

BUILDING DECARBONIZATION PATHWAYS FOR EUROPE

ENGIE'S SCENARIO



JUNE 12, 2023

OUR 5 BELIEFS

1

Activate all possible levers
for decarbonization

4% / annual reduction in emissions

To achieve « Net zéro » 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

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- 3** All levers are required to achieve decarbonization
 - 3.1** The challenges of mass electrification
 - 3.2** The key role of decarbonized gases
 - 3.3** The major importance of infrastructure
- 4** Conclusions & recommendations



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AN ANALYSIS DERIVED FROM GLOBAL EXPERIENCE

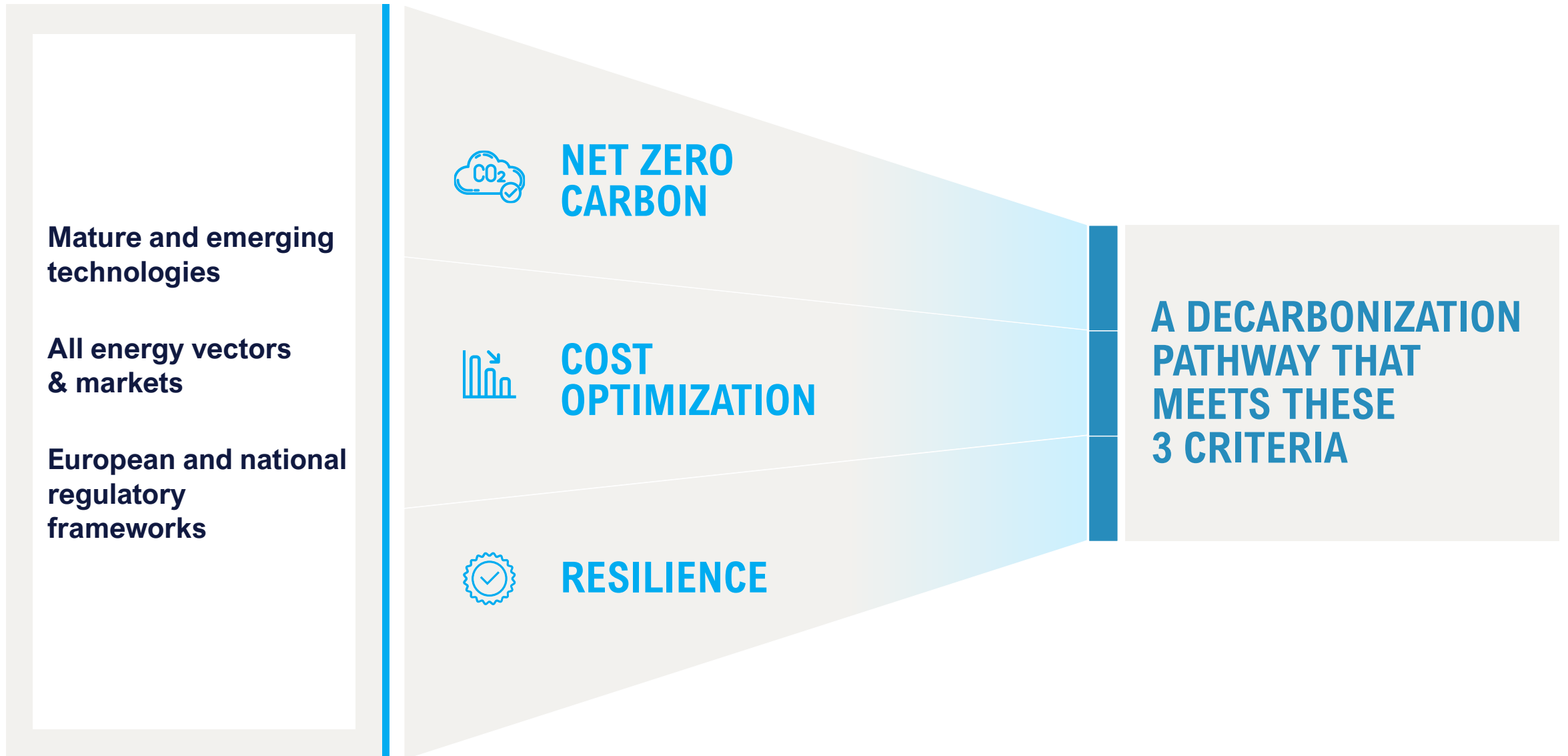
ALL LEVERS OF DECARBONIZATION



AN INTERNATIONAL FOOTPRINT



A PRAGMATIC APPROACH TO DECARBONIZATION



A ROBUST METHODOLOGY



A European vision

- Modelling of **15 European countries**, with their strongly interconnected energy systems



