eurelectric

Decarbonisation Pathways

Eurelectric represents the interests of the electricity industry in Europe. Our work covers all major issues affecting our sector. Our members represent the electricity industry in over 30 European countries.

We cover the entire industry from electricity generation and markets to distribution networks and customer issues. We also have affiliates active on several other continents and business associates from a wide variety of sectors with a direct interest in the electricity industry.

We stand for

The vision of the European power sector is to enable and sustain:
- A vibrant competitive European economy, reliably powered by clean, carbon-neutral energy
- A smart, energy efficient and truly sustainable society for all citizens of Europe

We are committed to lead a cost-effective energy transition by:

investing in clean power generation and transition-enabling solutions, to reduce emissions and actively pursue efforts to become carbon-neutral well before mid-century, taking into account different starting points and commercial availability of key transition technologies;

transforming the energy system to make it more responsive, resilient and efficient. This includes increased use of renewable energy, digitalisation, demand side response and reinforcement of grids so they can function as platforms and enablers for customers, cities and communities;

accelerating the energy transition in other economic sectors by offering competitive electricity as a transformation tool for transport, heating and industry;

embedding sustainability in all parts of our value chain and take measures to support the transformation of existing assets towards a zero carbon society;

innovating to discover the cutting-edge business models and develop the breakthrough technologies that are indispensable to allow our industry to lead this transition.

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Dépôt légal: D/2018/12.105/45

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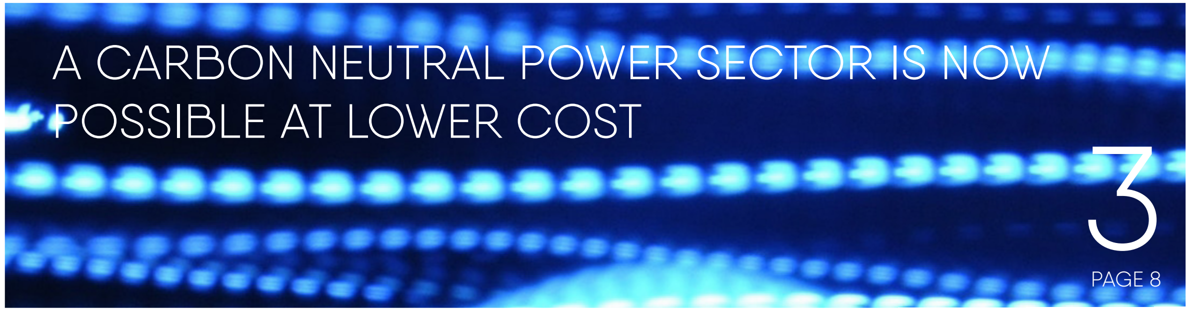

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THE EUROPEAN ELECTRICITY SECTOR IS LEADING THE WAY TO DELIVER ON EUROPE'S CLIMATE COMMITMENTS

In the 2015 Paris Agreement, 195 UN member states agreed to limit the global temperature rise to well below 2 degrees Celsius by 2100. The consequences of exceeding this temperature bound are likely to be dramatic: rising sea levels, higher frequency of forest fires and heavy precipitation events, but also longer and more intense droughts. According to the IPCC, continued emission of greenhouse gases will cause “long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems”.

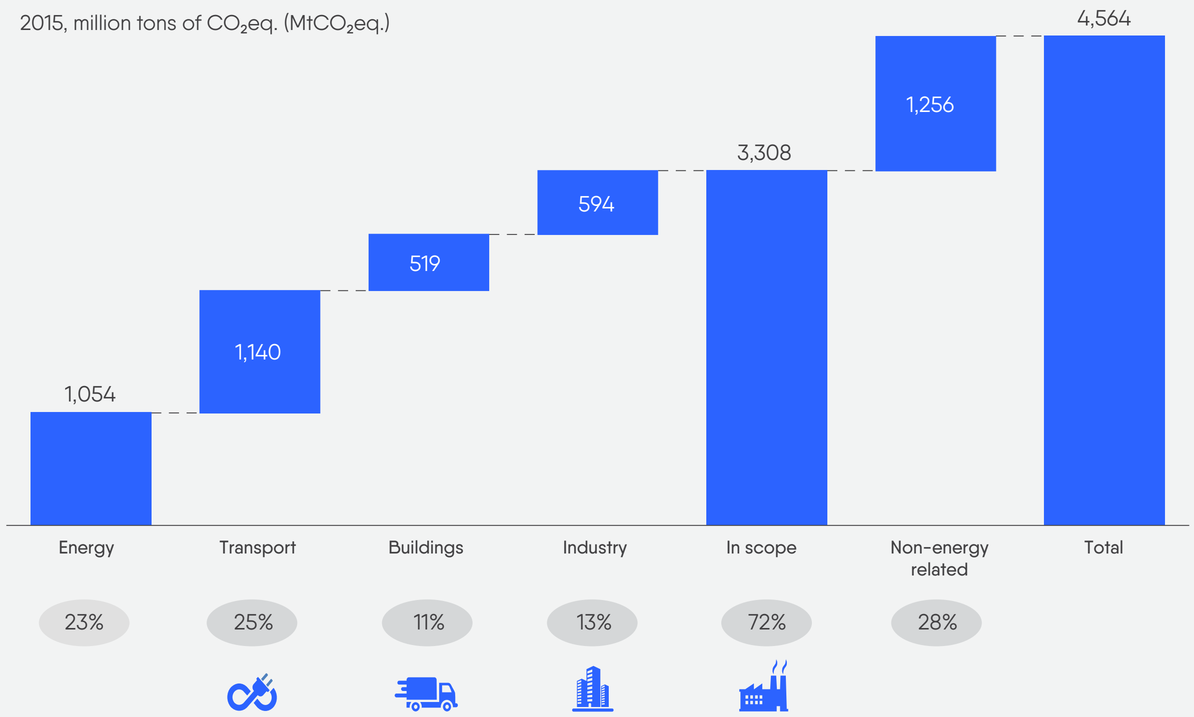
Decisive action on climate change by all sectors is needed to meet the goals set by the Paris agreement. The EU has committed to at least 40% emissions reduction below 1990 level by 2030 and has further set an aspiration of 80-95% reduction by 2050. Today, ~70% of emissions in Europe come from energy use across economic sectors. The power sector, represented by Eurelectric, is committed to leading the required energy transition and secure cost-effective decarbonisation that support European competitiveness in the global market place. In its new vision published earlier this year, the power sector made a pledge to become carbon neutral well before mid-century, considering different starting points and commercial availability of key transition technologies.

