ACHIEVING EUROPE'S DECARBONIZATION

ENGIE's Decarbonization Pathway for Europe

12 November 2024

Achieving Europe’s decarbonization

1. Methodology & key indicators
2. Final demand
3. Renewables & flexibility
4. Low Carbon molecules
5. Energy transition costs
6. Emissions
7. Ambitions at risk
8. Summary and call to action

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Methodology to define Europe's optimized decarbonization pathway

A European vision...

- Modelling of **15 European countries**[1] with strongly interconnected energy systems, representing more than 85% of Europe's[2] total energy consumption

… based on realistic techno-economic choices...

- Considering **only low-carbon technologies which have been proven industrially** (i.e., excluding technologies at R&D stage)
- Constrained by **existing near-term policies** (e.g., NECP), **industrial feasibility**, and **societal factors** (e.g. social acceptability)
- Using **external studies and benchmarks** for issues outside our area of expertise, e.g. agriculture, forestry (European Commission, ADEME, etc.)

… that optimizes decarbonization across all energy vectors...

- Seeking an economic optimum on the mid- to long-term (2030 and beyond) to achieve Europe's decarbonization objectives (-55% in 2030 vs. 1990, Net Zero by 2050)
- Capturing interactions between **electricity, methane, hydrogen, e-molecules and heat**
- Modelled with **hourly granularity** to capture energy system reliability and resilience

... to minimize overall energy transition costs.

- Based on a **comparison with a 'steady state' scenario** assuming no further decarbonization beyond 2023
- Assessing **total costs** (capex and opex) of decarbonization of **industry, transport, residential, and energy sectors**

[1] Austria, Belgium, Czech Republic, France, Germany, Hungary, Ireland, Italy, Slovakia, Spain, Switzerland, Poland, Portugal, The Netherlands, The United Kingdom
[2] Europe = European Union (27) + UK + Switzerland

All levers are needed to achieve Europe's decarbonization objectives

FINAL DEMAND

-30% Reduction in final energy demand, which is decoupling from economic growth (GDP: +1.3%/y)

ELECTRIFICATION

x5.5 Growth in wind & Solar power production

METHANE DEMAND

-45% Reduction in methane demand, which will be fully decarbonized

COST OF DECARBONIZATION

<2% of GDP from today to 2050

ENERGY DEPENDENCY

-65% Reduction in energy imports (fossil fuels and e-molecules)

FLEXIBILITY

x4.5 Growth in total flexible capacity, including three quarters coming from demand

HYDROGEN

x7 Growth in hydrogen & e-fuels demand, which will be fully decarbonized

POWER SYSTEM COST

~ Total cost per MWh to remain stable

All Indicators are 2023 vs 2050 except when indicated otherwise

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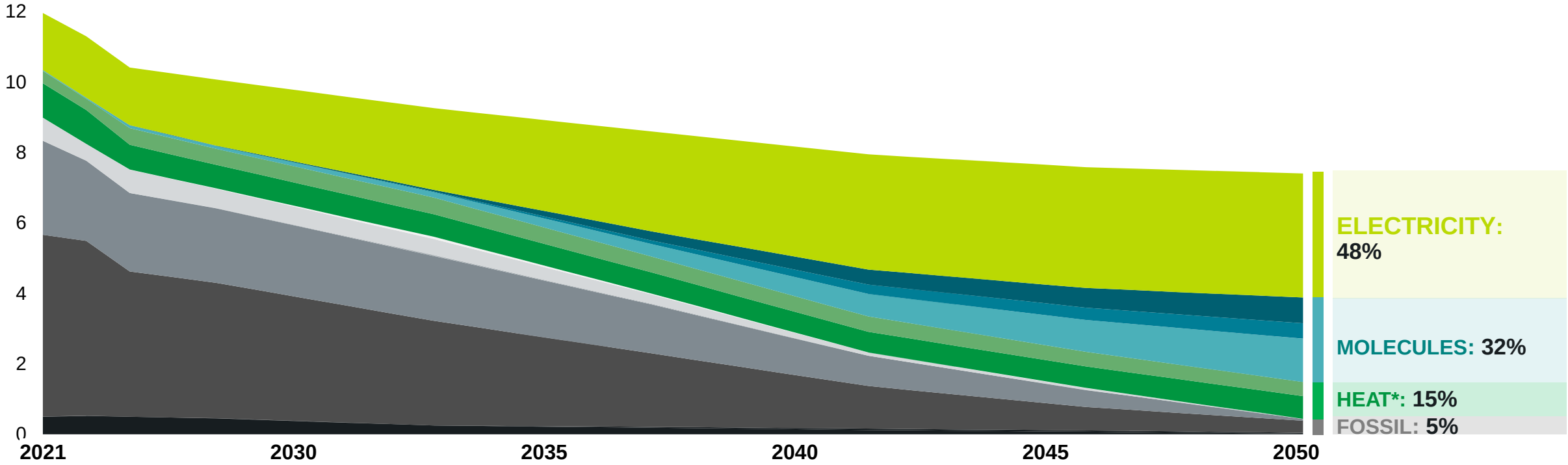
Final energy demand reduces significantly, with strong electrification complemented by decarbonized gases and heat

Optimized Final energy mix | Europe-15

Thousands TWh



FOSSIL FUELS

- Coal
- Oil
- Waste heat
- Methane
- Electricity
- Hydrogen

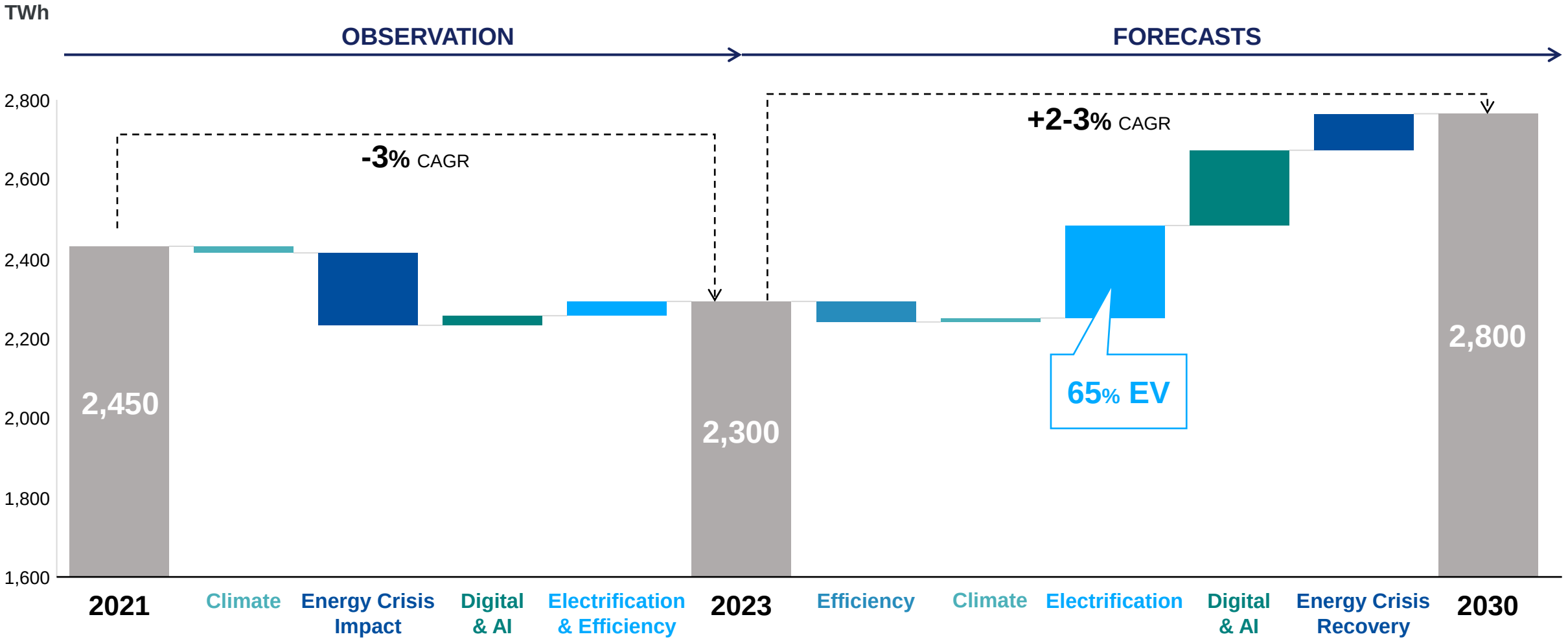
LOW-CARBON EMISSION ENERGIES

- Solid biomass
- Waste heat & Geothermal
- Methane
- Hydrogène
- Other molecules
- Electricity