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 reliability 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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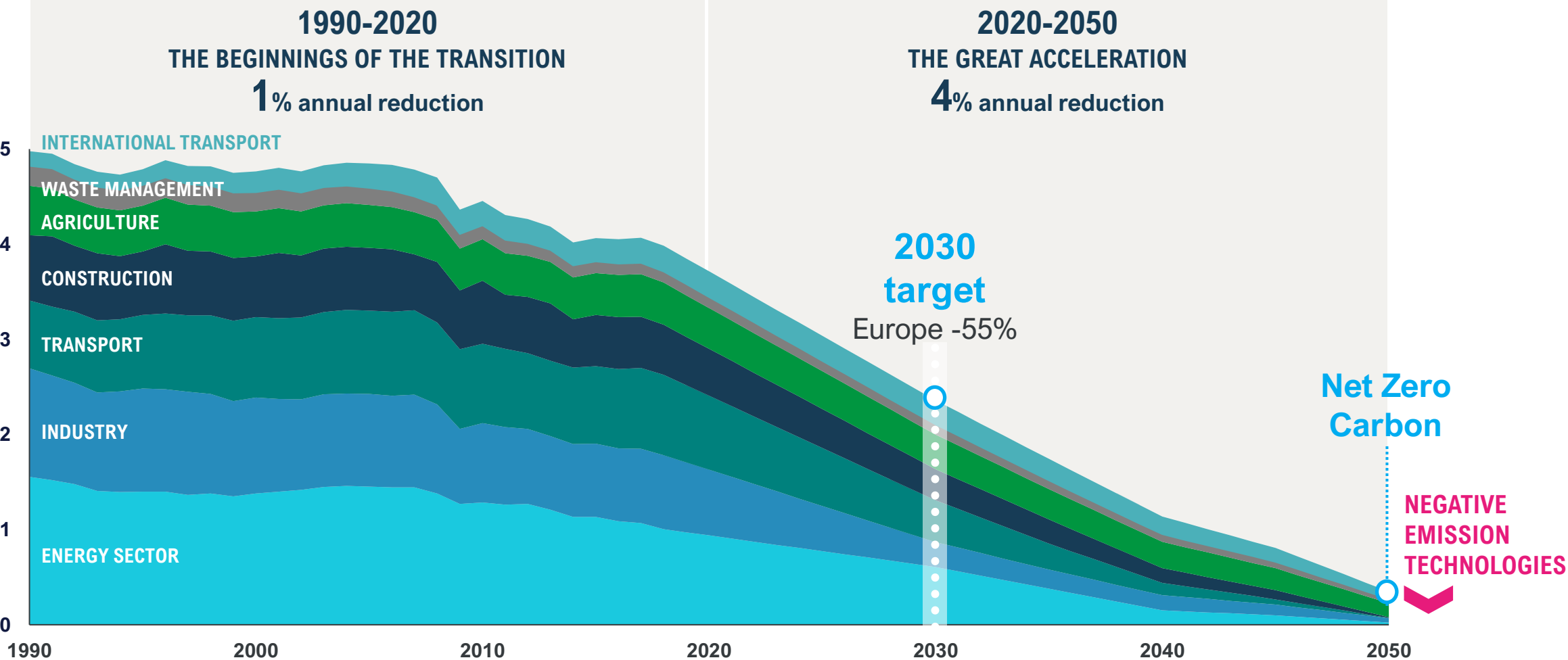




