Energy transition roadmap to 2050:

Exploring EU's pathway through scenario analysis

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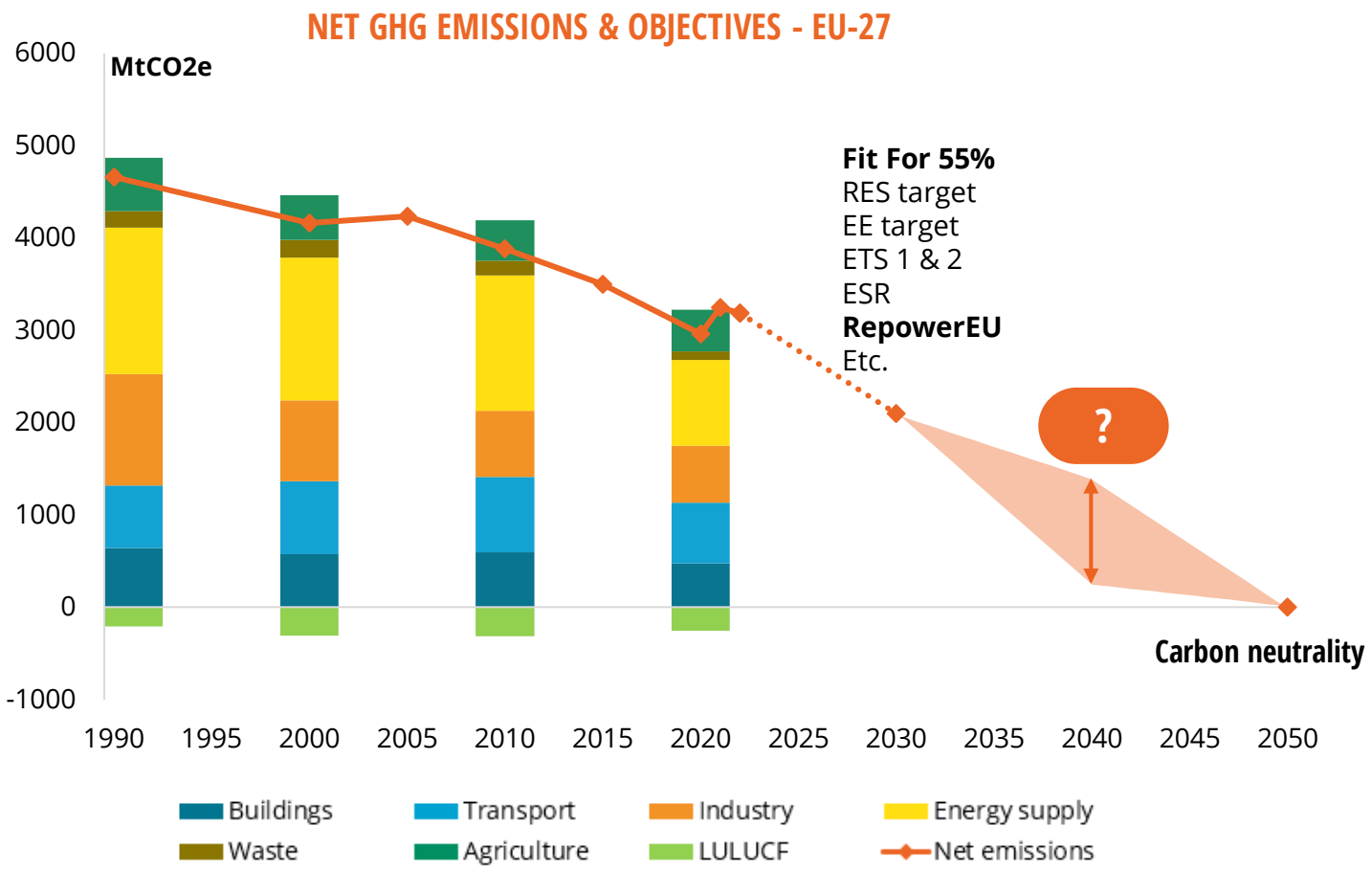
The EU has adopted targets for 2030 and 2050, but uncertainties remain for 2040

The European Union has set an emission reduction target of –55% by 2030 and a net zero target for 2050



- **2030 and 2050 are known quantities**
  - 2030 is now the object of numerous policies and objectives
    - Fit for 55 package
      - Emission Trading Schemes
      - Effort Sharing Regulation
      - Renewable Energy Directive
      - Energy Efficiency Directive
    - RepowerEU plan
    - Etc.
  - The 2050 end point is also set with the goal of carbon neutrality