* **Heat**: Biomass, Waste Heat and Geothermal. Electricity and Molecules includes energy to produce heat consumed via DHC
Methodology review vs 2023 exercise, excluding Non energy uses from energy mix
Low carbon methane accounts for biomethane, NG + CCS & e-methane, while other molecules correspond to ammonia, e-methanol & kerosene

Following important power demand reduction linked to the energy crisis, demand is expected to grow in the medium term

Power final energy consumption | Europe-15



Sources : Eurostat, Entso-E & ENGIE analysis

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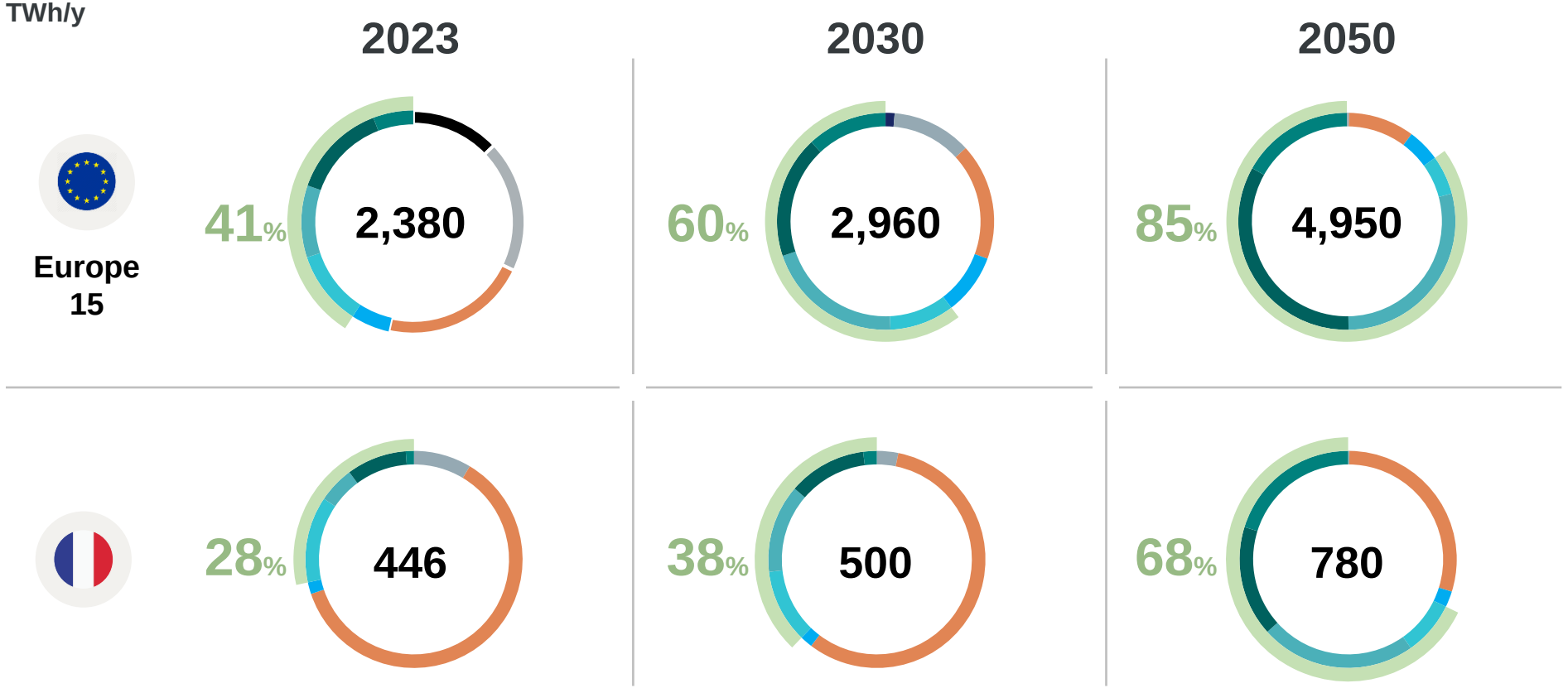
The power generation mix is fully decarbonized by 2050 primarily driven by the rapid growth of renewables, complemented by nuclear and thermal