A NECESSARY INCREASE IN EMISSIONS REDUCTION EFFORTS

Greenhouse gas emissions

CO₂e, Gt / year

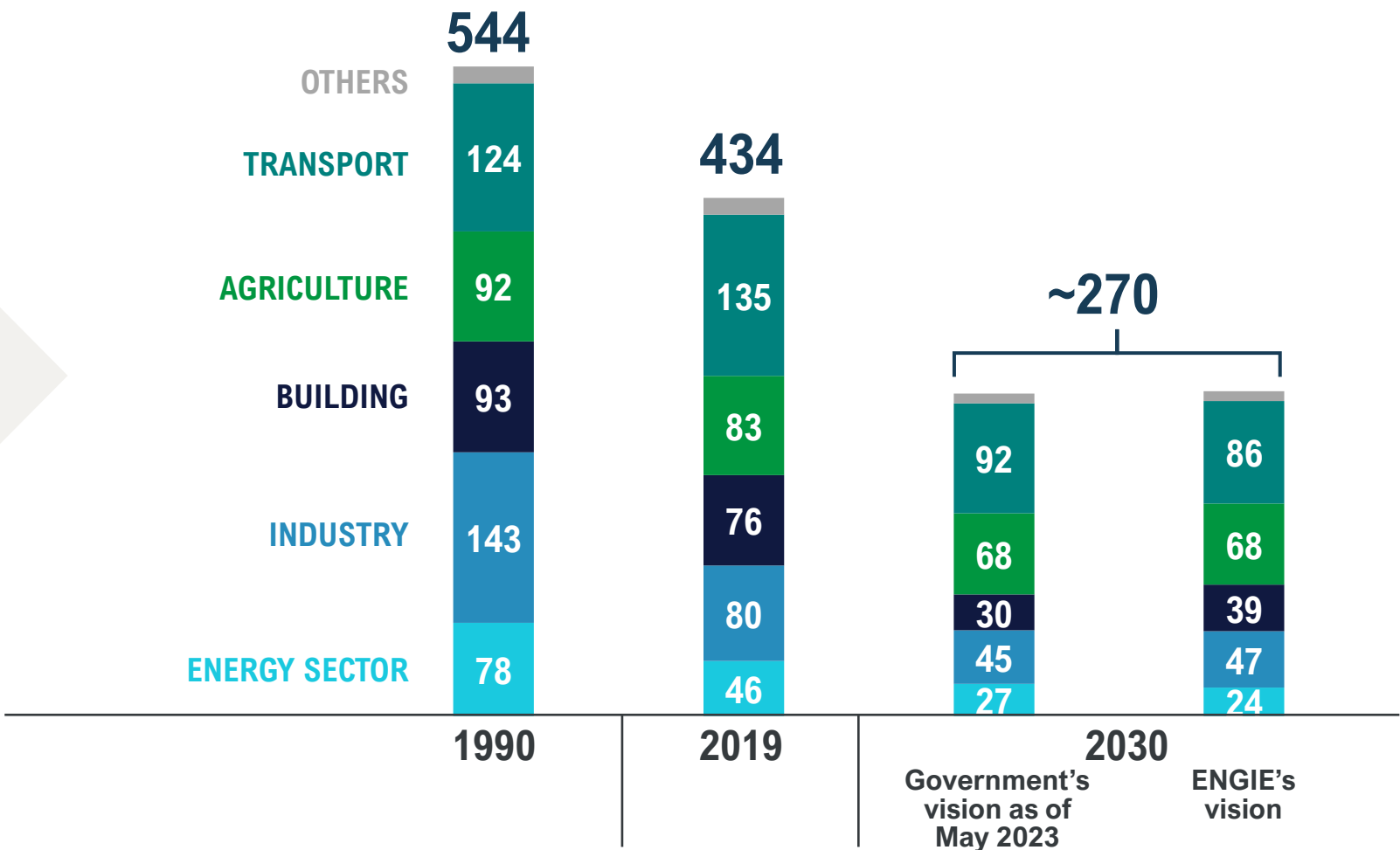


DIFFERENT ROUTES EXIST TO REACH FIT-FOR-55 TARGETS



**OUR APPROACH
OPTIMIZES
COSTS WHILE
maintaining
CO₂ emission
reduction
targets**

Greenhouse gas emissions
Mt CO₂e, 2030



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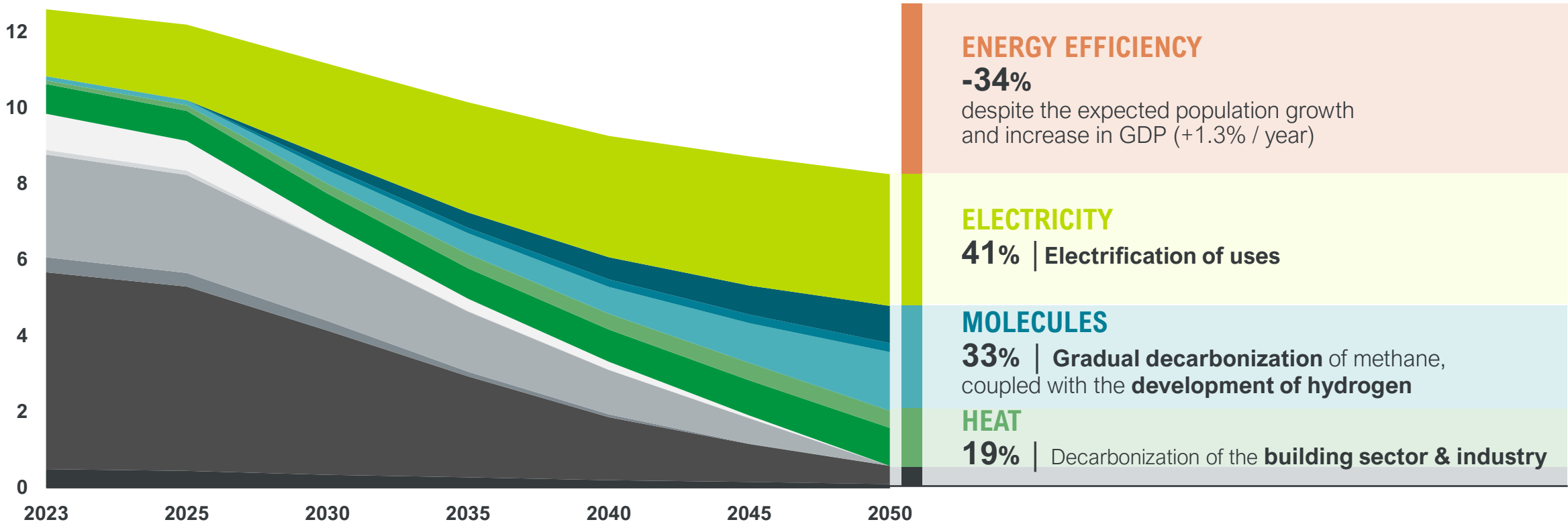