- **But the 2040 objectives will now become the main focus of EU policy makers for the years to come**
  - Uncertainties remain as to what target will be proposed for 2040
  - An Impact Assessment should be published by the Commission in the next few months

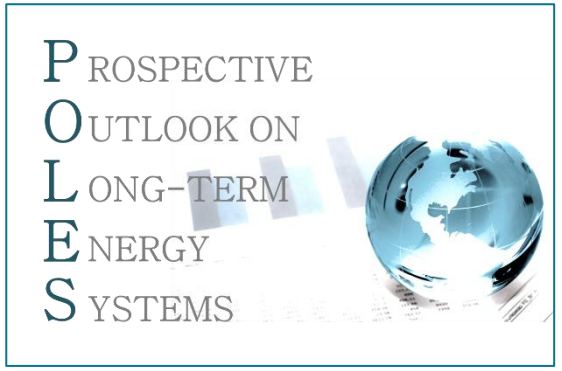
We define three contrasted scenarios in our EnerFuture outlook

Three energy-climate scenarios to explore possible futures of global energy systems

- Enerdata has prepared **three contrasted energy-climate scenarios** up to 2050 to explore **possible pathways for the global energy sector**

EnerBase (>+3°C)	EnerBlue (+2-2.5°C)	EnerGreen (<+2°C)
Continuation of existing policies and trends	**Achievement of new NDCs submitted up to end of 2022**	**Ambitious GHG emissions budget in line with the Paris Agreement**
Temperature increase above 3°C	*Temperature increase around 2.5°C*	*Temperature increase below 2°C*

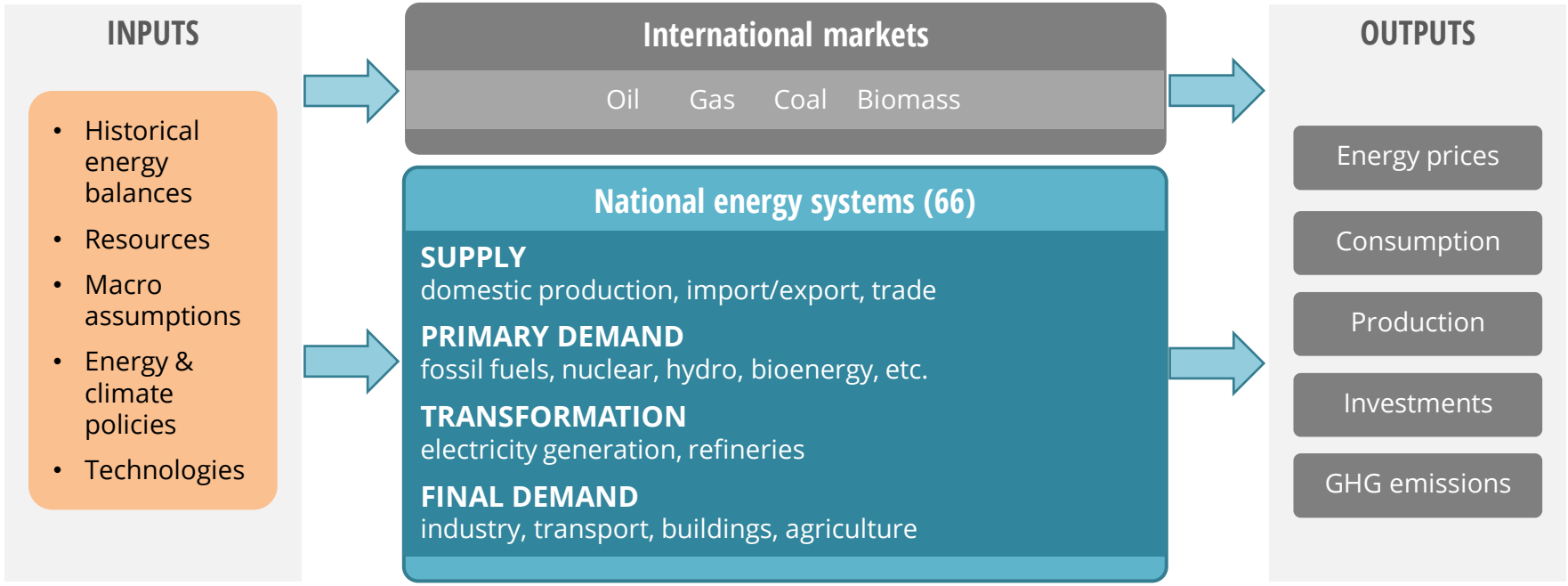
- **EnerFuture** is relying on the recognized **POLES-Enerdata model**, an energy-economy-environment model of the **global energy systems**, covering **66 countries and regions**, with dedicating modeling of the individual **end-use sectors**, **energy supply**, **prices**, and **GHG emissions**