Thereby, the power sector will support other sectors in their decarbonisation efforts via direct and indirect electrification. Eurelectric has completed a comprehensive study to assess the potential contribution of the power sector on economy-wide decarbonisation. In the first phase of the study, we have developed three EU electrification scenarios towards 2050 that achieve 80%, 90% and 95% decarbonisation of the main energy-using sectors: transport, buildings, and industry. In the second phase of the study, we have analysed the decarbonisation pathways to drive the power sector towards carbon-neutrality well before 2050 at the lowest possible cost for each of the three electrification scenarios defined in phase 1.

We find that electrification coupled with full decarbonisation of the power sector is a direct, effective and efficient way of reaching the decarbonisation objectives for society as a whole. 80 - 95% decarbonisation of energy used in the EU economy requires a strong step-up across a portfolio of decarbonisation levers, in which direct electrification of end-uses in buildings, industry and transport can play a significant role. Energy efficiency measures and other carbon-neutral fuels will complement electrification to deliver on these ambitions.

Emissions in EU28+EEA countries

2015, million tons of CO_2eq. ($MtCO_2$eq.)



SOURCE: Energy Insights, Eurostat, EU inventory,

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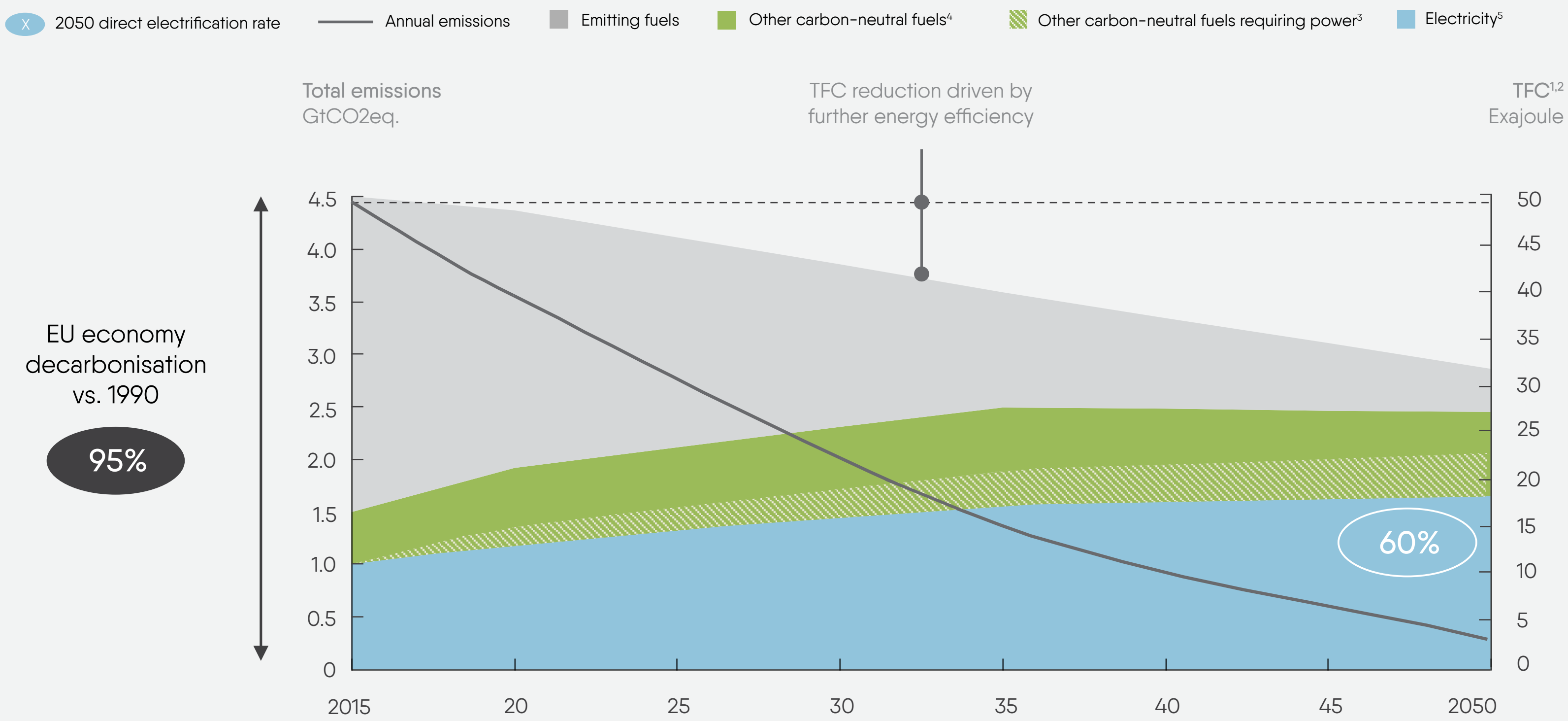
WITH ELECTRIFICATION THE EU CAN REDUCE 80 – 95% OF CO_2 EMISSIONS BY 2050

