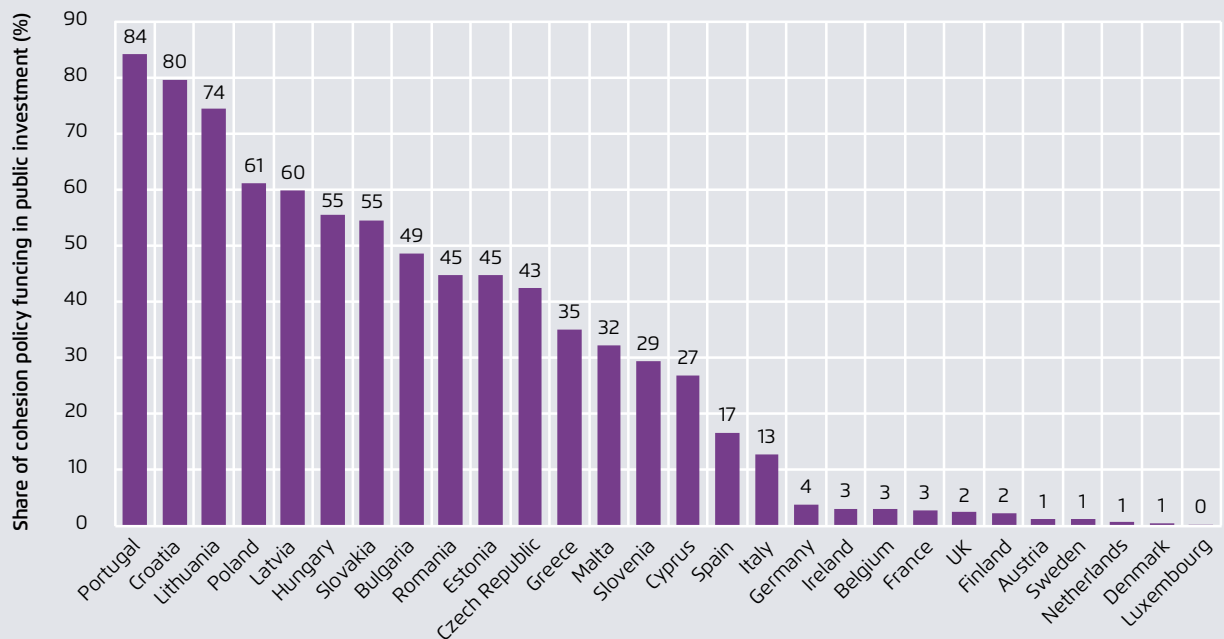
- (1) the adoption of planning to make a fair contribution to achieving EU targets on energy efficiency and renewables;
- (2) the development of a long-term building renovation strategy; and
- (3) the implementation of EU renewables and efficiency legislation.

EU budget laws¹⁴³ should explicitly ban funding for fossil fuels and set a shadow price of €80–100 for identifying infrastructure projects eligible for funding from the EU budget.

When negotiating “operational programmes” implemented by member states to determine how EU funding is spent, the European Commission should ensure that key financing needs in support of the European energy transition (see Box 2) are fully met and that the Energy Transition Support Service is able to support Implementation Flagship Initiatives that address the social dimension of the energy transition while breaking through existing bottlenecks.

Share of cohesion policy funding in public investment per Member State (%), 2015-2017

Figure 33



EC (2018)

Box 2: Key budget priorities to support member state implementation of the 2030 climate & energy targets

This report has highlighted various actions that can be taken to address the social dimension of the European energy transition and to surmount existing bottlenecks. Some of the measures we have described – such as the Implementation Flagship Initiatives described in priority 1 – seek to catalyze private sector activity and may require a contribution from public funds to go forward. In other cases, the described measures represent a mere prioritization of public spending. The budget priorities discussed in the following fall under this second category. However, we do not provide an exhaustive list of the areas in which public funds could usefully accelerate the European energy transition.

EU budget measures to support the European energy transition

Guarantee renewable investment to support the scaling of low-cost wind and solar

Some member states with significant untapped renewable energy potential are impaired by high financing costs for renewable energy investment. This makes renewables much more expensive than necessary, despite drastic declines in technology costs. Reducing the financing costs for renewables to levels currently found in Germany or France would save taxpayers and consumers many billions of Euros¹⁴⁴.

The EU budget should enable member states to transfer 5% of allocated Cohesion and Structural Funds to a European guarantee scheme that will reduce investor risk and thus lower the financing costs for renewable energy infrastructure. It appears advisable to maintain the EU budget guarantee and to expand its use, e.g. by combining it with the EU renewable energy financing mechanism (see below) or by allowing national and international public financial institutions to inject additional funds into the budget guarantee mechanism.

Contribute to the EU renewable energy financing mechanism

The new Energy Union Governance Regulation requires the Commission to establish an EU renewable energy financing mechanism by 1 January 2021. This financing mechanism is to serve as the key EU “gap filler” instrument in the event member state commitments to build up renewables do not add up to the EU-wide target (ambition gap), or if the EU is significantly off-track in meeting its planned trajectory (delivery gap). The mechanism would accomplish this goal by tendering support for new renewable energy projects. Currently no funds are earmarked for this purpose, the only funds foreseen are voluntary contributions by member states. To ensure the instrument can fulfil its intended function the Commission should annually transfer unused EU funds into the financing mechanism from the beginning of the next multi-annual EU budget.

Finance infrastructure for e-mobility and a modal shift

Overall, member states continue to allocate more EU funds to roads than to rail infrastructure and often do not specifically target rail freight needs. EU investment in multimodal projects (e.g. in rail-road terminals) has been low compared to other infrastructure. There is also a geographic imbalance in the distribution of multimodal TEN-T projects between EU member states (about 90% of such projects are within Western and Northwestern Europe). A similar geographic disparity between Western and Eastern Europe could temporarily develop in charging infrastructure for electric vehicles. While public charging infrastructure is generally expected to be adequate, Southern, Central and Eastern Europe will significantly lag

behind Northern and Western Europe, based on member state plans. EU funding from the Connecting Europe Facility should help to ensure the whole EU territory is given the same opportunity to be connected by rail and a comprehensive electric vehicle charging network.