Power Generation Mix & Total Demand

TWh/y



FOSSIL
- Coal, Lignite & Oil
- Fossil gases

LOW-CARBON
- Nuclear
- Decarbonized thermal

RENEWABLES
- Hydro
- Onshore wind
- Solar
- Offshore wind

TOTAL DEMAND
XXX TWh

Solar and wind generation

x5.5

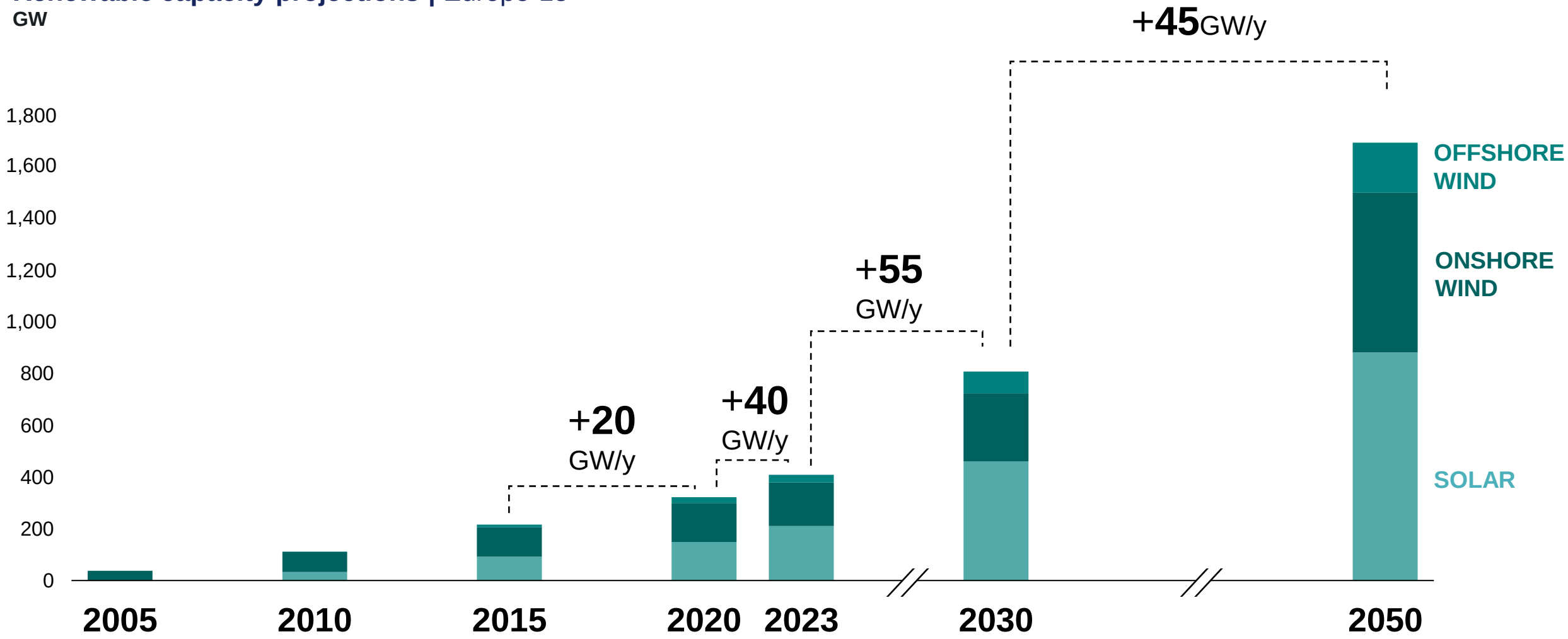
x6

by 2050

Sources: Entso-E, RTE & ENGIE Analysis,

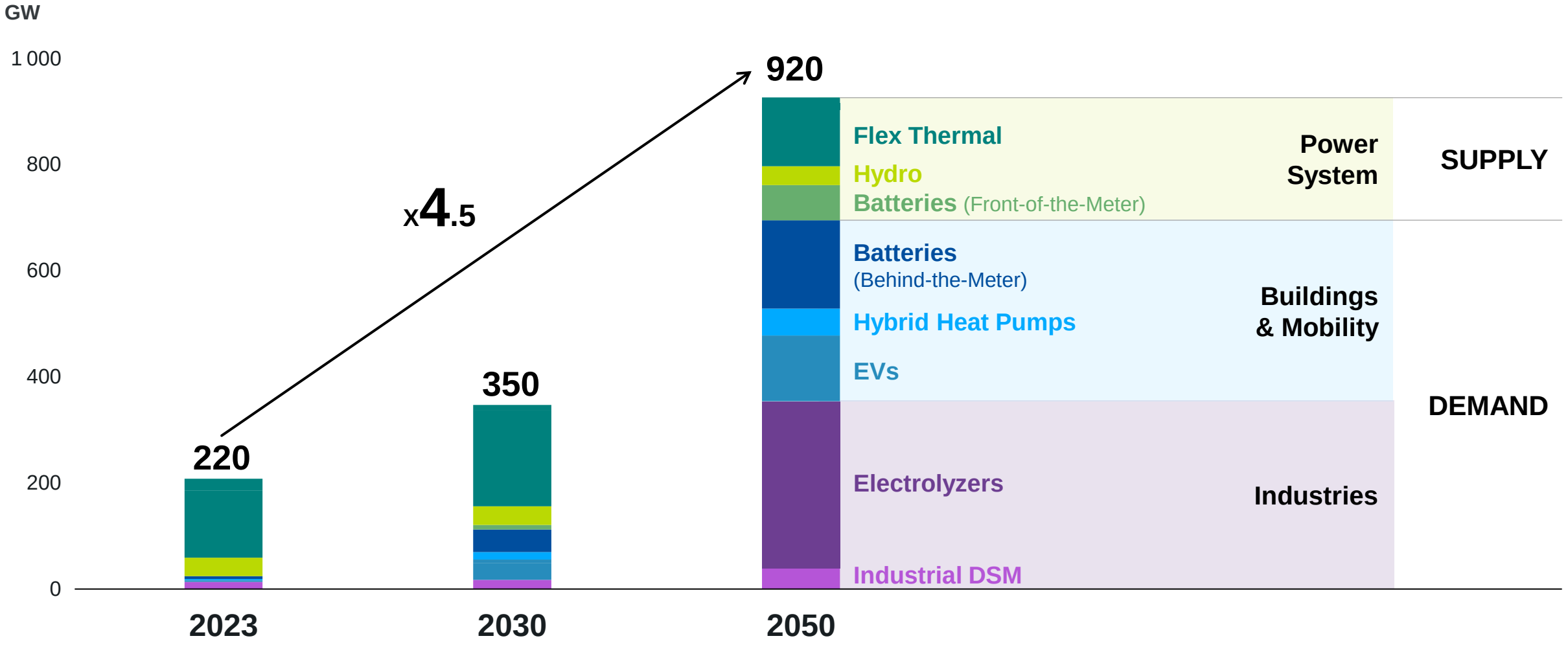
The needed acceleration in renewable power deployment to 2030 seems achievable considering recent developments

Renewable capacity projections | Europe-15



Power system flexibility capacity must be enhanced, in large part through batteries and demand side solutions

Total Flexible Capacity Mix | Europe-15



Not developing demand side flexibility levers would have major impact on system viability and costs

HYPOTHESIS

Scenario where only supply side flexibility solutions are developed to complement the growth in renewables (no demand side flexible solutions):

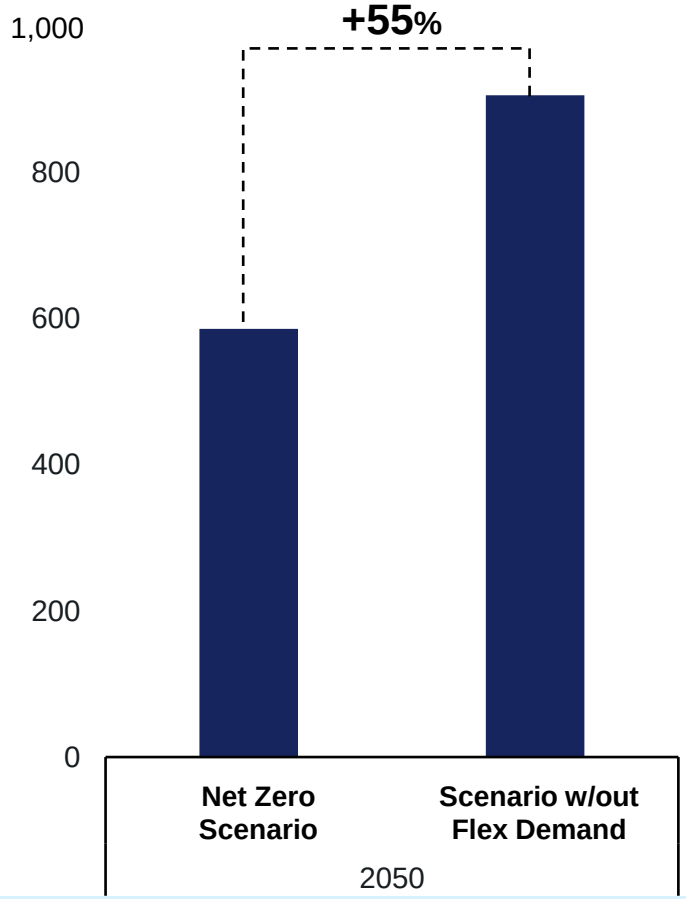
Electric vehicles
Deployed as anticipated, but not contributing to system flex via smart charging or V2G

Hybrid heat pumps
Only Heat Pumps are developed (i.e., no hybrid heat pumps)

Industrial demand side management
Not exploited for system flexibility

Electrolyzers
Limited deployment as per baseload functioning only

Peak Capacity| Europe-15
GW, 2050



KEY IMPLICATIONS

Compared to the Net Zero Pathway

Decarbonization Costs

+70% €150bn/y (avg. 2030-2050)

Average wholesale prices | France

+25% Increase in 2050

*All figures are compared to the Net Zero Pathway Scenario.