POLES-Enerdata allows us to explore the global energy transition

The POLES-Enerdata model uses a partial equilibrium approach to analyse the future of global energy systems

- The scenarios are based on the use of the POLES-Enerdata model, allowing for detailed prospective analysis of **energy supply and demand, prices, and the impact of energy and climate policies on energy markets**
- POLES-Enerdata is the version of the POLES (Prospective Outlook on Long-term Energy Systems) model owned, maintained, and operated by Enerdata
- The model is running, and scenarios are prepared, **for 66 countries and regions with global coverage and annual step until 2050**

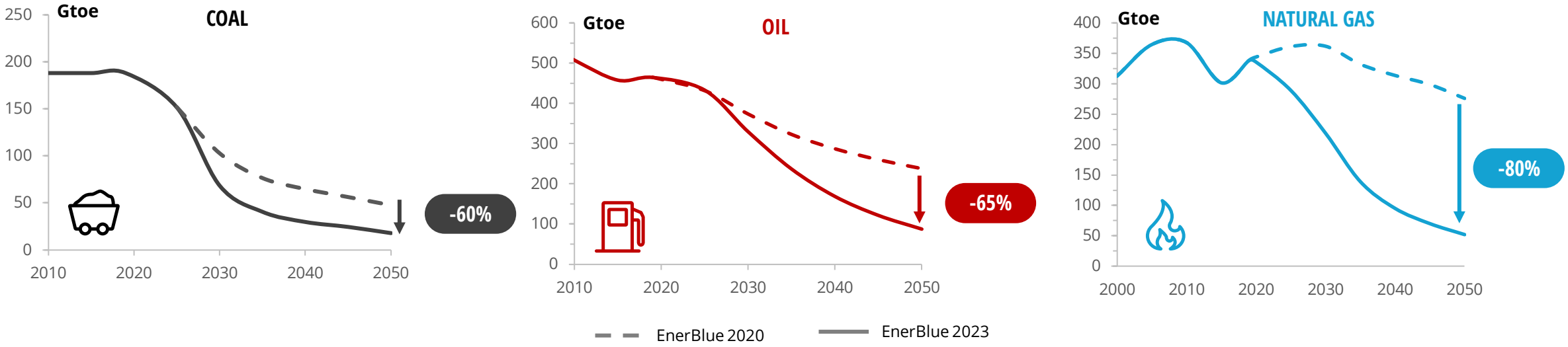


Note: The POLES model has been initially developed by IEPE (Institute for Economics and Energy Policy), now GAEL lab (Grenoble Applied Economics Lab).

The past few years have seen substantial changes in EU energy outlook

EU's increased ambition, the COVID pandemic, and more recently the Ukraine crisis, had large impacts on EU energy systems and policy

FOSSIL COAL, OIL AND GAS CONSUMPTION IN EU-27 – ENERBLUE 2020 & ENERBLUE 2023 (ANNOUNCED POLICIES)