EU Budget for people and regions

Scale up finance for building renovations in Central and South-Eastern Europe

Much of the cost-effective potential for renovating buildings is located in Central and South-Eastern Europe. This region includes the poorer member states of the EU. Energy poverty and vulnerability to gas-supply disruptions are additional challenges. At the same time, EU funding plays a key role in the region: five of the region's member states draw more than 50% of their public investment funding from EU cohesion funds; the corresponding EU-wide figure is just 13%. However, these Member States do not have policies to encourage large-scale building renovations and often lack project development capacity at the regional and local levels.

The Clean Energy for All Europeans package includes a "Smart Finance for Smart Buildings" initiative that aims to make investment in residential energy efficiency projects more attractive to private-sector investors. The EU budget should be used to follow through on this important initiative; among other things, the budget should introduce: (1) financial platforms, and (2) one-stop shops at the regional level to help reduce the cost of energy renovation by bundling small projects into larger ones. The Commission's newly established "Energy Transition Support Service" could help to disseminate expertise and best practice in the region while also facilitating the implementation partnerships between member states.

EU budget for research and innovation

Fund research & innovation in immature, early-phase technologies

The EU should provide at least 1 billion euros in support from Horizon Europe and the ETS Innovation Fund for research and innovation projects focused on 100% hydrogen grids and hydrogen-based industrial decarbonization technologies (e.g. direct reduction of iron). To ensure full use of these funds, the funding programs should provide attractive co-financing conditions appropriate for the high-risk nature of these projects.

With regard to transport, the EU budget for research and innovation is limited (as it is only equivalent to 0.2% of the European automotive industry's total investment in R&D).¹⁴⁵ The money allocated for research and innovation in transport should target areas that otherwise might not find adequate private-sector funding. This includes the development and demonstration of less mature, early-phase technologies, including solid-state batteries, overhead electric catenary lines, electric passenger airplanes, and electrofuels

Fund innovation in direct air capture technologies

Direct Air Capture (DAC) technology will have to be further developed if the CO₂ for carbon-based electrofuels is to be sustainably produced over the long term. DAC is currently only available at the scale of pilot projects. As long as low-cost CO₂ is available from the cement and steel industries, investment in DAC will not reach the scale needed for rapid cost reductions. To deliver significant production volumes in the medium term, DAC must become cheaper in the next decade. Thus, the EU should provide direct financial support for the development of this technology using Horizon Europe funding.

7 Stepping up the EU's climate ambitions: The pathway to Net-Zero Europe

In view of the severe risks posed by global warming tipping points...

In October of 2018, the 195 governments that make up the Intergovernmental Panel on Climate Change (IPCC) released the Special Report on Global Warming of 1.5 °C.¹⁴⁶ The report describes the harmful effects that could result if the earth warms more than 1.5 °C above pre-industrial levels. More importantly, the report concludes that an increase of 2 °C or more is likely to trigger irreversible tipping points in climate systems, including the large-scale melting of polar ice and the release of huge reserves of methane currently trapped in ocean sediment and permafrost. It is imperative that we avoid crossing these tipping points. Indeed, the projected impacts of global warming differ dramatically depending on whether the temperature rises 1.5°, 2°, or to 2.5° C; every tenth of a degree counts.

...the EU must reduce greenhouse gas emissions to net zero by 2050

The signatories of the Paris Agreement, which include the Member States of the EU, have pledged to limit global warming to "well below 2 degrees". There is broad agreement that remaining "below 2 degrees" will require that the European Union reduce greenhouse gas emissions to net zero by 2050. Doing so will be a challenge. The EU's 2030 targets are merely the halfway point.

In March of 2018, the EU heads of state tasked the European Commission with developing a 2050 strategy.¹⁴⁷ The Commission presented a long-term strategy in November of 2018, a few days before the start of the UNFCCC Conference in Katowice, Poland. Based on its scenarios, the Commission found that

reaching carbon neutrality in 2050 is both technically feasible and economically affordable.

The problem is that the EU's current target for 2030 – a 40% reduction of greenhouse gases – is too timid. If the EU wants to reach carbon neutrality by 2050, it must move further and faster now. Otherwise it will have to double or triple its reductions in the years after 2030. Stepping up the EU's climate ambitions will be one of the main political challenges facing the incoming European Parliament and the European Commission.

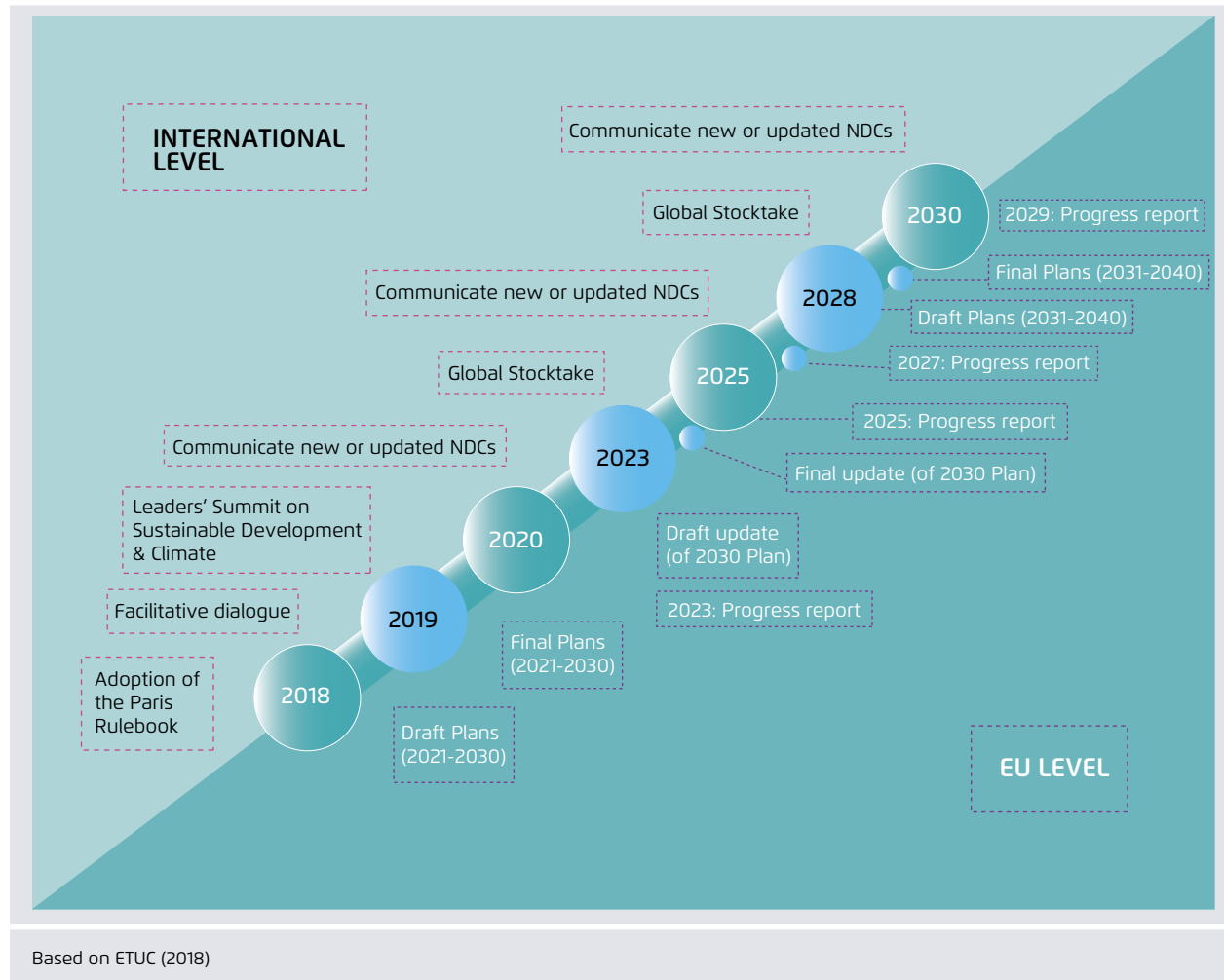
The question is not whether the EU should increase its 2030 climate ambitions but how much...