ALL LEVERS ARE REQUIRED TO ACHIEVE DECARBONIZATION

Final energy mix

Thousand TWh

14



FOSSIL FUELS

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

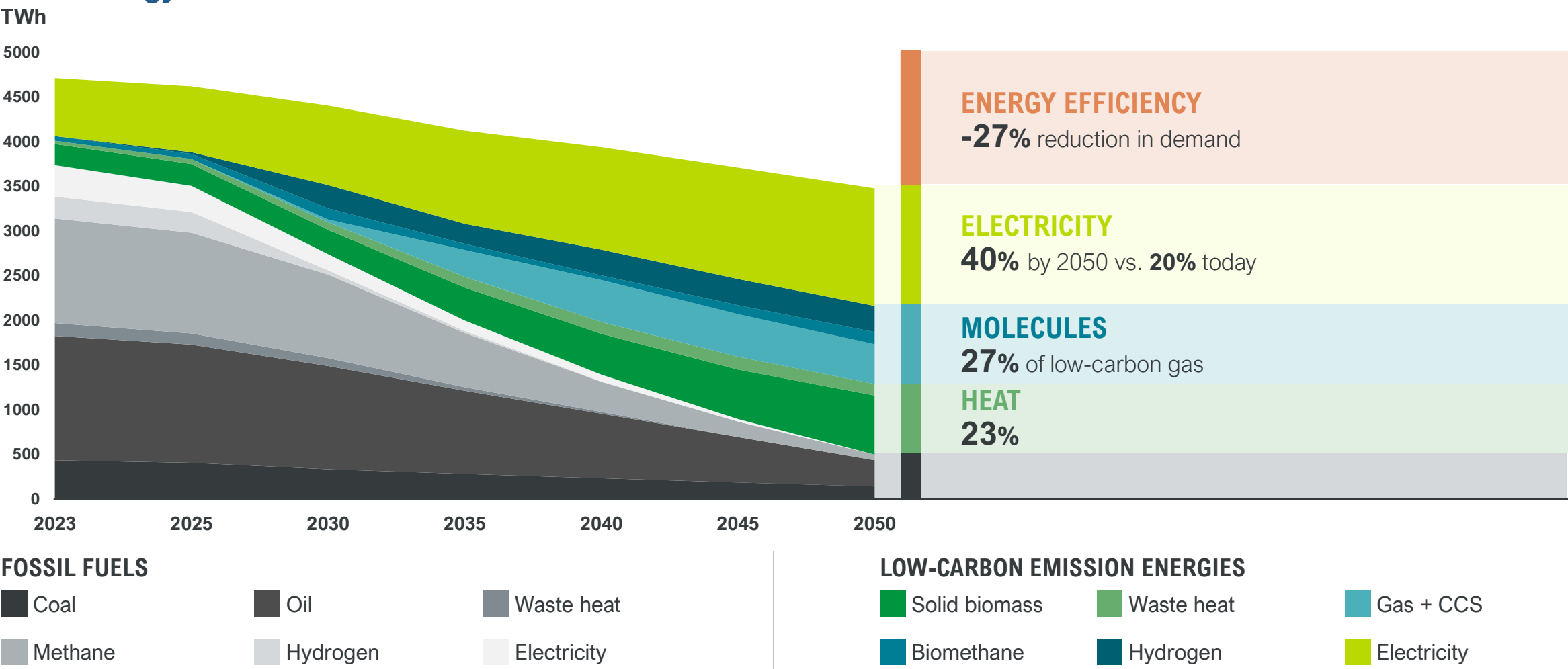
LOW-CARBON EMISSION ENERGIES

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



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

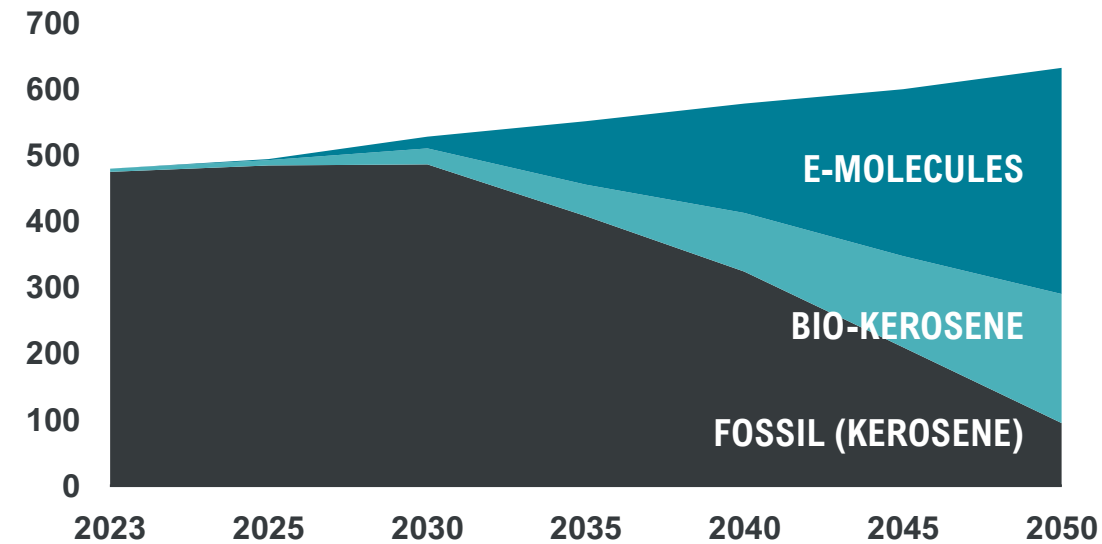
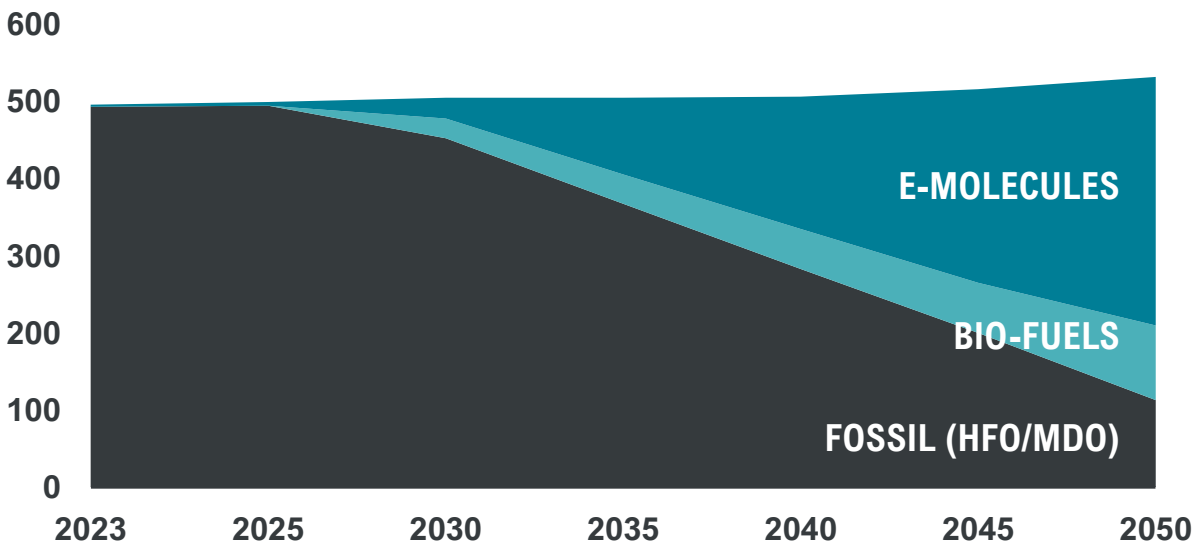
Final energy mix for the industrial sector



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

Final energy mix

TWh



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

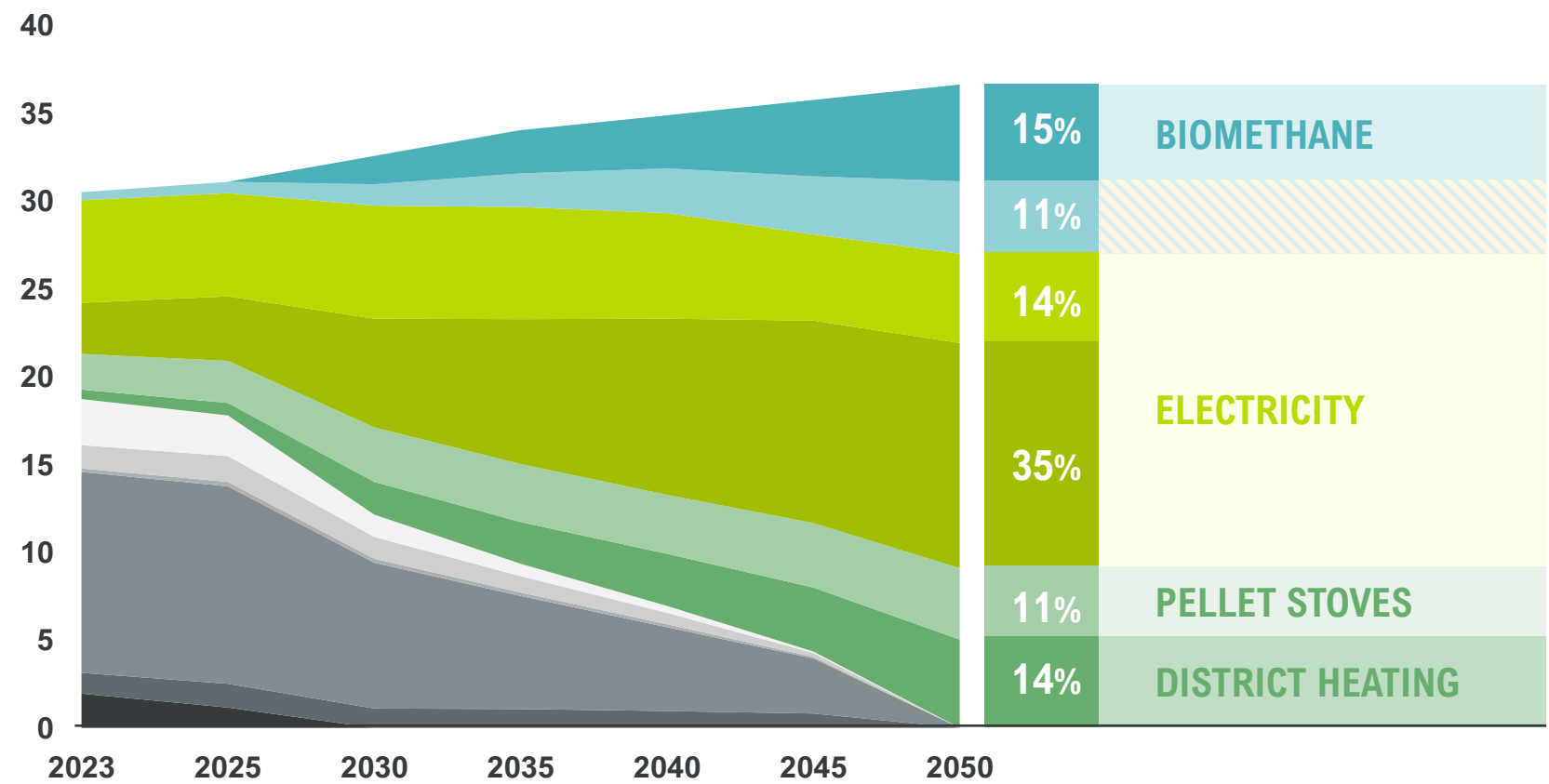
HFO: Heavy Fuel Oil,
MDO: Maritime Diesel Oil



