BUILDING DECARBONIZATION PATHWAYS FOR EUROPE

ENGIE'S SCENARIO

SEPTEMBER 21, 2023

INTRODUCTION

Claire Waysand
Corporate Secretary – ENGIE

OUR 5 BELIEFS

1 Activate all possible levers for decarbonization

4% / annual reduction in emissions

To achieve « Net zero » carbon in less than 30 ans

2 Combine electricity and molecules for a successful transition

450TWh of low-carbon gas by 2030

to meet “Fit for 55” objectives

3 Massive development of renewable power

80% increase

in electricity demand **in Europe** by 2050

x6

increase in power generation from solar and wind

4 Act now to anticipate flexibility needs

~x4

increase in flexibility needs **by 2050**

5 Energy efficiency is compatible with growth

34%

reduction in energy demand by 2050

BUILDING DECARBONIZATION PATHWAYS FOR EUROPE: ENGIE'S SCENARIO

Nicolas Lefevre-Marton
Group Chief Strategy Officer – ENGIE

& Pierre-Laurent Lucille
Chief Economist – ENGIE

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AN ANALYSIS DERIVED FROM GLOBAL EXPERIENCE

ALL LEVERS OF DECARBONIZATION…

… ACROSS AN INTERNATIONAL FOOTPRINT

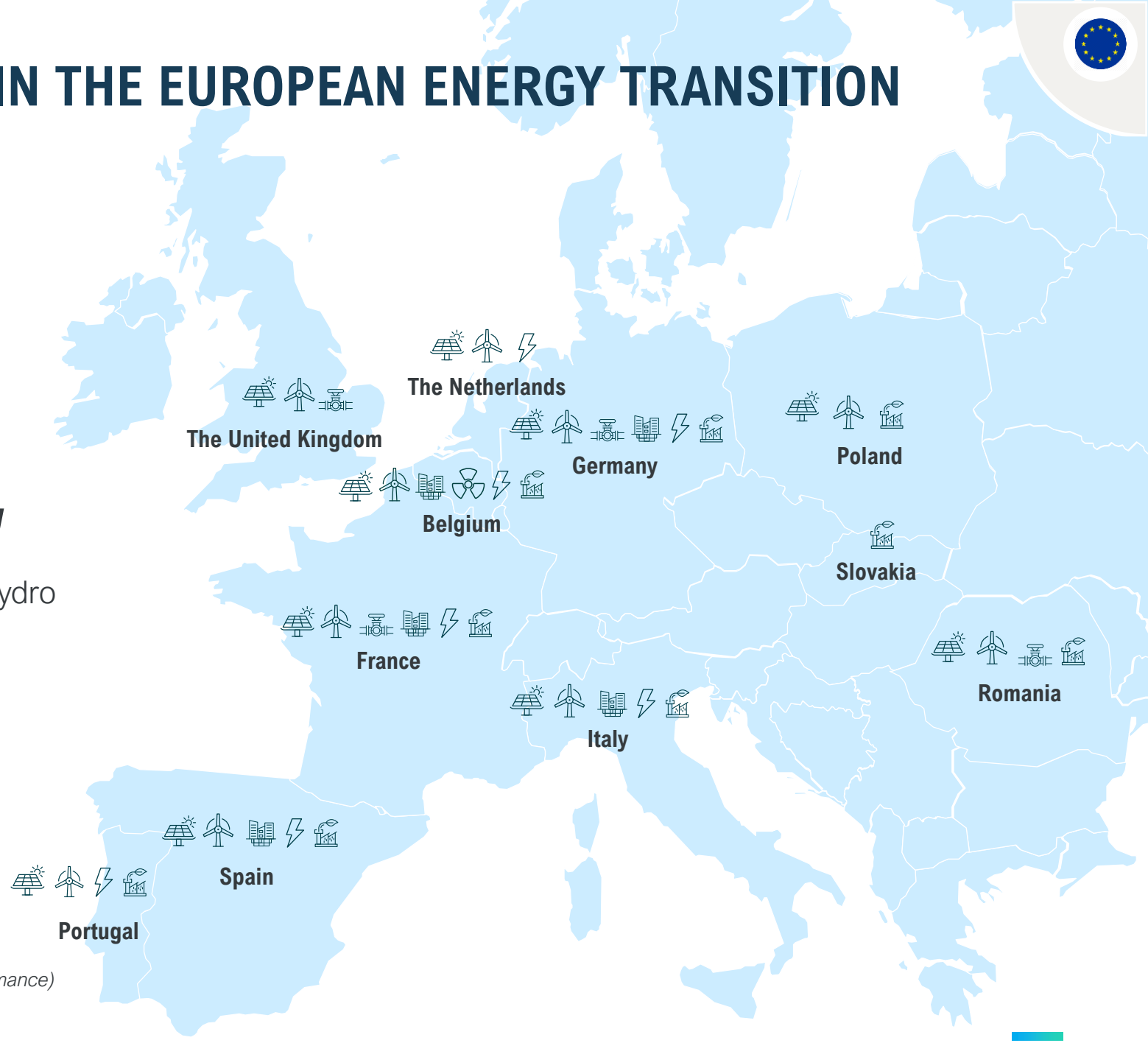
ENGIE : LEADING COMPANY IN THE EUROPEAN ENERGY TRANSITION

ENGIE today in Europe

62500
Employees

39BIL€
Revenue in 2022

22GW
Renewables & Hydro



ACTIVITIES

- Renewables
- Nuclear
- Gas Infrastructure *(Network, LNG, Storage)*
- Flexible capacity *(Thermal, BESS, Pump Storage)*
- District Heating & Cooling
- B2B energy services *(on site production, energy performance)*

A PRAGMATIC APPROACH TO DECARBONIZATION

Mature and emerging technologies

All energy vectors & markets

European and national regulatory frameworks

NET ZERO CARBON

COST OPTIMIZATION

RESILIENCE

ENGIE'S DECARBONIZATION PATHWAY FOR EUROPE

A ROBUST METHODOLOGY

A European vision

- Modelling of **15 European countries** whose energy systems are highly interconnected
- Focusing on FR, DE, BE, NL, UK, IE, ES, PT, IT, CH, AT, PL, HU, SK & CZ
  (**+85% of final energy consumption** in 2019 of EU27+UK, CH)

A model that incorporates a diverse range of energy vectors

- Based on **interactions between electricity, methane, hydrogen, e-molecules and heat**
- Modelled with a **fine-grained hourly timeline** to meet resource adequacy and resilience criteria

A realistic approach to technical and economic choices

- Based on **mature low-carbon technologies** (e.g. excluding marine energy and nuclear fusion)
- Incorporates **societal factors** (e.g. limitations to the deployment of carbon capture and storage)
- Uses **external studies and benchmarks** for issues outside our area of expertise,
  e.g. agriculture, forestry (European Commission, ADEME, etc.)

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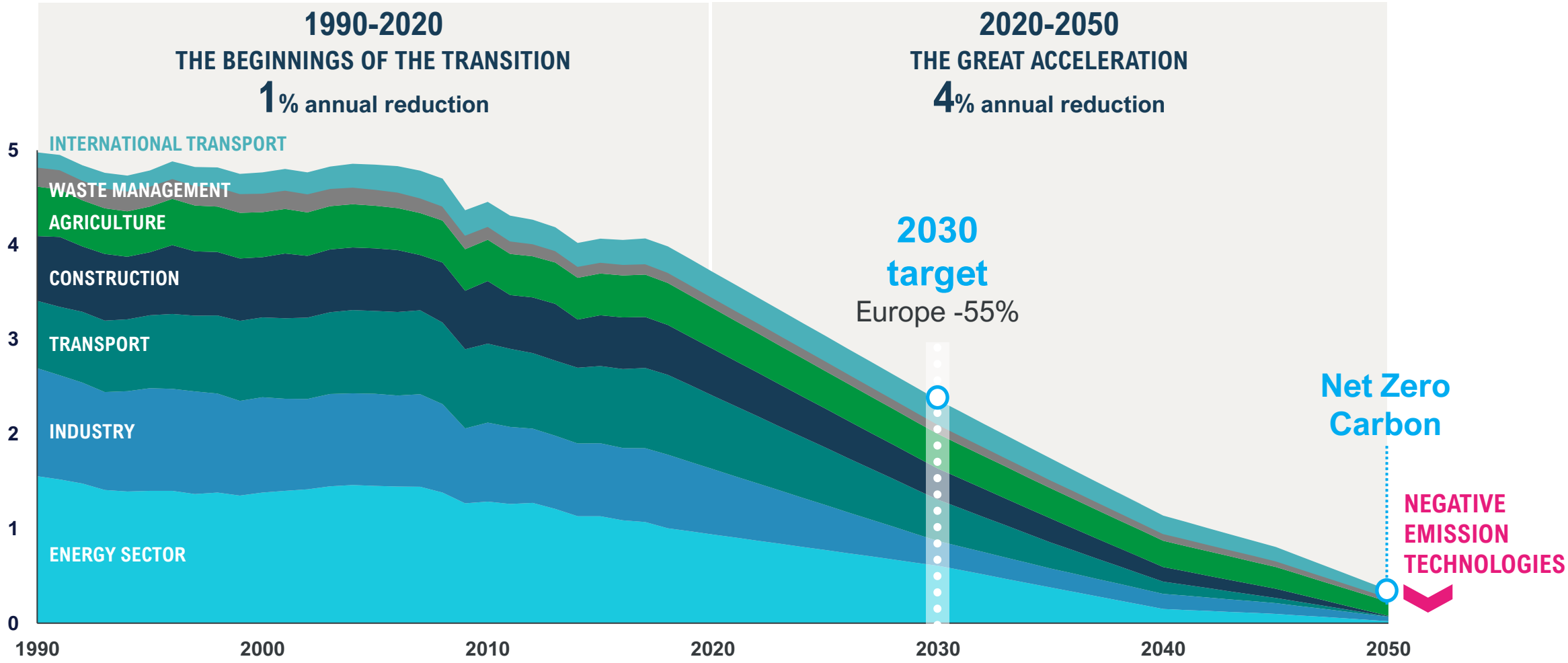
A NECESSARY INCREASE IN EMISSIONS REDUCTION EFFORTS