The issue of more ambitious climate targets will be on the EU's policy agenda immediately following the appointment of a new European Commission later this year. That is because the binding "review and ratcheting up" procedure of the Paris Agreement is scheduled to take place for the first time in 2020 (see figure 34). It requires that the 184 parties to the agreement review their national contributions for limiting global warming and set more ambitious targets as needed.

The first review and ratcheting-up process will be a crucial moment for the Paris Agreement because the outcome will show whether the climate treaty can deliver. During the process, the European Union and its Member States will be under the spotlight. There are a number of reasons for this: France hosted the 2015 global climate conference that adopted the Paris Agreement; Europe, a highly industrialized region, is expected to be at the forefront of devising effective strategies for combatting climate change; the EU and its Member States have traditionally been a

Time-table of important dates 2018-2030

Figure 34



leading voice in global climate policy; and, finally, the 2020 UNFCCC conference will take place in Western Europe as per UN rules.

Politically, therefore, the question is not *whether* the EU will increase its current pledge – a 40% reduction in greenhouse gas emissions by 2030 – but *how much*, and whether their new ambitious target will set Europe on a pathway to net-zero emissions by 2050.

What emission reductions can be expected from current policy?

The EU's current 2030 target of reducing greenhouse gas emissions by 40% dates back to a decision by EU heads of state in October of 2014, more than a year before the Paris climate summit. The EU's main climate change laws for 2030 (the Emissions Trading System and the Climate Action Regulation for emissions outside the ETS) were calibrated using this target. However, EU legislators *implicitly* decided to increase greenhouse gas reduction levels when setting the 2030 targets for energy efficiency and renewable energies (32.5% and 32%, respectively).

European Commission calculations for its long-term strategy show that the achievement of these targets would reduce greenhouse emissions in Europe by slightly more than 46% by 2030¹⁴⁸.

Achieving a 46% reduction by 2030 is easier said than done. And the kind of challenge it represents differs significantly between emissions under the EU's Emissions Trading System (roughly 40% of emissions) and emissions in sectors outside the EU ETS (transport, buildings, agriculture, parts of industry). As of this report's printing, the European Environment Agency has projected that only six Member States will meet their 2030 national reduction targets for emissions outside the EU ETS based on current trajectories.¹⁴⁹ The situation is particularly challenging because the EU's new vehicle efficiency standards stop short of what is technically possible and the current building retrofit rate is less than half of what would be needed to meet non-ETS targets. The task is less daunting on the ETS side. Indeed, market dynamics and increases in renewables make it likely that CO₂ emissions from fossil-fired power plants and industrial installations subject to ETS emission caps will continue to fall faster than needed to meet reduction targets for these areas. For more than a decade now, annual ETS allowances have exceeded market demand. In 2018, ETS emissions were 10% below the cap.¹⁵⁰

The rapid decarbonization of the power sector is a welcome development because it makes the electricity-led decarbonization of the transport and building sectors even more effective through sector coupling. The trend will also provide some flexibility for Member States, allowing them to offset a portion of their obligations in non-ETS sectors as part of a broader package to step up EU climate ambitions.

International cooperation enables more ambitious climate targets

Article 6 of the Paris Agreement permits its parties to cooperate when implementing their national contributions for emission reductions. That means that surplus reductions from countries that exceed their targets can count towards the targets of other countries. The objective is to make it easier for countries to set more ambitious climate targets. Three types of cooperation are possible: direct bilateral cooperation (Article 6.2), the sustainable development mechanism (Article 6.4), and non-market-based approaches (Article 6.8). The guidelines, rules, and terms of this cooperation are still being negotiated as part of the UNFCCC conferences; they will be finalized at COP 25 (November 2019, Chile) and COP 26 (November 2020, Western Europe).

In principle, Article 6.2 and Article 6.4 work much like the Emissions Trading Scheme and the Kyoto Protocol's Joint Implementation (JI) and Clean Development Mechanism (CDM). However, credits from unsound JI and CDM projects were the main reason for the severe crisis that the EU Emissions Trading Scheme experienced between 2011 and 2017. "Hot air" JI credits from the Ukraine and Russia flooded the EU ETS in 2011 and 2012, along with credits from Chinese HFC CDM projects with little environmental merit. After 2012, these credits were banned from the EU ETS, but the damage was already done: the 1.5 billion useless JI/CDM credits that entered the EU ETS greatly contributed to the surplus we still see in the scheme today. Only the latest reforms of the EU ETS – the introduction of a market stability reserve and a surplus cancellation mechanism – will finally resolved the issue, but they don't come into effect until 2023.

When completed, the rulebook for Article 6 of the Paris Agreement will offer a fresh approach to international cooperation with national climate targets. Assuming that the rules fully comply with environmental integrity standards, they will provide incentives for the EU to set more ambitious climate targets while increasing international cooperation.