Electrification reduces GHG emissions in three ways:

1. Firstly, electrification enables a switch from emitting fuels to carbon neutral electricity from variable renewable sources such as solar and wind power, hydro and nuclear.
2. Secondly, electrification reduces total energy demand thanks to the higher efficiency of electric solutions compared to conventional solutions for most applications. For example, electric vehicles consume only 25% of the energy consumed by conventional vehicles. In space heating, the coefficient of performance of heat pumps is 4 to 5 times higher than the coefficient of performance for typical gas boilers.
3. Thirdly, via electric production of fuels such as hydrogen and power-to-X, electrification can reduce emission in end uses where direct use of electricity is not appropriate, e.g. marine transport and aviation, and selected industrial processes.

95% decarbonisation through strong electrification, energy efficiency, and support from other non-emitting fuels

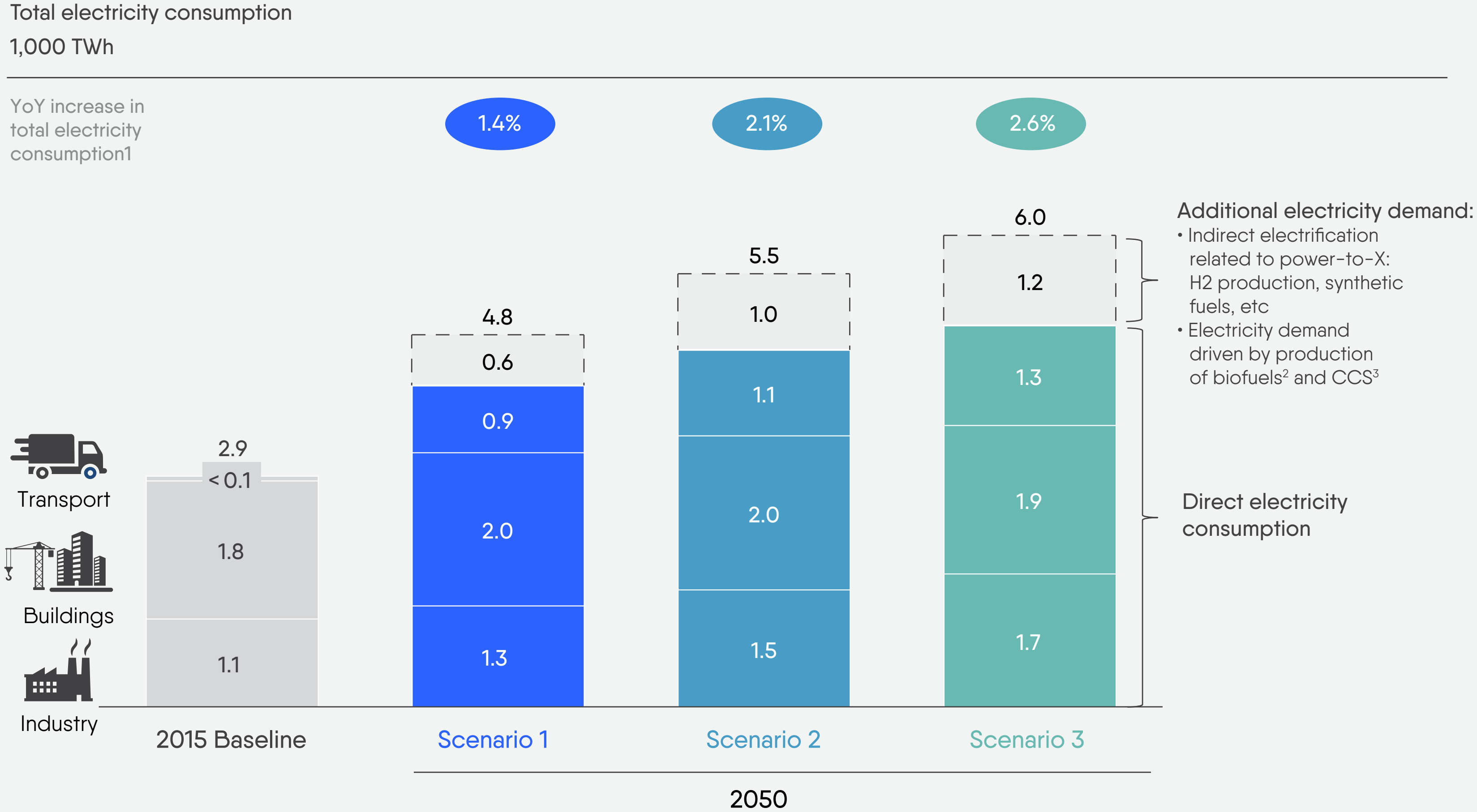
Impact of electrification on Total Final Energy Consumption (TFC) and EU economy emissions