Greenhouse gas emissions

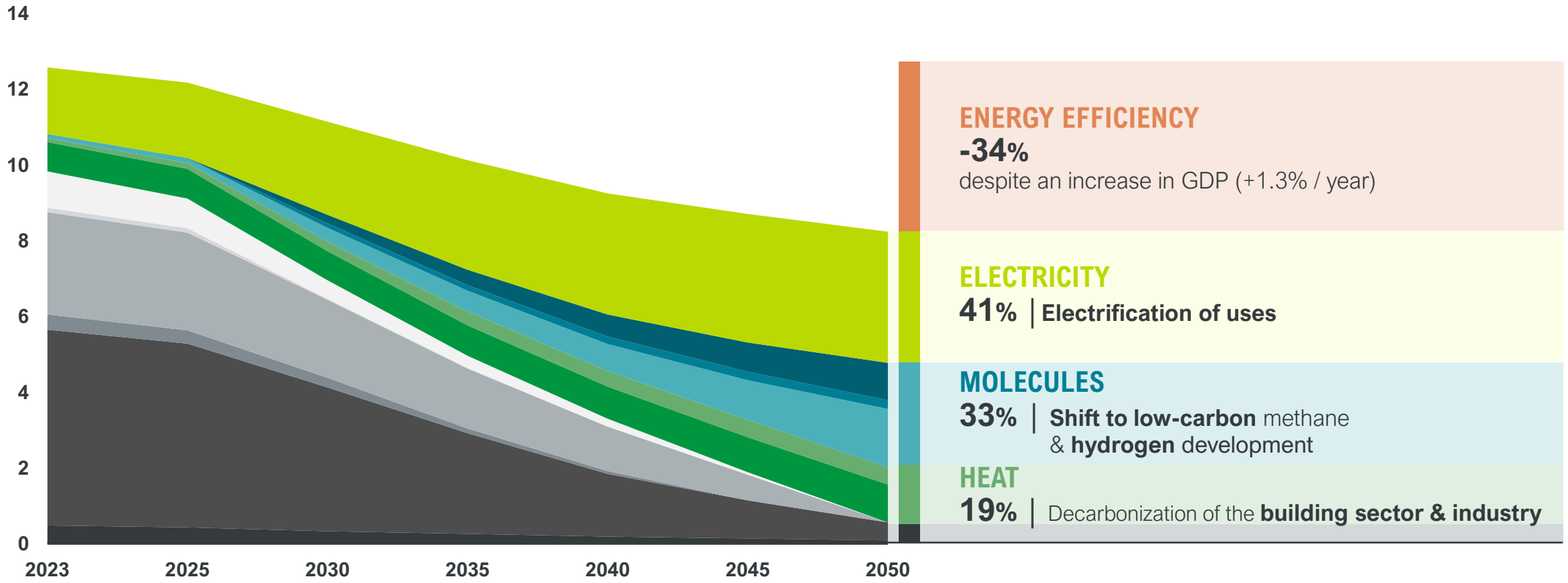
CO_2e, Gt / year



ALL LEVERS ARE REQUIRED TO ACHIEVE DECARBONIZATION

Final energy mix

Thousand TWh



FOSSIL FUELS

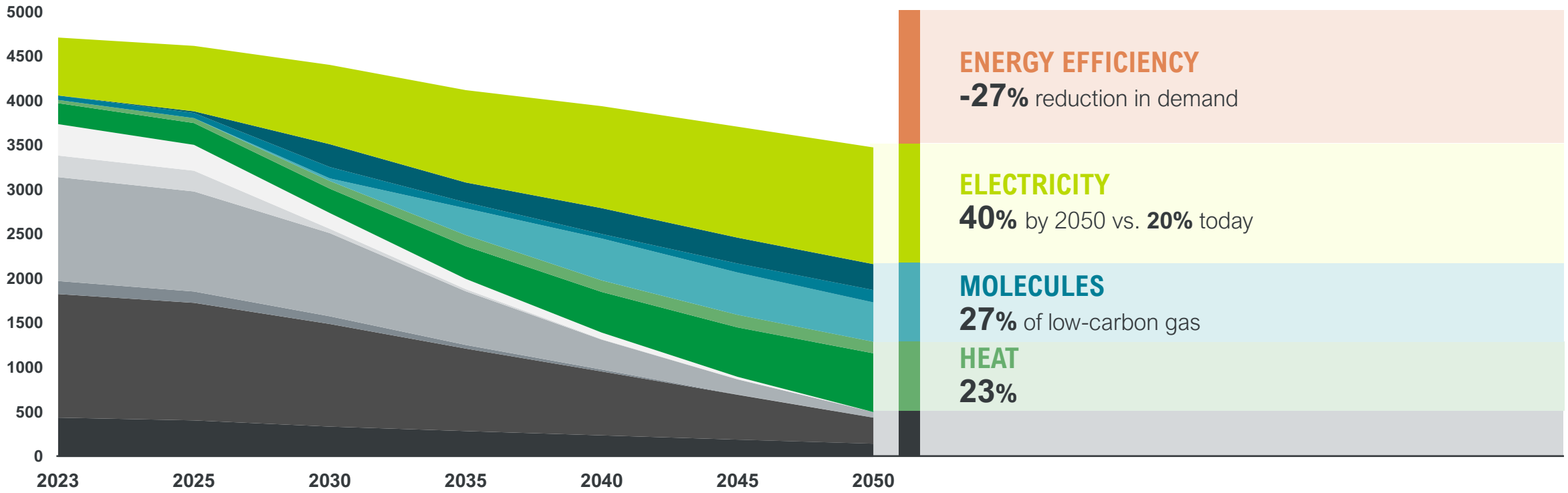
- Coal
- Oil
- Waste heat
- Methane
- Hydrogen
- Electricity

LOW-CARBON EMISSION ENERGIES

- Solid biomass
- Waste heat and Geothermal
- Methane
- Hydrogen
- e-Molecules
- Electricity

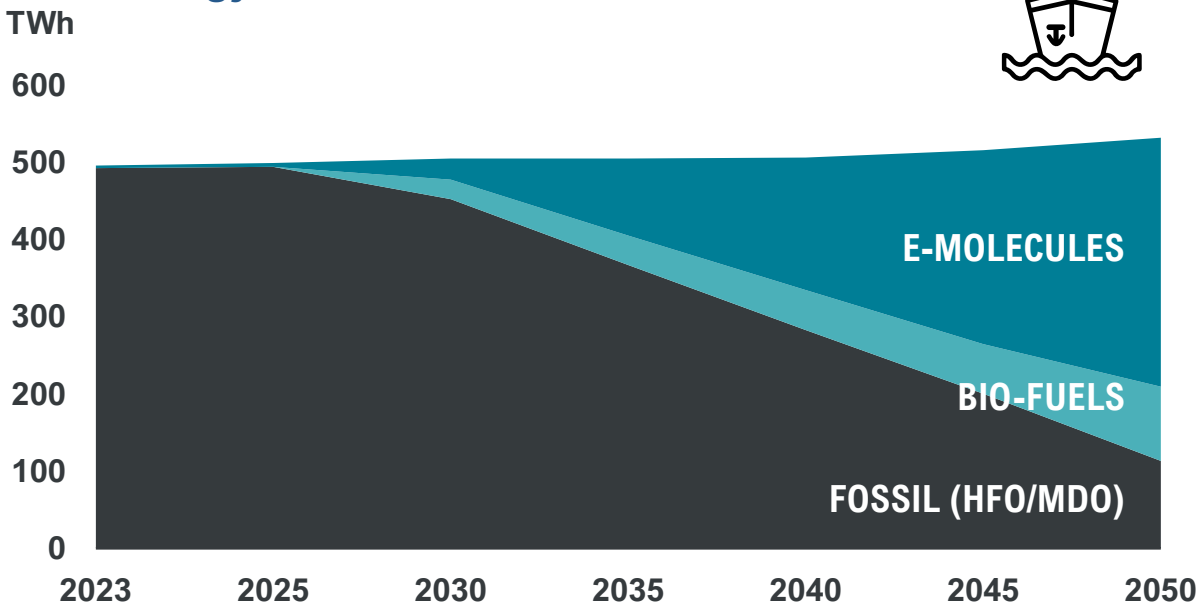
INDUSTRY: ELECTRIFICATION AND DECARBONIZED GASES ARE THE DRIVERS OF THE TRANSITION

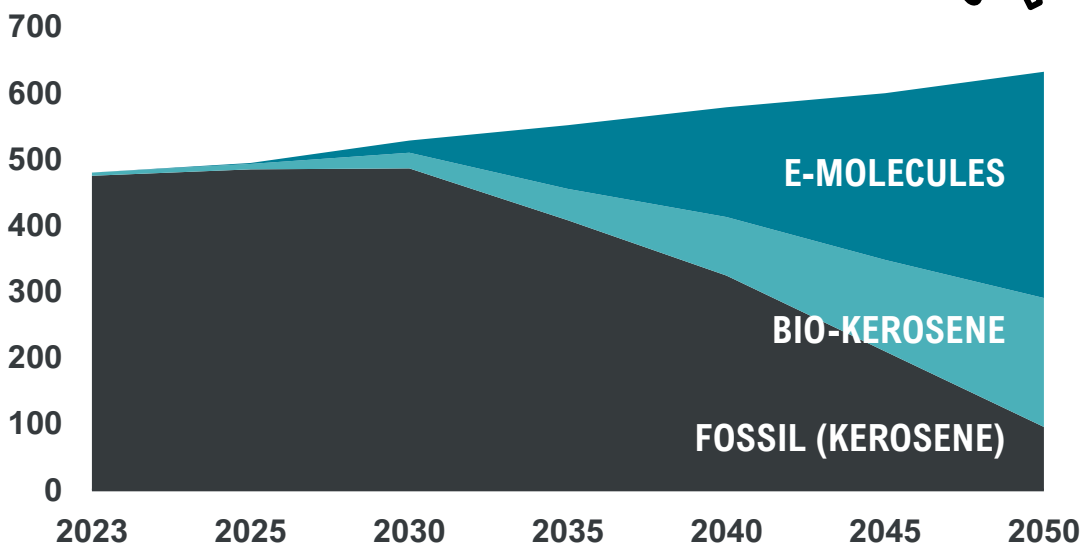
Final energy mix for the industrial sector



MARITIME AND AIR TRANSPORT: GREEN MOLECULES, MAIN VECTOR FOR DECARBONIZATION

Final energy mix





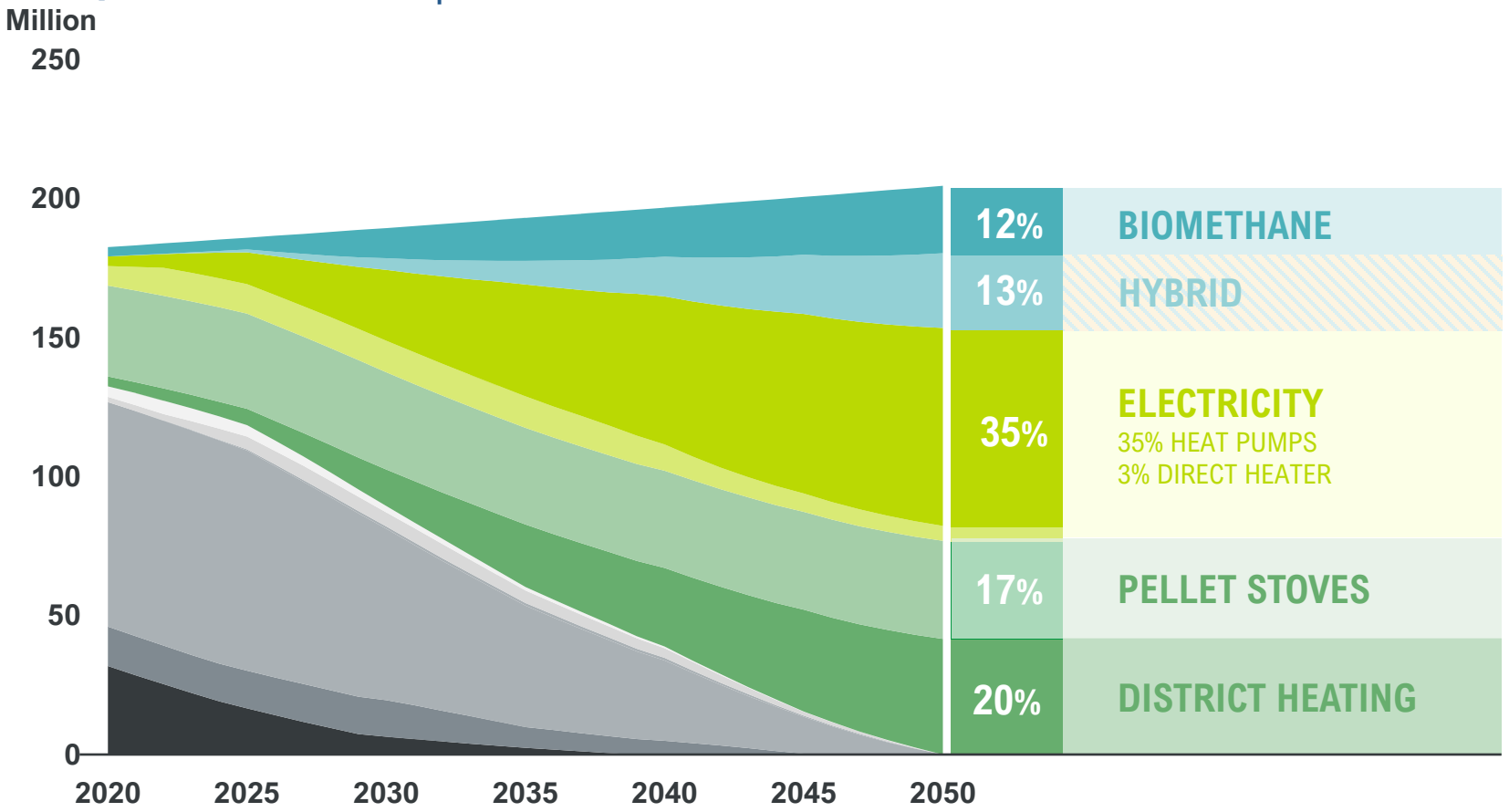
80% EMISSION REDUCTION TARGET ACHIEVED THROUGH USE OF

- e-molecules derived from low-carbon hydrogen
- bio-LNG and bio-diesel for Maritime Transport
- bio-kerosene for Aviation

HFO: Heavy Fuel Oil,
MDO: Maritime Diesel Oil

BUILDING: NEED FOR A RANGE OF SOLUTIONS

European households | Heating solutions



EFFICIENT RENOVATION BY 2050:

0.3 to 1.5% / year
Very strong increase
in the overall rate of renovation

50%
Buildings
fully renovated

Oil & Coal Stove
Heating networks
Gas boilers
Hybrid heat pumps
Heat pumps
Convection heaters
Heating networks
Pellet Stoves
Direct heater
Heat pumps
Hybrid Heat Pumps
Gas boilers (Biomethane)