A proposal for a new EU 2030 climate target: a 50% reduction in greenhouse gases relative to 1990 levels, with up to 4% through international cooperation under Article 6 of the Paris Agreement

In light of the points raised above, we propose that the European Commission, the European Parliament, and the European Member States come to an agreement for setting more ambitious climate targets. The agreement should consist of the following four elements:

1. The EU must resolve on achieving a 50% reduction of greenhouse gas emissions by 2030 relative to 1990 levels. 46% of the reduction must come from domestic action, while up to 4% may derive from international cooperation with non-EU partners, in accordance with Article 6 of the Paris Agreement.
2. The Commission must calculate the reduction contributions from the higher renewable energy and energy efficiency targets in the ETS and non-ETS sectors. Of the 4% reduction achievable through cooperation under Article 6.2 member states must clarify which emissions reductions will occur in the ETS and the non-ETS sectors; through domestic climate action or international cooperation. The ETS linear reduction factor and the national targets under the Climate Action Regulation should then be adjusted to reflect the 50% reduction.
3. The Climate Action Regulation must provide additional options for Member States to use ETS certificates to offset portions of their new national non-ETS targets. This new flexibility option will complement existing flexibility options that already allow a degree of offsetting for some member states.
4. The EU must create an independent body for verifying the merit of the projects and credits that fall under Article 6 of the Paris Agreement together with an effective appeals procedure. In order to identify problems quickly and to prevent the influx of junk JI and CDM credits, the independent body may temporarily suspend the use of emis-

sion reduction credits from Article 6 projects. In case of appeal, the body will assess the situation and decide whether to resume the emission credit system.

In light of the tight time-table ahead, discussions about the specifics of this agreement should start immediately after the new European Parliament is elected in May of 2019.

8 Conclusion

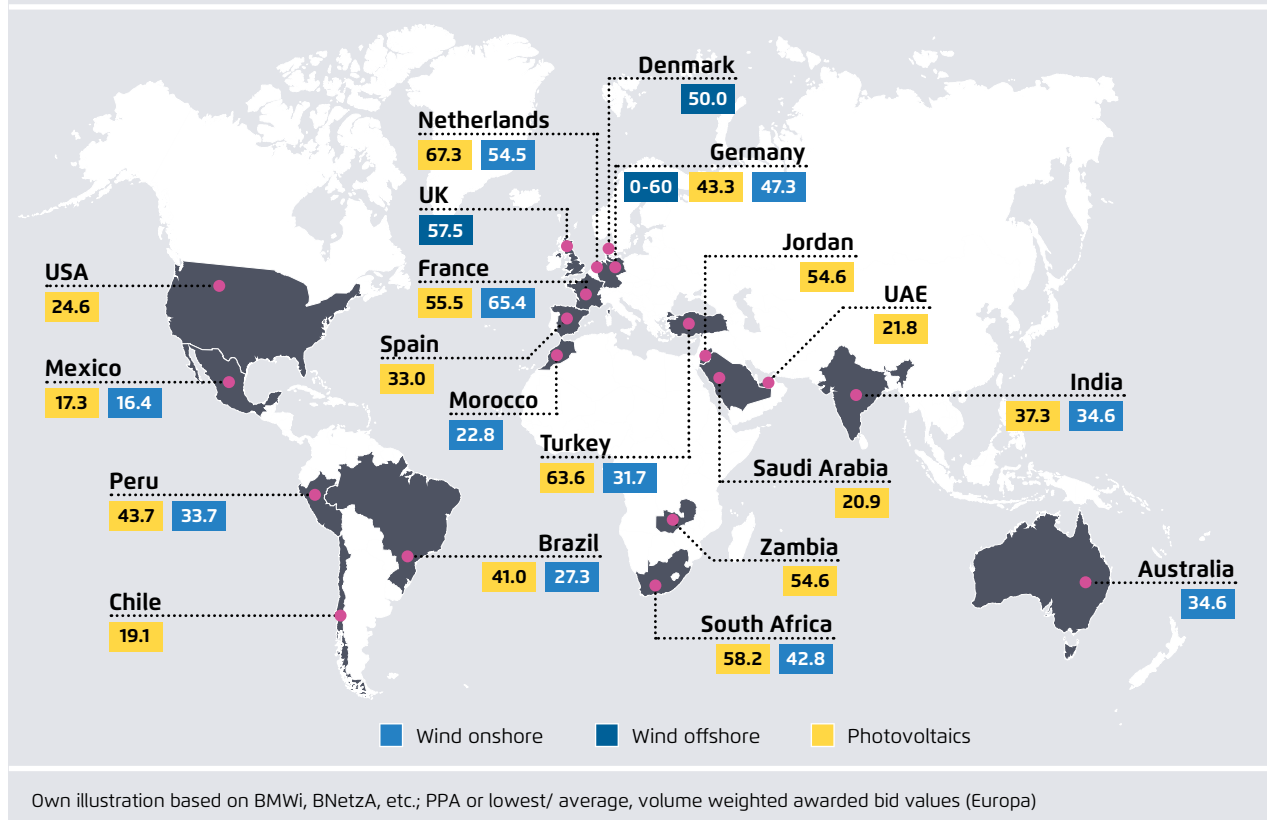
The clean energy transition has become a global phenomenon. It is based on a more efficient use of energy and the progressive replacement of polluting by clean energy sources.

There is some reason to be optimistic. The clean energy transition is not only about climate action and providing benefits to public health, but it also makes good economic sense. Month by month new wind and new solar projects achieve record-low prices that outcompete fossil alternatives on a global scale (figure 35). A similar break-through is expected for battery-electric vehicles, as the energy transition mega-trends described in Chapter 1 of this report will relentlessly be pushing forward.

However, in the 2020–2030 decade we are entering a new phase of the clean energy transition in Europe. Nothing illustrates this better than the projected increase in electricity from renewable sources: from an annual average of today 32.2 percent in 2018 to 57 percent in 2030 (figure 36). The large majority of this increase will come from wind and solar PV: electricity from wind is projected to more than double its share in the mix while electricity produced by solar PV projects will almost triple. Renewables will thus move centre stage in power systems throughout Europe. And renewable electricity will increasingly help to decarbonize the buildings, transport and industry sectors.