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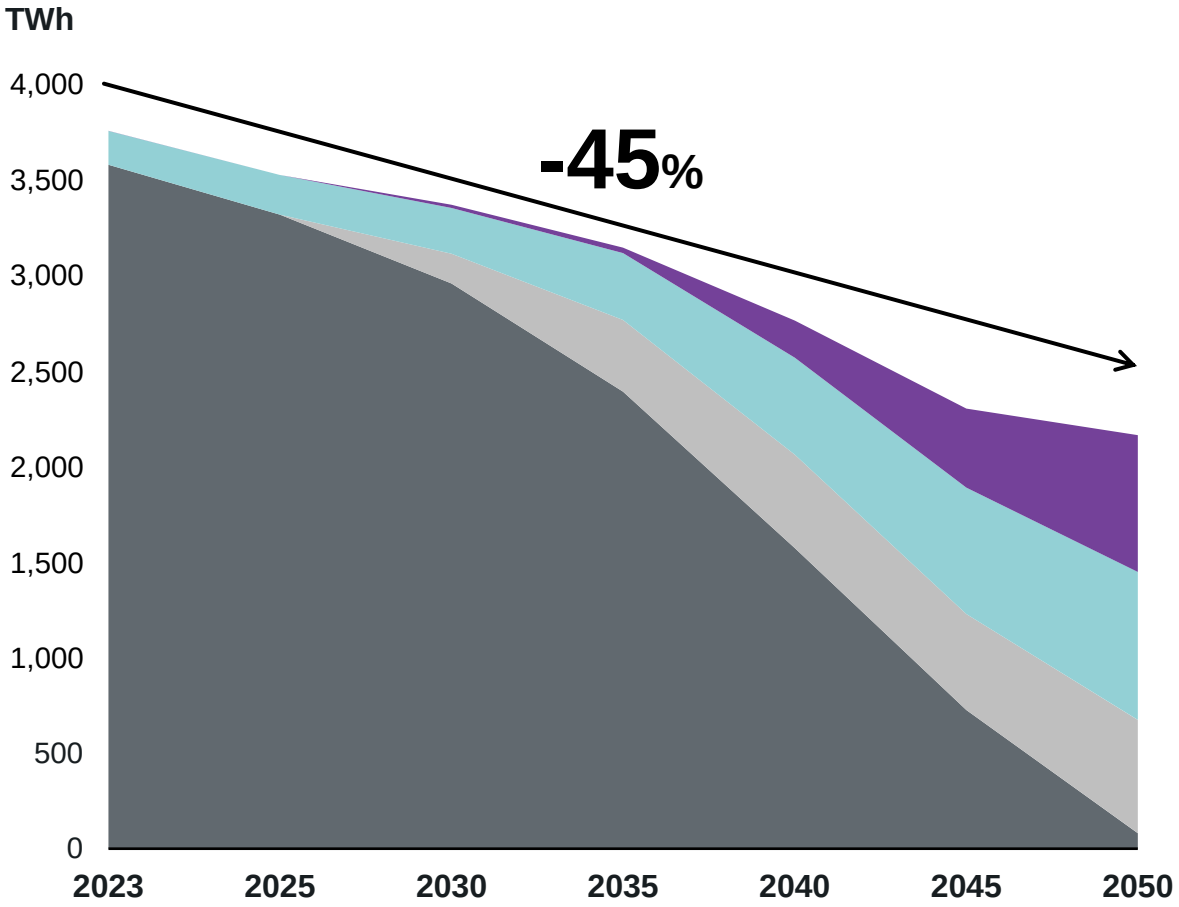
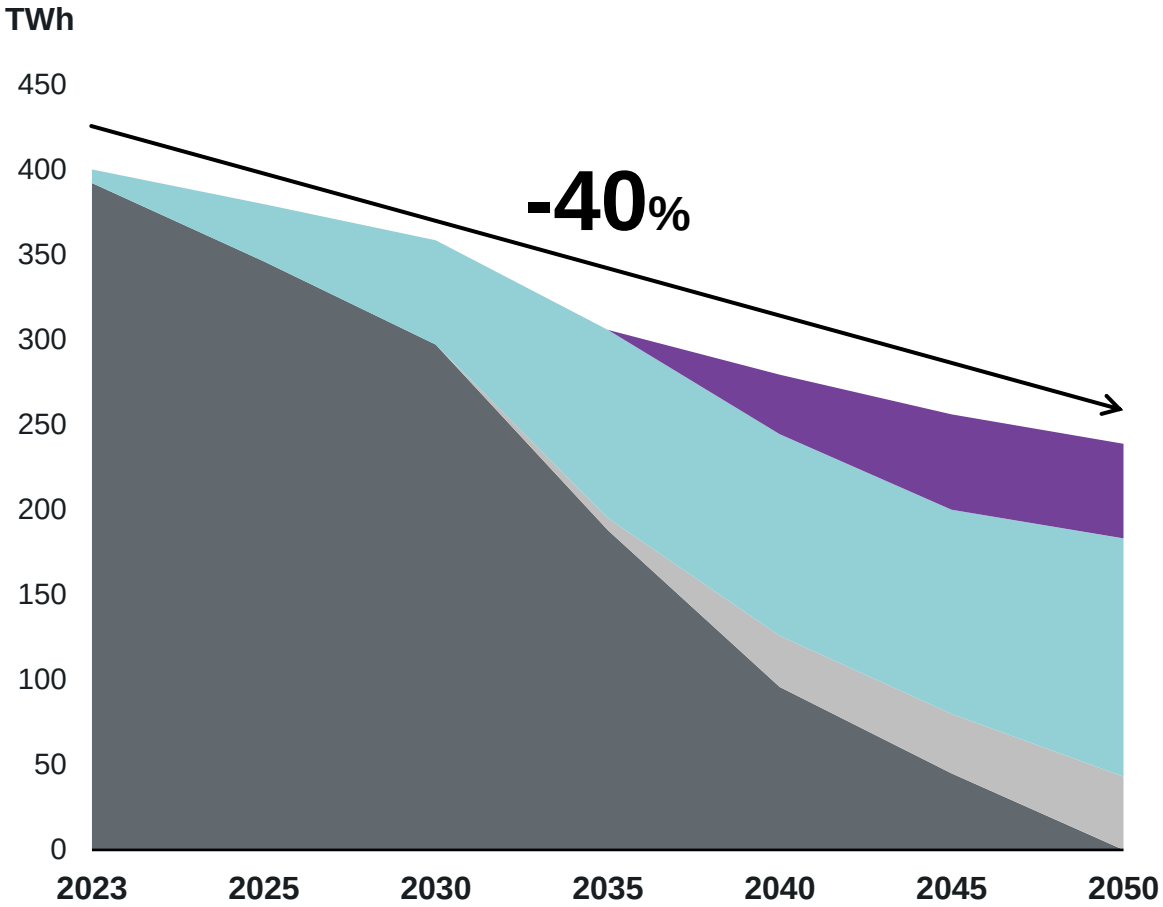
Methane demand is reduced massively and is entirely decarbonized by 2050

Methane demand | Europe-15



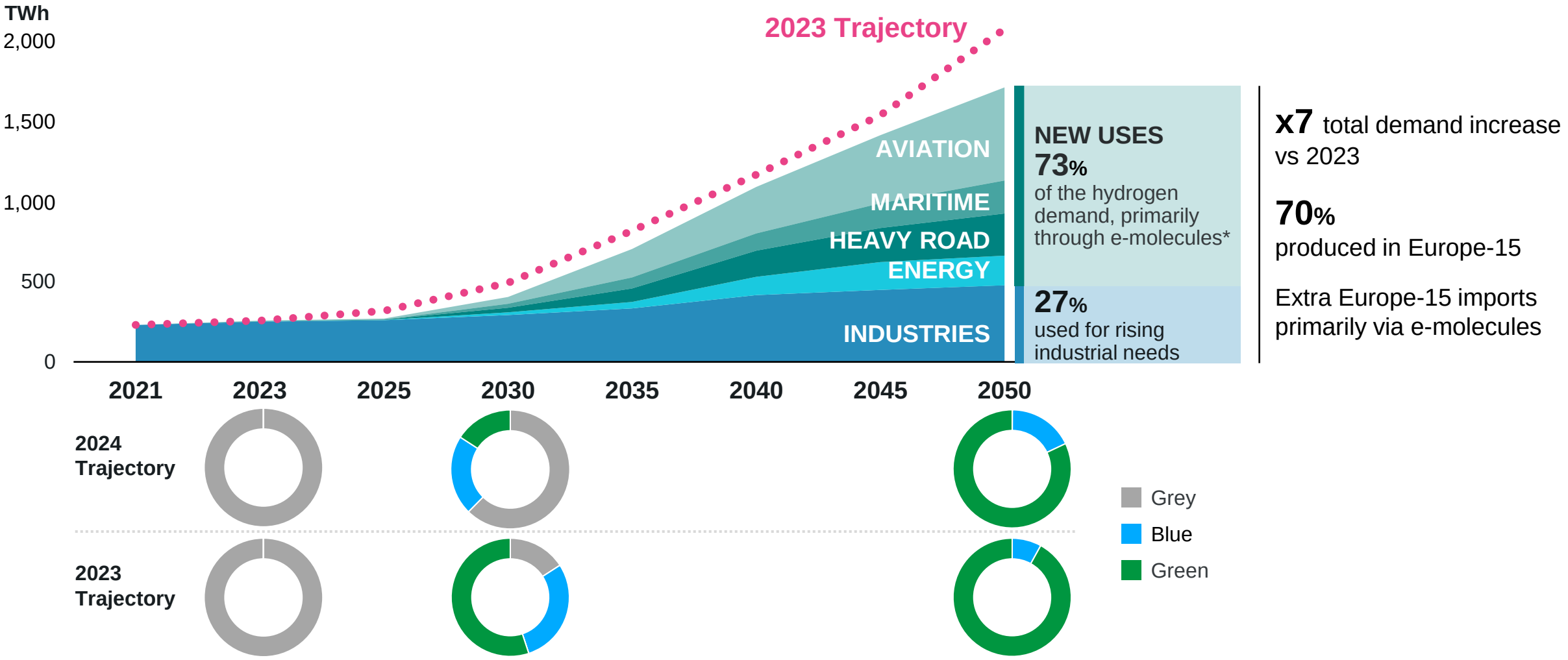
Methane demand | France



Natural Gas Gas + CCS Biogas & Biomethane E-methane

Low-carbon hydrogen deployment is delayed and reduced compared to what was anticipated in the 2023 Net Zero Pathway for Europe.

