Powering the future - a vision for Europe's energy system in 2050

CIP
Copenhagen Infrastructure Partners

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Electrification will spark European industrial competitiveness and improve energy security.

Europe's role on the global stage is being challenged. We must adapt to geopolitical shifts, technological revolutions, and economic volatility. In addition, the climate crisis presents a threat to our common future. The design of the future European energy system offers a solution to three challenges: energy affordability, energy resilience, and clean energy.

Affordable, resilient and clean energy are pre-conditions for any country or continent to prevail. The design of the future European energy system will define the competitiveness of European industries, our ability to deliver affordable and predictable energy to consumers, and our ability to protect the European economy against external energy shocks. The driver of the transformation is the sometimes-overlooked electrification of transportation, household and industrial heating.

Electrification changes the way we live and our energy consumption. As we gradually replace the fossil energy used in industrial manufacturing with electricity, as heat pumps replace gas heating in our buildings, and as cars, buses, and trucks switch to electricity, we increase our electricity consumption. While increased efficiency results in lower energy consumption, it will also require vast amounts of new electricity generation. This positions electrification as a unique opportunity to address the triple challenge of delivering affordable, resilient, and clean energy to European consumers and industries, reshaping the European economy, enhancing competitiveness and promoting viable, long-term growth.

EXAMPLES OF ELECTRIFICATION

CARS

Fueling your diesel car with 1 MWh equivalent of diesel will take your car approximately 2,700 km. A modern electrical car being fueled with the same electrical energy will take you 5,000 km.

HOMES

Heating an average European household for a year requires 18,500 KWh of natural gas. Heating the same house with a modern heat pump would require just 5,800 KWh.

ELECTRIFICATION OF VEHICLES

1 MWh OF ELECTRICITY = 5,000 KM
1 MWh OF DIESEL = 2,700 KM

= ENERGY EFFICIENCY GAIN, ELECTRICITY OVER DIESEL, -90%

ELECTRIFICATION OF HEATING SYSTEMS

YEARLY ELECTRICITY CONSUMPTION BY HEAT PUMP = 5,800 KWh
YEARLY CONSUMPTION BY NATURAL GAS = 18,500 KWh

= ENERGY EFFICIENCY GAIN, HEATPUMPS OVER GAS BURNERS, -215%

In this white paper, we have reviewed three scenarios: Net Zero, Low Price and Slow Transition.

We have focused time and effort on the Low Price scenario in line with the enablers of supplying European industrial growth and competitiveness.

The main findings include:

- It is a long but not impossible task to drive the energy transition.
- The transition will deliver on all three targets: affordable, resilient, and clean energy.
- At the same time, the transition provides increased growth, improved trade balance, and increased employment.
- The forecasted energy system in response to a series of externalities such as policy changes and new energy shocks.
- In terms of policy implications, the white paper points to an integrated and ambitious electrification agenda and outlines 15 concrete policy proposals in four categories: A) shift-change grid investments, B) market and investment predictability, C) regulatory regime fit-for-purpose and effective permitting, and D) resilient supply chains.

Meeting the demand for affordable, resilient, and clean energy while restoring European economic growth and productivity

Three factors drive the build-out of clean energy sources today: demand for affordable energy, which can improve industrial competitiveness, access to resilient energy to withstand external energy shocks, and the need for energy to limit CO2 emissions. This build-out simultaneously addresses the increasing demand for electricity, and increase the economic growth and productivity of Europe.

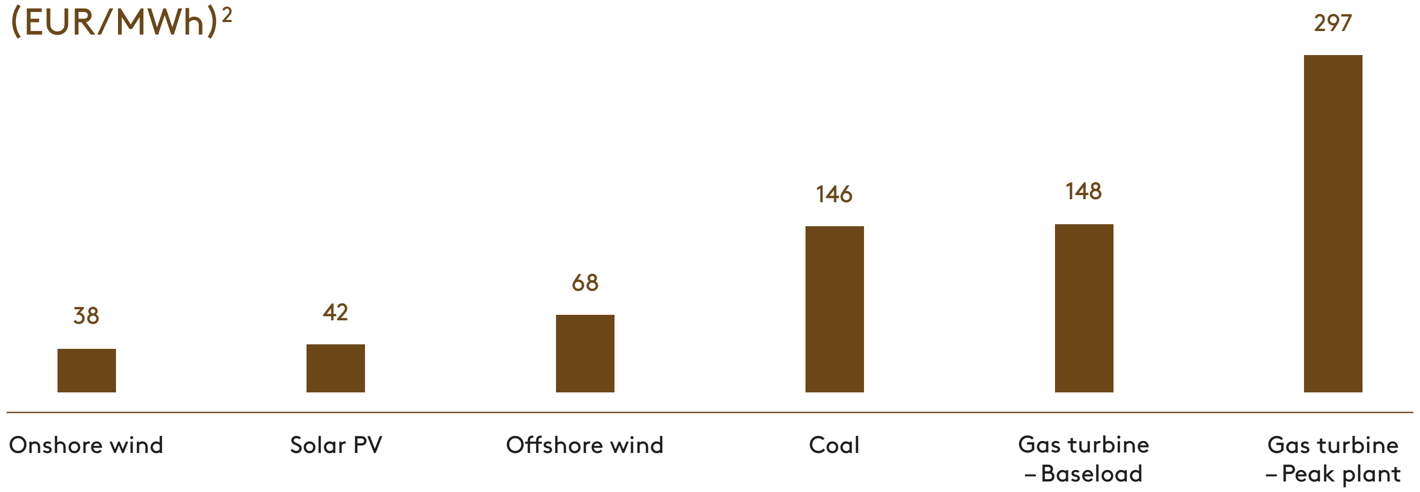
1. Affordable energy

Energy-related costs are front and center to securing industrial competitiveness at scale, and access to affordable energy represents a chance to strengthen European industries and improve European competitiveness. Affordable energy can be obtained in two ways. First, the transition from fossil energy (LNG, coal, others) to an electrified energy system through, for instance gas turbines.

Second, through a build-out of clean energy sources, which today is the cheapest and fastest source of new electricity generation.

In the past decade, the price of wind and solar PV energy has dropped significantly. Between 2015 and 2023, the cost of new electricity generation coming from wind and solar PV has decreased by more than 10% per year[1]. This has positioned onshore wind and solar PV as highly cost competitive, with price levels around half of the fossil-based alternatives, and with offshore wind prices just below or on par with the fossil-based sources.

LEVELISED COST OF ELECTRICITY FROM NEW ENERGY SOURCES IN 2024 (EUR/MWh)[2]



1. BloombergNEF 2015-2023 H2 LCOE report (2023)
2. Danish Energy Agency technology catalogue & EA Energianalyse

2. Energy resilience

In a volatile geopolitical context, the security of energy supply and energy resilience have been established as pre-conditions for stability and prosperity. A key lesson from Russia's invasion of Ukraine is that Europe must not be overly reliant on a single energy provider. Still, in 2025, Europe is predicted to import more than 50% of its total energy consumption, equivalent to a cost of more than EUR 450 billion, from various sources around the world.

Europe must create a resilient energy system by scaling its own energy production, driven primarily by increasing electricity generation. Additionally, Europe needs to diversify its energy imports from multiple sources and countries to reduce energy dependencies.

3. Clean energy

Finally, Europe must continue its efforts on decarbonisation and CO2 abatement to mitigate the impact of future climate-related hazards seen in recent years.

Europe should focus on and prioritise economically sound actions, i.e. investing where there would be the highest CO2 emission reductions per EUR spent.

4. Macroeconomic growth

Following the publication of the Mario Draghi report on European competitiveness (2024) and later the European Competitiveness Compass (2025), the need to restore European economic growth and productivity has become more apparent than ever. Especially in times when the fiscal balance of European economies will be challenged by increased military expenditure brought on by the current geopolitical situation.

As such, the macroeconomic model in this white paper also evaluates how an affordable, resilient, and clean energy system can enhance Europe's competitiveness and restore economic prosperity, helping to close the gap with the U.S. and China, as outlined in the EU Competitiveness Compass in February 2025.

Supporting Europe's energy push towards 2050

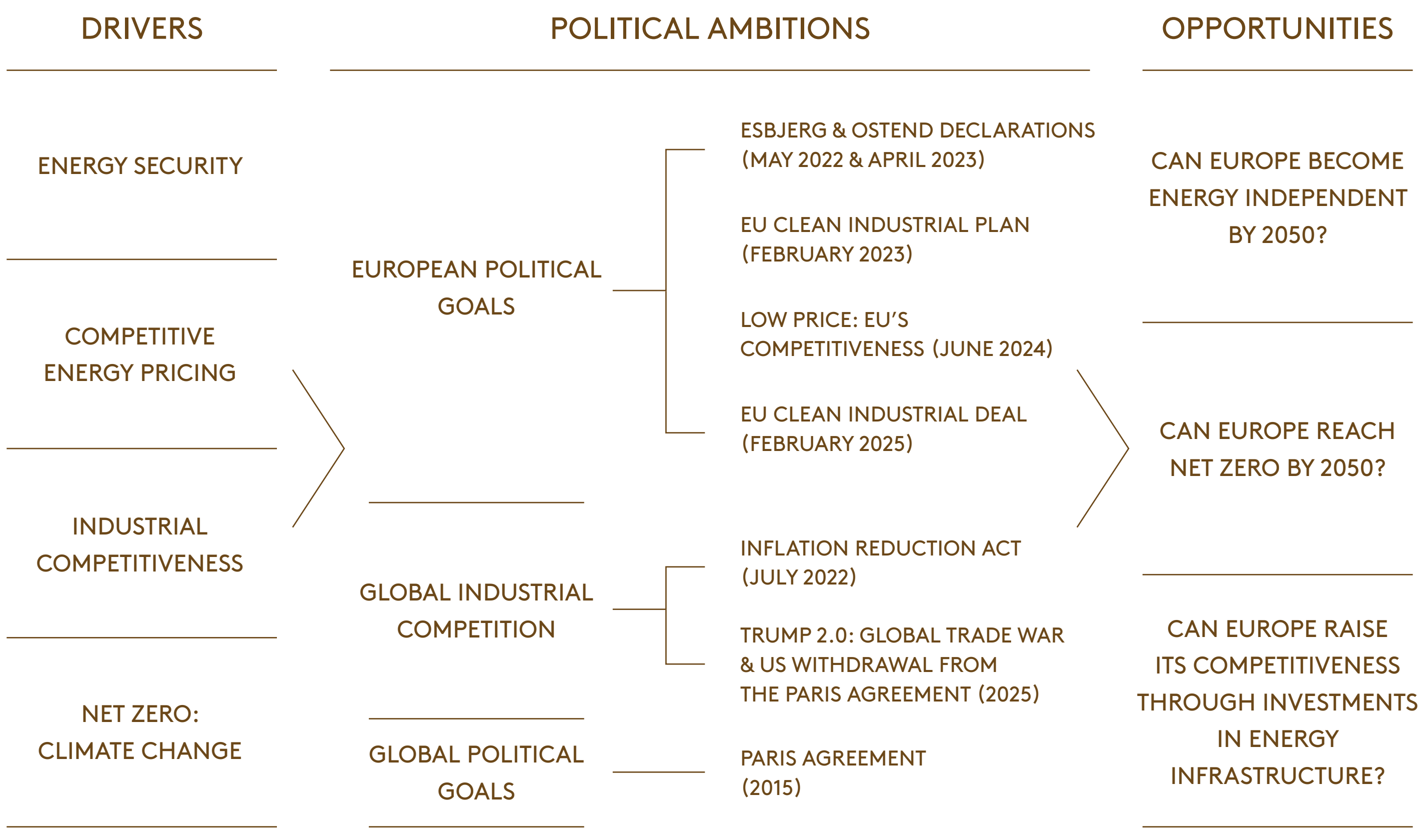
The key to address the triple challenge of delivering affordable, resilient, and clean energy in Europe is to accelerate electrification. This is a long, but not impossible task that will demand unprecedented investment, technical expertise, innovation, and cross-European coordination.

The Mario Draghi report estimates that annual investments of EUR 750-800 billion (including EUR 300 billion for energy) will be required towards 2050 to achieve Europe's targets for competitiveness, job creation, and economic growth. This white paper sheds light on how the energy dimension can be managed. A key requirement is investments in the European energy system of around EUR 5 trillion towards 2050.

Investments and policy actions needed

On the backdrop of the challenges faced by the European continent, we asked ourselves four questions, which this white paper aims to address:

1. To what extent can Europe increase its competitiveness through investments in energy infrastructure?
2. To what extent can Europe become energy-independent?
3. To what extent can Europe reach Net Zero emissions by 2050?
4. To what extent can Europe increase its economic growth and productivity through energy investments?



European legislators and governments need to take immediate action. The speed and impact of action will directly influence European competitiveness, our energy imports and our CO2 emissions.

Firstly, European policymakers must enable the electrification of Europe. Continued support is needed to replace private gas heaters with electric heat pumps and we need to phase out internal combustion engine vehicles and incentivise transitioning into electric vehicles. Governments may also consider other means to incentivise electrification, e.g. tax or tariff reliefs for industries that electrify quickly. Electrification will reduce European energy consumption - driven by energy efficiency - while at the same time reducing energy import dependencies.

Secondly, the build-out of transmission systems for power and hydrogen is essential. For both power and clean hydrogen production, the large-scale production centres will rarely be near demand centres like major cities or large industrial hubs. Consequently, Europe needs to invest heavily in power transmission and distribution – approx. EUR 100 billion per year towards 2050 – and a European hydrogen transmission backbone – approx. EUR 7 billion per year towards 2050. This requires European governments and transmission system operators (TSOs) to assess new means of public-private partnerships.

Thirdly, to facilitate the necessary investments, Europe needs a stable and foreseeable investment climate that is conducive to attracting private capital. European policymakers need to continue to improve permitting bottlenecks for both generation and transmission assets, improve tendering regimes across clean energy technologies, allow private capital in transmission projects to a greater extent, and establish a pragmatic and balanced approach to global supply chains.

A model-based approach

To provide an overview of the challenges ahead and to present a data-driven roadmap to deliver on the triple energy challenge, Copenhagen Infrastructure Partners (CIP) has developed a proprietary energy model integrating Europe's electricity, hydrogen, and heating systems. Integrating optimal capacity additions, optimal generation dispatch, energy cost levels, and CO2 emissions from the energy model into a macroeconomic model, we achieve a forecast of macroeconomic parameters such as economic growth, employment and how these are impacted by the energy infrastructure build-out.

The energy model was developed in collaboration with Ea Energianalyse (a specialist Danish consultancy) with input from renewable technology pioneer Stiesdal and the Danish TSO, Energinet. The macroeconomic model was developed in collaboration with the leading global economic advisory firm Oxford Economics, with input from Ea Energianalyse.

These models, in combination with this white paper, are a first-of-its-kind. It presents a fact-based, technical bottom-up study of the build-out of Europe's energy infrastructure ahead and the associated macroeconomic forecasts. The purpose has been to - independently and separate from political ambitions - show how a European integrated energy system could look like by 2050 from a scenario-based approach. The tested scenarios range from a 'Slow Transition'-scenario to a 'Net Zero'-scenario with a middle scenario called the 'Low Price' scenario, which optimises for European competitiveness.