BUILDINGS: HYBRID HEAT PUMPS NEEDED TO ENSURE SYSTEM RESILIENCE AND TO REDUCE COSTS

STRESS TEST

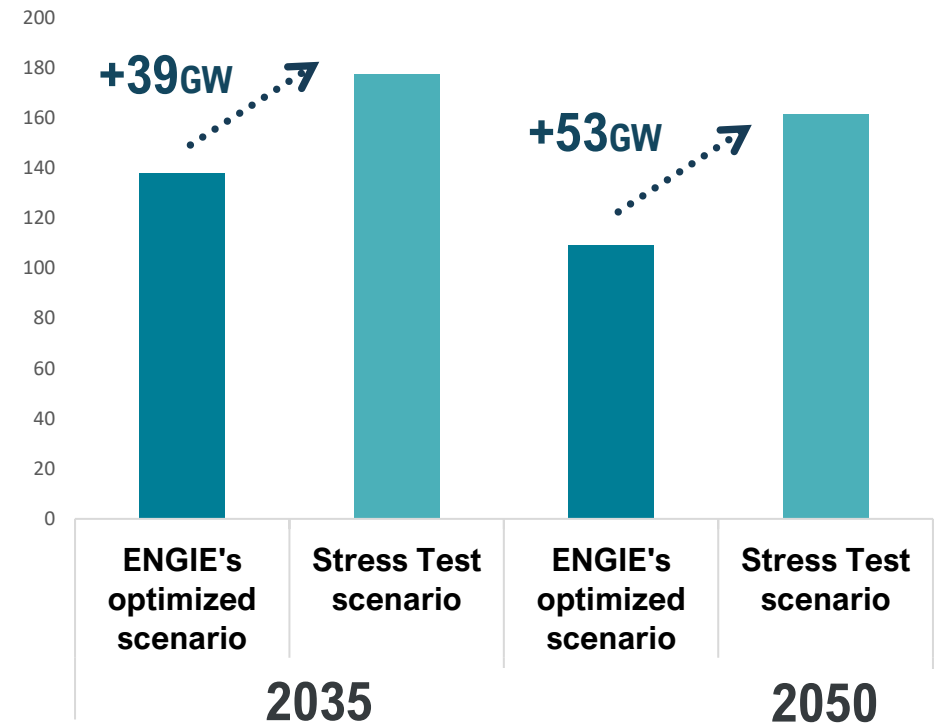
No installation of hybrid heat pumps

Replaced as follows:

- 80% by heat pumps
- 20% by convection heaters

IMPLICATIONS

Contribution of heating to the electric peak



+€11bn/year

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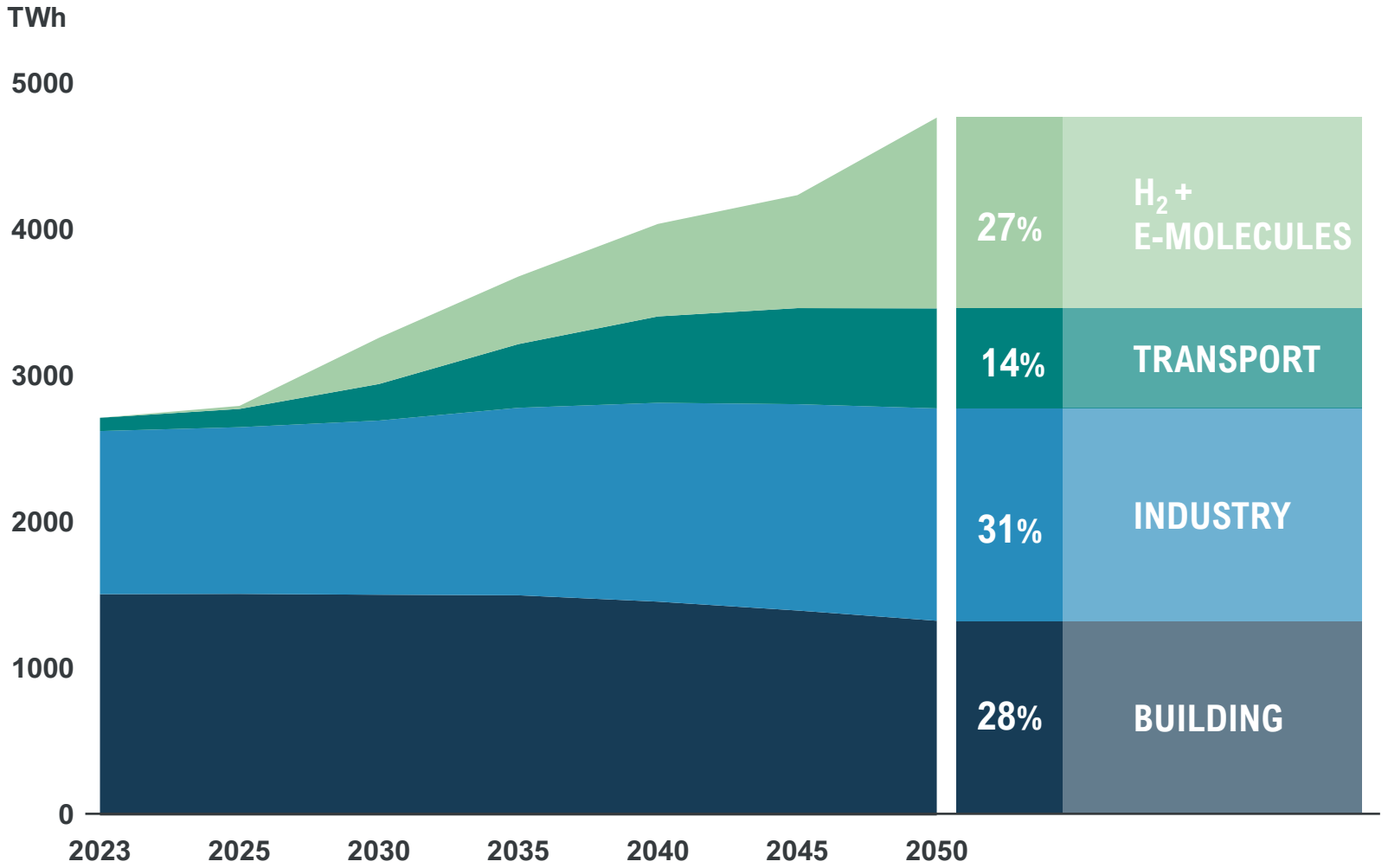
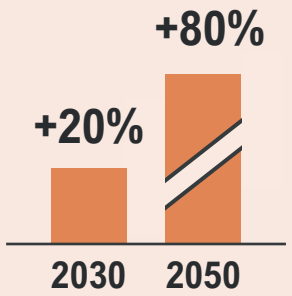
STRONG INCREASE IN POWER DEMAND BETWEEN NOW AND 2050

Power demand



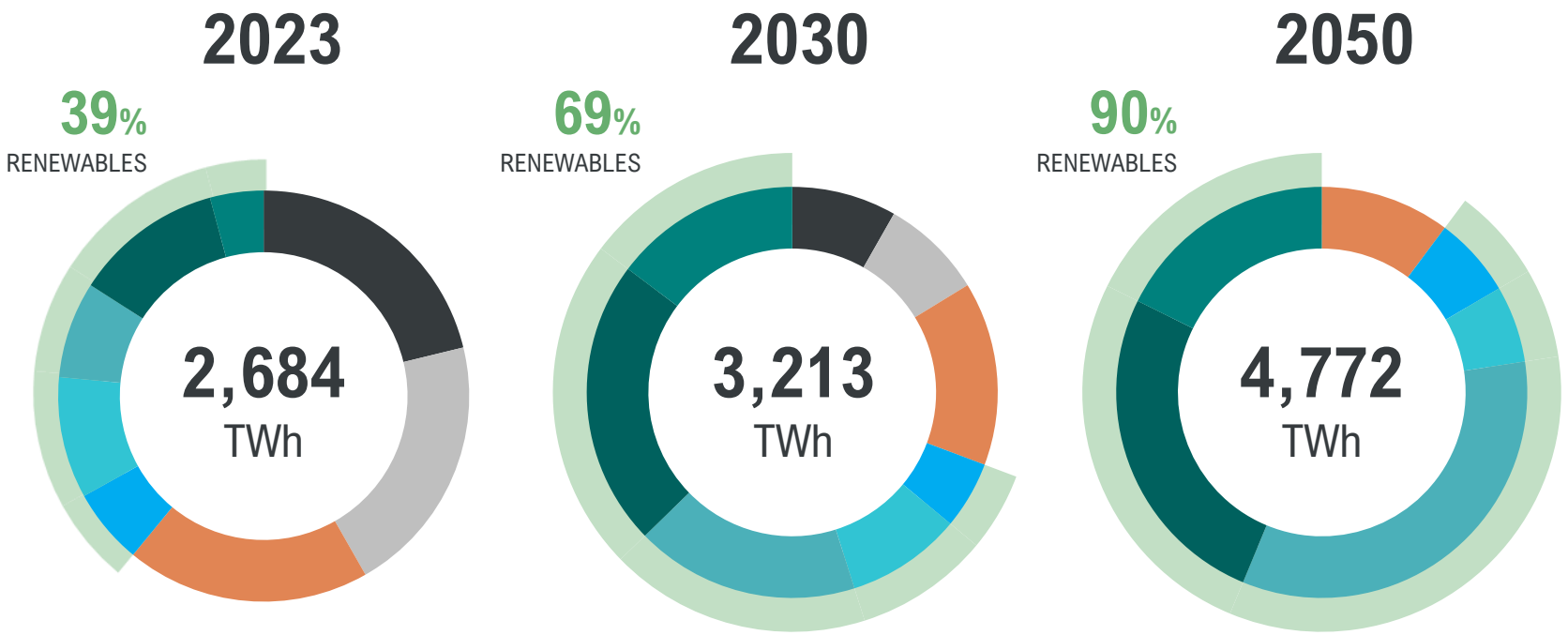
POWER DEMAND WILL INCREASE :



Very strong increase driven by transports and e-molecules

Energy efficiency measures **in industries and buildings** compensate electrification

MASSIVE INCREASE IN RENEWABLE POWER GENERATION



Solar and Wind generation

x6

by 2050

FOSSIL FUELS

- Coal, Lignite & Oil
- Fossil gases

LOW-CARBON EMISSION ENERGY SOURCES

- Nuclear
- Decarbonized thermal
- Hydraulic
- Solar
- Onshore wind
- Offshore wind