Hydrogen demand | Europe-15



x7 total demand increase vs 2023

70%
produced in Europe-15

Extra Europe-15 imports primarily via e-molecules

* e-ammonia, e-methanol, e-kerosene, e-diesel

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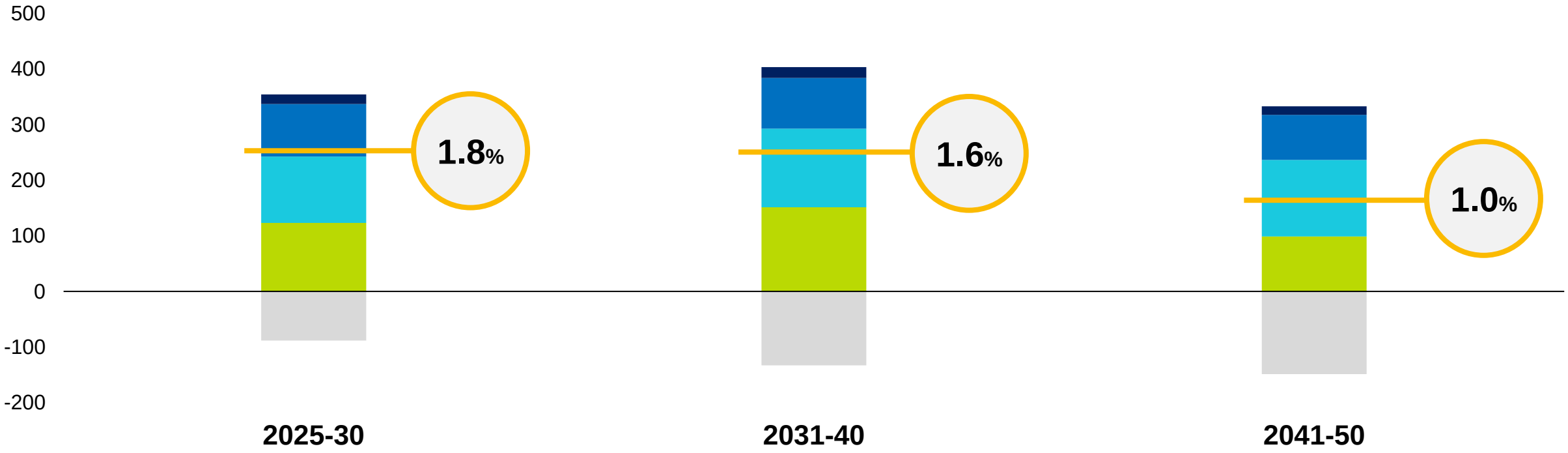
Investments necessary for the decarbonization of Europe are gradually partially offset by savings in fossil fuel

Decarbonization Costs & Savings | Europe-15

Investment Cost and net OPEX savings
€bn/y



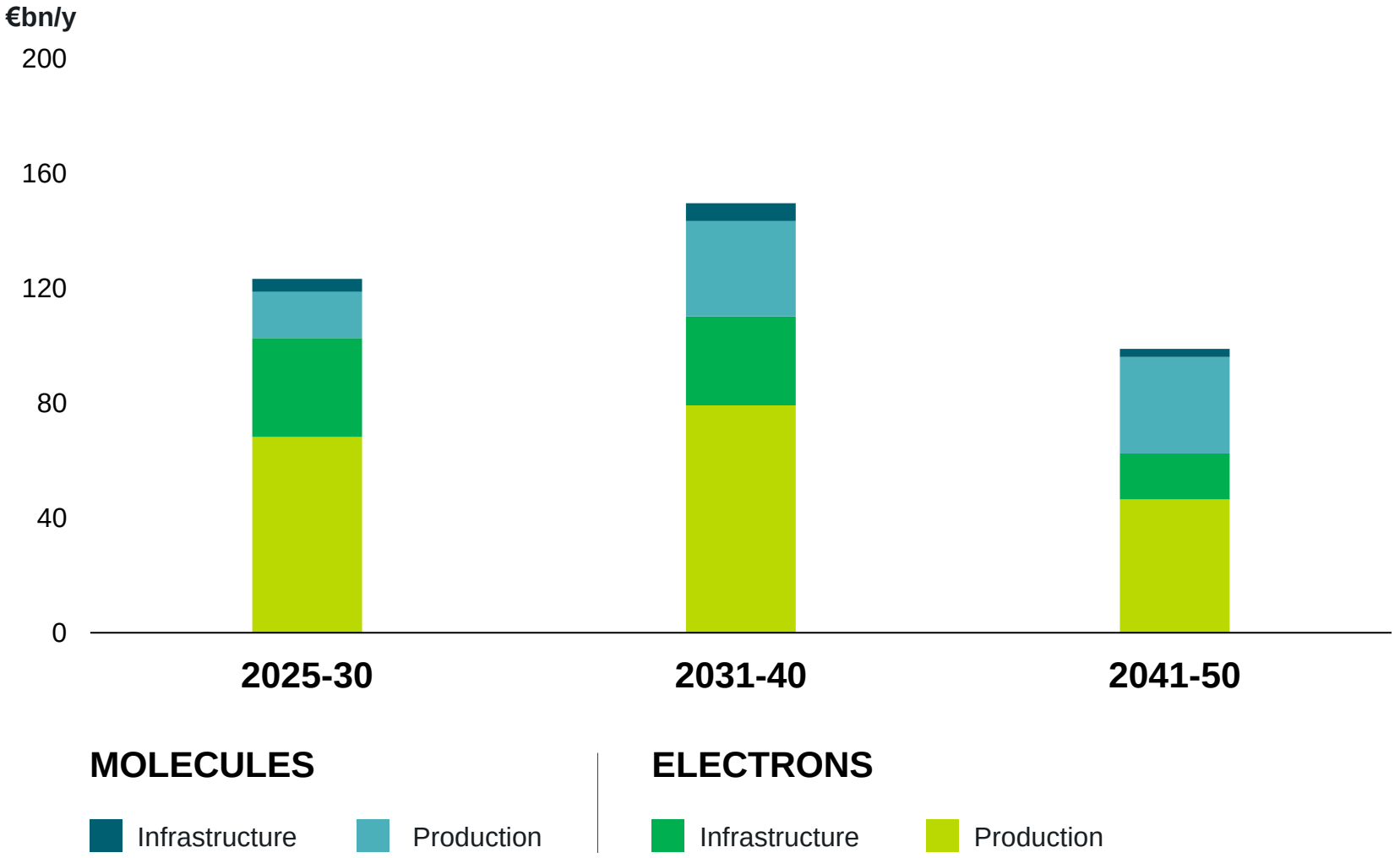
INVESTMENTS

- Low-Carbon Energy Production and Infrastructure
- Transport Fleet and Charging Infrastructure
- Building Renovation & Heating Solutions
- Industrial Processes
- Net OPEX savings
- Net Value
- X% GDP%

Costs excludes taxes & CO_2 prices

Power generation and networks account for the majority of investments needed to decarbonize the energy sector