In the **'Slow Transition scenario'**, it is assumed that

1. EU emissions targets are postponed or cancelled,
2. CO2 tax stays on par with historical averages, and
3. clean energy solutions built-out with reduced speed, leading to a delayed transition and continued reliance on fossil fuel imports.

In the **'Net Zero scenario'**, it is assumed that

1. the EU will reach Net Zero targets by 2050 as a result of mandated CO2 emission reductions
2. a high CO2 tax leading to a significant increase in clean fuels for energy-intensive industries, including shipping and aviation, and
3. clean hydrogen for peak-lead gas turbine plants.

In the **'Low Price scenario'**, a middle route is assumed,

1. low CO2 tax,
2. decarbonisation of energy-intensive industries is limited to the sectors where it makes economic sense, and
3. sectors with very high CO2 abatement cost, such as aviation or peak-plants, will continue to rely on fossil fuels.

In the process, the models provide a roadmap of where, how, and when to invest to achieve an optimal build-out that can deliver affordable, resilient, and clean energy while considering the macroeconomic effects before taking any political action. CIP has undertaken this work to provide structured input into the debate on the development of the European energy system. This is in light of a new European political landscape guided by the Clean Industrial Deal, where European industrial competitiveness is front and centre.

We recognise the shortcomings of the modelling but hope that this white paper can contribute positively to the debate. CIP remains committed to playing our part in building Europe's energy system of the future. We will continue to connect the world of capital with the world of energy projects to build value that matters and create attractive risk-adjusted returns for our investors while providing affordable, resilient, and clean energy and creating local growth and jobs.

THREE SCENARIOS FOR THE RENEWABLE ENERGY BUILD-OUT TOWARDS 2050

A model-based approach with three paths for the European transition.

01

SLOW TRANSITION

REDUCES DIRECT ELECTRIFICATION OF ENERGY-INTENSIVE INDUSTRIES

REMAINS DEPENDENT ON ENERGY IMPORTS

ENERGY SYSTEM REMAINS DEPENDENT ON FOSSIL FUELS

02

LOW PRICE

DIRECT ELECTRIFICATION OF ALL RELEVANT ENERGY-INTENSIVE INDUSTRIES

MINIMISES THE DEPENDENCE ON FOSSIL ENERGY IMPORTS

ENSURES A CLEAN TRANSITION OF THE EUROPEAN ENERGY SYSTEM EXCEPT SECTORS WITH THE HIGHEST ABATEMENT COSTS

03

NET ZERO

DIRECT ELECTRIFICATION OF ALL RELEVANT ENERGY-INTENSIVE INDUSTRIES

FULLY ENERGY INDEPENDENT

REACHES NET ZERO TARGET IN 2050

CIP Copenhagen Infrastructure Partners · OXFORD ECONOMICS · Stiesdal · ENERGINET · Ea Energianalyse

Main Results of the Low Price Energy System

To provide an in-depth understanding of the study and model, our six main results of the Low Price scenario are presented below. This section presents key parameters and provides additional background and nuances on some of the most interesting findings. The main results cover:

ENERGY AND ELECTRICITY DEMAND IN EUROPE BY 2050 — 01

DIVERSE ENERGY PRODUCTION AND INFRASTRUCTURE CAPACITY TO MEET DEMANDS BY 2050 — 02

SINGIFICANT INVESTMENT LEVELS NEEDED IN EUROPEAN ENERGY INFRASTRUCTURE — 03

OFFSHORE WIND PLAYS A KEY ROLE IN SUPPLYING EUROPE WITH AFFORDABLE, RESILIENT AND CLEAN ENERGY — 04

TRIPLING EUROPE'S ELECTRICITY TRANSMISSION AND EXPANSION OF HYDROGEN INFRASTRUCTURE — 05

CLEAN HYDROGEN: KEY TO DECARBONISING ENERGY-INTENSIVE INDUSTRIES BY 2050 — 06

Energy and electricity demand in Europe by 2050

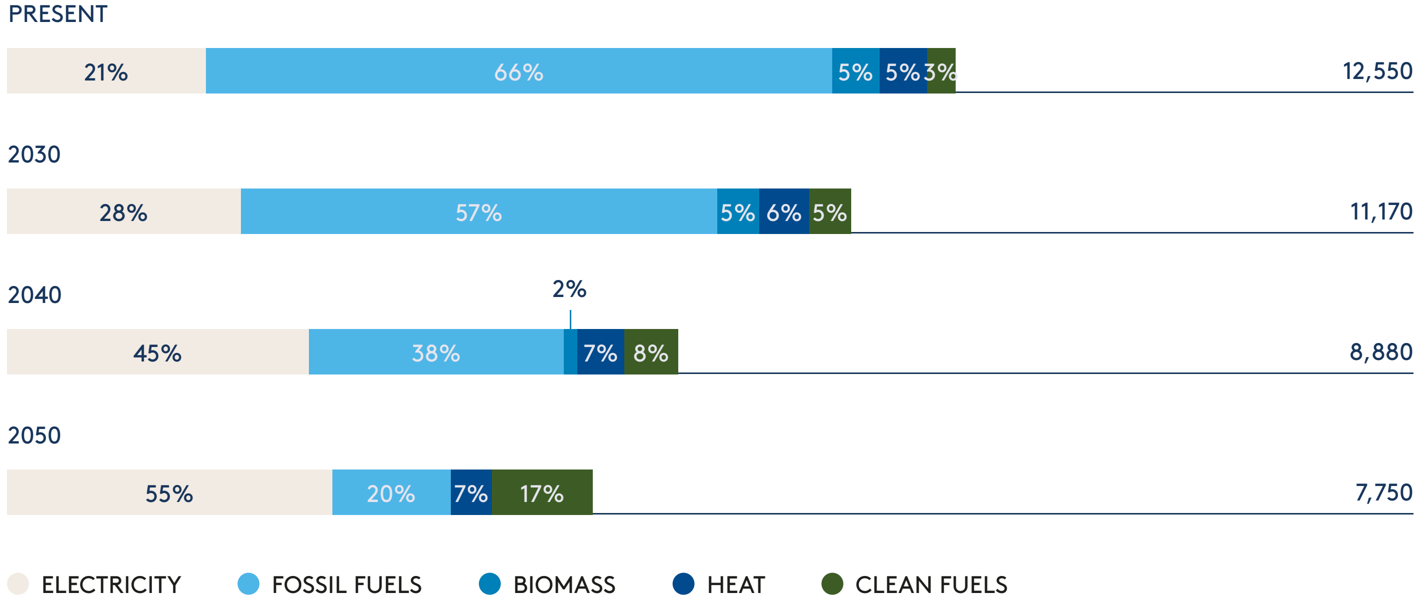
Following the Low Price scenario, an integrated and resilient energy system in Europe in 2050 is both realistic and achievable. And it will support European economic growth, job creation and an improved trade balance.

It requires a combination of offshore wind, onshore wind, and solar power as the main sources of electricity. Clean hydrogen – both produced in Europe and globally imported - is also poised to play a pivotal role in ensuring robust and affordable decarbonisation of industries. At the same time, natural gas has a significant role to play in our energy system across the three tested scenarios: Slow Transition, Low Price and Net Zero. However, the increase in clean energy production capacity must be accompanied by a build-out of the European transmission infrastructure. The benefits will be a reliable and resilient energy system that delivers affordable energy, provides substantial economic growth, improves the European trade balance and increases employment.

The transition from a fossil-based energy system to an electrified energy system significantly reduces final energy consumption due to the higher efficiency of electricity-based technologies. Increased electrification of energy consumption is expected in transport, households, and industry leading to a reduction of final energy consumption of 38% towards 2050 with electricity increasing from 21% to 55% of final energy demand in 2050. Fossil fuels will still provide 20% of the final energy mix, as most costly energy-intensive industries will continue to rely on fossil to ensure competitive energy prices.

INCREASED ELECTRIFICATION IN EUROPE REDUCES FINAL ENERGY DEMAND

Final energy demand by source (TWh)[3]



ENERGY CONSUMPTION
REDUCED
WITH 1/3

ELECTRIFICATION TO
MORE THAN DOUBLE
TOWARDS 2050

RENEWABLES ARE THE
FASTEST AND
MOST COST
COMPETITIVE ROUTE
TO NEW POWER CAPACITY

3. Adjusted ENTSO-E TYNDP 2024 Distributed Energy scenario

Diverse energy production and infrastructure capacity to meet demands by 2050

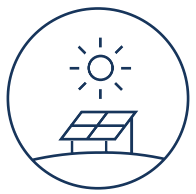
The optimal energy mix in 2050 has +90% clean energy sources with more than 70% of the final energy generation coming from solar and wind energy.

To achieve an affordable, resilient and clean energy system by 2050, a massive expansion of Europe's clean energy production capacity is needed. In the Low Price scenario, a total production capacity of 3,260 GW is necessary to supply an estimated ~6,050 TWh of power in 2050.

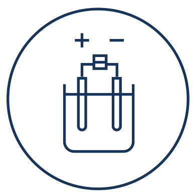
In the Low Price scenario, the economically optimal distribution of clean energy production capacity in Europe by 2050 will include[4]:

~235 GW
OFFSHORE WIND

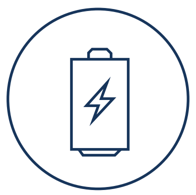
~550 GW
ONSHORE WIND



~1,470 GW
SOLAR PV



~245 GW
POWER-TO-X



~190 GW
BATTERY STORAGE

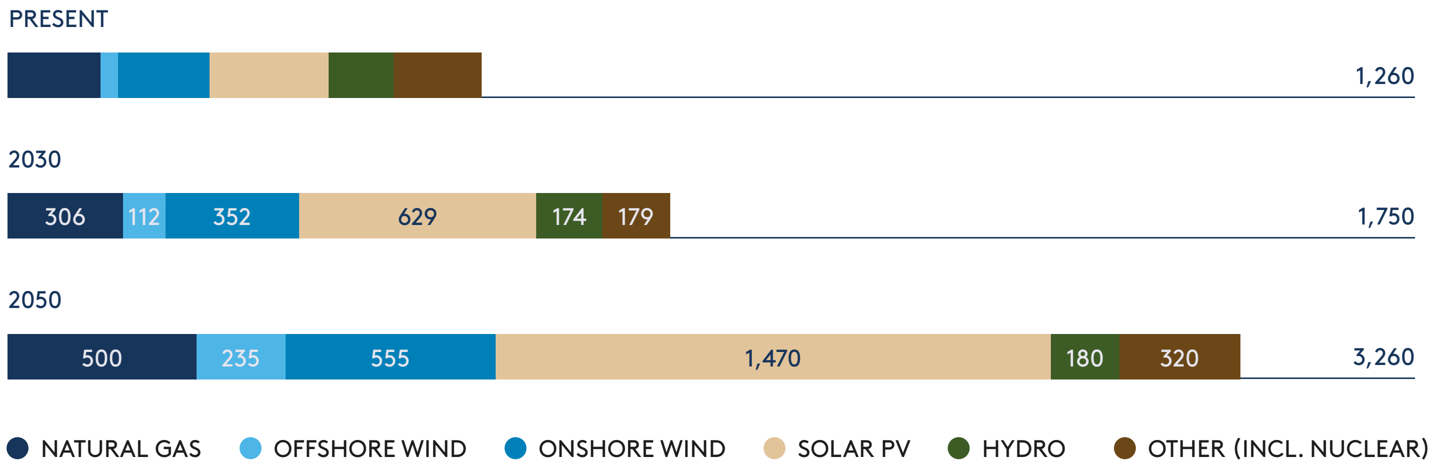
~500 GW
NG PEAKERS

This corresponds to an increase in offshore wind capacity by a factor of six, an increase in onshore wind capacity by a factor of two, and an increase in solar power capacity by a factor of four compared to present levels. Such expansions would require year-on-year investment levels around EUR 80 billion on average towards 2050.

4. Numbers rounded to nearest multiple of 5.

POWER CAPACITY AND GENERATION MIX FOR THE LOW PRICE SCENARIO IN EUROPE TOWARDS 2050

European electricity production capacity (GW)



Wind and solar to cover +70% of Europe's electricity generation in 2050

In the Low Price scenario, offshore wind, onshore wind and solar PV are expected to cover more than 70% of Europe's electricity generation in 2050. A mix of hydro-energy, nuclear power, and other clean sources will cover 20%, whereas just less than 10% of electricity will be covered by natural gas for peak-plants. This distribution reflects the cost competitiveness of wind and solar and the practical and political feasibility of rapid large-scale build-out of these sources.

Faster capacity build-out needed

This is necessary for the electrification as well as to power new electrical applications, data centres, and storage solutions and to produce clean hydrogen used for clean fuels for energy-intensive industries such as chemicals, steel, refining, shipping, and aviation.

Over the past two years (2023-2024), only 3 GW of offshore wind have been installed in Europe annually[5]. This obviously falls short of the year-on-year average build-out of ~8 GW that is needed to reach a capacity of 235 GW offshore wind in 2050.

Resulting electricity generation in Europe in 2050 (%)

5. WindEurope, Wind energy in Europe: 2023 Statistics and the outlook for 2024-2030

Significant investment levels needed in European energy infrastructure

Boosting electrification across the European continent will require unprecedented levels of investment. According to the Low Price scenario, the energy system calls for total investments of EUR ~5,000 billion towards 2050, corresponding to EUR ~200 billion per year, in line with assumptions in the Draghi report.

In the Low Price scenario, demand for investments is expected to be driven primarily by of electricity generation and electricity infrastructure. Investments into electricity generation alone are expected to total EUR ~2,000 billion by 2050. This includes offshore wind energy generation investment levels of EUR ~445 billion, onshore wind EUR ~715 billion, and solar PV EUR ~435 billion.

Also, significant investments into the European hydrogen transmission network are required to expand the European market for hydrogen. The Low Price scenario forecasts total investments of EUR ~180 billion towards 2050 in electrolysers and hydrogen infrastructure.

EUROPEAN ENERGY INFRASTRUCTURE INVESTMENTS

ELECTRICITY GENERATION
= EUR ~2,000 BILLION
(80 BILLION P.A.)

ELECTRICITY INFRASTRUCTURE
= EUR ~2,600 BILLION
(104 BILLION P.A.)

ELECTROLYSERS & H_2-INFRASTRUCTURE
= EUR ~180 BILLION
(7 BILLION P.A.)

TOTAL
= EUR ~5,000 BILLION
(200 BILLION P.A.)

Offshore wind plays a key role in supplying Europe with affordable, resilient, and clean energy

A large and rapid expansion of offshore wind capacity is necessary for an affordable, resilient, and clean energy system. According to the Low Price scenario, Europe needs a sixfold increase in offshore wind.