RENEWABLES: ACCELERATION CRITICAL TO MEET CLIMATE GOALS AND KEEP COSTS DOWN

STRESS TEST

5-year delay
in developing solar,
wind power
and the associated grid

IMPLICATIONS

“Fit-for-55” targets not reached

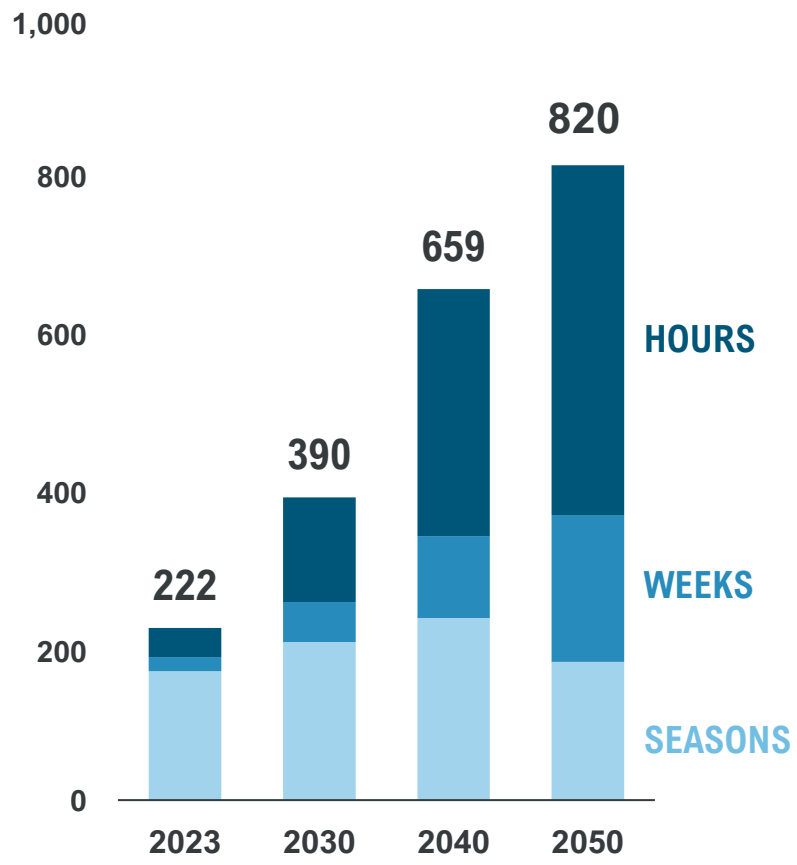
+3Gt CO_2

+€4bn/year until 2050

FLEXIBILITY LEVERS: A NECESSARY COMPLEMENT TO INTERMITTENT RENEWABLE POWER SOURCES

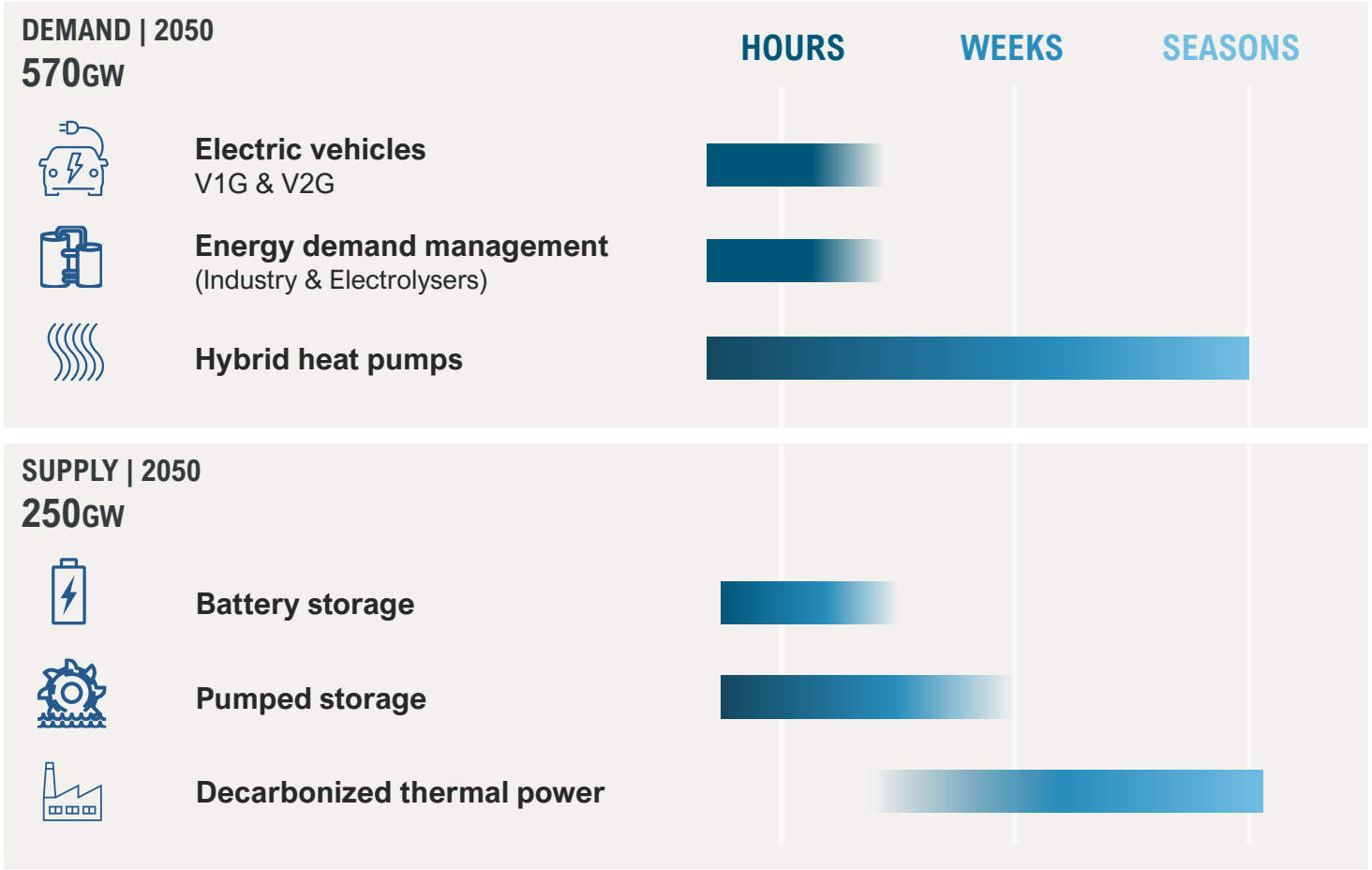
Flexible capacity

GW



Flexibility technologies

Various technologies for meeting specific needs



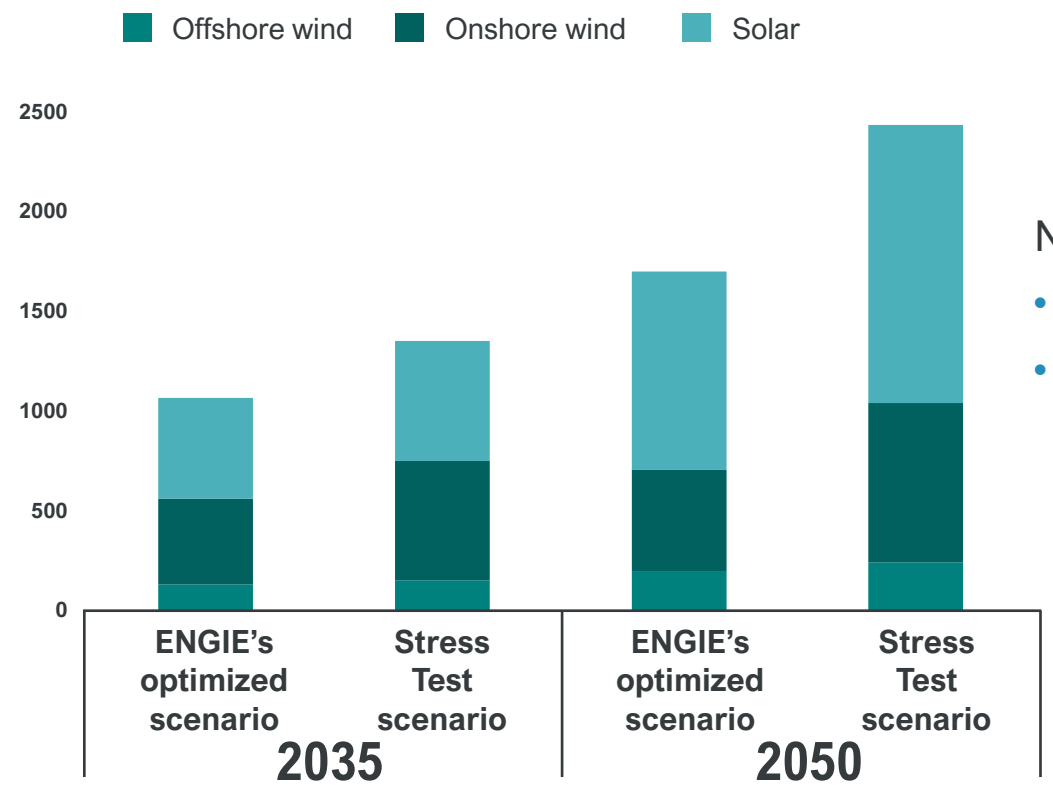
DECARBONIZED THERMAL POWER PLANTS ARE NECESSARY TO ENSURE SEASONAL FLEXIBILITY

STRESS TEST

No additional development of decarbonized thermal (105GW)

IMPLICATIONS

Renewable Energies



Need to install an additional

- **+700 GW of renewables**
- **+200 GW of batteries**

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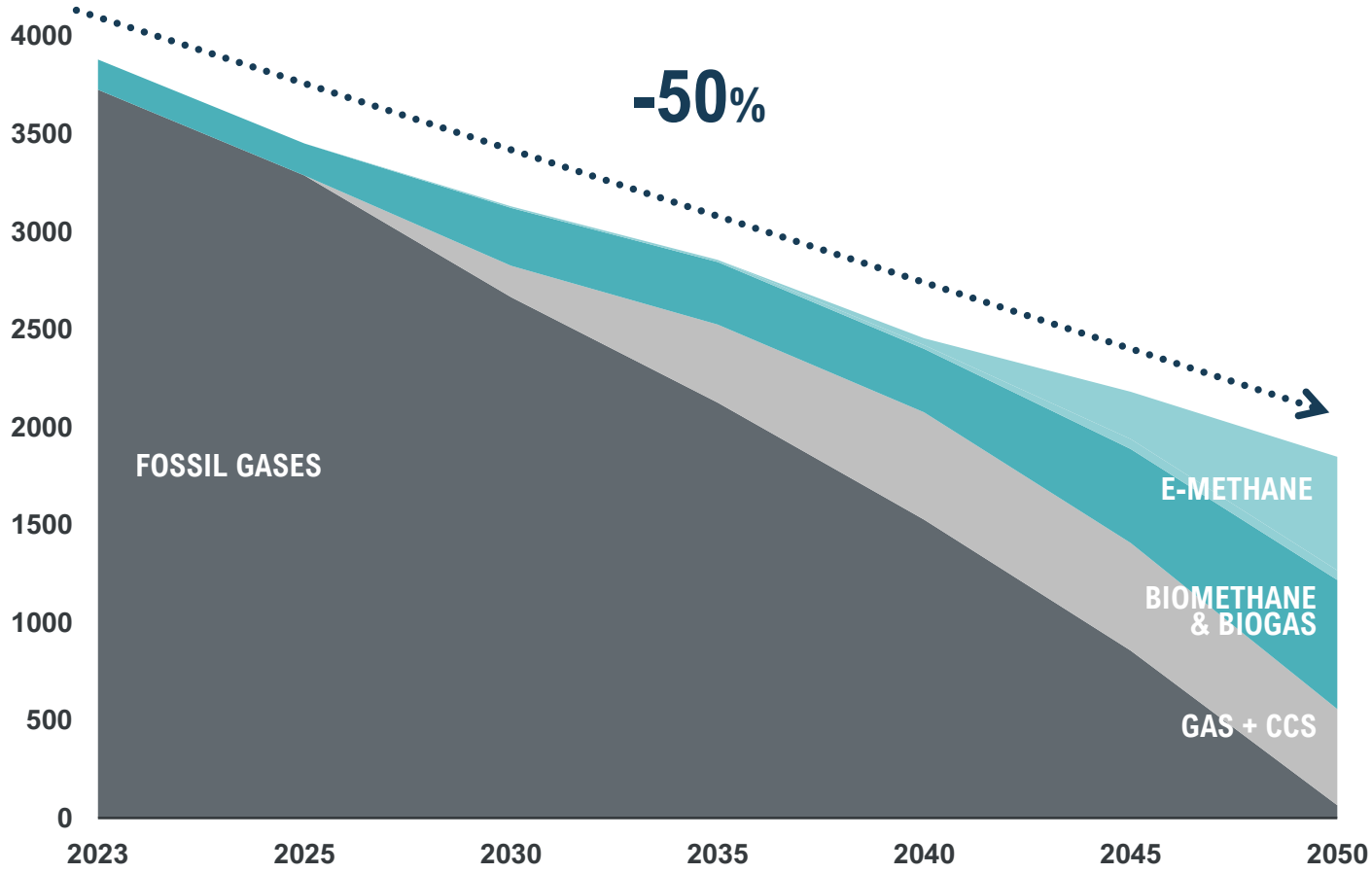
METHANE: DEMAND IS HALVED AND MET BY DECARBONIZED SOURCES BY 2050

Methane demand

TWh



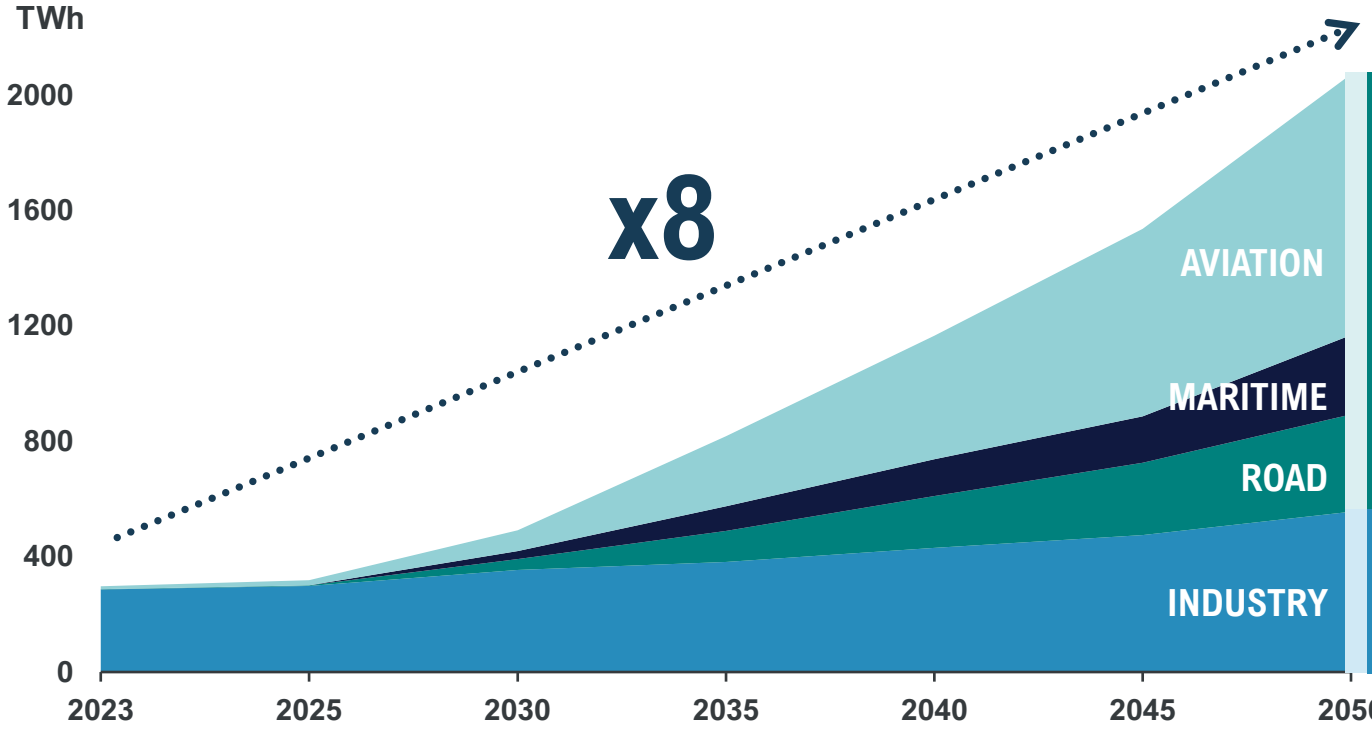
Low-carbon gases needed to reach “Fit-for-55” targets