Investments in low-carbon energy production and infrastructure by energy carrier | Europe-15



6x

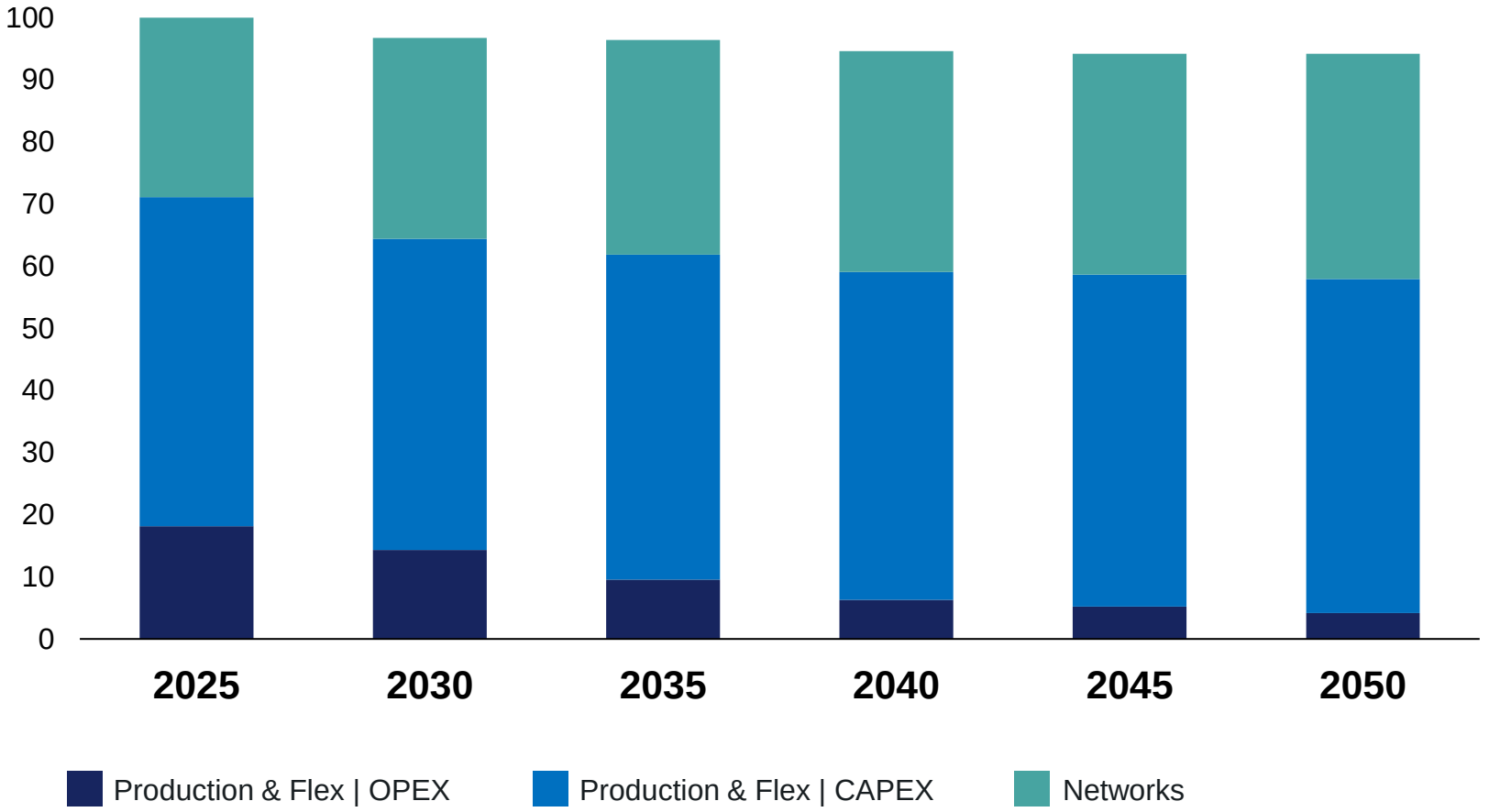
Investments in electricity vs gas infrastructure

Costs excludes taxes & CO_2 prices (tax recycling)

Despite important investments, total power system costs per unit of energy produced are expected to remain stable

Total Power System Cost | Europe-15

Annualized €/MWh, Index 2025 = 100



-10%

Estimated average wholesale prices France, 2050
Net Zero Pathway
vs average actual 2023-24

Costs excludes taxes, subsidies & CO_2 prices (tax recycling)

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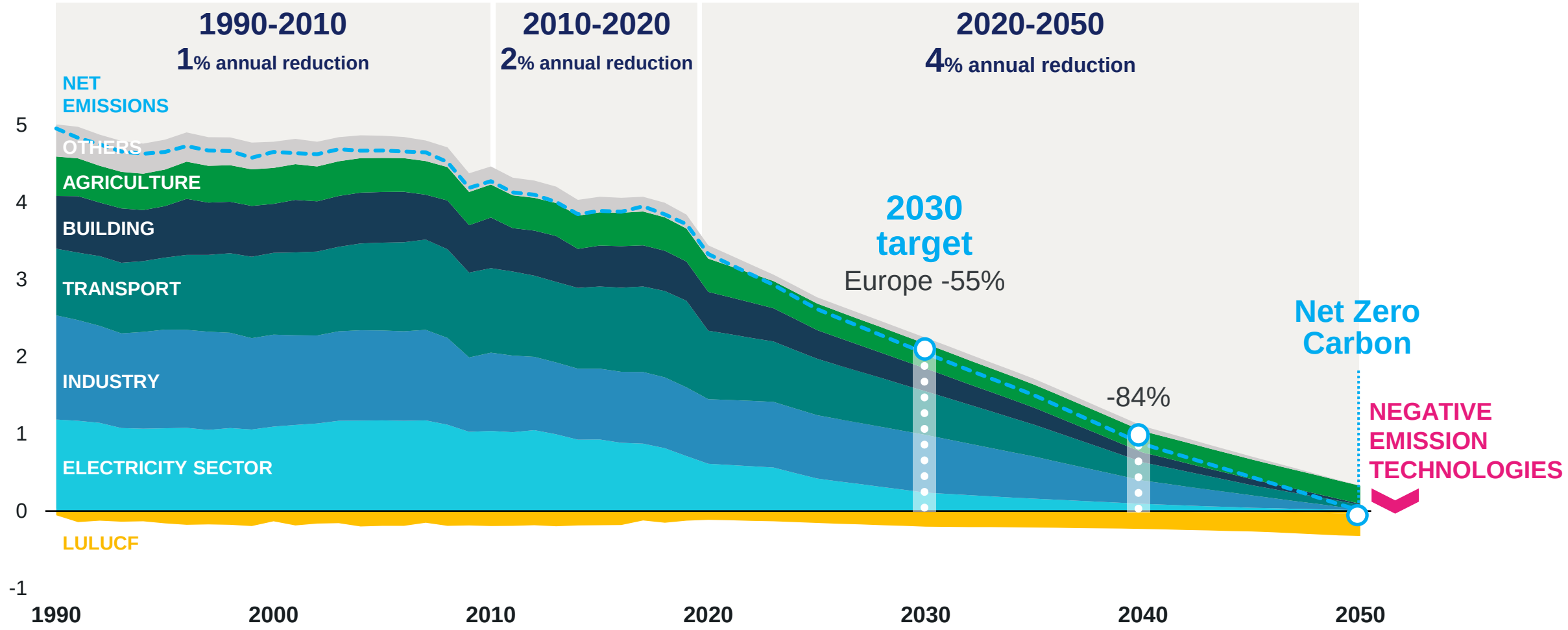
Emissions reductions must accelerate across all economic sectors to achieve Europe's Net Zero target