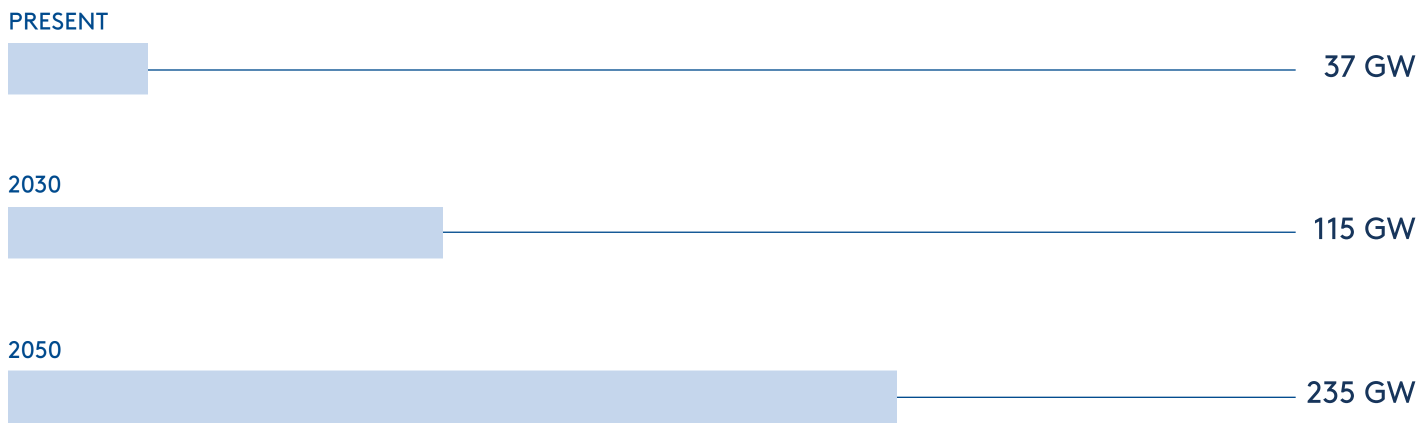
Offshore wind will play a vital role in the build-out of a competitive and resilient energy system. The Low Price scenario projects that offshore wind will deliver 16% of Europe's electricity supply by 2050, which corresponds to an offshore wind capacity of 235 GW. This build-out is expected to require investments of EUR ~445 billion towards 2050. While this is just 2/3 of the European political targets and the pledges from the Heads of State and Government announced in the Ostend Declaration, this capacity build-out resembles a sixfold increase of today's installed capacity in Europe. This underlines both the enormous potential and the urgent need to develop offshore wind capacity in the regions where Europe has the most promising potential, notably in the regions of the North and Baltic Seas.

Stable wind output

Offshore wind is an efficient way to produce clean energy. In places such as the North Sea, where the wind blows reliably all year, offshore wind can reach a capacity factor of up to 60%. For comparison, land wind has a capacity factor of about 40%, while solar energy has a capacity factor of 12-18%. Due to its' high capacity factor and reliable output, offshore wind is a stabilising factor in the energy system.

EUROPEAN OFFSHORE WIND CAPACITY TO EXPAND X 6 BY 2050

Forecasted offshore wind power production capacity in GW



Tripling Europe's electricity transmission and expansion of hydrogen infrastructure

Expanding the European electricity transmission infrastructure is key to realising a clean energy system that will allow energy to be shared across borders. Focusing on the cross-border transmission grids alone, tripling current capacity is needed. Europe needs to invest EUR ~2,600 billion towards 2050, making up roughly half of the energy infrastructure investments needed in electricity infrastructure.

Large investments in grid infrastructure

In the Low Price scenario, Europe and national governments must invest ~100 billion per year, towards 2050 in internal bidding zone transmission and local distribution systems to deliver in the robust and resilient energy system. These investments do not necessarily have to fall into place on an average year-on-year but should match – and hopefully anticipate – the build-out of more clean electricity generation throughout Europe. As such, the Low Price scenario points to annual investment levels around EUR ~75 billion in the years around 2030, EUR ~220 billion in the years around 2040 and EUR ~100 billion in the years around 2050.

Pan-European electricity transmission infrastructure to be expanded by ~165%

In the Low Price scenario, the current cross bidding-zone electricity transmission interconnector capacity of 170 GW will need to be expanded to 450 GW by 2050, a growth of +165%. The required build-out varies significantly by country and bidding zone. For instance, the Netherlands will need to expand its cross bidding zone electricity transmission interconnector capacity from 15 GW to 90 GW, while France will need to expand its capacity from 20 GW to 40 GW. Countries sourcing the North and Baltic Seas would require especially large and unprecedented cross bidding zone transmission interconnector investments.

The Low Price scenario estimates that cross-bidding zone interconnections require total investments of EUR ~100 billion, or EUR ~4 billion per year, towards 2050. Thus, the vast amount of the investments needed lies within internal bidding zone transmission and local distribution systems[6].

6. See Appendix VI for currently planned transmission projects

	CROSS BIDDING-ZONE ELECTRICITY TRANSMISSION INTERCONNECTOR BUILD-OUT (2025-2025)[7]			REQUIRED CAPEX INVESTMENTS (2025-2050)
GERMANY	70 GW	+115% →	150 GW	EUR ~20 billion
UNITED KINGDOM	10 GW	+500% →	60 GW	EUR ~15 billion
NETHERLANDS	15 GW	+500% →	90 GW	EUR ~20 billion
FRANCE	20 GW	+100% →	40 GW	EUR ~10 billion
REST	55 GW	+120% →	120 GW	EUR ~35 billion
TOTAL	170 GW	+165% →	450 GW	EUR ~100 billion

7. Numbers rounded to nearest multiple of 10

Major expansion of European hydrogen infrastructure needed towards 2050

Despite the lower-than-expected demand uptake in Europe, a significant expansion of the hydrogen transmission network is required - both onshore and offshore – through 2050. This will require considerable investments. To enable a European market for hydrogen, Europe needs to build an interconnected hydrogen infrastructure across Europe. This will allow the import of clean hydrogen from North Africa and the distribution of hydrogen from European production hubs, such as the North Sea region and the Iberian Peninsula, to the major demand centers notably in Germany, the Netherlands and France.

The Low Price scenario forecasts the needed hydrogen transmission grid capacity to be ~65 million tons per year (mtpa) in 2050. This capacity expansion contains transmission both internally in countries as well as cross-border, so for instance, a capacity expansion of 15 mtpa between Spain and France allowing transportation of hydrogen produced on the Iberian Peninsula and in North Africa to Central Europe. Similarly, transmission capacity needs to be heavily expanded towards ~7 mpta between France and Germany.

To reach the required capacity, there is a need for investments of EUR ~35 billion towards 2050 in hydrogen transmission.

FLOW	HYDROGEN PIPELINE CAPACITY	REQUIRED CAPEX INVESTMENTS (2025-2050)
SPAIN $\xrightarrow{H_2}$ FRANCE	~15 mpta	EUR ~7 billion
FRANCE $\xrightarrow{H_2}$ LUXEMBOURG $\xrightarrow{H_2}$ GERMANY	~7 mpta	EUR ~4 billion
FRANCE $\xrightarrow{H_2}$ UNITED KINGDOM	~3 mpta	EUR ~8 billion
UNITED KINGDOM $\xrightarrow{H_2}$ NETHERLANDS	~4 mpta	EUR ~1 billion
DENMARK $\xrightarrow{H_2}$ GERMANY	~3 mpta	EUR ~2 billion
OTHER	~30 mpta	EUR ~14 billion
TOTAL	~65 mpta	EUR ~35 billion

Clean hydrogen: key to decarbonising Europe's energy-intensive industries by 2050

Clean hydrogen technology is essential for the decarbonisation of energy-intensive industries sectors. In the Low Price scenario, European production will supply ~50% of the demand, while hydrogen imports from North Africa and liquid hydrogen derivatives imported from the global market will supply ~50% as a result of Europe's desire for affordable and clean hydrogen supply.

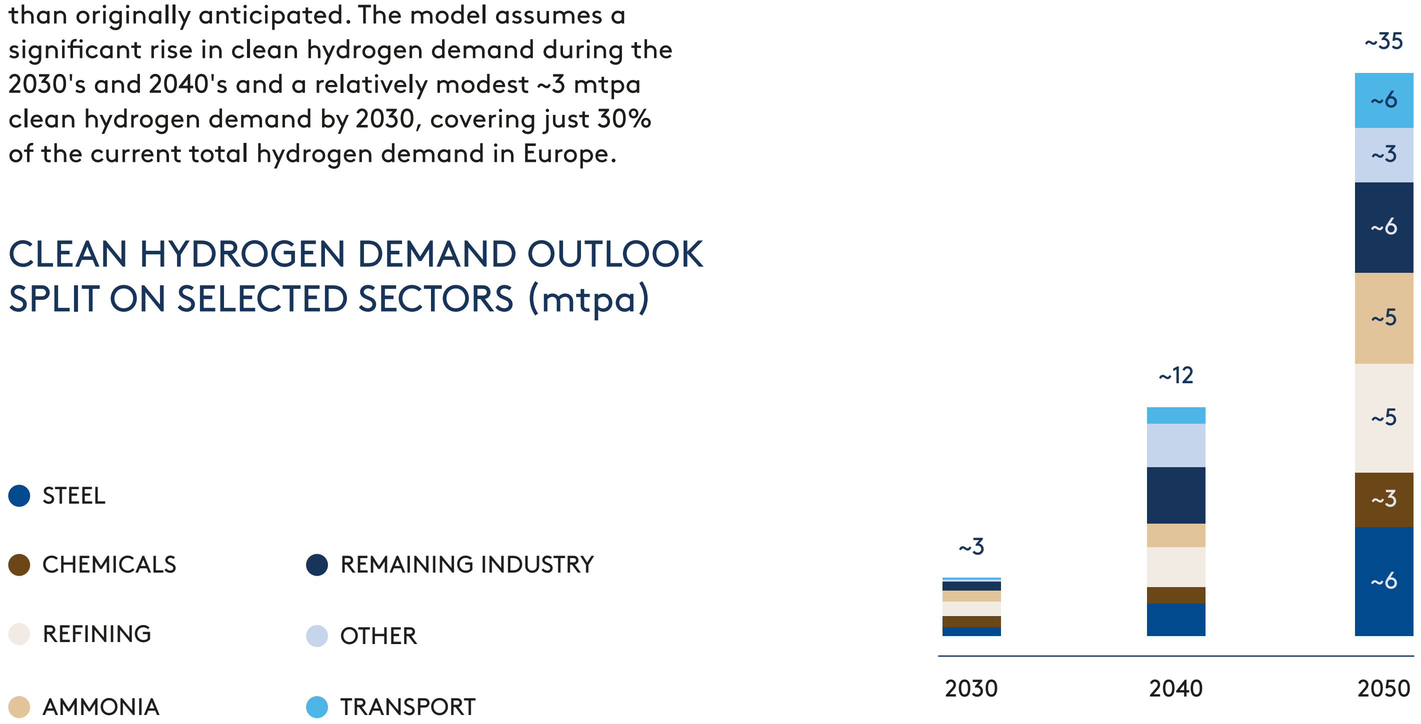
Clean hydrogen is set to play a central part in Europe's future energy system. Crucially, clean hydrogen allows for the decarbonisation of energy-intensive industries such as steel production, chemicals, refineries and heavy transport. Clean hydrogen production will emerge as a key and beneficial byproduct of the increased clean energy build-out and in areas with intermittent power production, supporting the decarbonisation of European industries.

Considering the very ambitious political clean hydrogen targets through the early 2020's, the Low Price scenario represents a more balanced and pragmatic ramp-up of the clean hydrogen demand than originally anticipated. The model assumes a significant rise in clean hydrogen demand during the 2030's and 2040's and a relatively modest ~3 mtpa clean hydrogen demand by 2030, covering just 30% of the current total hydrogen demand in Europe.

This is primarily driven by a delay of regulatory intervention and clarity on hydrogen infrastructure across Europe. However, the pragmatic forecast for hydrogen demand does not dramatically affect the 2050 clean energy generation capacity in Europe.

Hydrogen will be supplied from three sources: domestic European production, imports from North Africa, and global imports in the shape of clean liquid hydrogen derivatives, such as ammonia. The Low Price scenario points to a clean hydrogen production capacity in Europe of ~17 mtpa equivalent to an electrolysis capacity of ~245 GW.

CLEAN HYDROGEN DEMAND OUTLOOK SPLIT ON SELECTED SECTORS (mtpa)

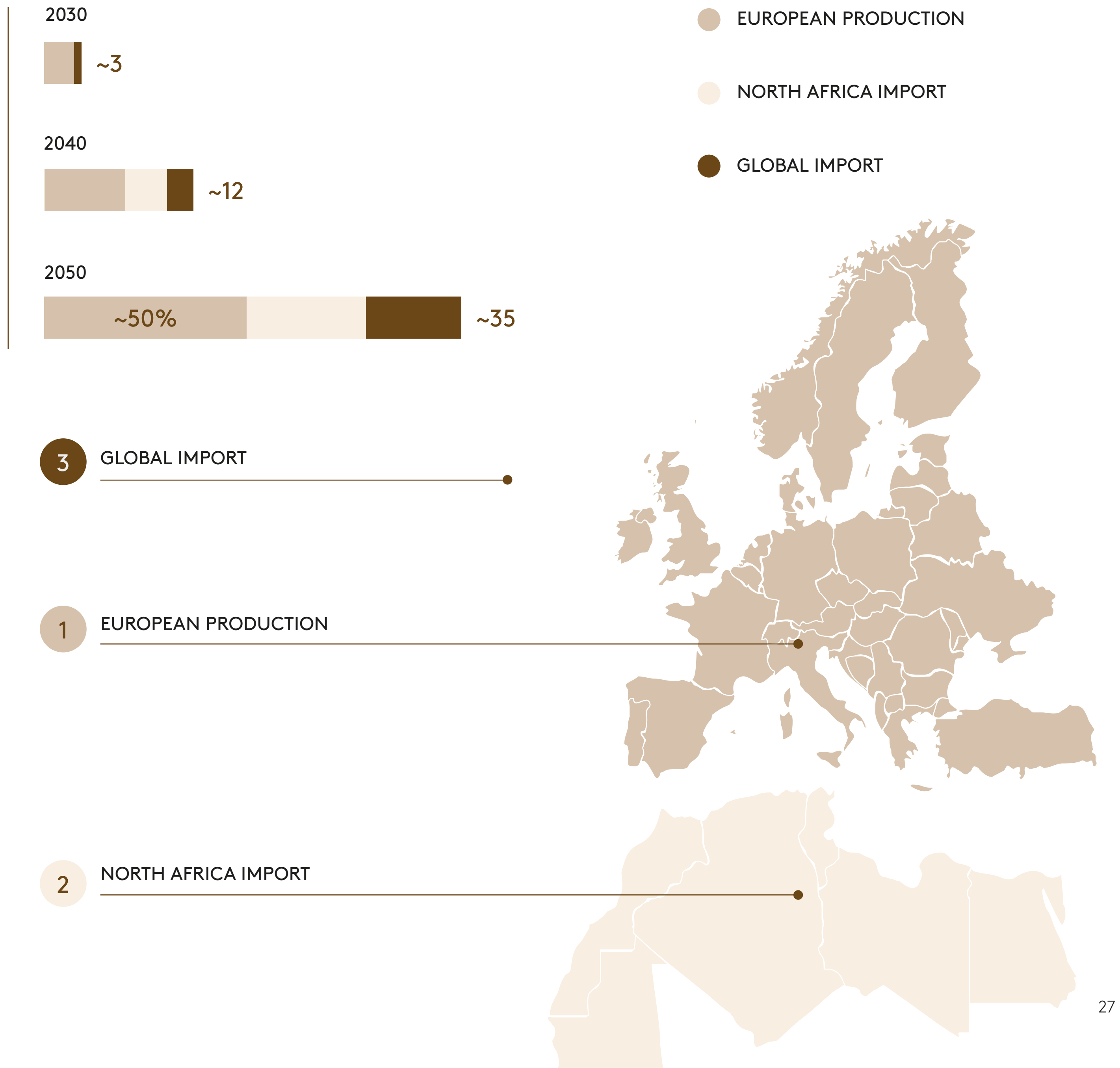


With less than 385 MW electrolysis capacity installed today, Europe faces massive future investments and needs to grow the current capacity levels towards 2050 by more than x 600 in the Low Price scenario and x 1,600 in the Net Zero scenario. The total European clean hydrogen demand is expected to reach ~35 mtpa in 2050, which means that domestic European production will be able to supply around 50% of its demand. This represents a total of EUR ~144 billion of capital investments required in clean hydrogen production plants within Europe.