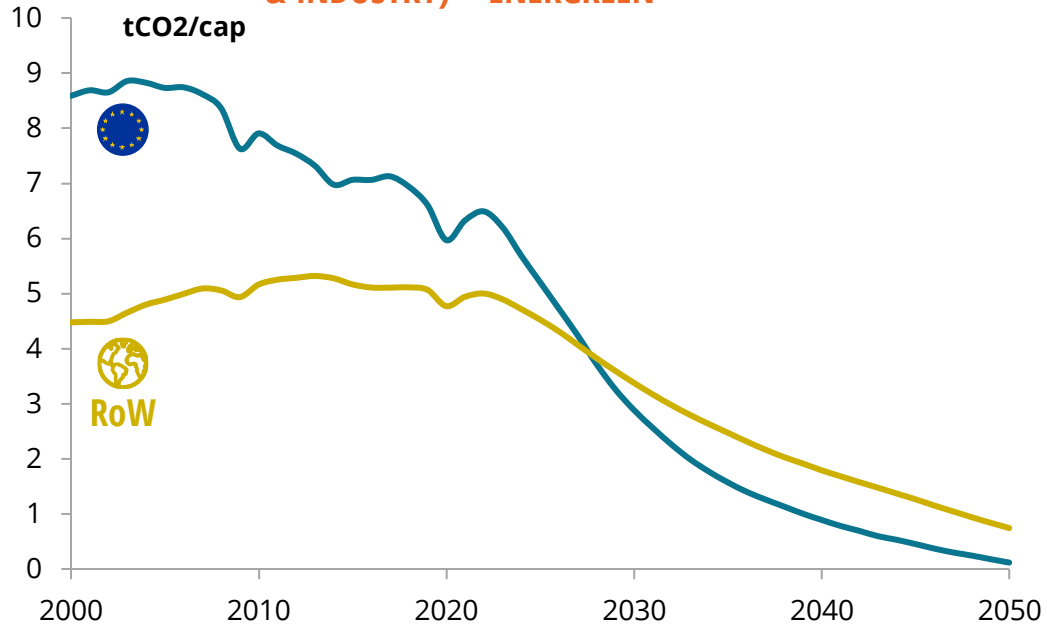


- **Energy projections have significantly changed between 2019 and 2023**
  - Driven by strong climate ambition and impact of Covid crisis and the war in Ukraine, the outlook for the European energy sector has completely changed between 2019 and 2023
  - Especially for gas, which is no longer seen as a transition energy
- **But uncertainties remain as to the final trajectory to be adopted to stay below 2°C.**
  - Today, current policies are not enough to put Europe on a 1.5°C trajectory
  - The reduction target for 2040 is a key milestone in the construction of this trajectory

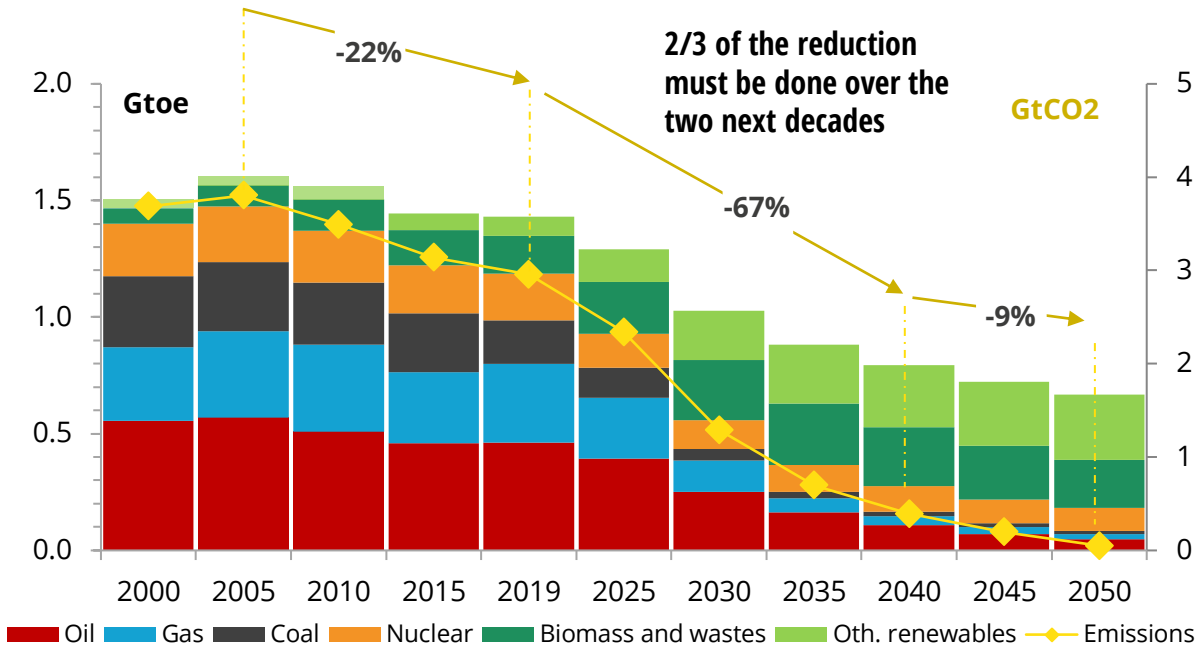
To keep its role of climate leader, Europe should transform most of its energy systems by 2040

In EnerGreen, CO_2 emissions from energy systems and industrial processes should decrease by 90% between 2005 and 2040