[1] Includes 32 countries in scope: EU28 + EEA; ENTSOE report additionally includes Turkey and other Eastern European countries adding up to a total of ~3,300 TWh
[2] Electricity consumption from transformation sectors not included;
[3] Includes non-emitting fuels that trigger indirect electrification through power-to-X (H2, synth fuels) as well as non-emitting fuels that trigger increased electricity demand to be produced such as biofuels;
[4] Includes all other non-emitting fuels/sources such as geothermal, solar thermal, and others;
[5] Direct electricity consumption

Currently, only approximately 22 % of energy consumption in the transport, industry and buildings sectors is electrified. **For the EU to reach 95% energy emissions reduction by 2050, direct electrification needs to supply close to 60% of final energy consumption.** Production of H2 and power-to-X will require an additional electricity production of 600 TWh to 1200 TWh. This corresponds to a total final electricity demand of 4800 – 6000TWh by 2050. This is achievable with an average 2,6% year-on-year growth of electricity supply between now and 2050 whilst at the same time reducing the total energy consumption by 1.3% per year through energy efficiency improvements. To achieve 80% and 90% decarbonisation, the average year-on-year growth of electricity supply would be 1.4% and 2.1%, reaching direct electrification rates of 38% and 48% respectively.

Strong electricity uptake in all sectors, with strongest increase in transport



[1] Includes both direct and indirect electrification (power-to-X) as well as electricity demand driven by production of CCS and biofuels

[2] Biofuels require feedstock as well as additional energy (either in form of thermal energy or power) for their production – see glossary

[3] Total CO_2 abated through CCS: <200 Mt Co_2; CCS may require technology improvement as well as increasing acceptability, e.g., for underground storage

Our study finds that the electrification potential is large in all sectors:

In transport, up to 63% of total final energy consumption will be electric in our most ambitious scenario. This will be driven largely by electrification of the vehicle segment where we see 96% of passenger vehicles, 48% of trucks and 58% of buses being electrified by 2050. Electrification of the vehicle fleet will be fuelled by market developments such as rapid decline in cost of batteries and expansion of charging infrastructure. In addition, regulatory constraints on ICEs, fleet emissions and cash incentives will further increase the uptake of EVs as is already happening in some markets, e.g. Norway.

Rail transport, which is already 70% electric will increase to 93%. By mid-century only few routes, where electrification is either technologically challenging or not economic, will continue to run on other fuels, for instance diesel, biofuel or potentially hydrogen in some cases. For the aviation and marine transport segments large-scale electrification will require further technology breakthrough to reduce cost of storage, increase energy density, and solve other technological problems.

In buildings, energy efficiency is the main source of emissions reduction, followed by electrification through heat pump adoptions. Heat pump economics are expected to become increasingly competitive due to an acceleration in cost reduction driven by industrialization and standardization of manufacturing, as well as increasing taxation on gas- and oil-fired heating units for decarbonisation purposes. While they are not cost-competitive against regular boilers yet, government incentives and regulation will continue to drive their uptake in many regions, thereby enabling learning effects and cost declines.