Greenhouse gas emissions | Europe-15

CO_2e, Gt / year



LULUCF: Land use, land use-change and forestry

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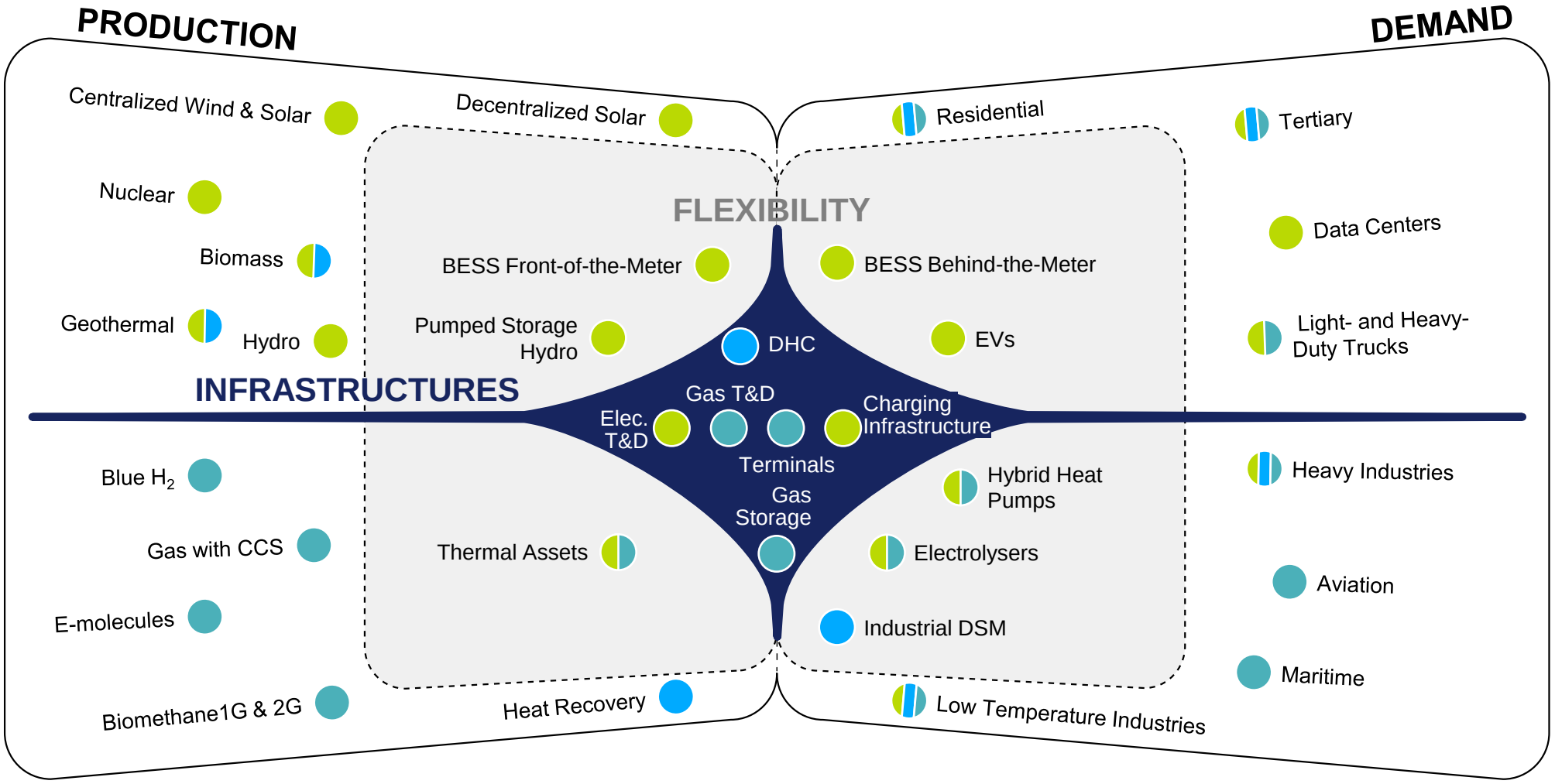
The energy transition requires the transformation of the entire energy system