CO_2 EMISSIONS PER CAPITA (ENERGY & INDUSTRY) – ENERGREEN



PRIMARY ENERGY CONSUMPTION & CO_2 EMISSIONS IN EU27– ENERGREEN



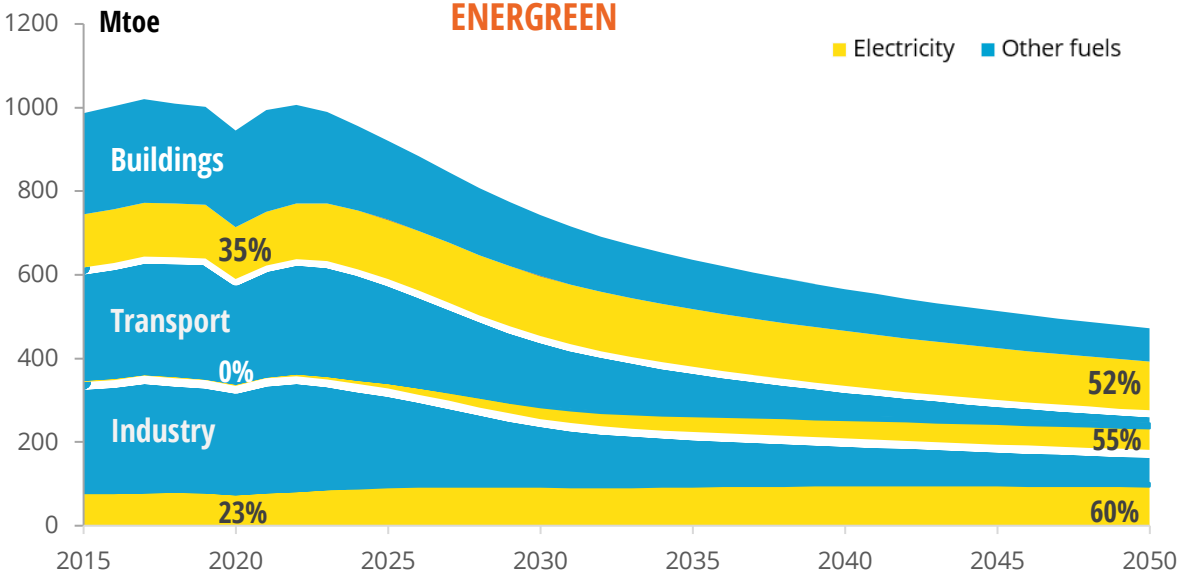
- **The EU is a front-runner in climate action**
  - To keep this position and to stay on track for a +2°C world, the EU needs to be decarbonised much faster than the rest of the world
  - Emissions linked to energy consumption are low-hanging fruits compared to agricultural emissions, and hence need to be cut rapidly. In EnerGreen, the EU must reduce CO_2 emission by 90% between 2005 and 2040

- **This requires a complete transformation of the European energy systems before 2050**
  - EU-27 must not only transform its energy systems by 2050, but a large part of the transformation has to occur before 2040
  - This will involve a sharp reduction in primary energy consumption, with a drop in fossil fuels offset by renewable electricity and biomass.

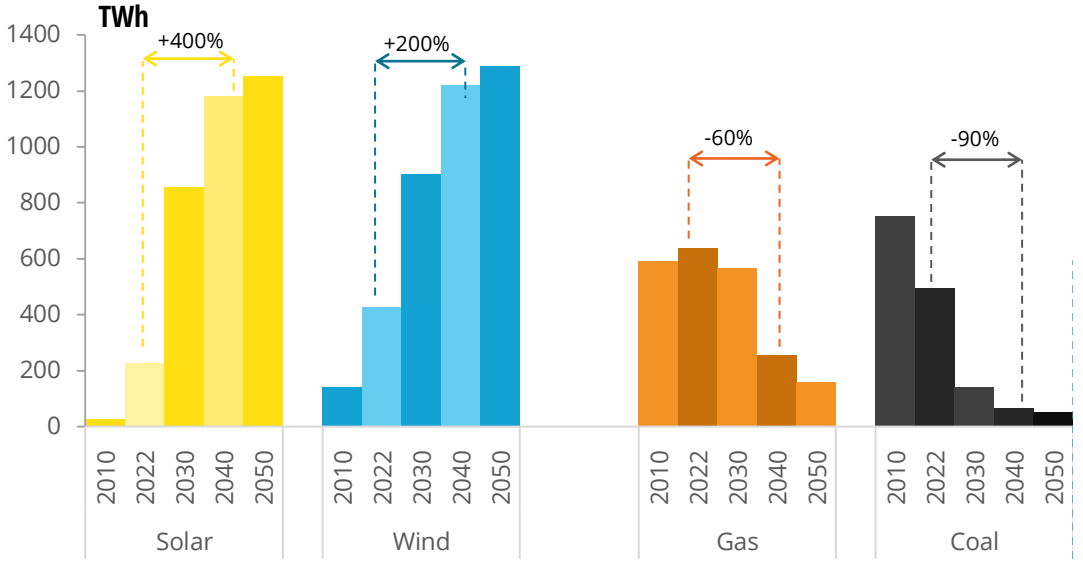
Electrification is a major lever to reduce emissions

In a context of demand-side electrification, the electricity system will have to move away from fossil generation towards more renewables