Select results of competitive auctions and power purchase agreements 2016–2018 in €/MWh

Figure 35



A cost-efficient pathway to 2030 combines a significant improvement in energy efficiency (overall energy consumption reduced by 17 percent) with a significant increase of renewables (grow by two-thirds to reach 32 percent of final demand), and a significant reduction of fossil fuel use by one third (including halving of coal use). Such an energy system is perfectly possible from a technical point of view. It is also affordable. As the economic analysis have demonstrated, the benefits of a just and clean energy transition will indeed outweigh the costs if properly planned and managed.

However, a just and clean energy transition although technically possible and affordable will not happen by itself. It requires sustained political will, forward planning, a robust institutional framework and market dynamics that are pushing clean energy solutions. It is therefore of particular significance that the European legislator, Member States in the Council and the European Parliament, has just concluded a comprehensive updating of the EU's climate and energy framework for 2030. This is a major achievement. It shows that the European Union institutions are able to deliver on a topic that ranks high on the list of concerns of citizens throughout Europe.

Effective implementation of the new framework and the unlocking of market forces in support of clean energy technologies will decisively advance the energy transition. For this to happen smoothly, however, national decision-makers, regulators and companies should be proactive and anticipate and prepare for the changes to come. This will also allow addressing distributional concerns as an integral part of effective energy transition strategies. This report has put forward then priority actions for the next EU commission and parliament, plus four flagship initiatives. We suggest to come up with new directives where needed, but are also putting a strong focus on implementation of the 2030 framework in the member states. Domestic action should be supported and facilitated as much as possible. The flagship initiatives should address the social dimen-

sion of the energy transition and identify strategies for eliminating existing bottlenecks. In this regard we propose focussing on advancing an industrialised approach to buildings renovation, on a ten million solar roof-tops initiative by 2025, on decarbonisation strategies for district heating & cooling networks as well as support for a just transition in regions still dependent on coal mining and coal use.

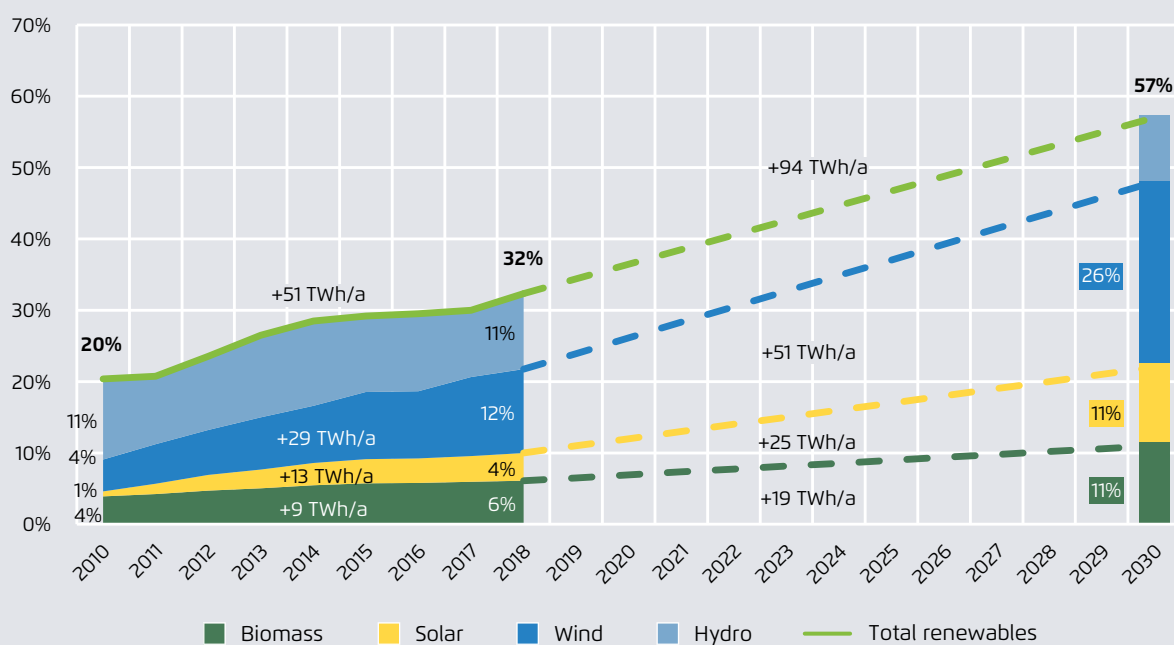
Furthermore, the EU should use its formidable power to standardise and shape markets to ensure that clean technologies that we know will be needed after 2030, will be available and more affordable at that time. This requires robust measures for scaling the market up-take for electrofuels in marine transport and aviation, for kick-starting a vibrant green hydrogen economy, for ensuring Europe is home to a strong and sustainable battery industry, and for ensuring that public infrastructure development progressively uses green cement and green steel.

Last but not least, the EU's multiannual budget that will run from 2021-2027 is the budget that must help countries throughout Europe to invest into a clean energy infrastructure and to ensure that the clean energy transition is broadly perceived as a just and inclusive project

European politicians – both in Brussels and in the member states – now have the chance to shape Europe's energy system such that it is fit for the future. The targets are set, and everything that is needed to reach them, both technically and economically, is there to grasp. What is needed after the 2019 European elections, is political will and political action to make it happen.

2030 projection of renewable electricity share in European Commission's Long Term Strategy

Figure 36



EUROSTAT data to 2016; own calculations for 2017 and 2018; 2030 projection from "Long Term Strategy", European Commission 2018, dashed lines show projection