Domestic clean hydrogen production is financially advantageous in regions with high potential for clean electricity generation, low electricity prices and intermittent electricity production. The Low Price scenario forecasts the Iberian Peninsula, the North Sea region, and the Baltic states as key European hydrogen production hubs. The Iberian Peninsula has the lowest cost of producing hydrogen (towards 5 mpta clean hydrogen by 2050) due to the amount of hours with high utilisation of solar resources. The North Sea (9 mpta in 2050) is an attractive region close to German industry and with best-in-Europe wind resources. And the Baltic region (2 mpta in 2050) has resources available to produce cheap hydrogen, with the main limitation being the road to consumer.

CLEAN HYDROGEN SOURCING FOR EUROPE

(mtpa hydrogen-equivalent)



Ensuring affordable, resilient, and clean energy for Europe

Affordable, resilient, and clean energy is essential for any country or continent to thrive. The future design of Europe's energy system will determine the competitiveness of its industries, the affordability and reliability of energy for consumers, the protection of the economy from external energy disruptions, and the response to climate change. A crucial yet often overlooked aspect of this transformation is increasing electrification.

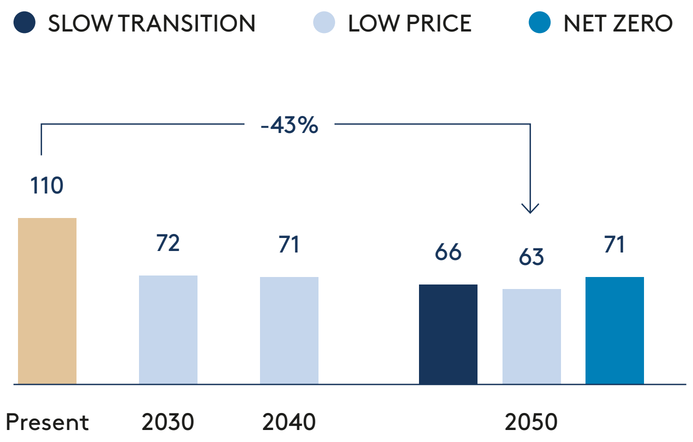
Affordable power for consumers and industries
The electricity prices forecasted in all three scenarios remain steadily decreasing through 2050.

The lowest electricity price point is reached in the Low Price scenario at 63 EUR/MWh in 2050, compared to 110 EUR/MWh today (2022-real prices).

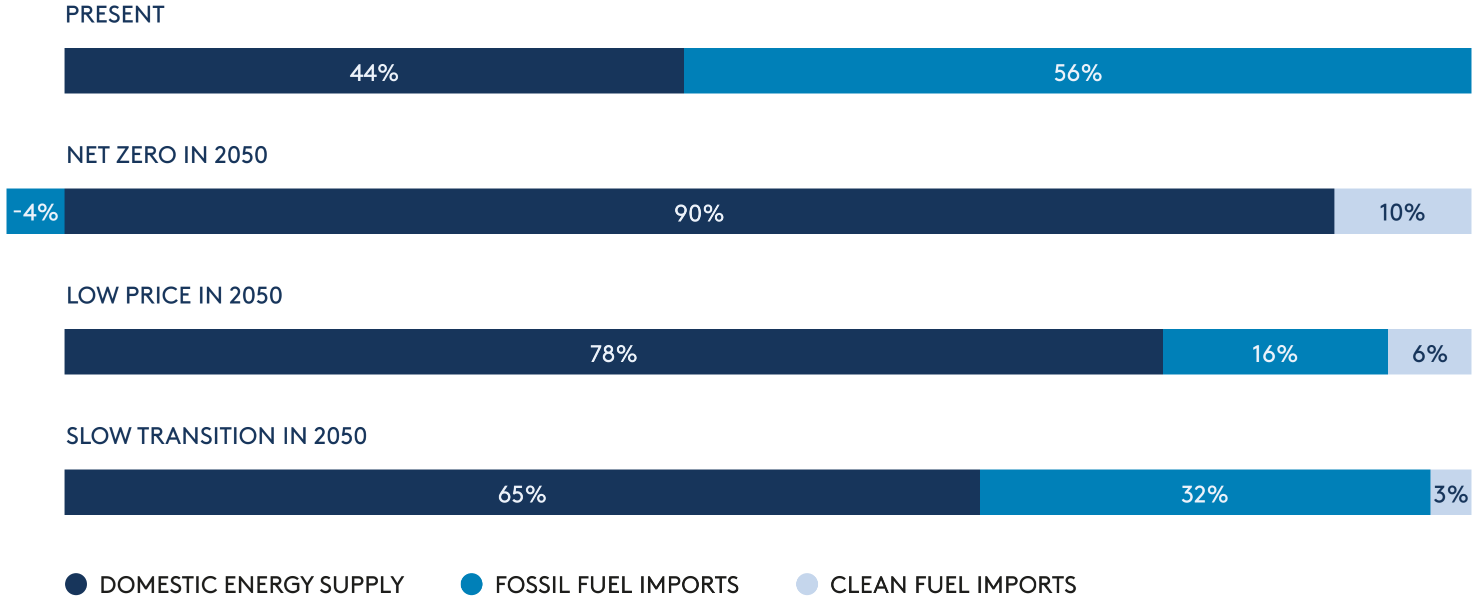
The Slow Transition scenario provides an energy system delivering electricity prices at 66 EUR/MWh, and the Net Zero scenario at 71 EUR/MWh. As a result, European households and industries could benefit from electricity prices, which are 40% less than today's cost levels in the Low Price scenario. These price levels include costs associated with building the overall energy infrastructure.

EUROPEAN AVERAGE WHOLESALE ELECTRICITY PRICS

(EUR22/MWh)



ENERGY SOURCING IN EUROPE (% OF TOTAL ENERGY)



An integrated European energy system and lowered imports will ensure energy resilience
The EU (including UK) is currently heavily dependent on imported fossil fuels. Today, the EU imports fossil fuels amounting to 58% of the final energy demand equivalent to a cost of EUR 450 billion.

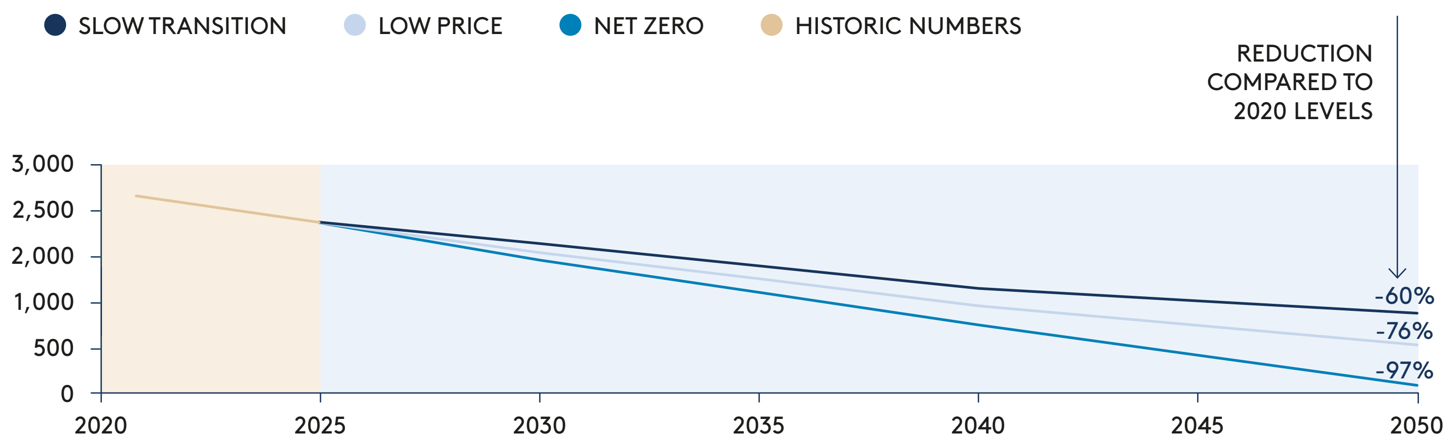
Energy import dependency across all three scenarios will decrease substantially, although most prevail in the Net Zero scenario. By 2050, fossil import is forecasted to 32% in the Slow Transition scenario, 16% in the Low Price scenario, while Net Zero has an export share of 6% by 2050.

In addition, clean fuels for energy-intensive industries are also expected to be imported due to lower production costs in global hot spots, but the dependency on these is purely economic, and the same fuels could be produced in the EU using clean technologies – though expectedly at a marginally higher price.

Delivering clean energy for and creating CO2 emission reductions
Across all tested scenarios, gross CO2 emissions are to decline towards 2050.

EUROPEAN EMISSION REDUCTION DEVELOPMENTS

Gross CO2 emissions (mpta)



Expanding energy infrastructure will drive economic growth

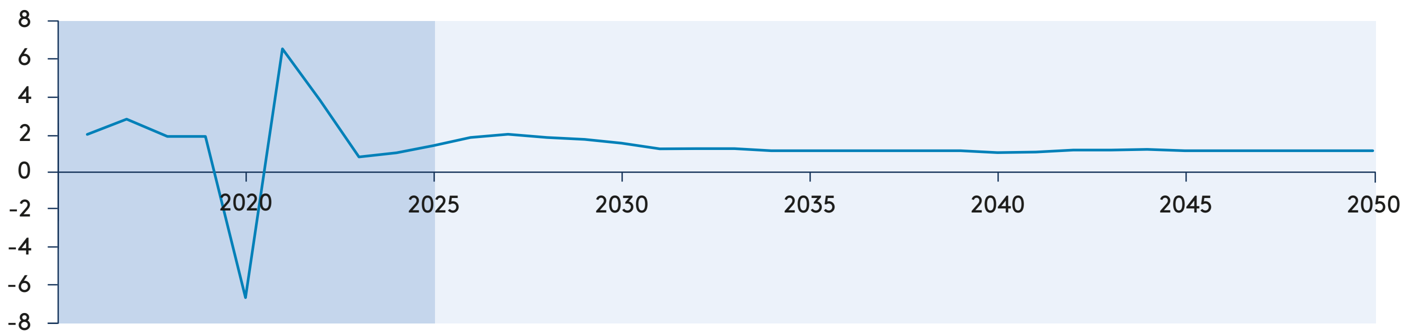
"The US innovates, China duplicates, the EU regulates" **is a saying that has been voiced over the last years by leading policymakers and business leaders as a pre-warning of the global competitiveness challenges faced by Europe.**

Economic growth and improved trade balance
From today towards 2050, Europe will experience strong economic growth as a direct result of the energy infrastructure investments following the Low Price and the Net Zero scenarios. In comparison to the Slow Transition scenario, Europe is projected to experience stronger growth in both the Net Zero and Low Price scenarios, with GDP multipliers of x 1.3 and x 1.9, respectively. Thus, the Low Price scenario delivers a more balanced composition of European economic growth relative to the Net Zero scenario, primarily driven by greater consumption and trade. This greater structural balance to European economy going forward will make it more resilient to potential future macroeconomic volatility.

As a result of a more robust and resilient energy system, Europe will be less reliant on energy imports, which will improve Europe's trade balance significantly.

REAL GDP GROWTH IN EUROPE TOWARDS 2050 (% P.A.)

HISTORIC NUMBERS   MODEL RESULT



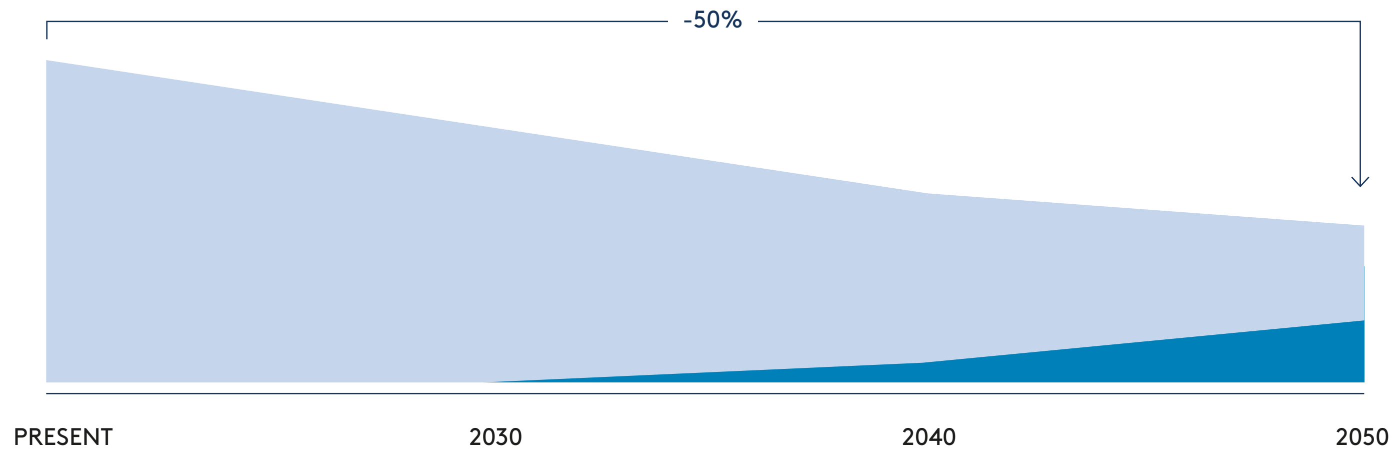
EUR 2.9 TRILLION CUMULATIVE RISE IN REAL GDP

MORE BALANCED GROWTH DRIVEN BY CONSUMPTION AND TRADE

GDP MULTIPLIER OF X 1.9 COMPARED TO THE SLOW TRANSITION

EUROPEAN FUEL TRADE BALANCE IN LOW PRICE SCENARIO

FOSSIL FUEL IMPORTS   CLEAN FUEL IMPORTS



Improved European trade balance
In both the Net Zero and Low Price scenarios, the European trade balance is improved through the reduction in imported fossil fuels, to be replaced by domestically produced electricity. In the Low Price scenario, fossil fuel imports are reduced by ~70% by 2050 compared to the present. However, an increase in demand for clean fuels also results in increased imports of such from global markets e.g. by ship and clean hydrogen via pipeline from North Africa. This results in an overall reduction of imported clean and fossil fuels by ~50% from 2025 to 2050, significantly improving the European trade balance[8].