ENERGY CONSUMPTION IN DEMAND SECTORS IN EU27 – ENERGREEN



ELECTRICITY GENERATION SHIFT IN EU27– ENERGREEN



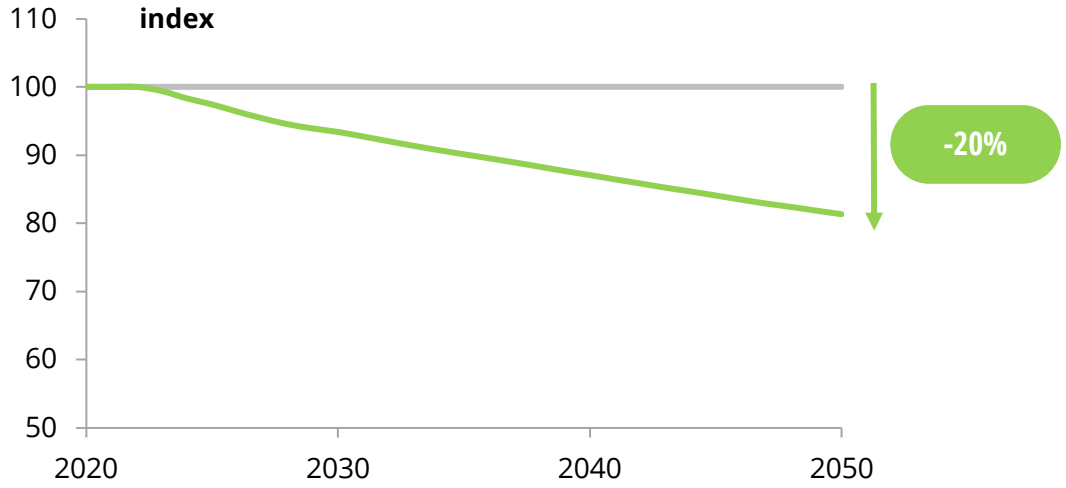
- **Electrification of final demand occurs in all sectors in EnerGreen**
  - Electricity jumps **from 21%** of the final demand in 2021 **to 50% in 2050**
  - Buildings: **45%** of dwellings are heated with **heat pumps** in 2040
  - Transport: **electric cars** represent **60%** of the stock in 2050
  - Industry: shift to DRI and EAF for iron & steel production and electrification of low-temperature heat
  - Due to better efficiency of electric devices, and a decrease in demand needs, **electricity demand only grows by 25% by 2040**

- **The power sector has to shift towards low-emissions power generation assets**
  - In EnerGreen, most of the transformation occurs before 2040.
    - Solar power production will be multiplied by 5
    - Wind production will be multiplied by 3
    - Gas production will be decreased by 60%
    - And coal production must almost disappear by 2040.

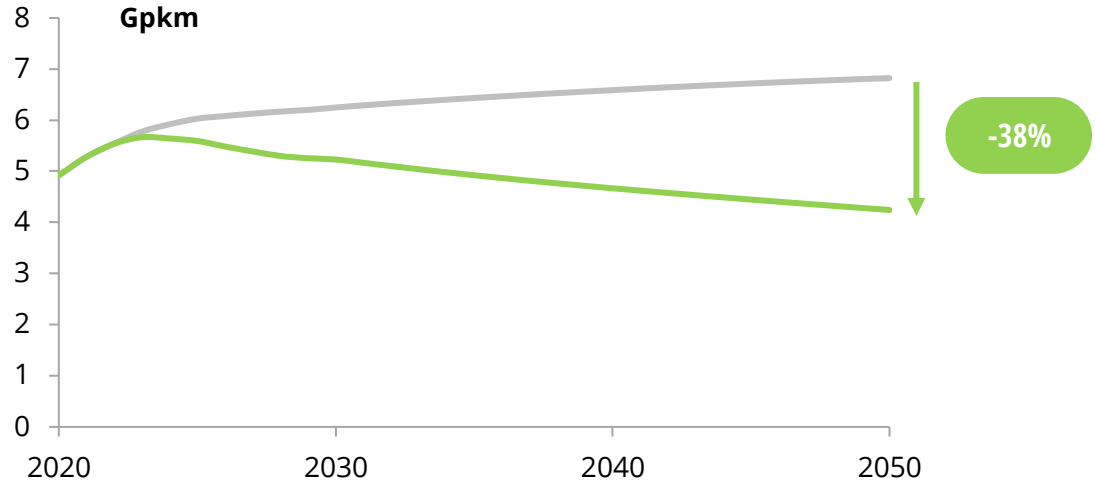
Sufficiency must be discussed and encouraged

Behavioral changes can have a large and structural impact on energy demand and therefore help to bridge the gap