BUILDING: NEED FOR A RANGE OF SOLUTIONS

French households | Heating solutions

Million



- Fuel oil
- Heating networks
- Gas boilers
- Hybrid heat pumps
- Heat pumps
- Convection heaters
- Heating networks
- Pellet Stoves
- Hybrid Heat Pumps
- Gas boilers (Biomethane)

EFFICIENT RENOVATION BY 2050:

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

50%
Buildings fully renovated

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

STRESS TEST

No installation of hybrid heat pumps

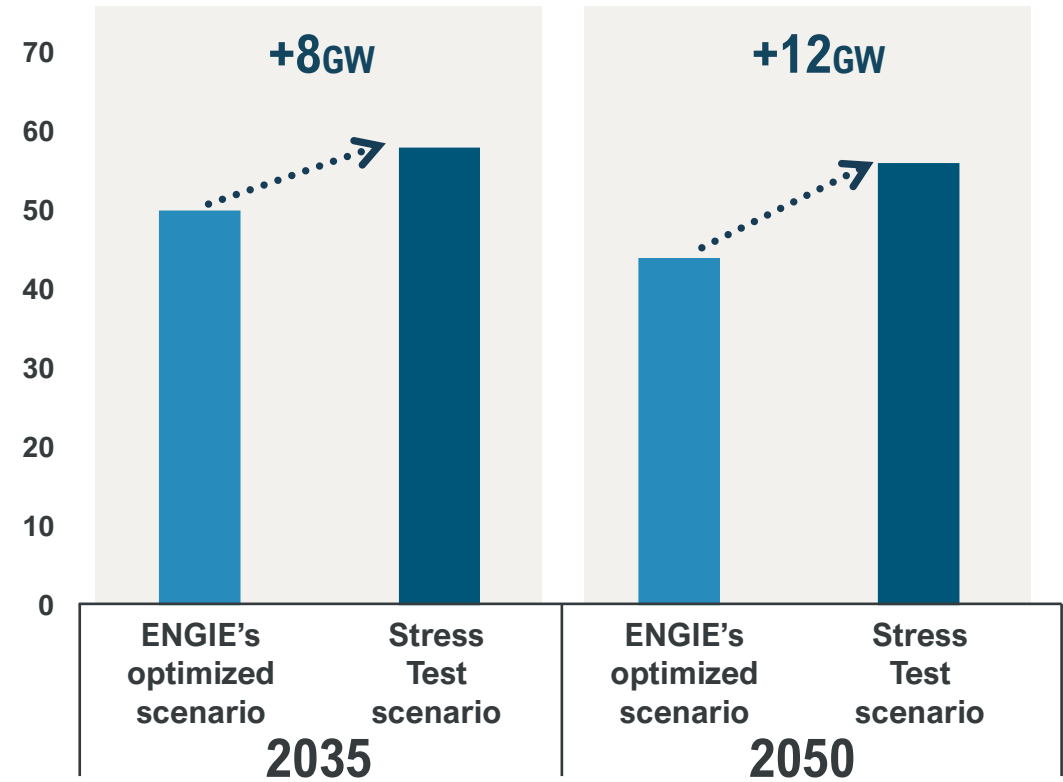
Replaced as follows:

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



IMPLICATIONS

Contribution of heating to the electric peak
GW



+€2.7bn/year

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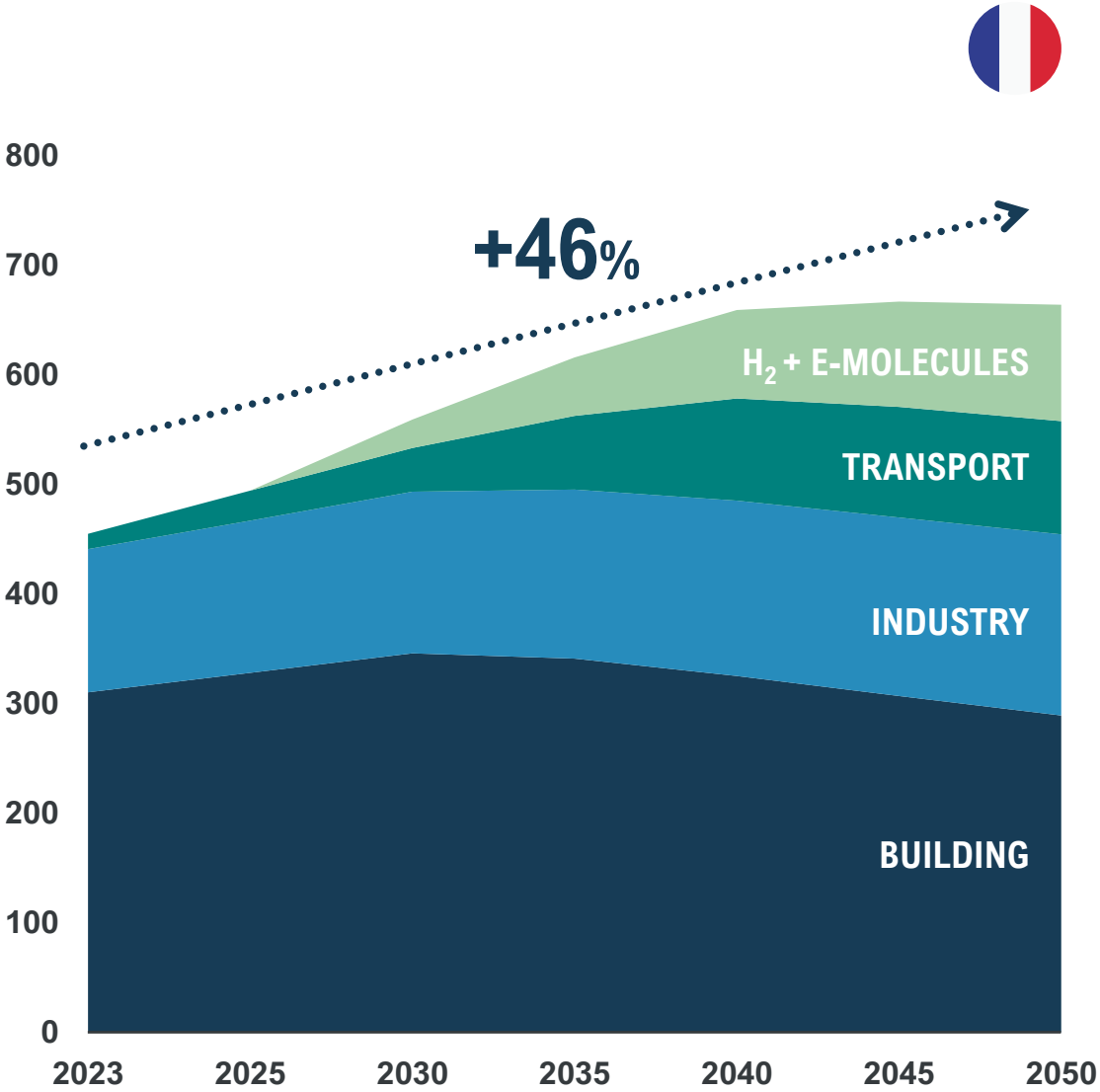
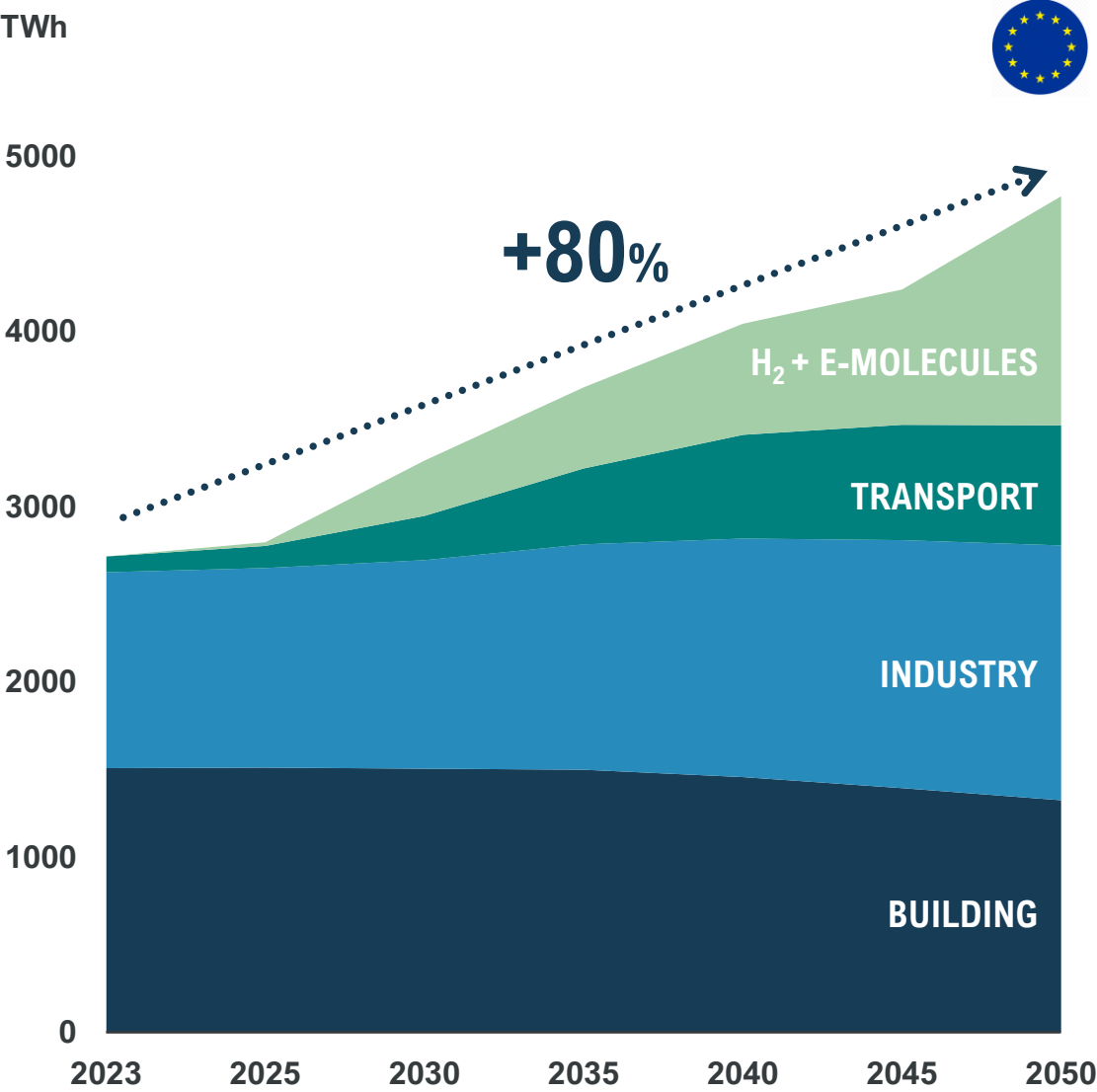
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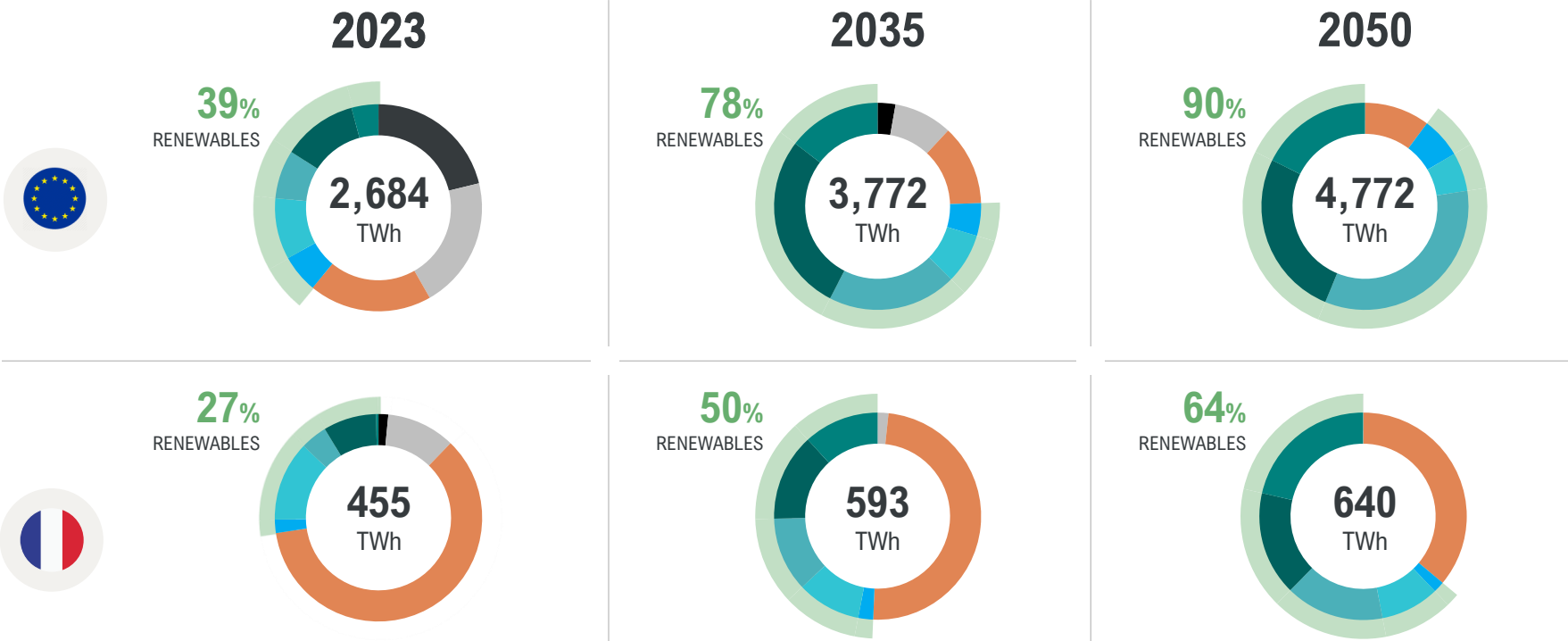
STRONG INCREASE IN POWER DEMAND BETWEEN NOW AND 2050