8. European Commission, May 2022

Policy recommendations towards an affordable, resilient, and clean energy system

To deliver an affordable, resilient and clean energy system, Europe will need to take an integrated and ambitious electrification approach and implement demand-side and supply-side measures. Below outlines 15 specific policy proposals in four categories: A) shift-change grid investments, B) market and investment predictability, C) regulatory regime fit-for-purpose and effective permitting, and D) resilient supply chains.

A) SHIFT-CHANGE INVESTMENTS INTO EUROPEAN POWER AND HYDROGEN GRIDS

It is crucial to expand the European transmission systems to transport power and hydrogen across national borders. This expansion is vital for enabling cross-border electricity transmission as well as distribution of clean hydrogen across Europe. To deliver on this, the EU and European governments should ensure a swift implementation of the EU Grid Action Plan and implement new measures in the upcoming Grids Package:

1. Identification of investment needs for national domestic transmission and distribution grids, cross-border transmission and flexibility services.
2. Planning and operation of electricity transmission and distribution networks to correlate with the planning and operation of energy storage. This will increase network flexibility, increase build-out of clean energy generation and reduce (or level out) the investments in grids.
3. Visibility, certainty and limited delays in European Ten-Year-Network-Development-Plans (TYNDPs), including both power transmission and hydrogen infrastructure, onshore and offshore, providing easier route to market and lower curtailment risk for generation projects.
4. New financing models to unlock more private capital, balancing a fair cost and risk allocation, with involvement of TSOs and the industry, based on pre-agreed contracts with the TSO, and with appropriate remuneration and with respect to unbundling rules.

At the same time, Europe must unlock investments in hydrogen infrastructure with coordinated offshore grid planning for hydrogen and electricity, including offshore energy hubs, and expedient permitting processes:

5. Leveraging Offshore Energy Hubs: To achieve objectives of ensuring affordable and resilient energy, development of renewables, in particular the offshore wind and cross border grids (both hydrogen and power) is crucial.
6. Revised Connecting Europe Facility (CEF) framework: CEF-support similar to the levels that build-out of cross-border natural gas grids has received in the past. This requires an increase in the volume of CEF funds. At the same time, the EU should de-risk the timing of the ramp-up of the hydrogen market, e.g., an intertemporal cost allocation mechanism similar to the German 'Kernnetz' regulation (one possibility could be to have EIB underwrite the intertemporal cost allocation mechanism at the EU-level similar to the role of KfW in Germany).

B) MARKET AND INVESTMENT PREDICTABILITY: IMPROVED RISK SHARING, INCLUDING VOLATILITY-PROOF REVENUE CERTAINTY FOR OFFSHORE WIND

In the efforts to achieve European clean energy targets, including the 32% electrification target by 2030, the EU and European governments must work towards building a truly integrated Energy Union, which includes increasing the volume of the market and predictability by following up on Electricity Market Design review, Wind Power Package and EC Communications on Auction Designs:

7. Implement policies that creates volatility-proof revenue certainty: Models for a new market reality, where governments assist in financially derisking projects, e.g. Contracts-for-Difference (CfDs), while allowing room for corporate PPA. CfDs need to counter negative power prices and price fluctuation associated with marginal pricing based on fossil fuels. Auction models also need to consider price indexation and realistic ceiling prices reflecting increases in input costs.
8. Ensure clear offshore wind auction schedules and take other actions to improve long-term visibility on build-out plans: Clear auction schedules 10 years ahead of projects' commercial operation date to provide developers with necessary clarity on market volume and planning horizon.

Additionally, clean hydrogen is poised to play a key role in the EU's ambitions to accelerate the decarbonisation of European industries. to achieve this goal, the EU should ensure long-term regulatory certainty and investment predictability on demand-side measures, including implementation and enforcement of blend-in requirements in the Renewable Energy Directive (RED) III, ReFuelEU Aviation, FuelEU Maritime:

9. Clear implementation and enforcement of the RFNBO-hydrogen blend-in requirements for heavy industries (such as steel and chemicals), including refineries (for aviation, shipping, and industry). Greenhouse gas legislation is to be sustained to provide regulatory clarity and support the hydrogen economy's growth.
10. New legislation should not create new uncertainties for the hydrogen industry regarding blend-in requirements and associated penalties, including the Industrial Decarbonisation Accelerator Act and the tailored action plans for the steel and chemicals sectors. Similarly, CIP warns to the adverse effects of signalling an opening of the Delegated Acts on RFNBO as this would hamper any clean hydrogen offtake commitment.

C) REGULATORY REGIME FIT-FOR-PURPOSE AND EFFECTIVE PERMITTING

As deployment of both grids, new electricity generation, storage and hydrogen production facilities will reach historical heights, the EU must also ensure fast-tracked permitting and provide sufficient public support to scale clean hydrogen:

11. National permitting regimes developed under the emergency measures on permitting are aimed at shortening and accelerating the permit-granting procedures for renewable energy projects, as well as for grid and infrastructure projects, hence the principle for 'overriding public interest', should be continued for grids, new electricity generation, storage and Power-to-X-facilities.

12. Clear outlook on level of support mechanisms and uncoordinated practices across EU and Member States for clean hydrogen, including volume and limited complexity in e.g. European Hydrogen Bank, the new European Competitiveness Fund, etc.

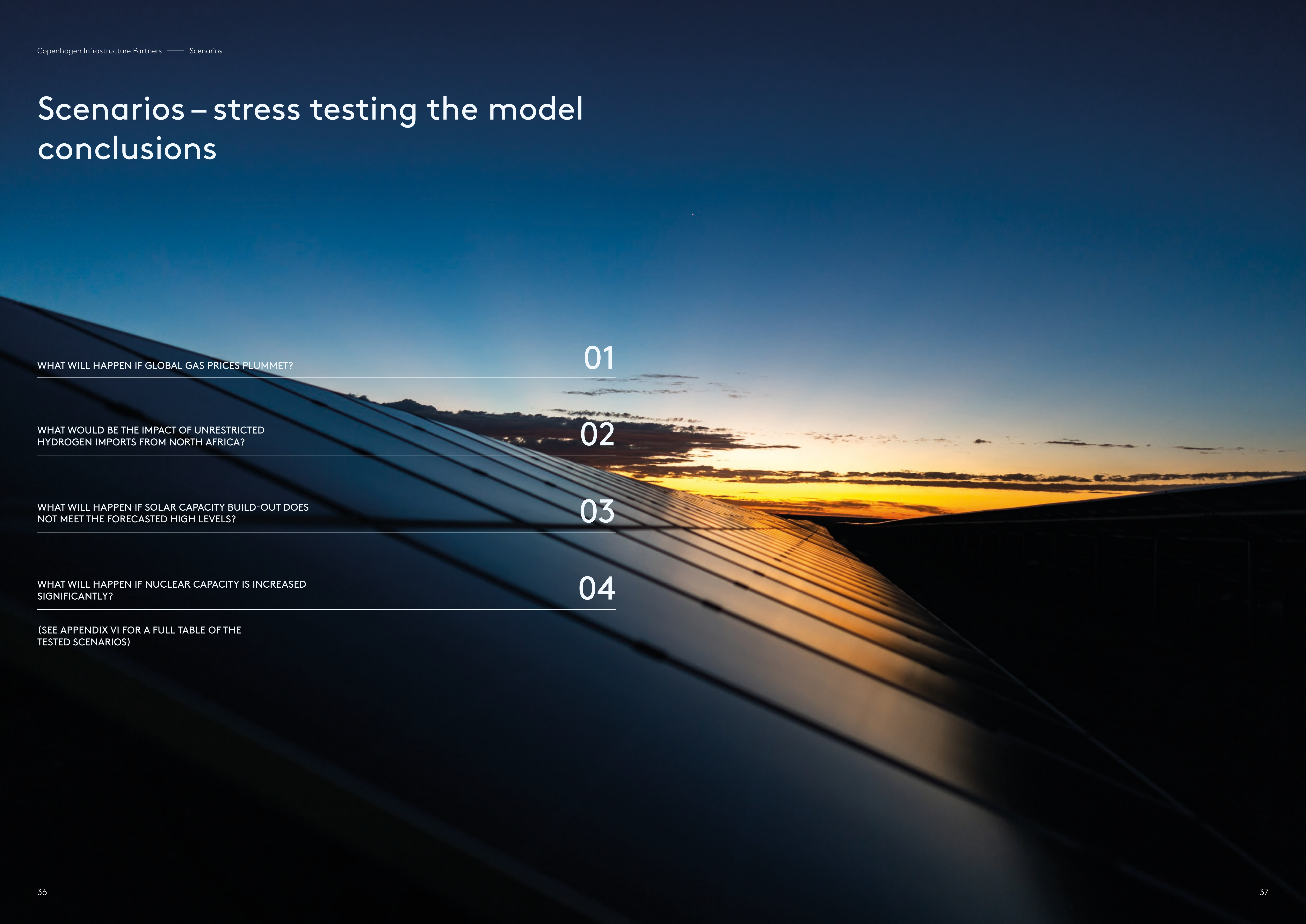
13. Attractive auction / funding allocation models: Promote attractive auction and allocations models that cater for mature hydrogen projects of industrial scale. Consider allocating more funding for DEVEX and allow subsidy accumulation.

D) RESSILIENT SUPPLY CHAINS TO DELIVER COST- COMPETITIVE TECHNOLOGIES

Finally, strategic resilience and competitiveness as key priorities for Europe Resilience will not be improved by limiting imports of components and materials without a clear and realistic plan for developing alternative supply routes. EU should adopt a "managed dependency" approach to mitigate risks associated with considerations on energy security and global supply chains:

14. The EU and European governments must increase their investments in European clean energy supply chains to be able to deliver on long-term ambitions. At the same time, short-term supply chain bottlenecks and global dependencies call for a balanced, fact-based and pragmatic approach to supply chain interventions, e.g. the Net Zero Industry Act & CBAM.

15. Attention to lead times and balance between speed and implications: The EU and European governments need attention to: 1) lead time to diversify the complex wind energy supply landscape; 2) lead time associated to the development and construction of many renewable energy projects; 3) ensure measures addressing strategic dependencies are balanced with energy security, costs, transition speed, and industrial competitiveness.



Scenarios – stress testing the model conclusions

WHAT WILL HAPPEN IF GLOBAL GAS PRICES PLUMMET? **01**

WHAT WOULD BE THE IMPACT OF UNRESTRICTED HYDROGEN IMPORTS FROM NORTH AFRICA? **02**

WHAT WILL HAPPEN IF SOLAR CAPACITY BUILD-OUT DOES NOT MEET THE FORECASTED HIGH LEVELS? **03**

WHAT WILL HAPPEN IF NUCLEAR CAPACITY IS INCREASED SIGNIFICANTLY? **04**

(SEE APPENDIX VI FOR A FULL TABLE OF THE TESTED SCENARIOS)

Scenario 01

What will happen if global gas prices plummet?

Lower gas prices have no significant impact on offshore wind build-out.

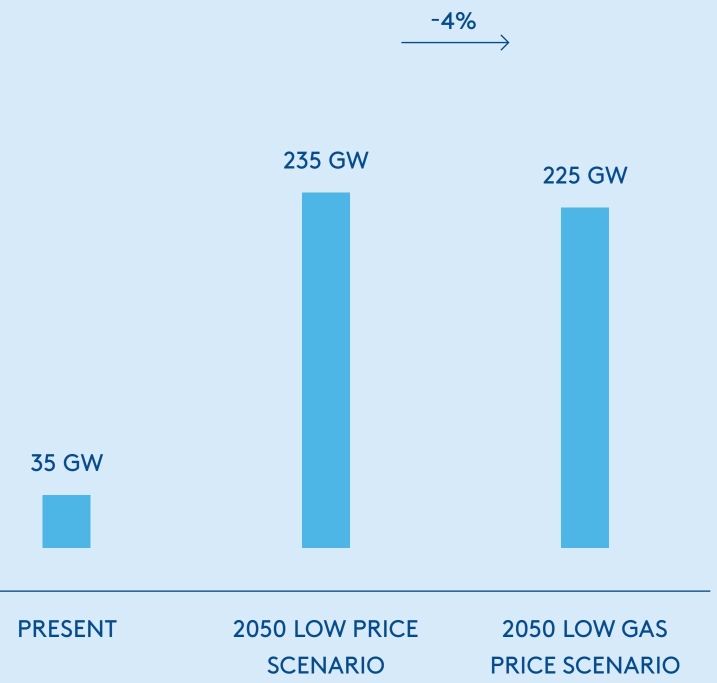
It is valid to question what would happen if global gas prices were to decrease further from the latest years' historically high levels. For instance, if a change in the geopolitical situation made importing cheap Russian gas politically viable again.
To test this, we modelled a scenario with no constraint on usage of fossil fuels and even lower long-term prices than we experienced before the Russian invasion of Ukraine[9].

The answer to this question is that a massively reduced gas price would impact the build-out of clean energy, but not dramatically so. With cheap gas, the offshore wind power capacity in 2050 would be around 225 GW, 5% lower than the base case scenario. This would still require an expansion of offshore wind power capacity of x 6 compared to 2024-levels.

This shows that carbon price, rather than the gas price, is the primary driver of the energy transition in Europe.

OFFSHORE WIND CAPACITY NEED REMAINS HIGH IN LOW GAS PRICE SCENARIO

(Offshore wind capacity in GW)[10]



9. IEA World Energy Outlook 2023 'Announced Pledges Scenario'
10. Numbers rounded to nearest multiple of 5

Scenario 02

What would be the impact of unrestricted hydrogen imports from North Africa?

Unrestricted import of North African clean hydrogen would impact clean energy generation and electrolyser capacity in Europe negatively.

North Africa holds an enormous potential for clean hydrogen production at an affordable price due to a high renewable energy potential. This provides Europe with a unique opportunity to import vast amounts of affordable clean hydrogen to speed up decarbonisation.

Increased hydrogen imports from North Africa do not have a large impact on the European energy system, as European electricity and hydrogen prices remain the same.

Considering European security of supply, the hydrogen produced in Europe is expected to be prioritised politically. Consequently, we have effectively imposed a cap on the import of clean hydrogen from North Africa to 10 mtpa in 2050 (~30% of European supply in 2050) in our base case scenario.

But what would the effects be on European power and hydrogen production in a scenario with no restrictions on hydrogen imports from North Africa? Without restrictions, imports of North African clean hydrogen would amount to 15 mtpa in 2050, making up ~43% of the European clean hydrogen supply in 2050. The resulting lower demand for European hydrogen has only a minor impact on the energy build-out, decreasing solar PV and offshore wind by 5% and onshore wind by 2%. The system is robust to the unrestricted import as the build-out supports the increased electricity demand, with cheap hydrogen being an added positive consequence.

UNRESTRICTED IMPORT OF H_2 FROM NORTH AFRICA[11]

	LOW PRICE SCENARIO		UNRESTRICTED IMPORT OF H_2 FROM NORTH AFRICA
HYDROGEN IMPORT (mtpa)	10	+50% →	15
OFFSHORE WIND CAPACITY (GW)	235	-6% →	220
ONSHORE WIND (GW)	555	-2% →	540
SOLAR PV (GW)	1,470	-6% →	1,380
ELECTROLYSER (GW)	245	-21% →	190
ELECTRICITY PRICE (EUR/MWh)	63	0% →	63
HYDROGEN PRICE (EUR/kg)	2.1	0% →	2.1

11. Numbers rounded to nearest multiple of 5, excluding electricity and hydrogen price

Scenario 03

What will happen if solar capacity build-out does not meet the forecasted high levels?