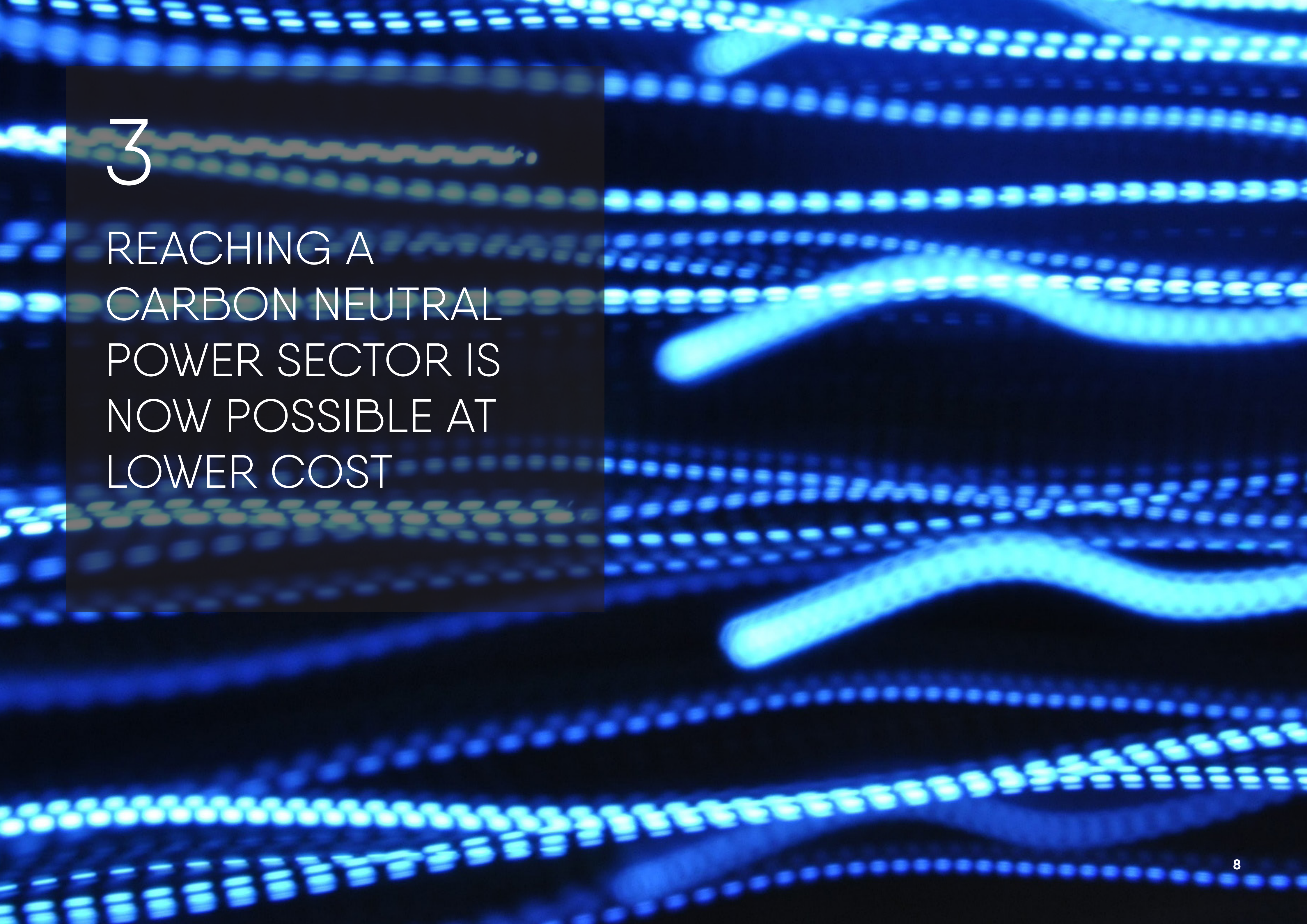
Finally, a series of **industrial processes** can technically be directly electrified to up to 50% of total energy consumption by 2050. The electrification ethylene production and electric arc furnaces (EAF) in iron & steel production are the most prominent examples for this potential. Further potential comes from indirect electrification, e.g. via producing hydrogen from electrolysis and using it to replace carbon-based feedstock in steel and ammonia production. The relative competitiveness of electricity against other energy sources and government support to level the playing field in international competition and avoid carbon leakage will be the critical driver for this shift.

Direct electrification results by scenario

		2015 Baseline	2050 Scenario 1	2050 Scenario 2	2050 Scenario 3
Total EU economy	EU economy decarbonisation vs 1990	22%	80%	90%	95%
	Direct electrification rate	22%	38%	48%	60%
Total transport	Direct electrification rate	1%	29%	43%	63%
Total buildings	Direct electrification rate	34%	45%	54%	63%
Total industries	Direct electrification rate	33%	38%	44%	50%

Different starting points

While the potential is great, there is large variation in starting points across regions. At one end of the scale are the Nordic countries which already reach a 32% electrification level, driven by high electrification of industry and buildings, but also the transport sector where a third of new private vehicles purchased are now EVs. At the other end of the scale are some Eastern-European countries such as Poland with an electrification level of close to 18%. These different starting points in terms of energy mix, economic situation and industrial activities require different pathways and levels of efforts across EU countries.