Notes

1. In 2017, renewables made up 70% of the world's newly added power capacity. See REN21 (2018).
2. See WMO (2018).
3. See UNEP (2017).
4. See McGlade and Ekins (2015).
5. See IRENA (2018).
6. See BNEF (2017).
7. See BNEF (2018).
8. See McKinsey & Company (2016).
9. See Agora Verkehrswende (2018).
10. See Agora Energiewende & Agora Verkehrswende (2018).
11. See Eurostat (2017a).
12. See EC (2017a).
13. See Agora Energiewende/IDDRI (2018).
14. See Transport & Environment (2017).
15. See Eurostat (2018c).
16. See the forthcoming EU regulation on risk-preparedness in the electricity sector.
17. See the forthcoming EU regulation on the EU cybersecurity agency and cybersecurity act.
18. This shift of consumer, environmental and other regulations in the direction of political jurisdictions with stricter environmental standards is sometimes referred to as the "California effect".
19. EU Member States work together to defend their trade interests at the EU level. Practically, the EU's international trade relations are conducted by the International Trade Directorate General of the European Commission in consultation with EU Member States and the European Parliament.
20. See EPRS (2017).
21. With respect to CO₂ emissions, which account for 82% of GHG emissions and 89% of energy-related emissions, the strategy provides for a 96–99% reduction below 1990 levels by 2050 in its net zero scenarios (a 20% reduction had already been achieved by 2015).
22. With respect to gross inland consumption of energy. See JRC (2018).
23. See EC (2018g) and EC (2018f).
24. With respect to final energy consumption in comparison with 2005. See EC (2018g).
25. See EC (2018g).
26. See EC (2018g).
27. With respect to gross inland energy consumption. See EC (2018g).
28. The consumption of biogas and gas from waste is projected to increase from 16 Mtoe in 2015 to some 30 Mtoe in 2030 and have the potential to double by 2050. See EC (2018g).
29. See ASSET (2018).
30. See JRC-IDEES 2018.
31. The Commission's modelling assumes that the share of nuclear generation will shrink from 26% to 18%, before plateauing or gradually rising around 2050. See EC (2018g).
32. Own calculations based on Commission target scenarios.
33. Own calculations based on Commission target scenarios.
34. EC (2018g).
35. See EC (2016d).
36. See BPIE (2017).
37. See COM (2016a).
38. District heating supplies between a third and 40% of residential heat demand in some northern member states and accounts for a significant market share in most of Eastern Europe.
39. Based on assumptions for population growth, household income, and business activity in the service sector in EC (2016c).
40. Net zero energy buildings are buildings that have very high energy performance and whose (limited) energy consumption is mostly covered by energy from renewable sources.
41. EC (2018g).
42. JRC (2018).
43. EC (2018g).
44. Between 1990 and 2015, emissions decreased significantly in all sectors with the exception of transport, where they rose by a quarter.
45. EC (2018g).

46. Despite efforts to decrease CO₂ emissions from new cars and vehicle taxes that aim to incentivise low-carbon vehicles, fuel consumption has barely fallen. One reason for this is the increasing discrepancy between the fuel economy data published by car manufacturers and the real data values.
47. See EC (2018g).
48. The Commission target scenarios project that the total stock of electrically chargeable cars & vans (full electric, plug-in hybrids, fuel cells) will reach around 40 million units in 2030, and more than 80% of the passenger road vehicle stock by 2050. A separate Commission study estimates that an increase in passenger vehicles at this scale would increase electricity demand by about 356 TWh, or roughly 10% of overall EU electricity demand by 2030. See EC (2016e) and METIS (2018).
49. With the exception of the chemicals sector, no other EII has achieved pre-crisis production levels. Furthermore, while gross added value in energy intensive industries grew by 19% between 2000 and 2016, the rest of the EU economy grew at a faster rate. See VUB-IES (2018).
50. Energy-intensive industry is defined as iron and steel, non-ferrous metals (such as aluminium, copper, lead, and nickel), chemicals, non-metallic minerals (mainly cement, ceramics, and glass production), and the paper and pulp industries.
51. EC (2018g).
52. Material Economics (2018) finds that ambitious 'circular economy' resource efficiency measures could eliminate up to 56% of energy-intensive industrial emissions in the EU by 2050.
53. Producing materials using recycled products generally requires less energy and feedstock than producing virgin materials. Producing steel from steel scrap, for example, requires only around a quarter of the energy required to produce virgin steel.
54. There is also significant potential for the electrification of low temperature industrial heat using heat pumps (up to approximately 100 °C) or electric boilers (below 300 °C) in areas such as pulp and paper production, or in the chemicals sector.
55. See Agora Energiewende (2018b).
56. See Agora Energiewende (2014) and Energy Union Choices (2016).
57. See Agora Energiewende (2017).
58. Some member states are making efforts to modernise and expand old systems, while others are building new systems. Nevertheless, some older systems have also shrunk in recent years due to a lack of investment, unfavourable price regulation, poor performance, or negative consumer perceptions.
59. See Statista (2018). See Statista (2018).
60. One study estimates the total cumulative cost of public charging infrastructure to be €12 billion by 2030, compared to around €20 billion for private charging infrastructure. See Cambridge Econometrics (2018).
61. See Platform for Electric Mobility (2018).
62. See Spottle, M. et al. (2018).
63. See Transport & Environment (2018).
64. While gas is expected to still be largely supplied by fossil methane in 2030, the transition to a net zero economy will require a significant increase in renewable gases post-2030. The overall sustainable potential of decarbonized gases is estimated to be between 36 and 122 billion m³ by 2050. See ICCT (2018b) and Ecofys (2018).
65. Due to the ageing gas infrastructure, significant investment will be required to maintain and replace grid components in order to ensure that the infrastructure remains safe and reliable. Decarbonising the gas supply will also lead to more decentralized gas production, which has important implications for the resulting gas flows and infrastructural needs.
66. See RAP (2016).
67. These damages were estimated to total between 5 and 20 billion euros per year in the decade