450TWh

by 2030

HYDROGEN AND E-MOLECULES: DEMAND DRIVEN BY HEAVY-DUTY TRANSPORT AND INDUSTRY

Sectors of the hydrogen economy

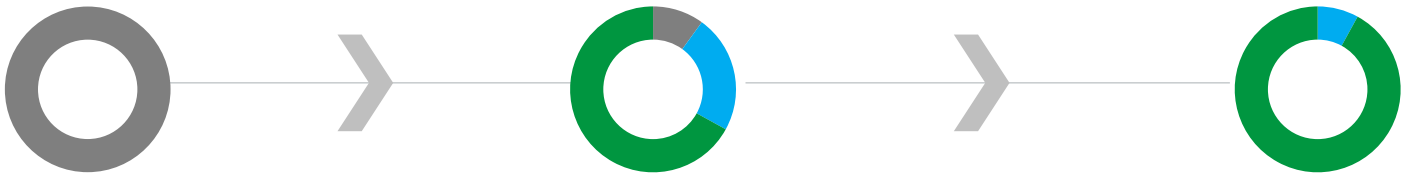


TRANSPORT

75% of the hydrogen demand, through e-molecules[1]

25% used for industrial sectors that are difficult to decarbonise (**steel and high temperature**)

Half of hydrogen demand locally produced in 2050



H_2 mix

Gray Blue Green

[1] e-ammonia, e-methane, e-methanol, e-kerosene, e-diesel

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ENERGY INFRASTRUCTURE: AN ESSENTIAL LEVER FOR SUCCESSFUL DECARBONIZATION

ELECTRICITY
Investments significantly increase until 2040

Cross-border interconnections
+€2 bn/year

Transport and distribution associated with increasing electrification
+€21 bn/year

Charging infrastructure for transport
+€16 bn/year

METHANE & HYDROGEN
Rely on existing infrastructure

Adaptation of part of the network to hydrogen and construction of new corridors
€2 bn to €8 bn/year

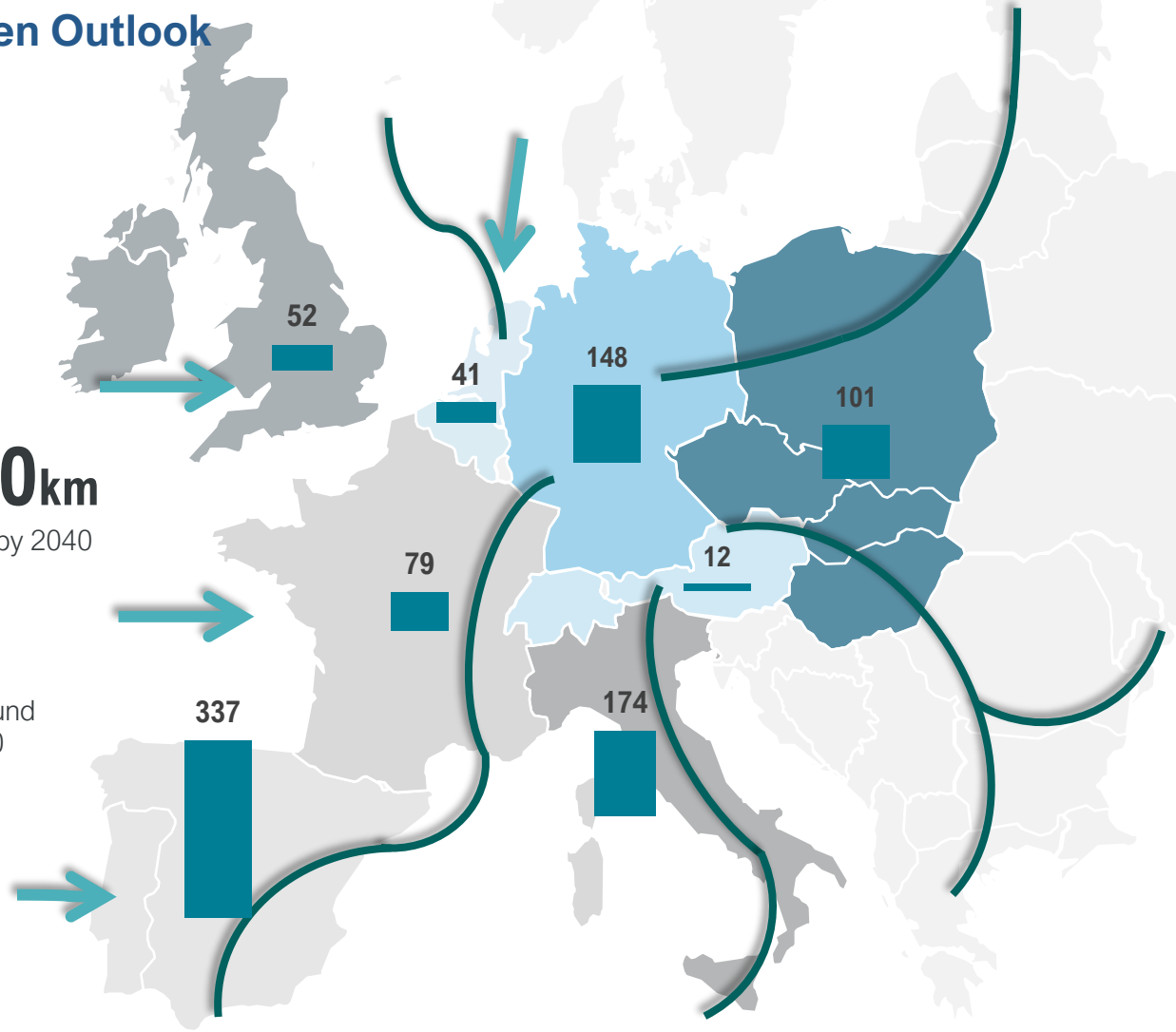
Modernisation of the network to incorporate low-carbon gases
+€1.5 bn/year

The electricity infrastructure allows the deployment of renewable energies
The gas infrastructure plays a crucial role in meeting demand peaks and making the energy system more flexible

H_2 BACKBONE DELIVERS FLEXIBILITY TO THE EUROPEAN ENERGY SYSTEM AND ENSURES COMPETITIVENESS OF EUROPEAN PRODUCTION

Hydrogen Outlook

TWh, 2050



53,000km
of H2 transport by 2040

24TWh
of H2 underground storage by 2050

STRESS TEST

No pan-European development of hydrogen cross-border transport and underground storage infrastructures

IMPLICATIONS

+€5.7bn/year

+26%
in local hydrogen production costs

-182TWh
in EU hydrogen production

CONTENTS

A BALANCED ENERGY MIX HAS MULTIPLE BENEFITS

NET ZERO ACHIEVED

Alignment with European targets

No technological gamble

Balance between contributions from the various sectors

OPTIMIZED COST

Use of a wider range of competitive decarbonization options

Better use of existing infrastructure / facilities

Optimization at the European and global level through carefully considered imports

INCREASED RESILIENCE

Diversified mix providing insurance against industrial risks

Optimization of flexibility solutions

Enhanced reliability of the energy system

KEY RECOMMENDATIONS

Guillaume Gillet
Group Public Affairs VP

MOVING FASTER ON ENERGY TRANSITION : RECOMMENDATIONS

1/ ACT ON ENERGY DEMAND & PROMOTE THE ENERGY EFFICIENCY FIRST PRINCIPLE

2/ ENSURE SECURITY OF SUPPLY IN A EUROPEAN PERSPECTIVE

- Take advantage of the **integrated European energy market** and promote **cross-border benefits**
- Leverage **system integration and synergies between all energy vectors,** for a cost-efficient system adequacy and reliability

3/ ACCELERATE DEVELOPMENT OF RENEWABLE ENERGY FOR THE BENEFIT OF ALL CONSUMERS

- Stabilize the **investment framework, including long-term price signals (PPAs, CfDs)**
- Facilitate and speed up grid **connections** and **permitting**
- Support **development of a liquid market for EU Guarantee of Origins**, for all energies and across geographies

4/ PROMOTE FLEXIBILITY ON THE DEMAND & SUPPLY SIDES

- Integrate renewable energy efficiently with **different sources of flexibility**: demand response, batteries, decarbonized thermal…
- Ensure **appropriate remuneration models** for firm capacities and flexible assets

5/ DEVELOP RENEWABLE & LOW CARBON MOLECULES

- Provide perspectives with a **European target for biomethane (35 bcm)** by activating all levers with effective **support mechanisms**
- Take action **throughout the hydrogen value chain**
- Adopt swiftly a **cost-efficient H_2 regulatory framework** leveraging on existing governance, infrastructure and skills
- Ensure that **appropriate funding mechanisms** are granted quickly and that **H_2 conversion** of gas infrastructure is financed

QUESTIONS / ANSWERS

BUILDING DECARBONIZATION PATHWAYS FOR EUROPE

ENGIE'S SCENARIO

SEPTEMBER 21, 2023

DISCUSSION

Sasha Twining
Moderator

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MEP, ITRE Committee

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Andris Piebalgs
Professor at EUI, former Energy Commissionner

Claire Waysand
Corporate Secretary – ENGIE

BUILDING DECARBONIZATION PATHWAYS FOR EUROPE

ENGIE'S SCENARIO

SEPTEMBER 21, 2023

QUESTIONS / ANSWERS

CONCLUSION

Claire Waysand
Corporate Secretary– ENGIE

APPENDICES

GROWTH IN RENEWABLES, INSURANCE AGAINST THE CHALLENGES FACED BY NUCLEAR POWER IN FRANCE

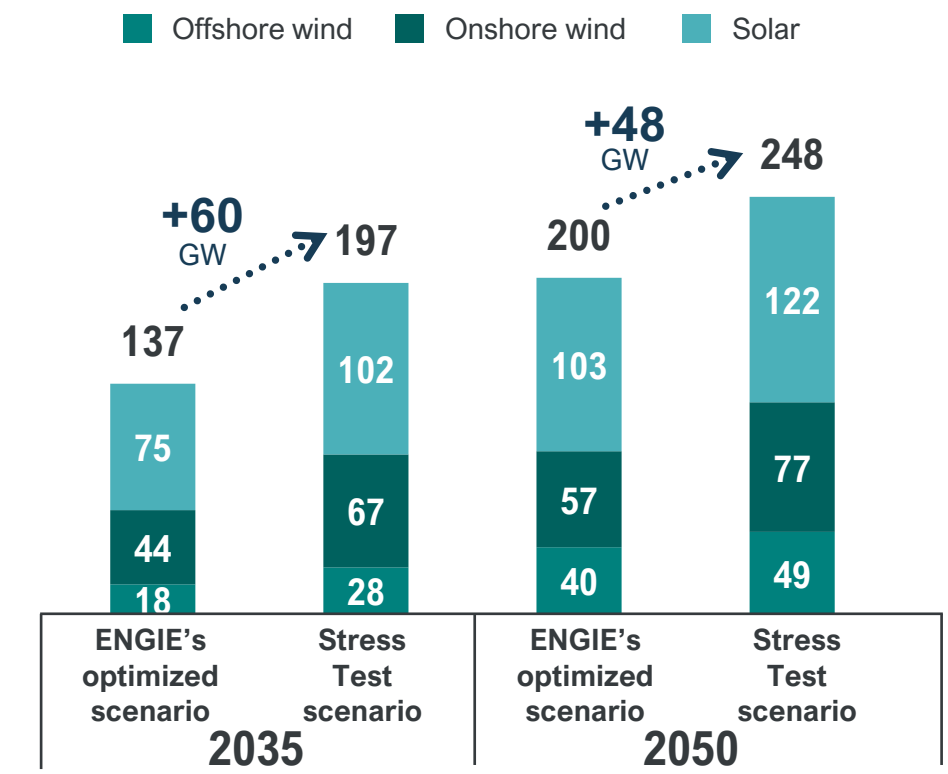
STRESS TEST

Lower availability of nuclear power

5-year delay in building new EPRs
(10 EPRs in 2050)

IMPLICATIONS

Installed renewable power capacity
GW



Additional renewable power generation **will ensure climate targets are met**

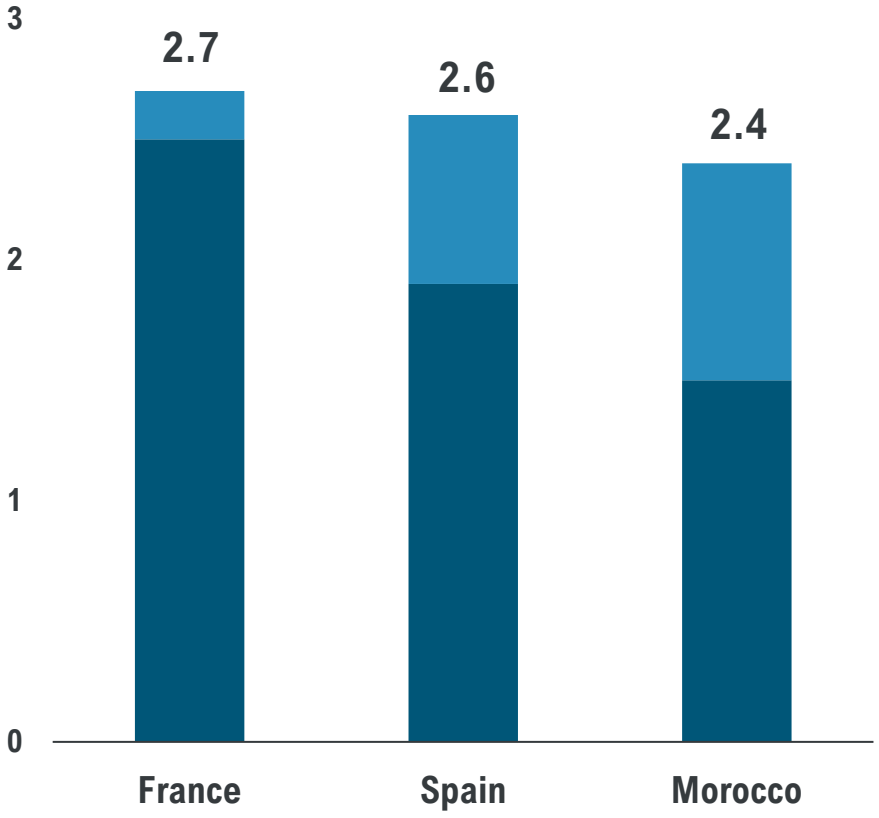
ASSUMING THE STRESS TEST DOES NOT MATERIALIZE