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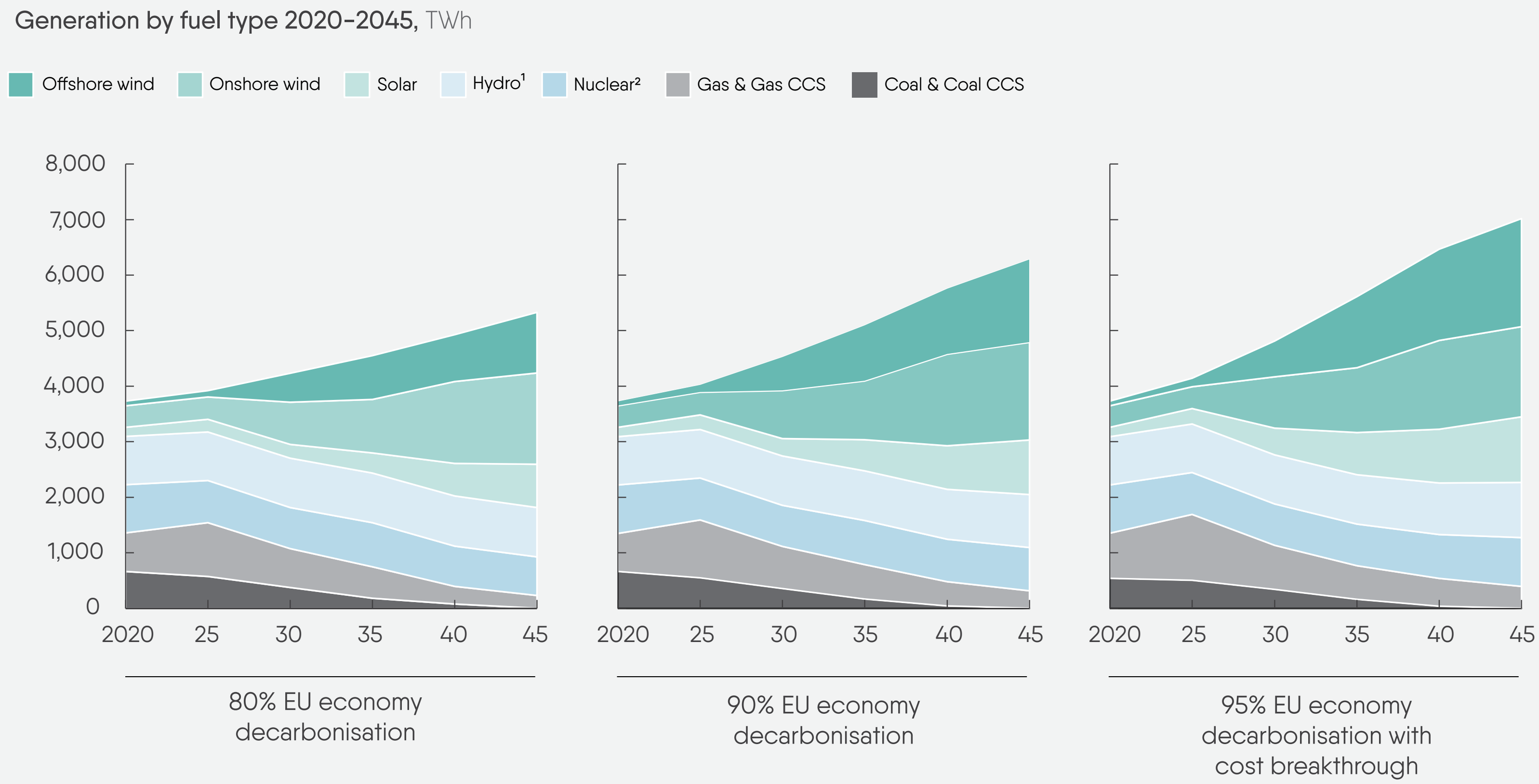
REACHING A CARBON NEUTRAL POWER SECTOR IS NOW POSSIBLE AT LOWER COST

Electrification of economic sectors reduces energy emissions only to the extent that the electricity is not emitting. Our study shows that it is possible to meet increased electricity demand, and at the same time fully decarbonise the power sector well before 2050 in a cost-effective way. The least-cost energy systems that can achieve carbon neutrality are characterised by 4 factors:

Very high penetration of renewables and high transmission build. Renewables, including hydropower and sustainable biomass will represent more than 80% of energy supply by 2045 driven by rapid cost decline, increasing capacity factors, and large untapped resource potentials. Solar and wind will account for ~15 % and ~50% of supply respectively. This will be enabled by significant transmission build within and between regions, which allow the benefits of renewables to be shared across Europe.

In the least-cost, carbon neutral energy system the bulk of electricity is provided by renewables and nuclear



Renewables represent more than 80% of energy supply by 2045

[1] Includes also geothermal, biomass and biogas

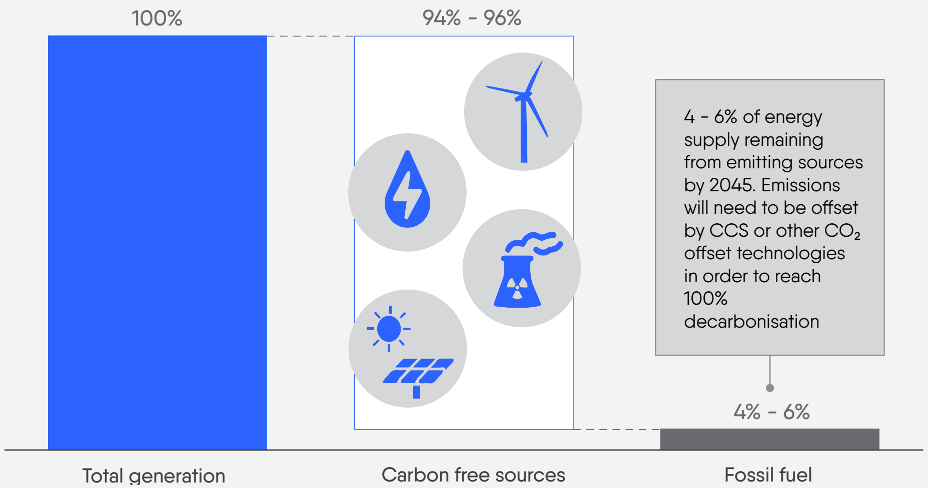
[2] National policies on nuclear and coal phase out have been reflected

Important need for system balancing and flexibility provided by multiple sources. A system-wide shift from dispatchable generation to renewables require hour-to-hour as well as seasonal balancing to respond to the variability of production. In a high-renewables future this will be provided by competing sources from both within and outside the power sector. Traditional sources include conventional firm generation capacity such as hydro and nuclear power. In addition, we will see a much larger role played by demand side response from dispatch of new electric end-uses such as electric vehicles, as well as storage and flexible production of electric fuels such as hydrogen and power-to-gas or power-to-liquids.