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- leading up to 2015. These figures do not include loss of human life or damage to ecosystems. See Eurostat (2017b).
68. The EEA projects damages amounting to 120 billion euros per year in a 2 °C scenario and 190 billion euros per year in a 3 °C scenario by 2050. See EEA (2017).
69. See COACCH (2018).
70. This includes European Commission modelling over the past decades to assess the economic and social impacts of different climate and energy policy choices in Europe.
71. In 2016, the EU produced 45% of the energy it consumed. Of the 55% it imported, almost all the energy consisted of fossil fuels. Oil imports represent the bulk of these imports (60%), followed by natural gas (30%) and coal. See EC (2018g).
72. See Eurostat (2018b).
73. The 26% increase in EU energy import costs from 2016–2017 is estimated to have reduced EU growth by 0.4% of GDP in 2018 and caused a 0.6% rise in inflation. See EC (2019).
74. Reduced expenses for transport fuels nearly offset increased expenses for electricity, gas, and heating oils. See EC (2018g).
75. See EC (2018g).
76. This excludes transport. See EC (2019).
77. See Eurostat (2017b).
78. See EC (2017b).
79. See EC (2019).
80. See EC (2018g); EC (2016c); and EC (2016e).
81. See EC (2018g); EC (2016c); and EC (2016e).
82. See EIB (2016).
83. See CE Delft (2016a).
84. See Cedefop, OECD (2015) and Pollin et. al. (2009).
85. See Eurostat (2018c).
86. Domestic oil and gas production is expected to fall by 50% by 2030 relative to 2010 levels. In the 2021–2030 period, the value of imported fossil fuels is projected to reach 421 billion euros per annum on average. EC (2018g).
87. See EC (2014).
88. See EC (2018g).
89. The Commission estimates that Europe's energy import dependence would fall to 20% and natural gas imports would decline by 92% if a net zero carbon footprint is reached by 2050. See EC (2018g).
90. See EEA (2018a).
91. See WHO & OECD (2015).
92. See EC (2013).
93. See EC (2016c) and EC (2018h).
94. See EC (2016c); EC (2016e); and EC (2018h).
95. See EC (2018g).
96. In 2030, every household is expected to spend on average of EUR 570 per year more for energy services than in 2015 (based on 2013 prices). However, rising GDP and household income levels mean that energy-related expenses in 2030 will amount to roughly the same share of household income (7.3%) as in 2015. See COM (2018g).
97. See EC (2016c); EC (2016e); and EC (2018h).
98. See CE Delft (2016a).
99. See EC (2018c).
100. See EC (2018m).
101. See EC (2018l).
102. See EC (2018k).
103. EEA (2018b).
104. See EC (2018k), Art. 33.
105. See EC (2018c), Art. 7; and EC (2018l), Art. 8.
106. EC (2018k), Art. 17.
107. See EC (2018f).
108. See EC (2018d).
109. See EC (2018e).
110. EC (2009).
111. See ICCT (2019).
112. See ICCT (2019).
113. See EC (2018e), Art. 25; ICCT (2018a).
114. ICCT (2018a)
115. EC (2010).
116. EC (2009).
117. See EC (2018c), Art. 1 (14).
118. EC (2016b).
119. EC (2018j).
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120. The complete set of measures described in Chapter 7 is also transposed into a technical document published in parallel with this report. For each of the proposed measures, the technical document describes the specific legal acts that will need to be amended or changed.
121. See EEA (2018b).
122. See articles 35, 36 and 44 of EC (2018k).
123. See www.energiesprong.org
124. CE Delft (2016b).
125. GfK Belgium et al. (2017).
126. CE Delft (2016b).
127. See Luhmann, H. (2018).
128. IISD&i24c (2017).
129. However, the EIB does not strictly apply a shadow carbon price for all energy sector investments and is still subsidizing fossil fuels. In 2014–2016, the EIB provided financing for 27 gas infrastructure projects worth €1.6 billion/year. See: ODI (2017).
130. See <https://www.cdp.net/en/campaigns/commit-to-action/price-on-carbon> [Last accessed February 2019].
131. The High-Level Commission on Carbon Prices (HLCCP), co-chaired by Nobel Laureate Joseph Stiglitz and Lord Stern, recommended carbon prices of \$40–80 per tonne of CO₂ by 2020 and \$50–100 per tonne by 2030 to keep global warming below 2 °C.
132. EC (1999).
133. EP (2018).
134. Delgado et al. (2017).
135. See EC (2018b).
136. European Commission (2016f).
137. REFERENCES to DIRECTIVES
138. See the forthcoming Clean Vehicles Directive.
139. Energy Transitions Commission (2018).
140. See Assembly Bill No. 262, Chapter 816, “Buy Clean California Act”, Filed on 15 October 2017.
141. REFERENCE TO COM WE
142. E3G (2018).
143. The proposal does not mention the 25% climate spending target. See EC (2018i).
144. Agora Energiewende (2018a).
145. Bruegel (2018).
146. IPCC (2018).
147. EUCO (2018).
148. See EC (2018g).
149. These are HR, GR, HU, PT, SE, SK. See EEA (2018b).
150. Agora Energiewende and Sandbag (2019).

References

Agora Energiewende and Sandbag (2019): The European power sector in 2018. Up-to-date analysis on the electricity transition.

Agora Verkehrswende (2018): Transforming transport to ensure tomorrow's mobility - 12 insights into the Verkehrswende.

Agora Energiewende & Agora Verkehrswende (2018): The Future Cost of Electricity-Based Synthetic Fuels.

Agora Energiewende & IDDRI (2018): The "Energiewende" and the "transition énergétique" by 2030.

Agora Energiewende (2018a): Reducing the cost of financing renewables in Europe: Report of a multi-stakeholder dialogue on the proposed EU Renewable Energy Cost Reduction Facility. Berlin: Agora Energiewende.

Agora Energiewende (2018b): Toolbox für die Stromnetze: Für die künftige Integration von Erneuerbaren Energien und für das Engpassmanagement.

Agora Energiewende (2017): Smart-Market- Design in deutschen Verteilnetzen: Entwicklung und Bewertung von Smart Markets und Ableitung einer Regulatory Roadmap.

Agora Energiewende (2014): Benefits of Efficiency on the German Power System;

ASSET (2018): Sectoral integration: long-term perspectives in the EU energy system.

BNEF (2017): New Energy Outlook 2017.

BNEF (2018): Electric Vehicle Outlook 2018.

Bruegel (2018): Addressing Europe's failure to clean up the transport sector. Policy Brief, Issue 2, April 2018.

BPIE (2017): Factsheet - 97% of buildings in the EU need to be upgraded.

Cambridge Econometrics (2018): Fuelling Europe's Future (FEF) II

Cedefop, OECD (2015): Green skills and innovation for inclusive growth;

CE Delft (2016a): Investment challenges of a transition to a low-carbon economy in Europe.

CE Delft (2016b): The potential of energy citizens in the European Union;

COACCH (2018): The Economic Cost of Climate Change in Europe: Synthesis Report on State of Knowledge and Key Research Gaps Delgado et al. (2017): Fuel efficiency technology in European heavy-duty vehicles: Baseline and potential for the 2020-2030 timeframe.

E3G (2018): Sectoral legislation in the post-2020 EU budget. Ensuring effective climate spending.

EC (2019): Energy prices and costs in Europe

EC (2018a): Cohesion Open Data Platform.

EC (2018b): Communication on "Europe on the move: Sustainable Mobility for Europe: safe, connected and clean", COM(2018)298, Annex 2. 17 May 2018.

EC (2018c): Directive (EU) 2018/410 amending Directive 2003/87/EC to enhance cost-effective emission reductions and low-carbon investments, and Decision (EU) 2015/1814, Art. 1 (14).