- Limited additional costs: **€2bn/year**
- Additional emissions avoided: **320Mt CO_2e**
- **Accelerated development** of green hydrogen and e-molecules

IMPORTED H_2 & E-MOLECULES LIKELY CHEAPER THAN LOCAL PRODUCTION

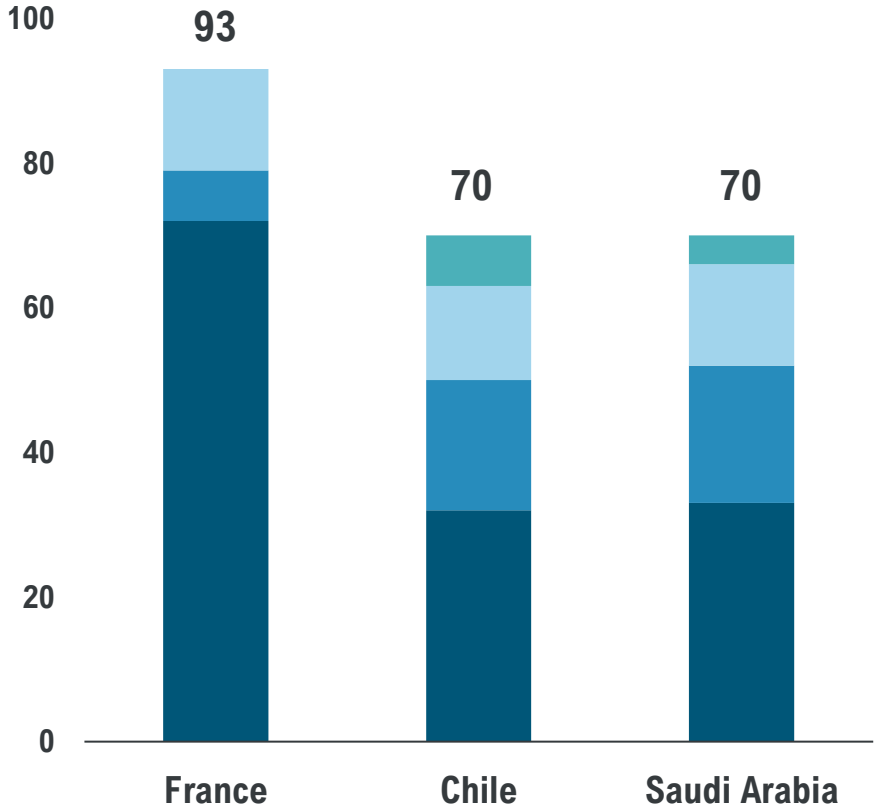
Hydrogen production & imports costs

$€_{2021}$/kg H_2 , 2040



Ammonia production & imports costs

$€_{2021}$/TWh NH_3 , 2040



H_2 Production | H_2 Storage & Pipeline | Conversion to NH_3 | Shipping

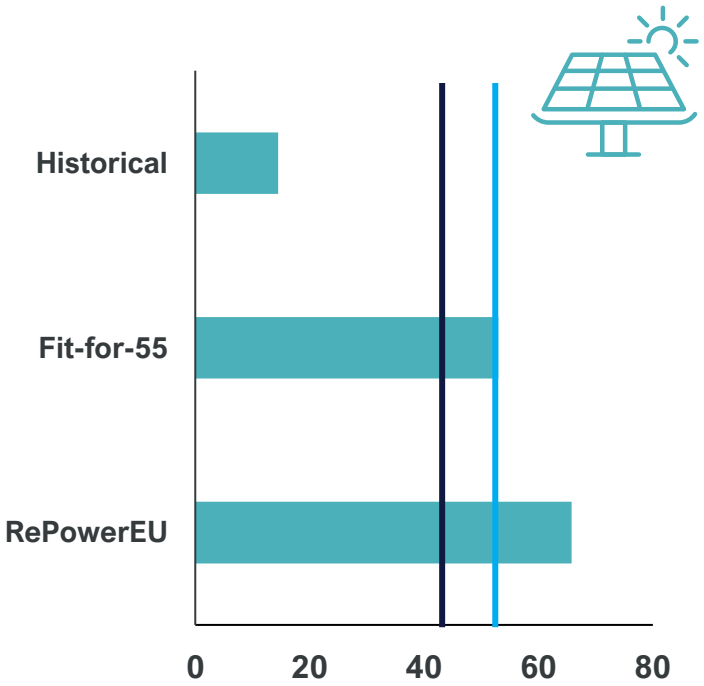
AN ACCELERATION IN RENEWABLE POWER GENERATION BETWEEN NOW AND 2030

Average annual increase in capacity by technology between 2023 and 2030

Current pace — Projected needs

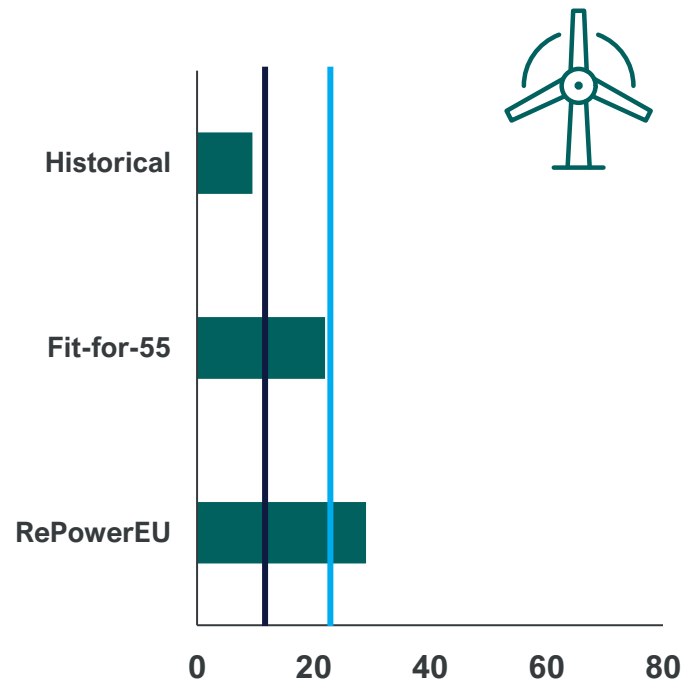
Solar

GW



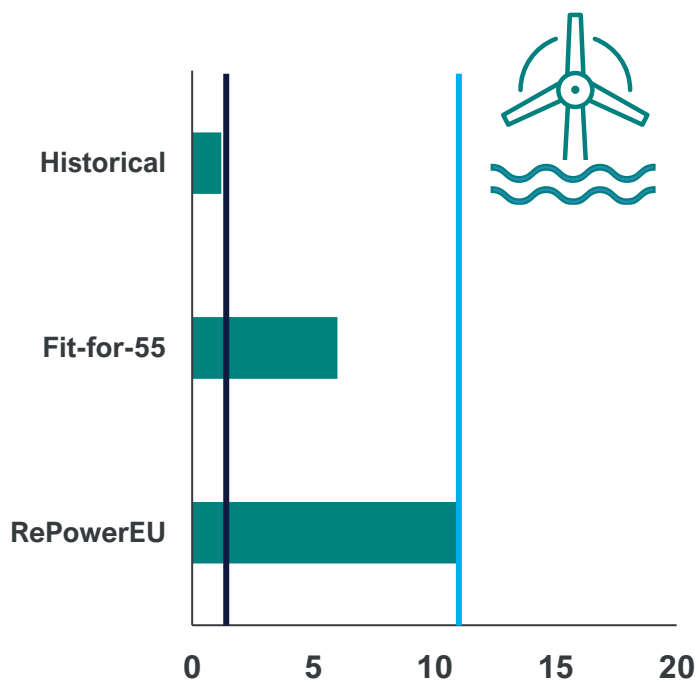
Onshore wind

GW



Offshore wind

GW



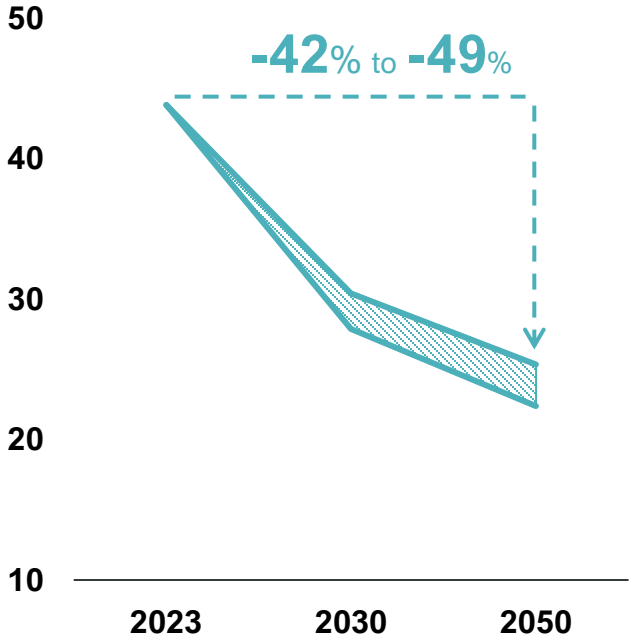
Overview of EU-27 targets (**Repower EU**): 592GW of solar power and 510GW of wind power, of which 95GW offshore.
History based on the 2010-2022 average (S&P data), excluding the UK.

RENEWABLES COMPETITIVENESS WILL BE BOOSTED OVER THE NEXT FEW YEARS, WITH THE MAIN COST REDUCTIONS COMING FROM OFFSHORE WIND

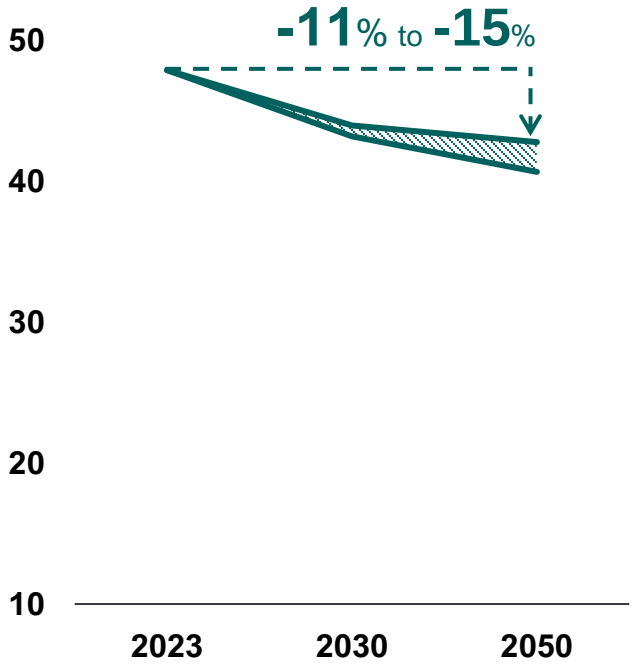
Levelized cost of electricity

MWh

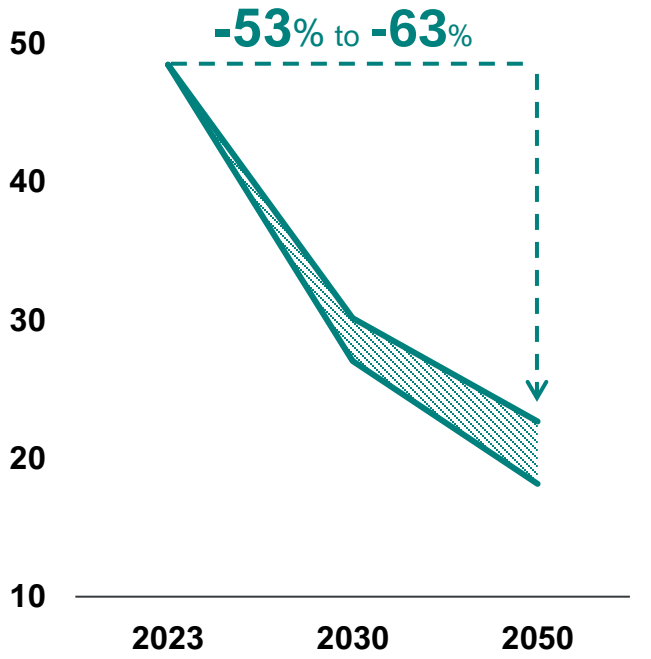
PV



Onshore wind



Offshore wind



Source: IEA World Energy Outlook 2022

GAS BANS IN THE HEATING SEGMENT

Germany

Regulation and Market situation

- The Green (currently in power) has drafted a law which would **exclude the installation of gas boilers in both new and renovated buildings from 2024**. The liberals are however fighting against such prompt and structuring initiative. (source March 2023)
  - Hybrid HP will be allowed. (source April 2023)
  - Discussion is still on going