Changing role of fossil generation. Fossil energy supply will be gradually phased out and represent only ~5% of total energy supply by 2045. However, gas will still account for ~15% of total installed capacity in order to secure system reliability, especially in regions that don't have access to hydro or nuclear.

Decreasing costs of carbon neutral technologies as well as innovation to develop technologies that can abate the last tons of CO_2 emissions. Uptake of renewables will rely on continued technological development and cost improvements for these technologies, especially in less developed industries such as offshore wind. Additionally, while ~95% of emissions can be abated through a transition to carbon neutral electricity supply, immature technologies such as CCS and negative emission technologies will be required to abate the final emissions coming from the marginal use of the remaining thermal capacity.

95% of emissions are abated through a transition to carbon neutral electricity supply



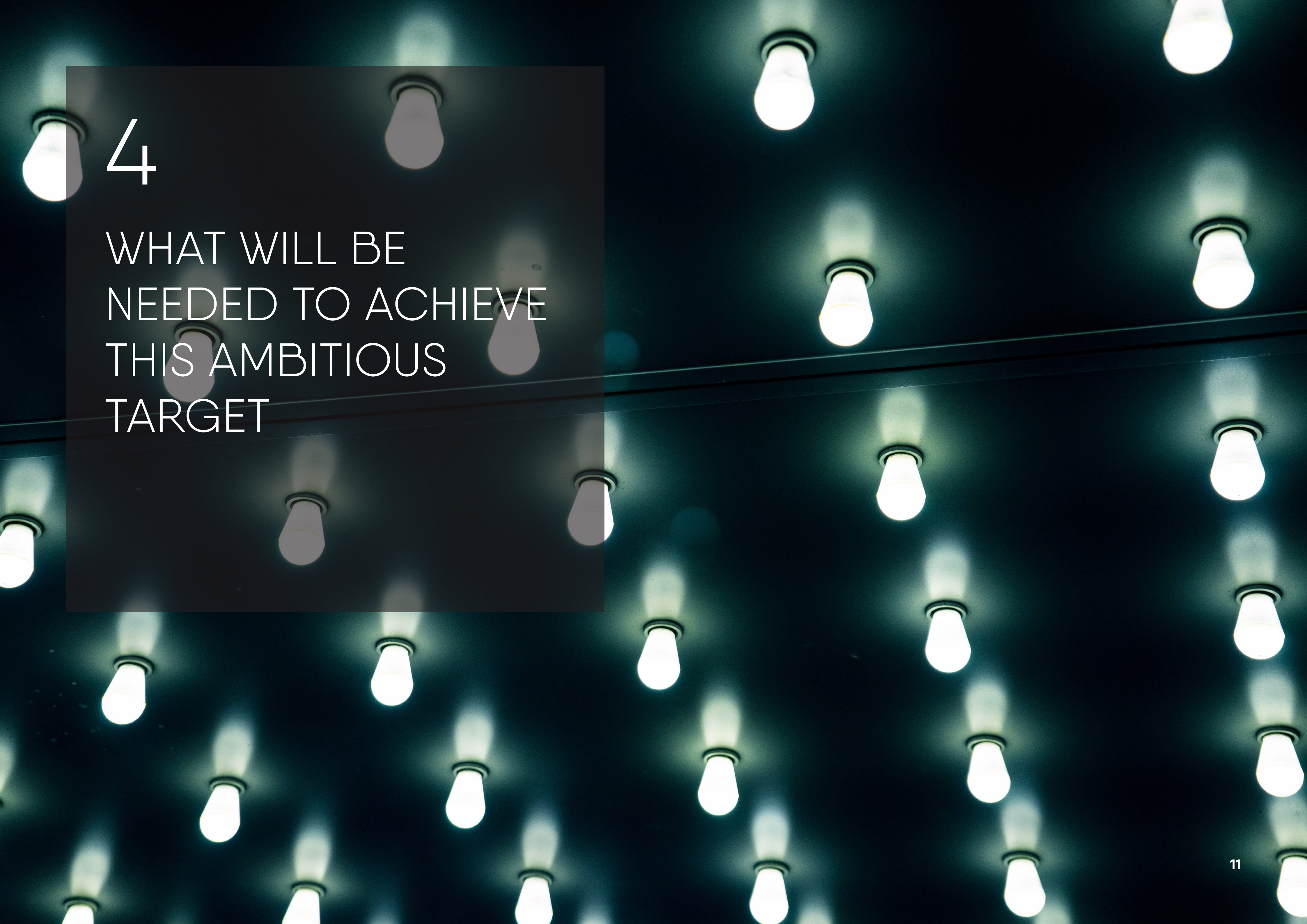
Key findings

While each of these four factors are needed to achieve the ambitious decarbonisation goals, **each region will take a different path given different starting points with their existing electricity supply mix**. For example, Norway's power sector is already ~90% carbon-free while Poland relies on coal for 80% of energy supply. In addition, regions have varying access to energy supply resources (e.g. solar in southern Europe vs wind in the North Sea). Countries also put different weight to decarbonisation objectives in their energy policies such as ambition on renewables penetration, and schedules for coal and nuclear phase out. For example, Poland is currently discussing a policy to maintain 40% coal in their energy mix through 2040. This would imply large additional costs for Poland to abate or offset the emissions associated with this coal production.