Power demand

TWh



MASSIVE INCREASE IN RENEWABLE POWER GENERATION



FOSSIL FUELS

- Coal, Lignite & Oil
- Fossil gases

LOW-CARBON EMISSION ENERGY SOURCES

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



Solar and wind generation

x6

by 2050



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 CO₂



+€4bn/year until 2050

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



STRESS TEST

Lower availability
of nuclear power

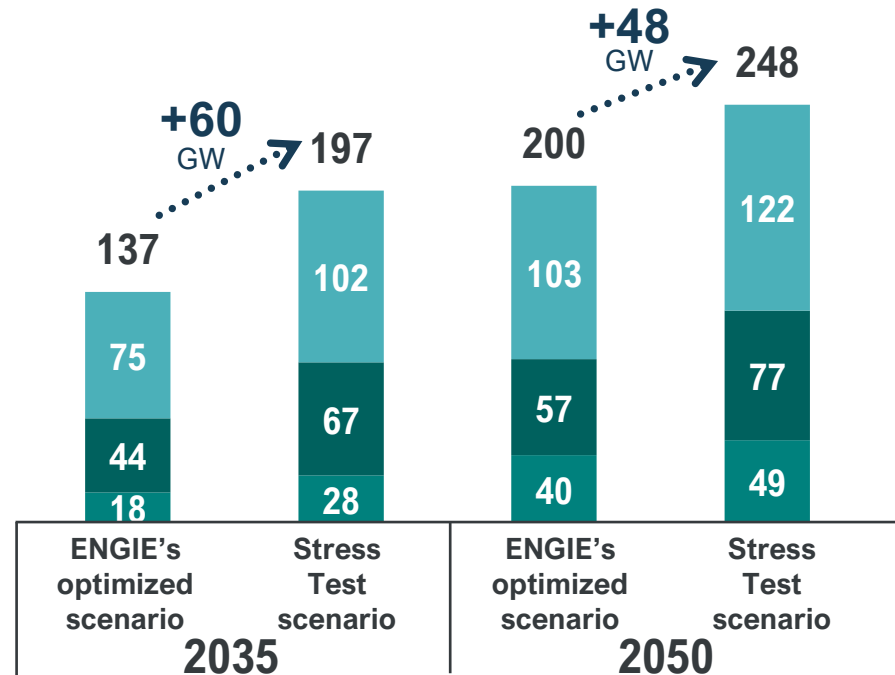
5-year delay
in building
new EPRs
(10 EPRs in 2050)