ENERGY SERVICE NEEDS IN BUILDINGS IN EU27 – ENERBASE/ENERGREEN



PASSENGER CAR TRAFFIC IN EU27 – ENERBASE/ENERGREEN



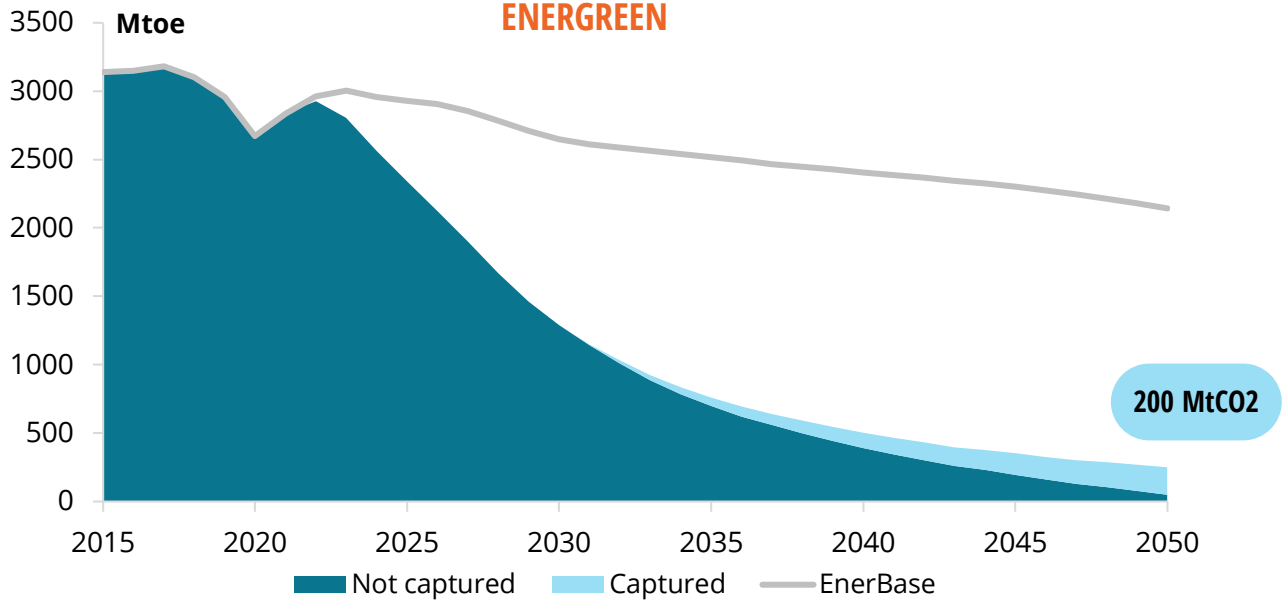
- **Sufficiency policies could allow to reduce the total energy demand by 10% to 20%**
  - Better control of temperature in buildings for heating and cooling, limiting over equipment…
  - Carpooling, active transportation, and public transport have a direct impact on energy demand in buildings and transport
  - Other policies on the size of buildings, number of cars, or on food habits could also have an indirect impact on industry production

- **Sufficiency could lead to more resilient pathways**
  - Sufficiency had a key role in limiting power peak this winter and could continue in the power system with a large share of renewables
  - Sufficiency could reduce the risk linked to uncertainties around maturity of developing technologies (e.g. CCS, Direct Air Capture)
  - Sufficiency would also reduce pressure on other environmental issues (metal production, resources, critical minerals, etc.)

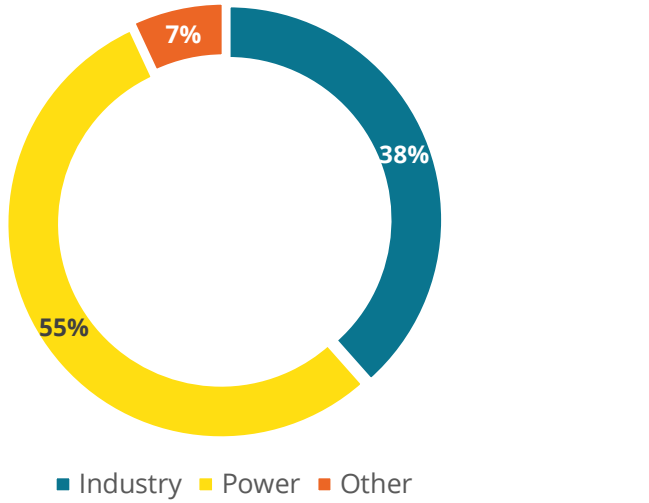
Carbon capture may have a limited role in the energy transition in Europe