Reaching this carbon neutral power system while meeting an increase in electricity demand that is unprecedented in recent times will require significant investments. Overall, average annual investments of 90 – 110 bn EUR will be needed to achieve the required capacity build to meet increasing demand and transition to a carbon-neutral generator stack. These investments contribute not only to the decarbonisation of the power system, but to the decarbonisation of other economic sectors that cut emissions through electrification.

Abatement of the majority of emissions can be achieved at a cost of 18 – 65 €/ton CO_2. However, as expected, the last tons of emissions are much more expensive to abate. These emissions are assumed to be offset by immature technologies such as CCS and direct air capture. The cost therefore depends highly on the pace of cost reduction and technological development for these solutions, which is inherently difficult to predict. Furthermore, there may be an option to exchange negative emissions with other sectors in the future, reducing the total societal cost of decarbonisation of the electric sector by linking it to economy-wide efforts.

The outlook for the cost of wholesale electric supply in a decarbonised power sector is changing rapidly. **Due to cost declines in renewables the overall cost of carbon-neutral electricity generation has been reduced drastically in recent years.** We expect the cost of wholesale electric supply (excl. taxes and levies) in a fully decarbonised system to be 70 – 75 EUR/MWh including storage. This is significantly lower than previous est*imates, e.g. from the European Commission's 2011 roadmap which forecasts generation costs of 105 EUR/MWh for power supply that is only 80% decarbonised.



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WHAT WILL BE NEEDED TO ACHIEVE THIS AMBITIOUS TARGET

To reach the required levels of electrification and decarbonisation and put the EU economy on a pathway towards full carbon neutrality by 2050, several enablers will be needed both for electricity supply and for the demand side.

First, political commitment to deep decarbonisation across all regions and sectors of the economy is critical. Decarbonising the power sector will require stronger coordination and integration within and across European regions than today. Regional resource availability (e.g., solar and wind) imply that high transmission build between regions will be needed to share the benefits of low-cost renewable capacity across Europe. On the demand side, joint policy mechanisms to encourage the uptake of electric solutions and the creation of a "level playing field" will be important. Especially for industries exposed to regional and global market prices.

Second, active involvement of citizens in a more decentralised power market will be a key enabler. This includes demand side response and self-generation, local energy communities, as well as increased social acceptance for high renewables build out and new transmission lines. Addressing taxes and levies in electricity to ensure fair competition between clean energy carriers will be a must to achieve consumers' uptake.

Third, co-operation between economic sectors will be important to make use of synergies and enable spill-over effects on the decarbonisation pathways. For instance, while CCS may play a marginal role to abate remaining emissions for the power sector it would also be an important part of the solution for industries where no alternative technical solution exists, e.g. abatement of process emissions from the cement industry. Another example is electric fuel production which can both enable decarbonisation in industry and transport, and provide important balancing to a high renewables power system. In addition, the relatively low-cost flexibility these electric fuels provide to the power sector also depends in part on the existing gas pipeline infrastructure which represents a vast energy storage system capable of providing seasonal storage. This also reduces the probability of stranded costs as pipeline infrastructure and thermal generation can be re-used and repurposed in a low carbon and highly electrified system.

Fourth, efficient market-based investment frameworks and adequate market design to address the investment and operational challenges of a high RES-based power system. For example, all resources must be valued based on their contribution to reliability and resiliency and carbon neutral investments could benefit from voluntary long-term energy contracts. Meaningful CO_2 price signals will also be required to sufficiently incentivise full decarbonisation and induce needed investments both on the energy supply and demand side.

Fifth, a smarter and reinforced distribution grid will play an important role in integrating new market participants, such as decentralised solar PV and local flexibility sources, as well as in consumer empowerment through managing local congestions and redispatch, security of supply and grid resilience issues. The challenges for distribution grids such as the integration of more decentralised resources, digitalisation through smart metering, charging infrastructure for EVs, and access to local flexibility resources will require large investment needs up to 2050. Furthermore, the increasing uptake of prosumers will trigger additional investment needs at distribution level with an entirely new set of network customers, e.g. local storage facilities. Therefore, it is crucial to elaborate future DSO investment needs accordingly and in conjunction with eventual cost structure changes as well as the role and responsibilities of DSO in future analysis.

Finally, a just transition means that no region in Europe shall be left behind. Support and dedicated funding will be required for member states that face a more difficult starting point in the electrification and energy transition journey. Support for investment costs must be especially targeted at coal-reliant regions as well as on energy-intensive industries subject to carbon leakage risks. Regional integration and shared resources can also reduce the cost of this transition for those just beginning the journey.


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