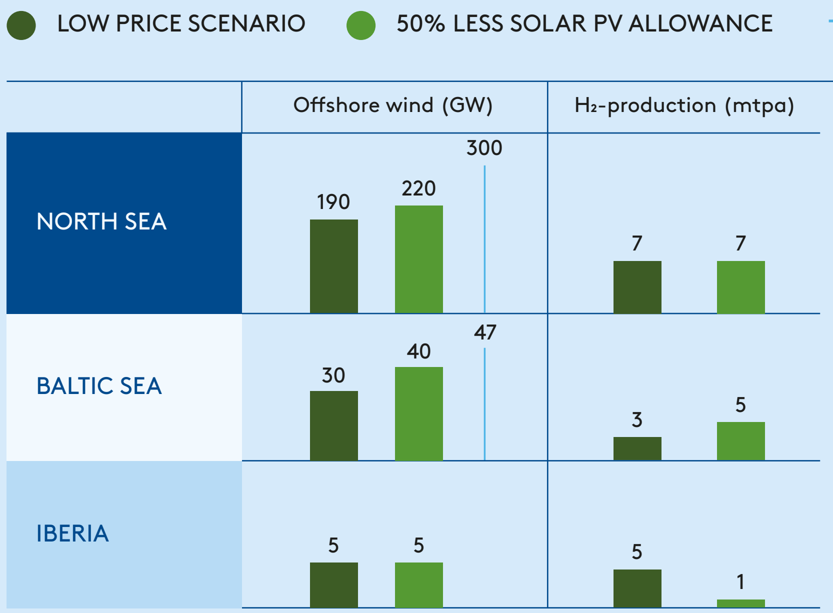
Restricted solar PV build-out allowance would be offset by more offshore wind.

The Low Price scenario assumes that no more than 1.5% of current agricultural land in each bidding zone can be used for solar PV by 2050. Considering ongoing not-in-my-back-yard (NIMBY)-effects and local and political opposition towards solar PV build-out, this assumption carries significant uncertainty.

To examine the effect of reduced solar PV build-out, we modelled a scenario with a solar PV build-out restriction of 50% of the Low Price scenario for each bidding zone.

With this assumption changed, our model predicts that the solar PV capacity will be 1,137 GW by 2050, which is 22% less than in the Low Price scenario. Electricity generation relocates from Iberia to North Europe and especially to the countries surrounding the Baltic Sea and North Sea; consequently, offshore wind build-out increases by 15% in The North Sea and 35% in The Baltic Sea. The new distribution relocates ~3 mtpa of the clean hydrogen production from the Iberian Peninsula to the North- and Baltic Sea.

RESULT OF DECREASING PV ASSUMPTION ON OFFSHORE WIND AND HYDROGEN PRODUCTION IN EUROPE[12]



12. Numbers rounded to nearest multiple of 5, excluding H_2-production and commitments of regions

Scenario 04

What will happen if nuclear capacity is increased significantly?

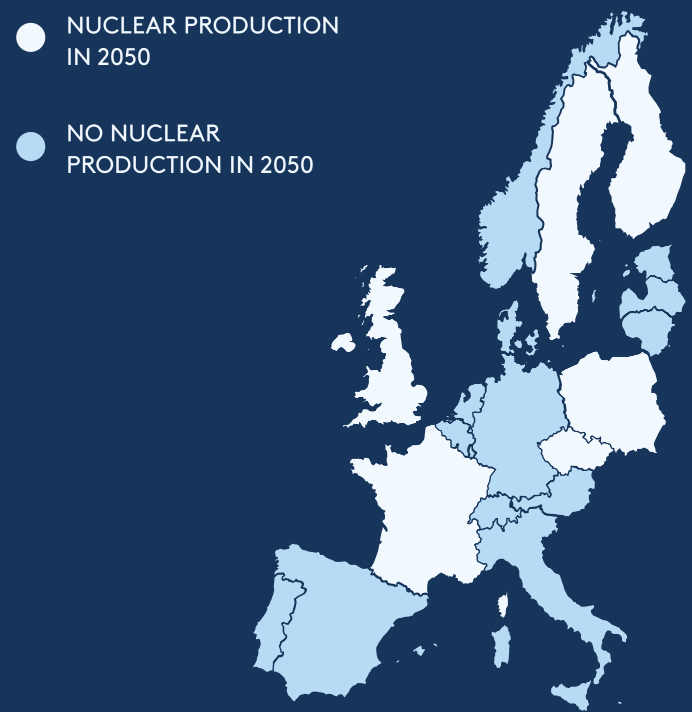
Nuclear energy capacity ramp up has limited impact on build-out of renewables towards 2050.

The Low Price scenario does not assume a significant net expansion of the total nuclear capacity towards 2050. The assumption is that the maintenance and potential expansion of nuclear capacity is complex and not cost competitive. Furthermore, it is not conducive to fast expansion in clean energy generation capacity.

To investigate the impact of European nuclear expansion, we have stress-tested the model assumptions and expanded nuclear capacity by 50% from 90 GW to 135 GW in 2050 in countries with existing nuclear capacity, namely Sweden, Finland, the United Kingdom, Poland, The Czech Republic, and France.

The build-out of clean energy sources remains robust to the increased nuclear capacity. The increased nuclear capacity mainly replaces offshore wind, as it is the marginal investment in the model. The offshore wind decreases by 23% in the Baltic countries and by 11% in the North Sea region.

The clean energy build-out in Southern Europe remains almost unchanged, indicating the build-out in Northern Europe is most sensitive to nuclear capacity growth.



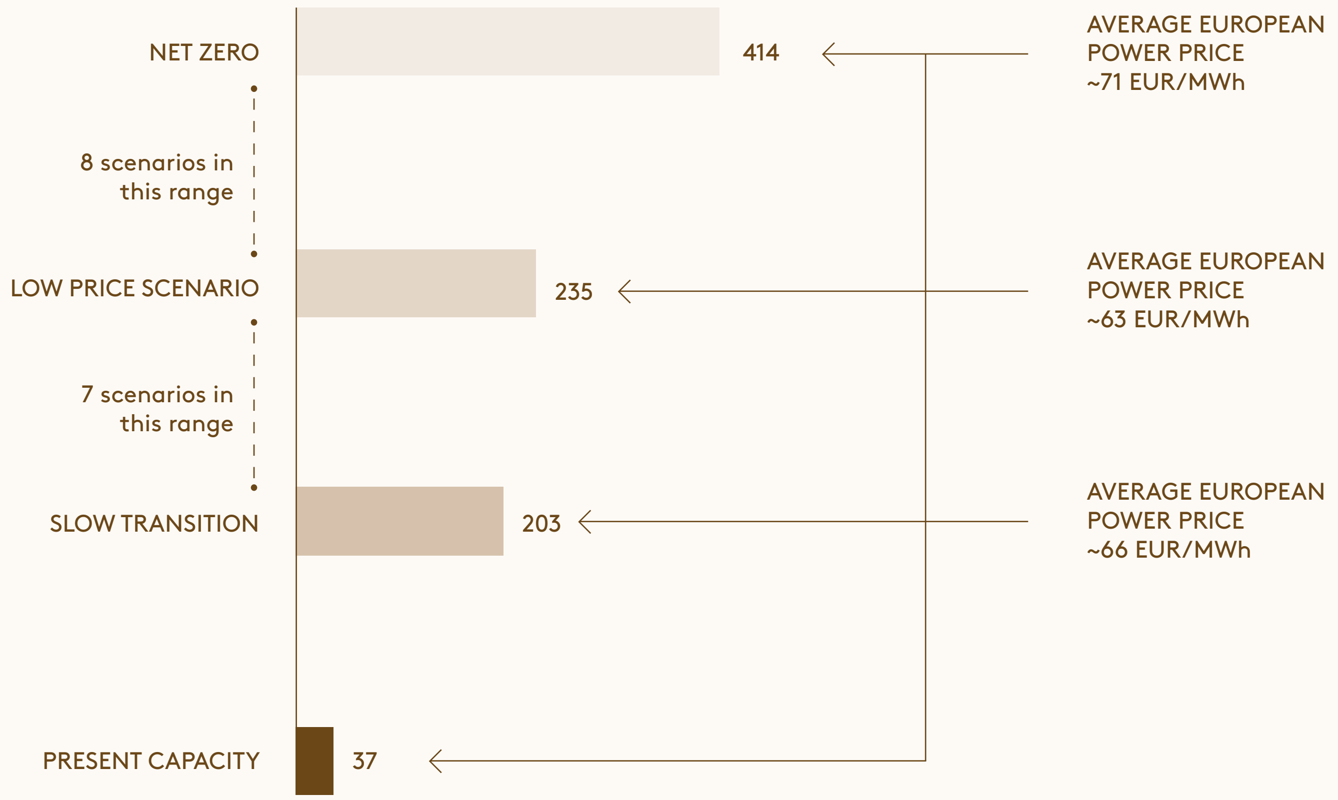
INCREASED NUCLEAR CAPACITY BY 50%[13]

	LOW PRICE SCENARIO		INCREASED NUCLEAR
NUCLEAR CAPACITY (GW)	90	+50% →	135
OFFSHORE WIND CAPACITY (GW)	235	-12% →	205
ONSHORE WIND (GW)	555	-3% →	535
SOLAR PV (GW)	1,470	-4% →	1,410
ELECTROLYSER (GW)	245	-0% →	243

13. Numbers rounded to nearest multiple of 5

European offshore wind build-out is robust across all tested scenarios

OFFSHORE WIND BUILD-OUT CAPACITY IN GW



We conducted a sensitivity analysis, testing 17 different scenarios to determine how changed assumptions would impact the outcome of offshore wind build-out.

Our sensitivity analyses show a significant and stable build-out of offshore wind across all scenarios. In nine scenarios, the offshore wind build-out is larger than the Low Price scenario estimate of 235 GW, while it is smaller in eight scenarios.

The most optimistic scenario is the Net Zero scenario in which 414 GW of offshore wind is needed by 2050. The most pessimistic scenario is outlined by the Slow Transition scenario, in which a capacity of 203 GW offshore wind is required. In any case, the scenarios highlight the important role offshore wind is going to play in the future energy system, as well as the unprecedented build-out required towards 2050 with the worst-case requiring a sixfold increase the installed capacity today.

Achieving more affordable power prices raises dilemmas

By opening a discussion about political dilemmas, Europe could aim to reduce energy prices even more than illustrated in the Low Price scenario, which includes increasing clean energy imports from notably North Africa, increasing solar PV build-out and onshore wind build-out and faster and heavier build-out of transmission systems.

In an alternative modelling exercise, the lowest possible electricity prices for European consumers and industries were optimised. By loosening some of the model's restrictions, we were able to achieve an average European electricity price of 60 EUR/MWh in 2050, which is 4% lower than the Low Price scenario of 63 EUR/MWh. Ultimately, it is a political question whether these adaptations should be made to achieve an even lower electricity price and whether an additional 4% decrease is "politically worth it".

	LOW PRICE SCENARIO		OPTIMISED FOR EUROPEAN CONSUMERS
EUROPE average price EUR/MWh)	63	-4% →	60
DENMARK average price EUR/MWh)	58	-3% →	56
NETHERLANDS average price EUR/MWh)	63	-4% →	60
UNITED KINGDOM average price EUR/MWh)	59	-3% →	58

To achieve this lower power price, three political concessions are necessary:

1. Allowance for additional build-out of onshore wind and solar PV capacity overcoming NIMBY, opposition and resistance from farmers and local communities: +25% increase in onshore wind capacity allowance and a +100% increase in solar PV allowance.

2. Faster and heavier build-out of both power and hydrogen infrastructure. No delays in European TYNDPs and a +100% increase in expansion options for electrical transmission (750 MW per corridor every five years instead of 375 MW).

3. Increased participation of electric vehicles in vehicle-to-grid systems: 50% of all-electrical vehicles to participate in vehicle-to-grid systems using 50% of their battery capacity. Vehicle-to-grid systems allow for more flexibility in electricity demand.

Appendix I

Model and assumptions

The insights and predictions in this white paper are based on a state-of-the-art energy model that we leveraged to predict the most efficient build-out of Europe's energy system in three scenarios and afterwards using these findings as input to the Oxford Economics GEM model to forecast the impact of each scenario on the European economy

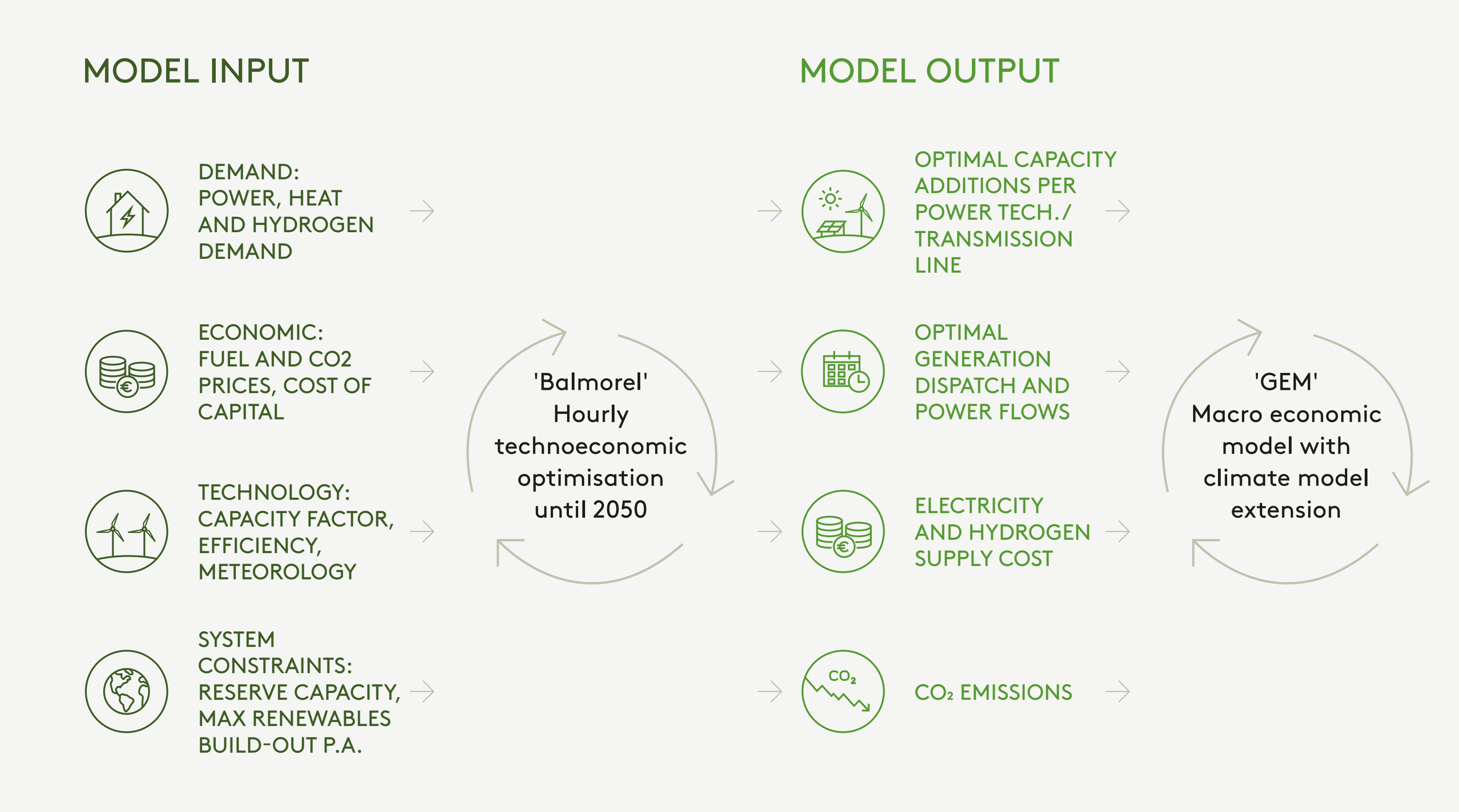
We put this task on ourselves to answer four questions about the challenges faced by the European continent:

1. To what extent can Europe increase its competitiveness through investments in energy infrastructure?
2. To what extent can Europe become energy-independent?
3. To what extent can Europe reach Net Zero emissions by 2050?
4. To what extent can Europe increase its economic growth and productivity through energy investments?