United Kingdom

Regulation and market situation

- From 2025 : **ban of gas boilers on new built homes** ("government will consult on ending new connections to the gas grid")
- From 2035 : aim to **phase out gas boilers in existing homes** → new boilers installed will need to be "low carbon"
- Major strategic decisions on the **role of Hydrogen for heat** to be taken by 2026 (still not considered in our scenarios)

Source: UK Heat and Buildings Strategy

Netherlands

Regulation and market situation

- While a gas ban in new buildings is already on going (source), a gas ban in **renovated buildings** will also be set in motion **from 2026**. The Netherlands plans on installing a fair share of HPP, especially in existing buildings. (source)
- the government plans on having its heat production in the buildings sector coming **from full power HP (1/3), HHP (1/3) and collective systems (1/3).** (source)

Insight from the OneRetail Dutch Marketing&Strategy team: Paul Van Velzen and Peter Van Dijk

Belgium

Regulation and market situation

- Flanders: **Gas ban in new build from 2025** has been announced, the **ban includes hybrid HPs**. Flanders represents ~60% of dwellings in Belgium (source)
- **Brussels**: more subsidies will be given the HP and HHP and subsidies for efficient gas boiler (condensing gas boiler) will stop. Brussels represents ~10% of dwellings in Belgium. (source)

Insight from the OneRetail Belgian Marketing&Strategy team: Arnaud Devleesschauwer and Nicolas Rorive

Romania

Regulation and market situation

- While the European Commission has high electrification objective for the entire European Union. Romania similarly to all Eastern European is struggling to meet this EU target.
  - Congestion issue from the power grid
  - The country instead of reinforcing the power grid has set market design incentives for household to be connected to the gas distribution network.
  - In rural area, households are switching from wood pellets towards gas boilers
  - In urban area, households are switching from DH towards gas boilers
  - Household Purchasing Power as a barrier to Heat Pumps
  - Currently **gas boiler** market share is close to **90%**

Insight from the OneRetail Romanian Strategy&Marketing team : *Victor Manoliu, Ileana Naum and others.*

Italy

Regulation and market situation

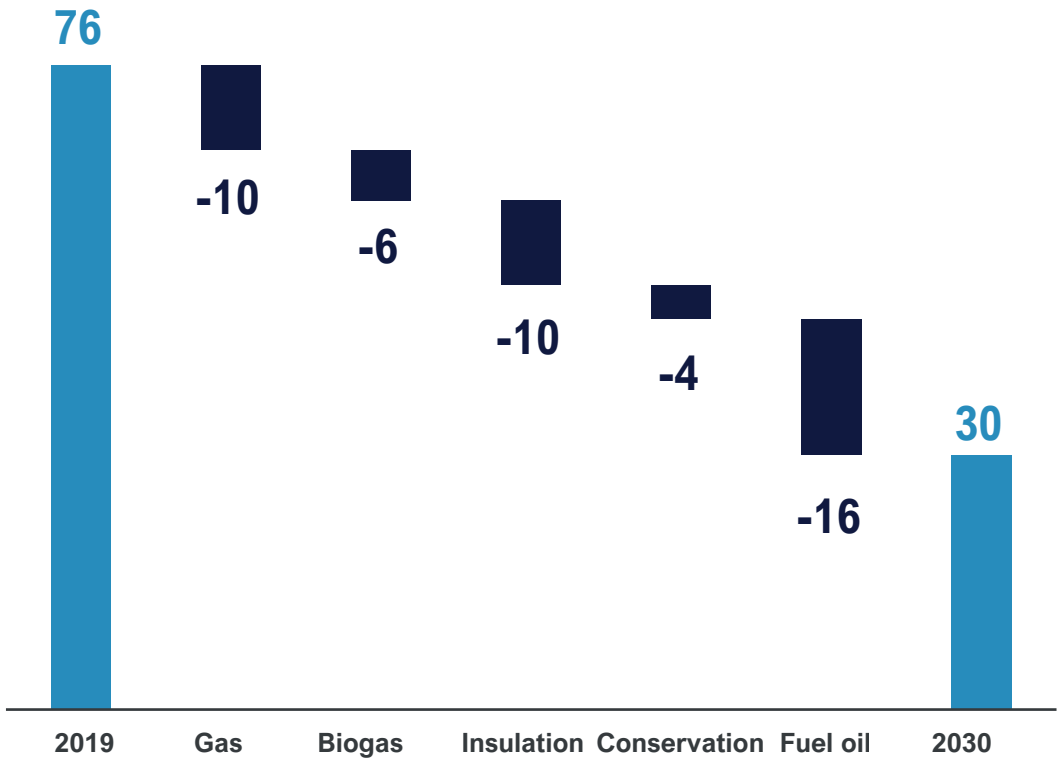
- Current government in power (conservative) are not pushing electrification and the rate at which HP are developing does not meet the target. (30K unit last year sold)
  - In the market, it is observed that the sales of gas boilers has surged (including for ENGIE)
  - Since subsidies to install HP has stopped, the number of HPs installed has drastically decreased

Insights from OneRetail Italy Marketing Director: *Amaury Lamarche*

BUILDINGS: ENGIE'S OPTIMIZED SCENARIO TO REACH THE GOVERNMENT'S TARGET OF 30 MT CO_2E IN 2030

Levers for reduction of greenhouse gas emissions in buildings

Mt CO_2e, 2030



1. Replacement of gas boilers at end of life with hybrid heat pumps in individual houses (1.5 million by 2030) and by Very High Energy Performance equipment in apartment blocks and the tertiary sector (1.5 million by 2030). Installation of electric heat pumps for "boiler backup" (1.5 million by 2030)
   → **-10Mt CO_2**

2. Greening of gas for buildings (30TWh of renewable gas)
   → **-6Mt CO_2**

3. Building renovation
   → **-10Mt CO_2**

4. Energy conservation, 5% reduction in consumption
   → **-4Mt CO2**

5. Phasing out 75% of oil-fired boilers (SNBC trajectory)
   → **-16Mt CO_2**

BIOMETHANE POTENTIAL : AGRICULTURE COULD PROVIDE A LARGE SHARE OF THE FEEDSTOCK

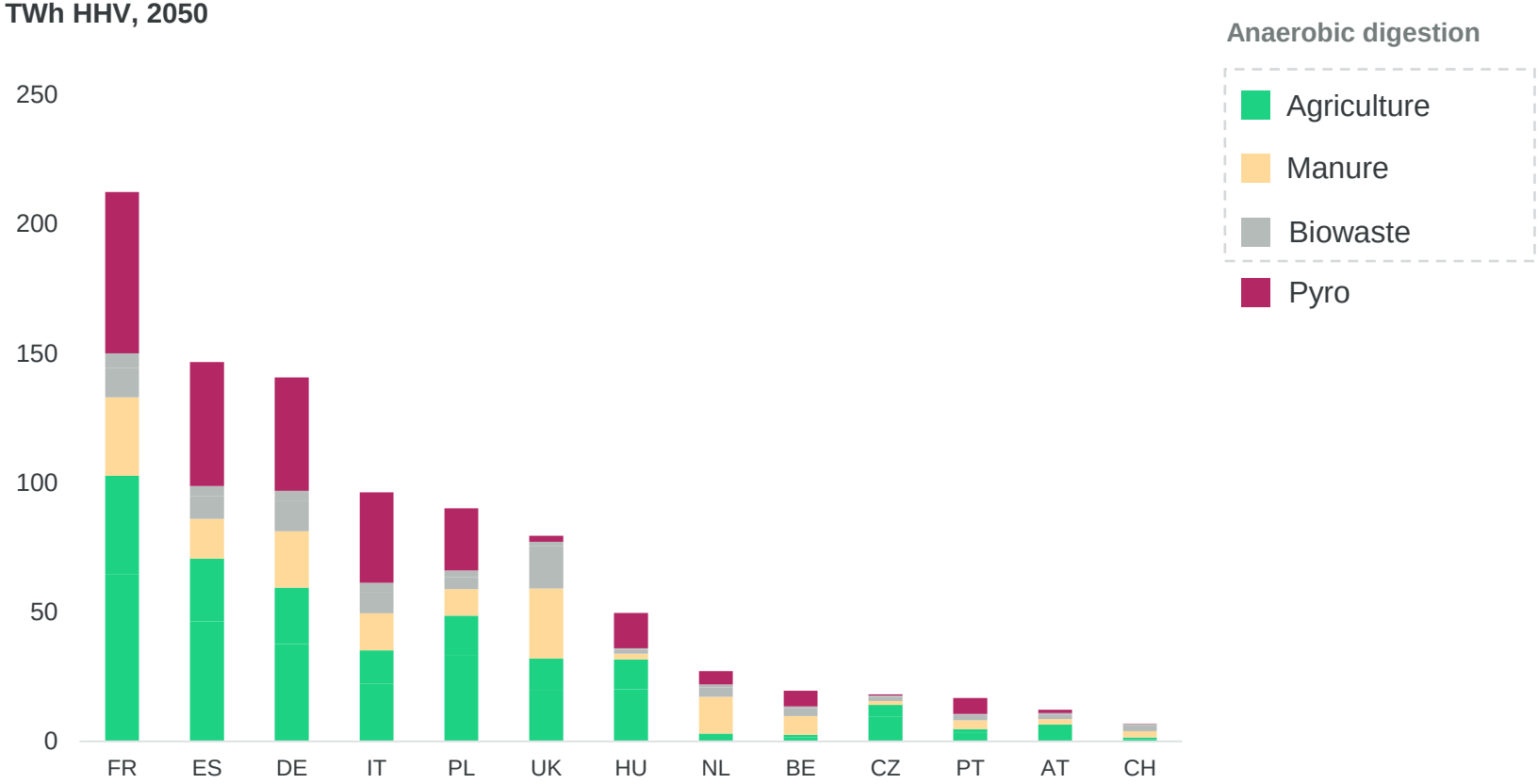
83%

of EU15 potential used for biomethane in 2050

- 884 TWh HHV of biomass are available through anaerobic digestion and pyrogaseification
- **Anaerobic digestion**
  90% from agriculture and manure
  10% from industries and households
- **Pyrogaseification** : waste wood, agroforestry and solid waste provide key additional resources

Zoom on biomethane potentials

TWh HHV, 2050



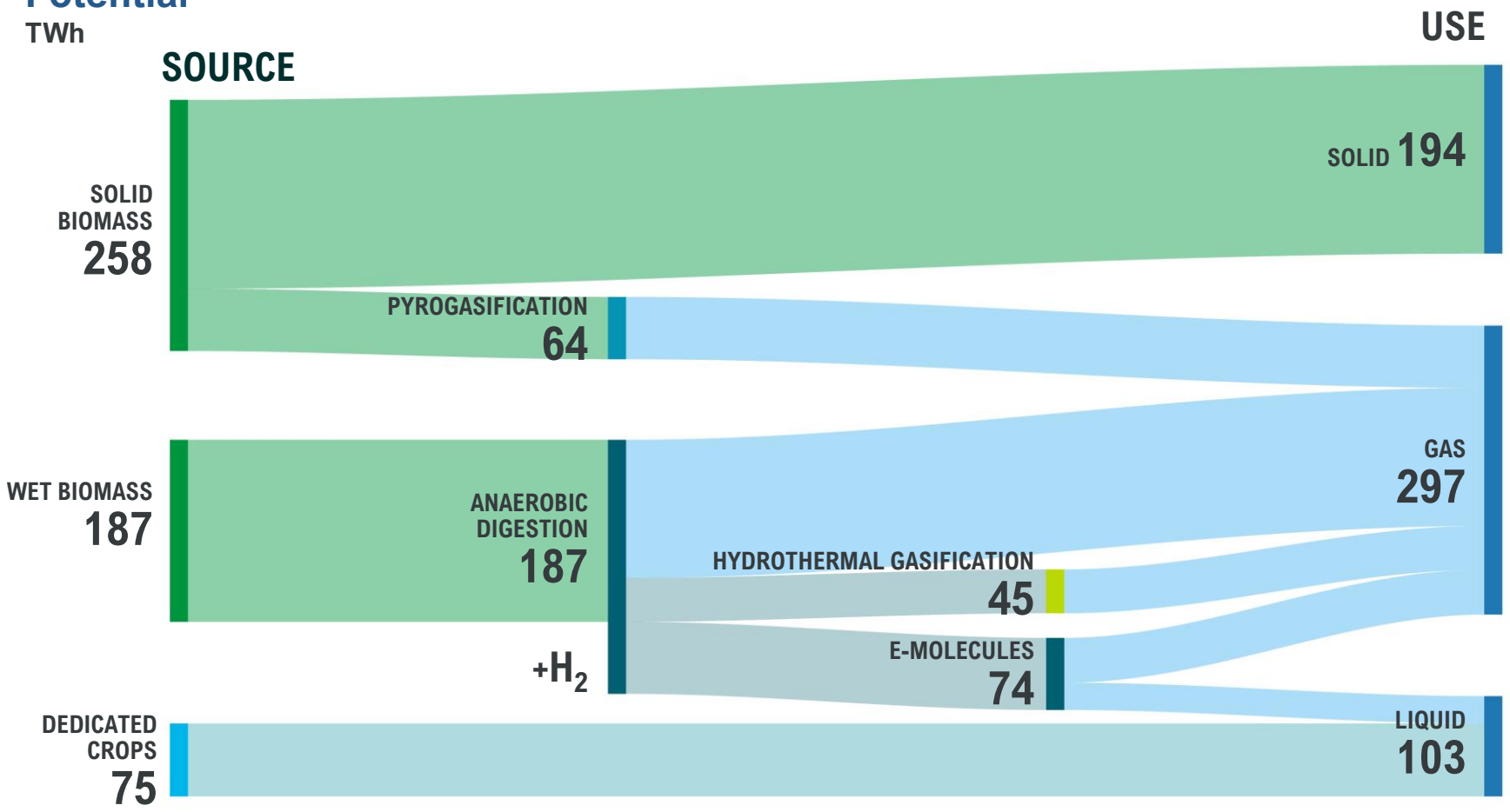
ENGIE scenario reflects IPCC's "Middle of the road"' (RCP 4.5)