EC (2018d): Directive (EU) 2018/844 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency.

EC (2018e): Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources, Art.

EC (2018f): Directive (EU) 2018/2002 amending Directive 2012/27/EU on energy efficiency.

EC (2018g): In-depth analysis in support of the Commission communication COM (2018) 773.

EC (2018h): Non-paper on complementary economic modelling undertaken by DG ENER.

EC (2018i): Proposal for a Council Regulation laying down the multiannual financial framework for the years 2021 to 2027, COM(2018)322 final. The proposal does not mention the 25% climate spending target.

EC (2018j): Proposal for a Directive on the reduction of the impact of certain plastic products on the environment, COM(2018)340.

EC (2018k): Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action.

EC (2018l): Regulation (EU) 2018/841 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU, Art. 8.

EC (2018m): Regulation (EU) 2018/842 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013.

EC (2017a): Communication on strengthening Europe's energy networks, COM(2017)718 final.

EC (2017b): Industry in Europe. Facts & figures on competitiveness & Innovation

EC (2016a): An EU Strategy for Heating and Cooling, SWD (2016) 24.

EC (2016b): Ecodesign Working Plan 2016–2019, COM(2016) 773.

EC (2016c): EU Reference Scenario 2016 – Energy, Transport and GHG emissions – Trends to 2050.

EC (2016d): Impact assessment on the sustainability of bioenergy, SWD(2016) 418.

EC (2016e): Impact assessment accompanying the Energy Efficiency Directive, SWD(2016) 405.

EC (2016f): Public Procurement Indicators 2015.

EC (2014): Energy Security Strategy, COM(2014)330.

EC (2013): Executive summary of the impact assessment accompanying the Clean Air Programme for Europe;

EC (2010): Directive 2010/75/EU on industrial emissions.

EC (2009): Directive 2009/125/EC establishing a framework for the setting of ecodesign requirements for energy-related products.

EC (1999): Directive 1999/94/EC relating to the availability of consumer information on fuel economy and CO₂ emissions in respect of the marketing of new passenger cars.

Ecofys (2018): Gas for Climate: How gas can help to achieve the Paris Agreement target in an affordable way.

EUCO (2018): European Council Meeting (22 March 2018) – Conclusions, EUCO 1/18.

Data Driven Yale et al. 2018: Global climate action of regions, states and businesses.

EEA (2018a): Air Quality in Europe – 2018 report.

EEA (2018b): Trends and projections in Europe 2018: Tracking progress towards Europe's climate and energy targets.

EEA (2017): Climate change, impacts and vulnerability in Europe 2016.

EIB (2016): Restoring EU competitiveness.

Energy Transition Commission (2018): Mission possible: reaching net-zero carbon emissions from harder-to-abate sectors by mid-century.

Energy Union Choices (2016): Efficiency First: From Principle to Practice – Real World Examples from across Europe.

EP (2018): Research for TRAN Committee – Modal shift in European transport: a way forward, European Parliament, Policy Department for Structural and Cohesion Policies, Brussels.

EPRS (2017): How the Budget is Spent: Horizon 2020.

ETUC (2018): A guide for trade unions – Involving trade unions in climate action to build a just transition.

Eurostat (2018a): Distribution of population by degree of urbanisation, dwelling type and income group – EU-SILC survey [ilc_lvho01].

Eurostat (2018b): Extra-EU imports of energy products, trade in value, 2017 (EUR billion).

Eurostat (2018c): Where do we import energy from.

Eurostat (2017a): Regional Yearbook 2017.

Eurostat (2017b): Sustainable development in the European Union – Monitoring report on progress towards the SDGs in an EU context.

GfK Belgium et al. (2017): Study on “Residential Prosumers in the European Energy Union”, commissioned by the European Commission.

ICCT (2019): CO₂ emission standards for passenger cars and light-commercial vehicles in the European Union, policy update.

ICCT (2018a): Final recast Renewable Energy Directive for 2021-2030 in the European Union, policy update.

ICCT (2018b): What is the role for renewable methane in European decarbonization.

IISD&i24c (2017): Leveraging the Power of the Public Purse: Using public procurement of lowcarbon innovation for sustainable infrastructure – Recommendations to the European Commission and EU Member States.

IPCC (2018): Special Report on Global Warming of 1.5 °C

IRENA (2018): Renewable power generation costs in 2017.

Luhmann, H. (2018): All too modest goal. Development and Cooperation. e-Paper no. 7 2018, 2018/07, Page 29.

Material Economics (2018): The circular economy: a powerful force for climate mitigation.

McKinsey & Company (2016): The digital utility: New opportunities and challenges.

McGlade and Ekins (2015): The geographical distribution of fossil fuels unused when limiting global warming to 2°C. In: Nature 517: 187–190.

METIS (2018): Effect of electromobility on the power system and the integration of RES S13 Report

ODI (2017): Phase-out 2020 –Monitoring Europe's fossil fuel subsidies.

Platform for Electric Mobility (2018): How EU Member States Roll Out Electric Mobility: Electric Charging Infrastructure in 2020 and beyond.

Pollin et. al. (2009): The economic benefits of investing in clean energy

REN21 (2018): Global Status Report.

Spottle, M. et al. (2018): Research for the TRAN Committee: Charging Infrastructure for Electric Road Vehicles.

Statista (2018): Percentage of the railway lines in use in Europe in 2016 that were electrified.

Transport & Environment (2018): Roll-Out of Public EV Charging Infrastructure in Europe: Is the Chicken and Egg Dilemma Resolved?

Transport & Environment (2017): Clean Mobility Package. MEP briefing for the plenary debate.

UNEP (2017): Emissions gap report 2017.

VUB-IES (2018): Industrial value chain: A bridge towards a carbon neutral Europe.

WHO & OECD (2015): Economic cost of the health impact of air pollution in Europe: Clean air, health and wealth.

WMO (2018): WMO Statement on the state of the global climate in 2017.

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Agora Energiewende develops scientifically based and politically feasible approaches for ensuring the success of the energy transition in Europe and internationally. We see ourselves as a think-tank and policy laboratory, centered around dialogue with energy policy stakeholders. Together with participants from public policy, civil society, business and academia, we develop a common understanding of the energy transition, its challenges and courses of action. This we accomplish with a maximum of scientific expertise, oriented towards goals and solutions, and devoid of any ideological agenda.



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