If the energy transition is sufficiently anticipated, CCS retrofit of existing carbon assets will remain limited

EMISSONS CAPTURED AND NOT CAPTURED IN EU27 – ENERGREEN



EMISSIONS CAPTURED BY SECTOR IN 2050 – ENERGREEN

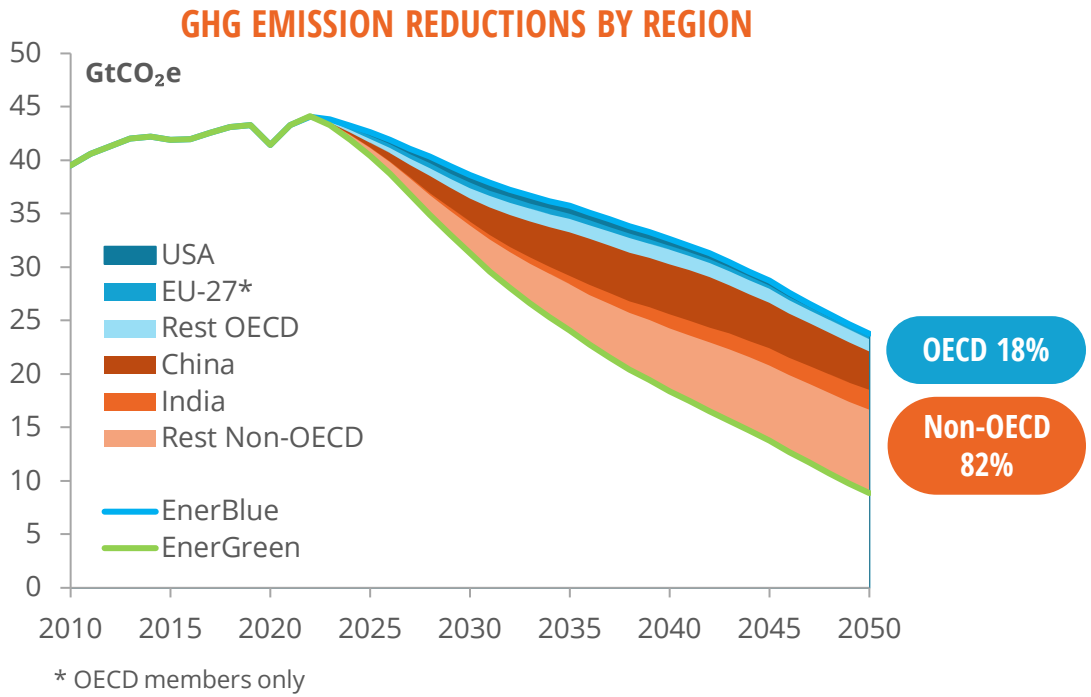


- **Carbon capture will account for 200 $MtCO_2e$ in 2050, less than 7% of current emissions**
  - The two major sectors concerned by CCS will be the power sector and industrial emissions (especially process)
  - Limiting the future needs for CCS requires to plan the necessary investments today

- **Uncertainties on CCS & DAC solutions**
  - The Sleipner and Snøhvit CCS projects have faced issues, and shown that it is difficult to predict the real storage potential
  - Uncertainties on the cost of the future technologies and construction capacity buildup rate
  - Questions on policy design: will CCS & DAC be integrated in the EU ETS? What incentives to make it competitive?

Support efforts in developing countries is necessary to achieve a fast transition

Over 80% of additional decarbonisation efforts in EnerGreen should be done by non-OECD countries



Cumulated reductions, 2022-2050		
USA	15 $GtCO_2e$	5%
EU-27*	10 $GtCO_2e$	3%
Rest OECD	29 $GtCO_2e$	10%
China	89 $GtCO_2e$	30%
India	26 $GtCO_2e$	9%
Rest Non-OECD	126 $GtCO_2e$	43%

- The gap between current NDCs and a below 2°C scenario is mostly concentrated in Non-OECD countries
- The question of **global climate finance** is key: advanced economies such as the EU need to enable developing countries to access financing to continue developing while limiting their emissions
- As climate change is a global problem, helping to reach mitigation potentials outside the EU with lower abatement costs should not be overlooked

HELPING YOU SHAPE THE ENERGY TRANSITION

About Enerdata:

Enerdata is an independent research company that specialises in the analysis and forecasting of energy and climate issues. We do this at a variety of different geographic and business / sector levels.
Our company is headquartered in Grenoble, France, where we were founded in 1991, and has a subsidiary in Singapore.
Leveraging our globally recognised databases, business intelligence processes, and prospective models, we assist our clients – which include companies, investors, and public authorities around the world – in designing their policies, strategies, and business plans.

Enerdata

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