Our energy model is based on the 'Balmorel'-model[13], which is developed to optimise energy generation and transmission subject to various constraints. This model integrates the European electricity, heating and hydrogen systems into one energy model, always ensuring a balanced energy system across Europe. The model accounts for the hour-by-hour energy generation and transmission from today towards 2050. This approach offers coherence across borders and thus provides a detailed overview of the European integrated energy landscape of the future.

The energy model assumptions were developed in collaboration with Ea Energianalyse, a best-in-class energy economics consultancy based in Denmark and Oxford Economics. It was peer-reviewed by our partners at Stiesdal and Danish TSO Energinet. Jointly, Copenhagen Infrastructure Partners (CIP) and Copenhagen Infrastructure Service Co. (CISC) managed the project.

The model has several inputs in the form of economic, technological, and meteorological data. Wherever available, it is based on external sources. To determine the robustness of the model outputs, we tested 19 scenarios with different assumptions (See Appendix VI for the sensitivity analysis results).



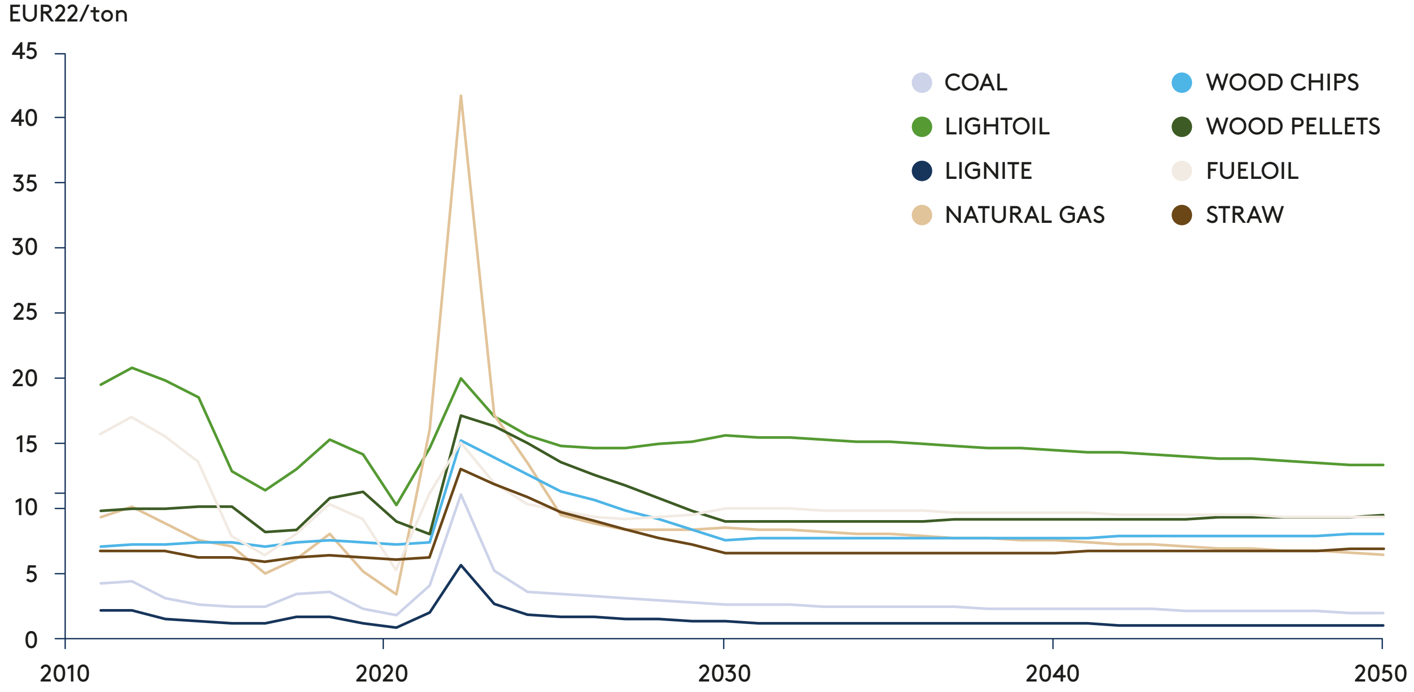
Examples of assumptions built into the model

- A key assumption is that the total energy demand (electricity and bioenergy) in Europe will decrease by roughly 1/3[14]. This is primarily driven by increased energy efficiency. Meanwhile, electricity demand will more than double by 2050.
- The model includes economic data on, for instance, fuel and CO2 prices[15] (see Appendix II). A central assumption is that the capital expenditures of offshore wind, onshore wind, solar energy, and gas turbines will decrease from 2030-2050[16] (e.g. -13% for offshore wind and -25% for solar energy (see Appendix III)).
- The model includes technological data such as wind and solar capacity factors for various locations and efficiency estimates of electrolysers, gas turbines, and lithium batteries. It also includes meteorological data[17] (see Appendix IV).
- Finally, the model includes restrictions on the build-out of clean energy sources. These include, for example, a national-level restriction on solar energy of 1.5% of agricultural land by 2050. Similarly, onshore wind is restricted by NIMBY or national targets, while offshore wind is restricted by available sites, based on depth, distance to shore, and wind speeds. Grid buildout is limited to a maximum expansion of each corridor of 375 GW every five years.

14. Model developed by EA EnergiAnalyse.
15. The model covers the EU-27 countries and the UK
16. Global Ambition scenario from TYNDP2022, adjusted for geographical scope and hydrogen demand
17. CAPEX assumptions based on Danish Energy Agency's CAPEX in Energikataloget adjusted for recent changes to CAPEX cost on wind turbines
18. Wind/solar annual profiles uses NASA MERRA 2 database

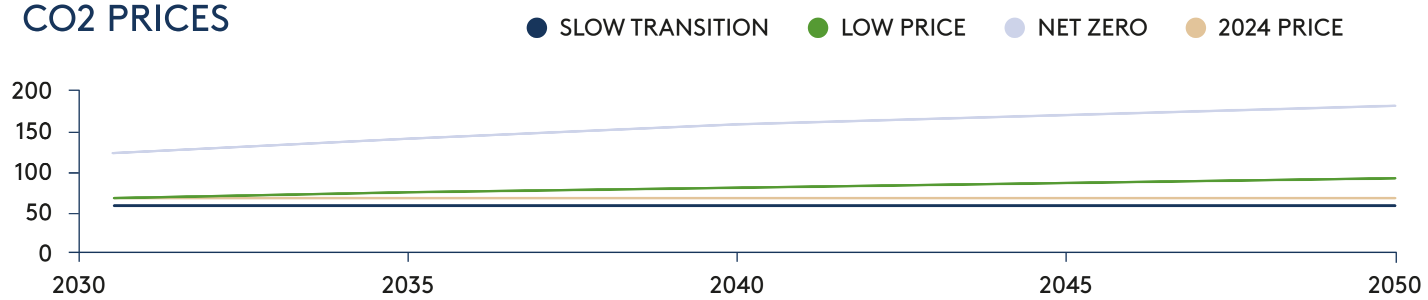
Appendix II

FUEL PRICES



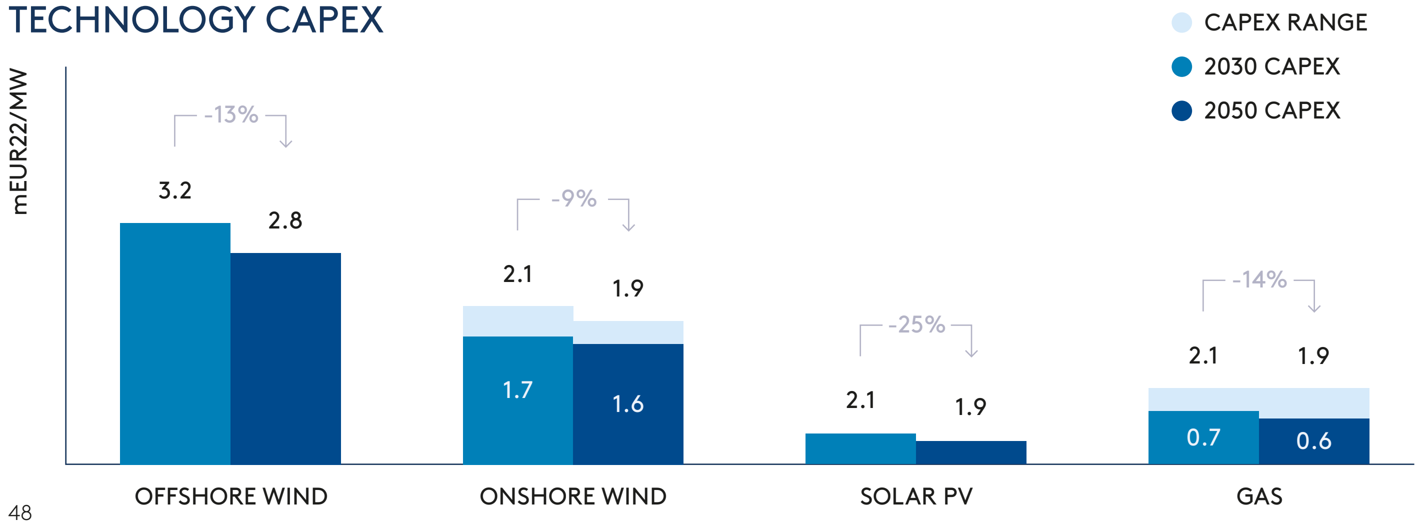
Appendix III

CO2 PRICES



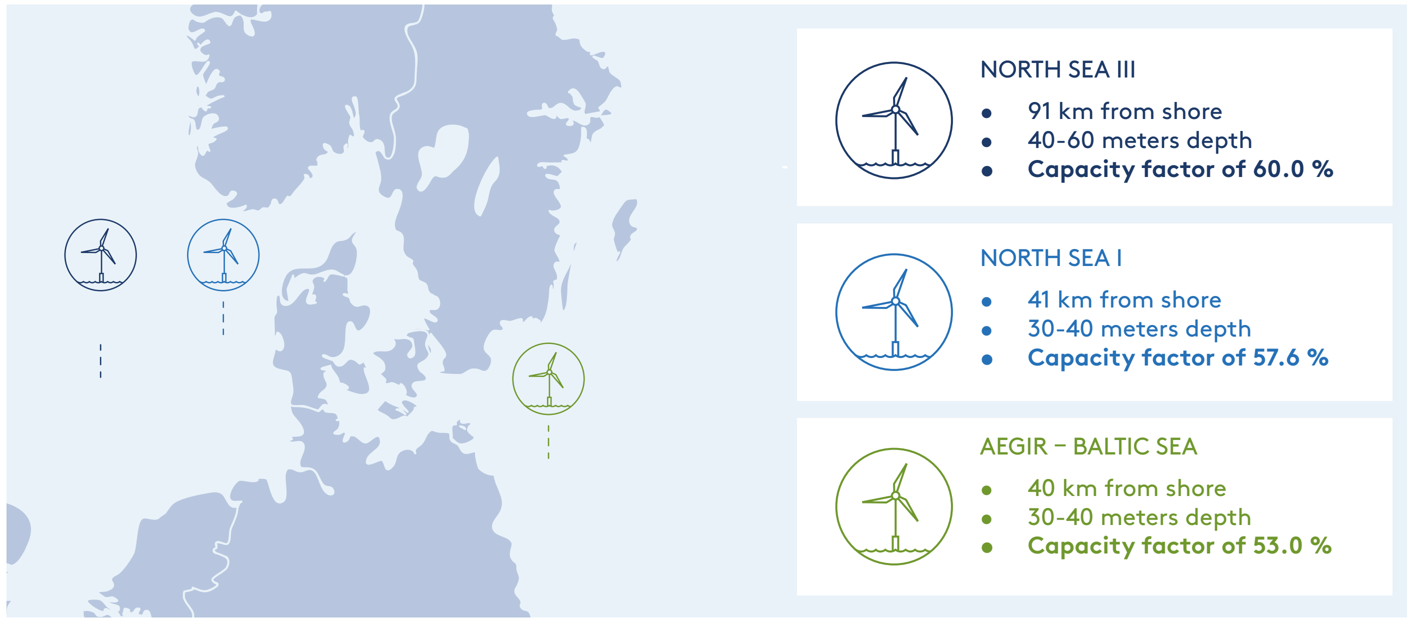
Appendix IV

TECHNOLOGY CAPEX



Appendix V

EXAMPLE OF KEY ASSUMPTION



CAPACITY FACTOR

	Wind	Solar
DK	44.2%	11.8%
DE	41.4%	11.7%
ESP	38.9%	17.9%

EFFICIENCY

	2030	**2040**	**2050**
Electrolyser (Alkaline)	0.61	0.67	0.74
Gas turbine (combined cycle)	0.58	0.58	0.60
Gas turbine (simple cycle)	0.41	0.41	0.43
Lithium-ion batteries	0.92	0.92	0.92

Appendix VI

TRANSMISSION GRID

- CONSTRUCTED
- UNDER CONSTRUCTION
- PLANNED – NOT PERMITTED
- UNDER CONSIDERATION
- UNDER PERMITTING
- UNKNOWN

ENTSO-E TYNDP planned link towards 2030 (GW)