Components of Europe's 2050 net zero energy system

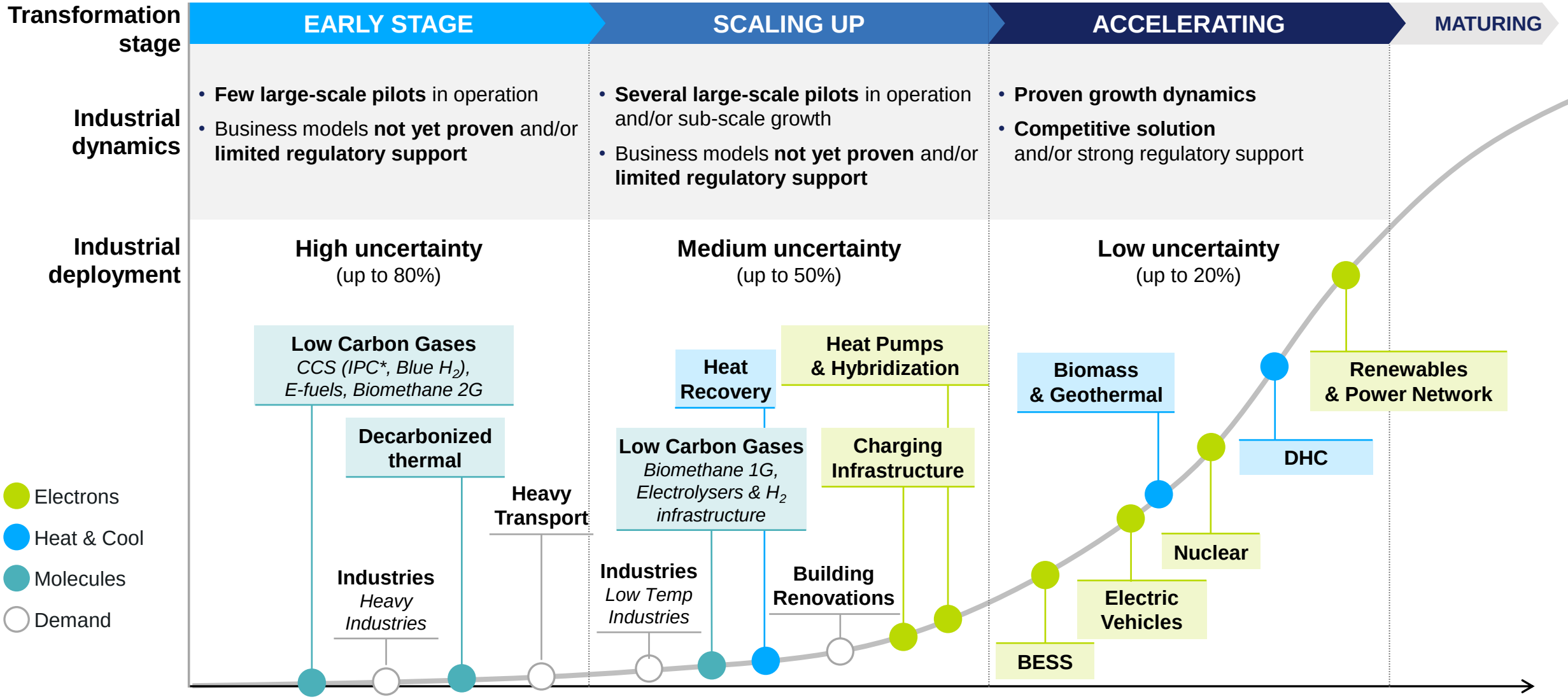
Electrons

Heat & Cooling

Molecules

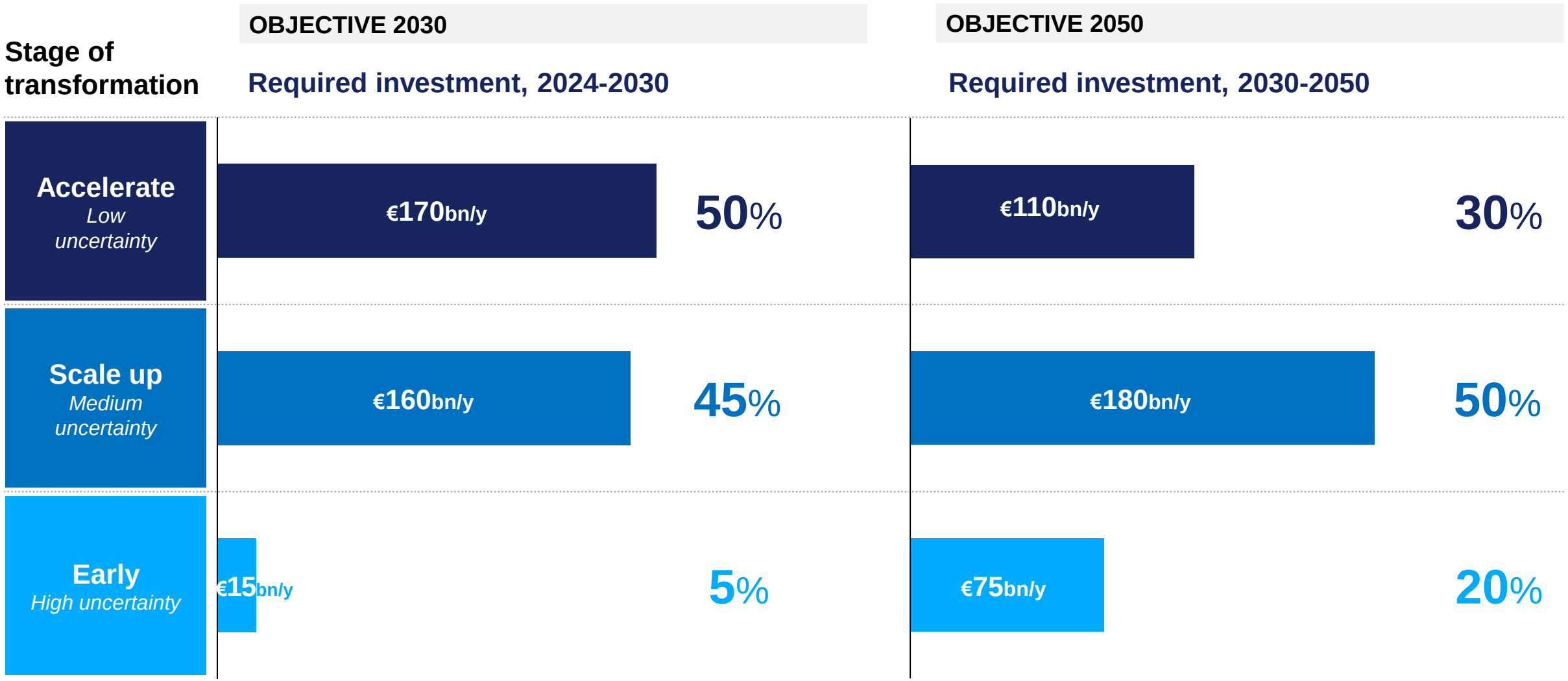


The components of Europe's net zero energy system are today at different stages of transformation



*IPC: Industrial Point Source Capture

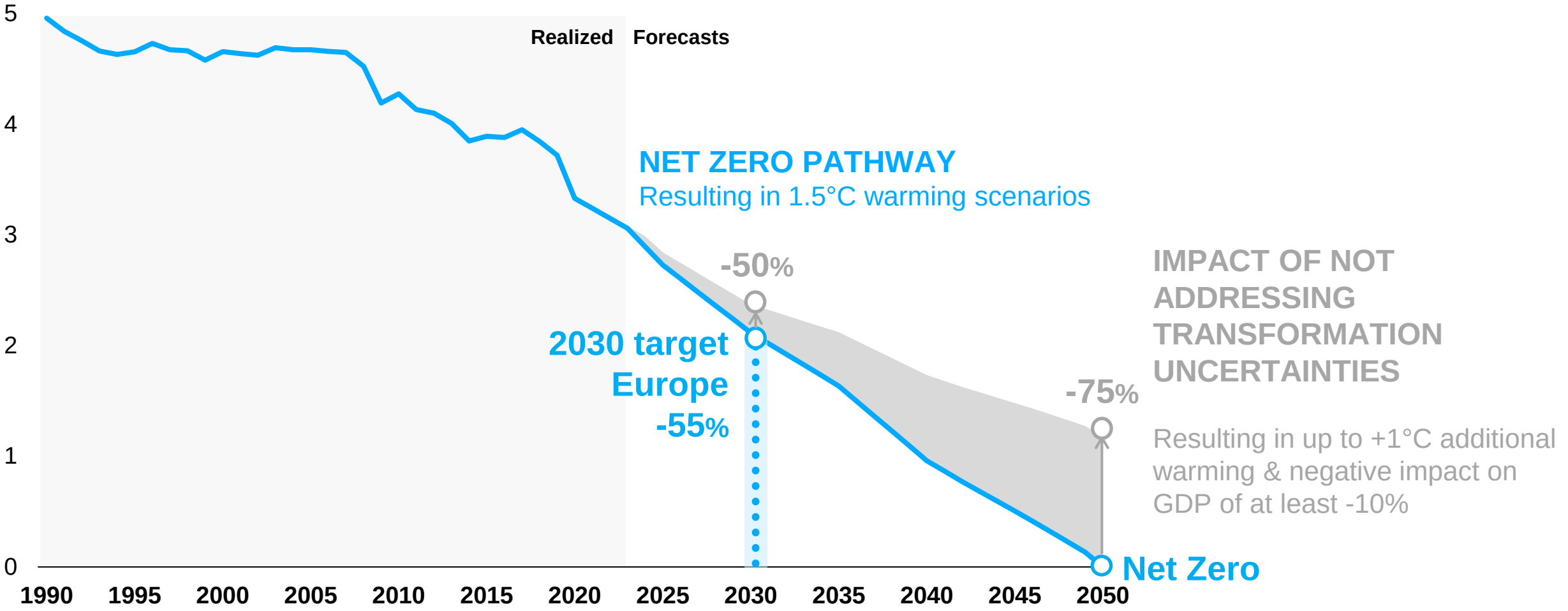
Achieving Europe's decarbonization objectives implies shifting investments towards portfolios of solutions at earlier stages of transformation



These transformation uncertainties imply that Europe could miss its targets if actions are not taken to ensure the timely development of all necessary solutions

Net Greenhouse gas emissions | Europe-15

CO_2e, Gt / year



Sources : ENGIE Analysis CO_2, GDP : Kotz et al. (2024), Bilal & Kanzing (2024)

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Summary of key messages

- **Achieving Europe’s decarbonization ambitions remains possible.** This requires a constant drive and a highly pragmatic approach, leveraging electrification which must be complemented by decarbonized gases and heat
- **The energy transition is a transformation of the entire energy system.** The levers of the energy system of tomorrow are at different stages of transformation today.
- **Europe’s 2030 target seems achievable**, as it depends more on mature levers. However, it requires continued efforts around renewable power, the electrification of light transport, and building renovations.
- **Europe's 2050 target is significantly more at risk**, as it depends in a higher proportion on less mature levers still needing significant derisking, particularly heavy transport, and industry solutions.
- **The costs of decarbonization are significant but remain within reach.** Estimated at <2% of GDP across transport, industry, buildings, and energy transformation.
- **Europe must take decisive actions today.** To ensure we remain on track to 2030, and invest in the necessary levers to achieve our 2050 Net Zero objective

10 bold measures to achieve Europe's objectives

TRANSVERSAL	1.	Introduce a carbon price floor increasing over time
	2.	Optimize the energy system at European scale
SUPPLY	3.	Remove regulatory bottlenecks for renewable power deployment and facilitate trans-European green power PPAs / CfDs* through access to long term cross-border transmission right
	4.	Articulate low-carbon gases objectives based on carbon content alone
DEMAND	5.	Boost large scale demand for renewable and low carbon gases in hard-to-abate sectors
	6.	Capture the full potential of heat recovery
	7.	Target renovation efforts on most inefficient buildings and low-income households
FLEXIBILITY	8.	Valorize both demand-side flexibility and supply-side flexibility
INFRASTRUCTURE	9.	Require infrastructure operators to anticipate grid developments ahead of Renewables, Battery Energy Storage System (BESS), as well as H_2 projects
	10.	Facilitate investments of private capital in European energy infrastructures to address investment gap

* Power Purchase Agreement / Contract for Difference