***Biomethane potential** : amount of gas that can be produced from available biomass [for AD : after non-energy uses, for pyro : after non-energy uses and combustion]*

BIOMASS: SUFFICIENT RESOURCES EXIST TO MEET PROJECTED NEEDS

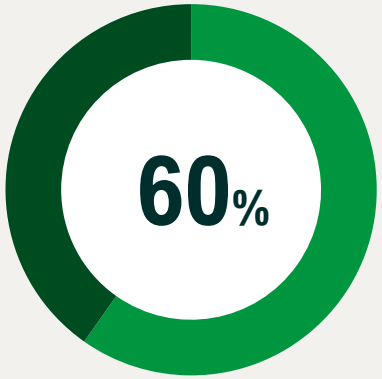
Potential

TWh



Sources: ADEME, IGN and INRAE, IPCC & France Agrimer

USE OF TOTAL BIOMASS POTENTIAL 2050

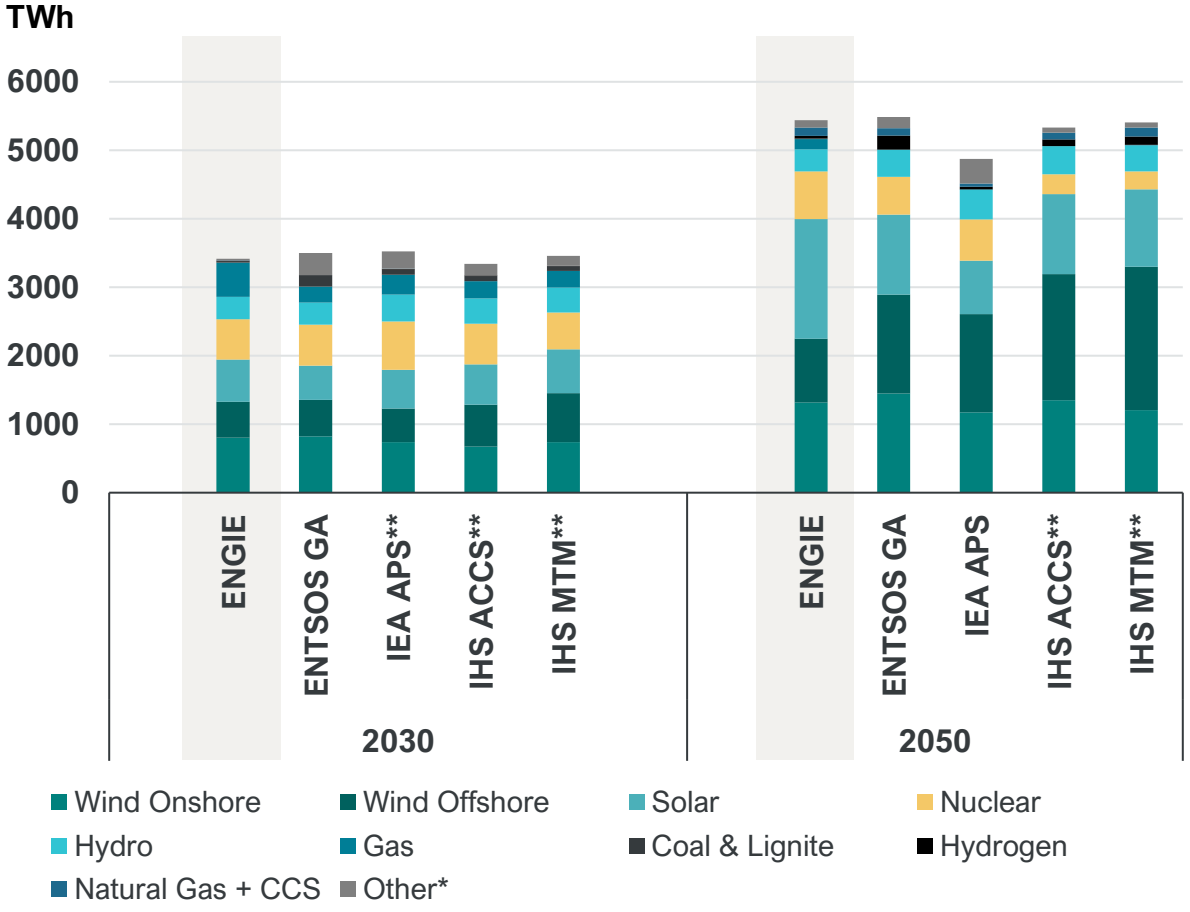


Mobilized in ENGIE's optimized scenario

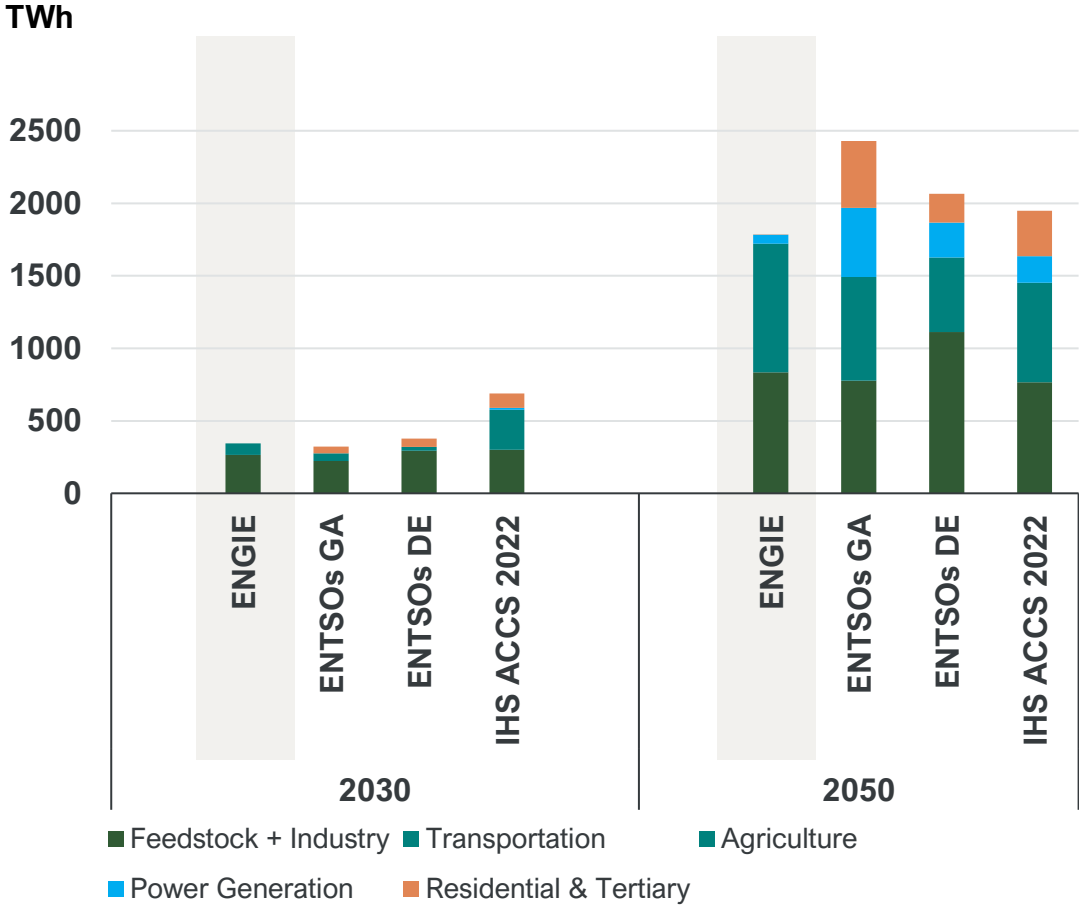
Estimated potential including the effects of climate change

COMPARING ENGIE'S DECARBONIZATION PATHWAY WITH OTHER BENCHMARKS: POWER GENERATION AND HYDROGEN DEMAND IN EUROPE

Power Generation



Hydrogen Demand by Sector

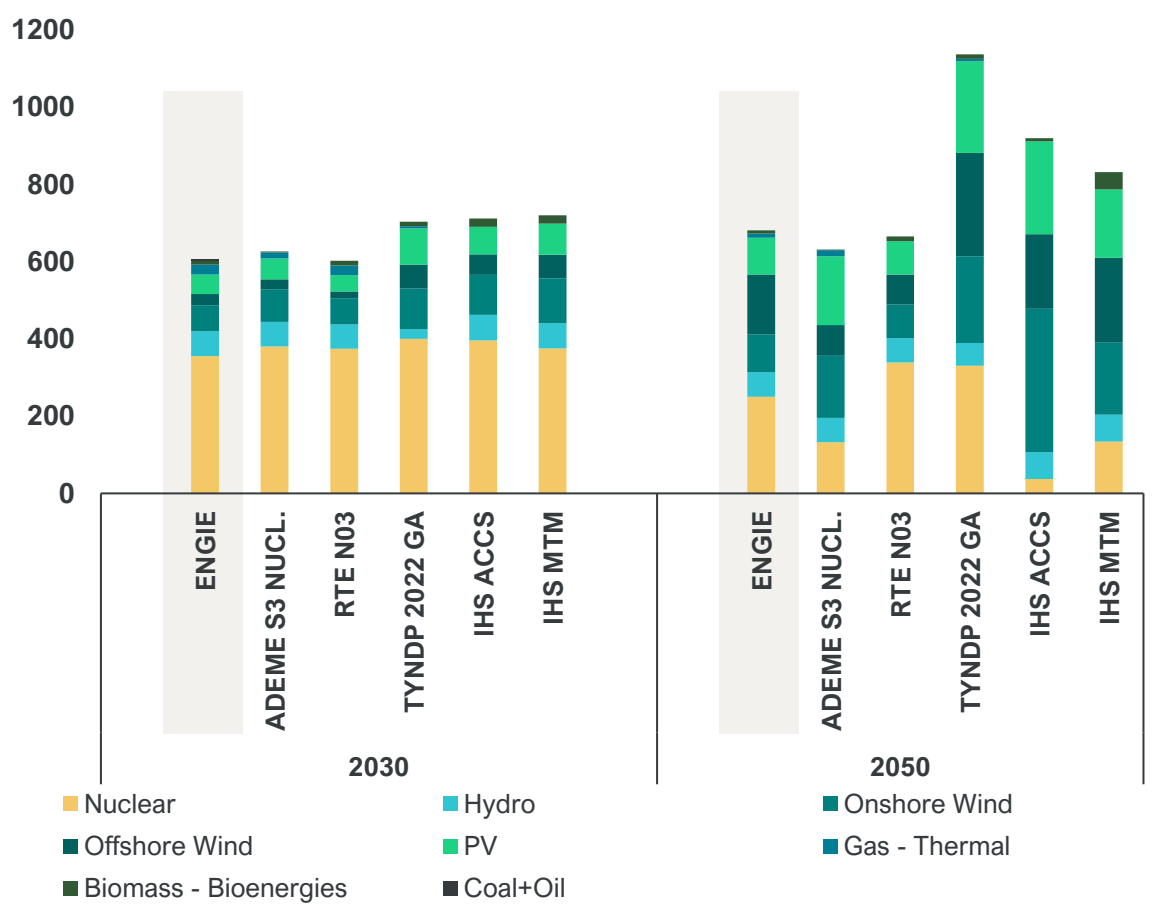


* Other non-renewable, other renewable, geothermal.

COMPARING ENGIE'S DECARBONIZATION PATHWAY WITH OTHER BENCHMARKS: POWER GENERATION AND METHANE SUPPLY IN FRANCE

Power Generation

TWh



Gas supply

TWh