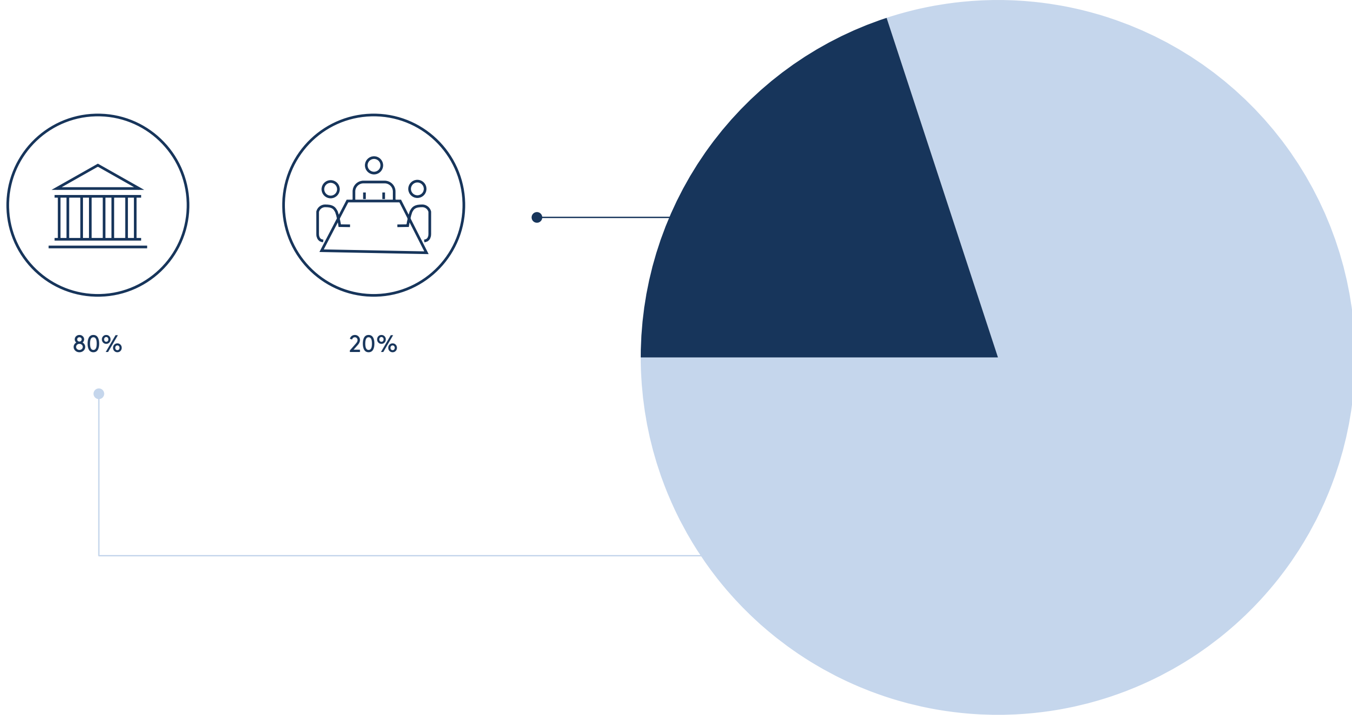
					Status
NORTH SEA LINK	GB	-	NO (NO2)	1.4	Constructed
VIKING LINK	GB	-	DK (W)	1.4	Constructed
NEUCONNECT LINK	GB	-	DE (NW)	1.4	Under permitting
MULTIPLE LINKS	GB	-	FR	5.8	Under permitting
AVELIN-HORTA	FR	-	BE	1.5	Under consideration
VIGY-UCHTELFANGEN	FR	-	DE (CS)	3.7	Planned – not permitted
	FR	-	CH	0.6	Under consideration
SACOI3	FR	-	IT	0.1	Under permitting
MULTIPLE LINKS	IT	-	CH	1.7	Under permitting
MULTIPLE LINKS	IT	-	AT	0.6	Under construction / Under permitting
	CH	-	AT	0.5	Under consideration
	CH	-	DE (CS)	0.8	Under consideration
MULITPLE LINKS	AT	-	DE (CS)	2.5	Under permitting
	DE (CS)	-	CZ	2.2	Under permitting
MULTIPLE LINKS	DE (CS)	-	LU	1	Planned – not permitted
MULTIPLE LINKS	DE (CS)	-	NL	0.7	Under consideration
MULTIPLE LINKS	DE (CS)	-	DE (NW)	10	Planned – not permitted
	DE (CS)	-	DE (MW)	7	Unknown
ZUIDDWEST & OTHER	NL	-	BE	2.9	Under permitting
OFFSHORE HYBRID	NL	-	DE (NW)	0.2	Under consideration
WEST COASTLINE & OTHER	DE (NW)	-	DK (W)	1.9	Under permitting
GERPOL INPROVEMENTS	DE (ME)	-	PL	2.2	Under construction
	DE (ME)	-	DE (NE)	5.3	Unknown
	DE (NE)	-	PL	0.1	Under construction
KRIEGERS FLAK CGS	DE (NE)	-	DK (EAST)	3.2	Under consideration
HANSA POWERBRIDGE I/II	DE (NE)	-	SE (SE4)	0.7	Under permitting
BALTIC STATES SYNC	PL	-	LT	2	Under construction
3RD IC	LV	-	EE	0.7	Under consideration
3RD AC / 4TH AC	FI	-	SE (SE1)	?	Under permitting
	FI	-	SE (SE1)	?	Under consideration
FENNO-SKAN 3	FI	-	SE (SE3)	0.8	Under consideration
	NO (NO3)	-	NO (NO4)	1.2	Unknown

Appendix VII

OVERVIEW OF MACROECONOMIC KEY ASSUMPTIONS

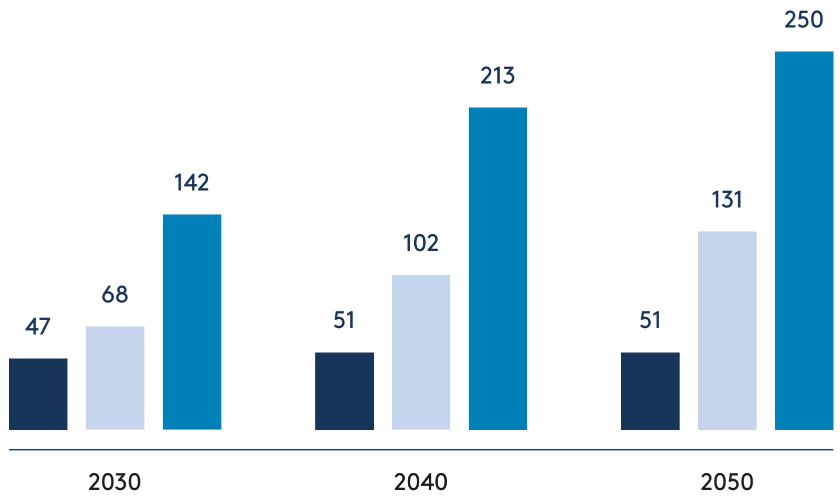
INVESTMENT SPLIT (%)

- GOVERMENT INVESTMENTS
- PRIVATE INVESTMENTS



EFFECTIVE CO2 PRICE (EUR22/TON)[17]

- SLOW TRANSITION
- LOW PRICE
- NET ZERO



Appendix VIII

SENSITIVITIES PERFORMED ON RESULTS FROM 2050 (1/2)

- HIGHEST #
- LOWEST #

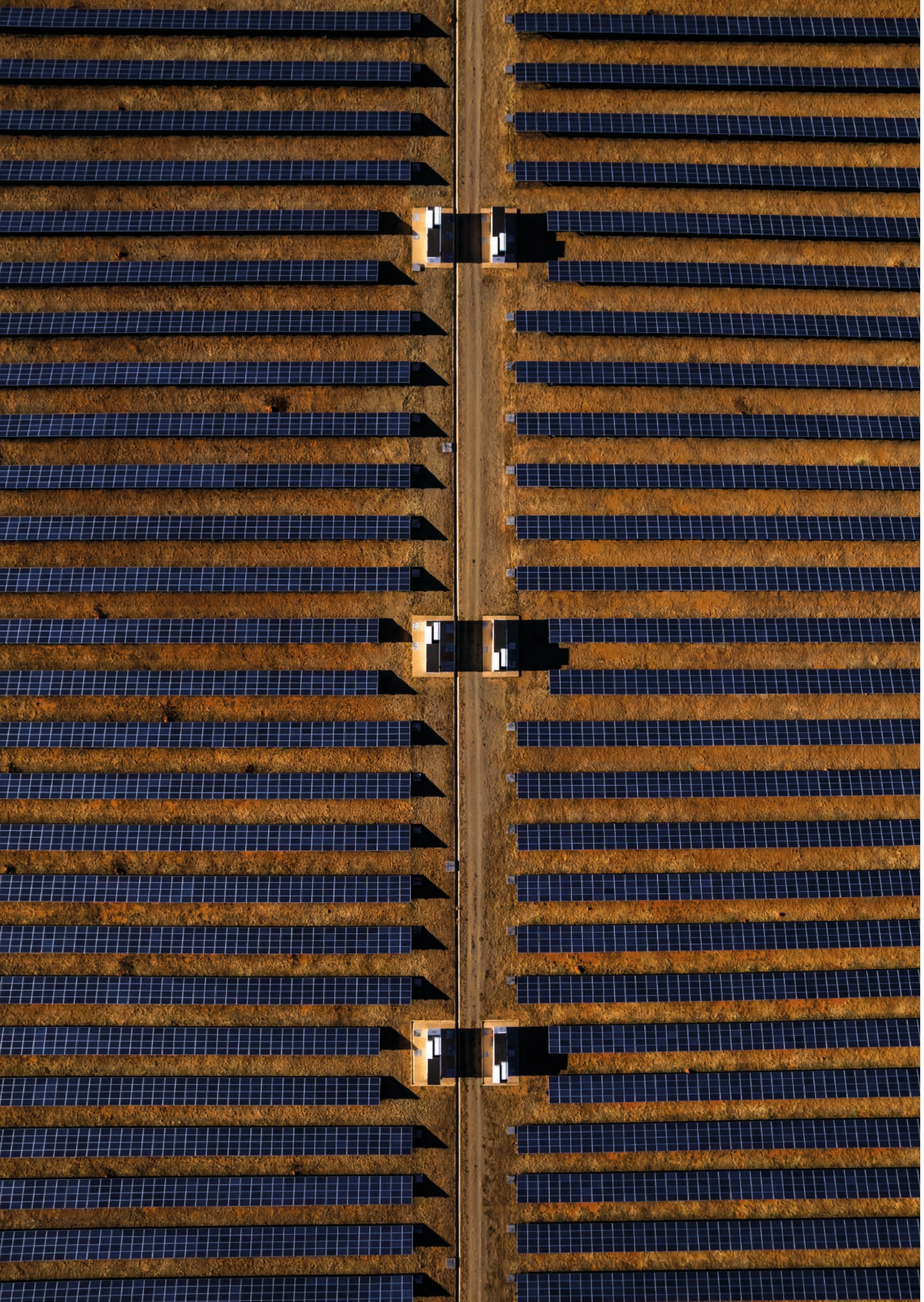
	Parameter	Low Price	Slow Transition	Net Zero	Unrestricted import of H2	Low ELZ cost	More PV and ONV	Reduced PV build out	WACC 1%-point higher	More PV	Behind the meter ELZ	Consumer scenario
ELECTRICITY	Total power consumption (TWh)	5,992	5,000	7,364	5,795	6,112	6,015	5,959	5,969	5,999	6,224	5,827
	Offshore power capacity (GW)	235	203	414	222	243	200	278	225	233	245	195
	Onshore power capacity (GW)	553	403	597	542	556	633	567	548	552	560	634
	PV power capacity (GW)	1,471	1,022	2,061	1,378	1,515	1,451	1,145	1,466	1,511	1,570	1,358
	Installed electricity storage (GW)	187	187	187	187	187	187	187	187	187	187	187
	Average electricity price (EUR/MWh)	63	66	71	63	61	60	69	66	62	61	60
	North Sea offshore wind capacity (GW)	190	167	317	179	197	159	218	181	189	197	158
	Baltic offshore wind capacity (GW)	29	20	73	26	29	25	39	28	27	30	21
	UK average electricity price (EUR/MWh)	59	59	72	59	59	58	65	63	60	60	58
	ES average electricity price (EUR/MWh)	61	60	82	60	61	57	70	64	59	62	53
HYDROGEN	Total installed ELZ capacity (GW)	244	57	632	192	312	249	235	254	255	371	196
	Average H_2-production cost (EUR/KG H_2)	2.1	2.1	2.5	2.1	2.1	2.1	2.4	2.2	2.1	2.1	2.2
	European H_2-production (Mt of H_2)	18	4	48	14	21	18	18	18	18	24	14
	External H_2-imports (Mt of H_2)	10	7	10	15	8	10	10	10	10	5	14
	Peak plant consumption (Mt of H_2)	0.3	0.1	13.2	0.4	0.5	0.4	0.1	0.2	0.3	0.7	0.4
	North Sea H_2-production (Mt of H_2)	7	2	19	6	8	8	7	7	7	9	6
	Baltic H_2-production (Mt of H_2)	3	1	10	2	3	3	5	3	2	4	2
GRID	Power Grid investments (billion EUR)	105	77	162	103	103	101	116	102	103	103	123
	H_2 Infrastructure investments (GW H_2)	240	125	380	262	243	251	218	243	257	187	258

Appendix VIII

SENSITIVITIES PERFORMED ON RESULTS FROM 2050 (2/2)

- HIGHEST #
- LOWEST #

	Parameter	Low Price	Slow Transition	Net Zero	No pipeline	High ELZ cost	Faster transmission buildout	No fossil constraint +Cheap NG	Nuclear 150% capacity	WACC 1%-point lower	No DK/DE H2 connection
ELECTRICITY	Total power consumption (TWh)	5,992	5,000	7,364	6,445	5,974	5,992	5,968	5,996	6,097	5,990
	Offshore power capacity (GW)	235	203	414	290	238	248	223	207	259	236
	Onshore power capacity (GW)	553	403	597	565	552	555	549	537	562	553
	PV power capacity (GW)	1,471	1,022	2,061	1,681	1,490	1,465	1,466	1,409	1,516	1,475
	63Installed electricity storage (GW)	187	187	187	187	187	187	187	187	187	187
	Average electricity price (EUR/MWh)	63	66	71	62	63	62	60	62	59	63
	North Sea offshore wind capacity (GW)	190	167	317	233	191	199	182	168	208	191
	Baltic offshore wind capacity (GW)	29	20	73	37	30	30	25	22	30	29
	UK average electricity price (EUR/MWh)	59	59	72	61	60	60	58	59	56	59
	ES average electricity price (EUR/MWh)	61	60	82	64	61	61	58	59	59	61
HYDROGEN	Total installed ELZ capacity (GW)	244	57	632	389	234	256	253	243	277	252
	Average H_2-production cost (EUR/KG H_2)	2.1	2.1	2.5	2.5	2.2	2.1	2.1	2.1	2.1	2.1
	European H_2-production (Mt of H_2)	18	4	48	28	18	18	18	18	20	18
	External H_2-imports (Mt of H_2)	10	7	10	0	10	10	10	10	8	10
	Peak plant consumption (Mt of H_2)	0.3	0.1	13.2	0	0.2	0.3	0.1	0.2	0.3	0.2
	North Sea H_2-production (Mt of H_2)	7	2	19	12	8	7	7	7	8	7
	Baltic H_2-production (Mt of H_2)	3	1	10	5	3	3	2	3	3	3
GRID	Power Grid investments (billion EUR)	105	77	162	110	104	131	91	97	103	103
	H_2 Infrastructure investments (GW H_2)	240	125	380	203	242	244	251	248	243	237



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