IMPLICATIONS

Installed renewable power capacity GW

Offshore wind Onshore wind Solar



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

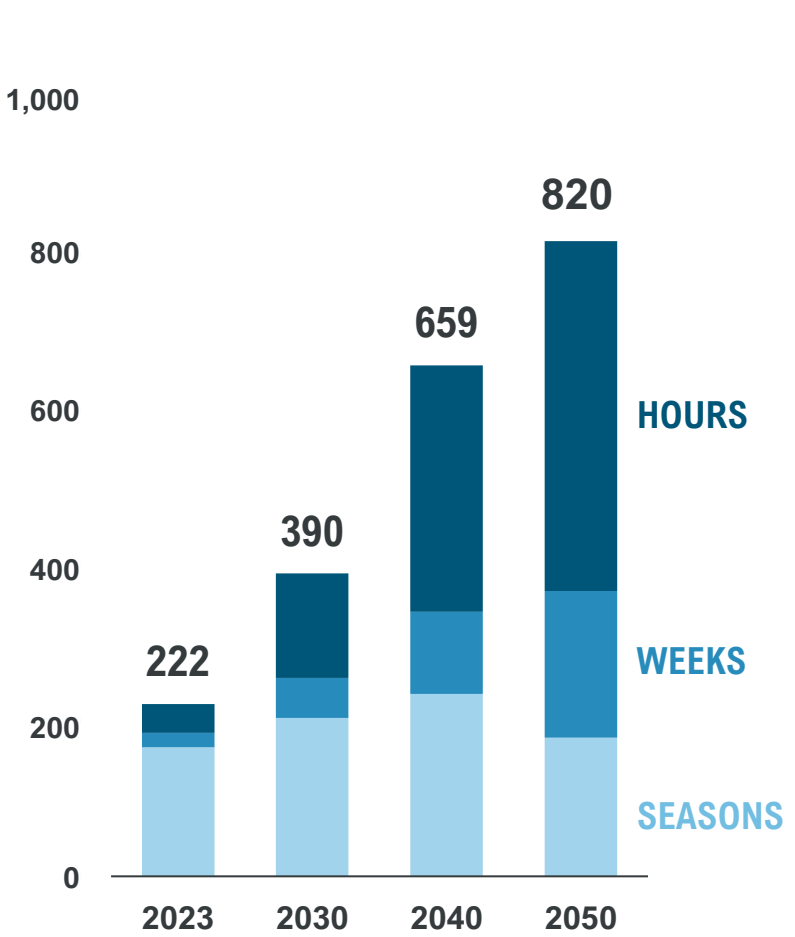
ASSUMING THE STRESS TEST DOES NOT MATERIALIZE

- Limited additional costs:
€2bn/year
- Additional emissions avoided:
320Mt CO₂e
- **Accelerated development**
of green hydrogen
and e-molecules



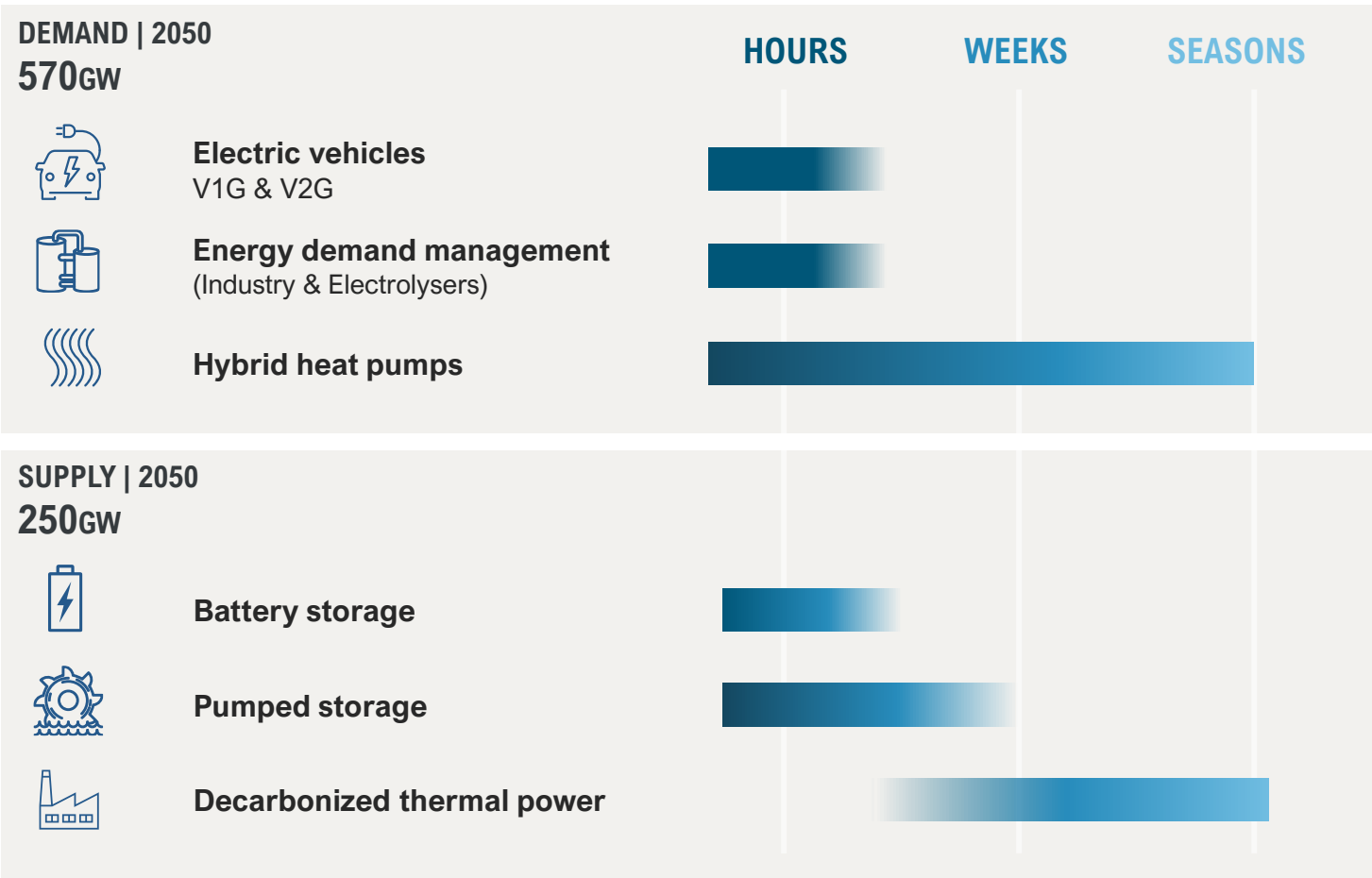
FLEXIBILITY LEVERS, A NECESSARY COMPLEMENT TO INTERMITTENT RENEWABLE POWER SOURCES

Flexible capacity
GW



Flexibility technologies

Various technologies for meeting specific needs





DECARBONIZED THERMAL POWER PLANTS ARE NECESSARY TO ENSURE SEASONAL FLEXIBILITY

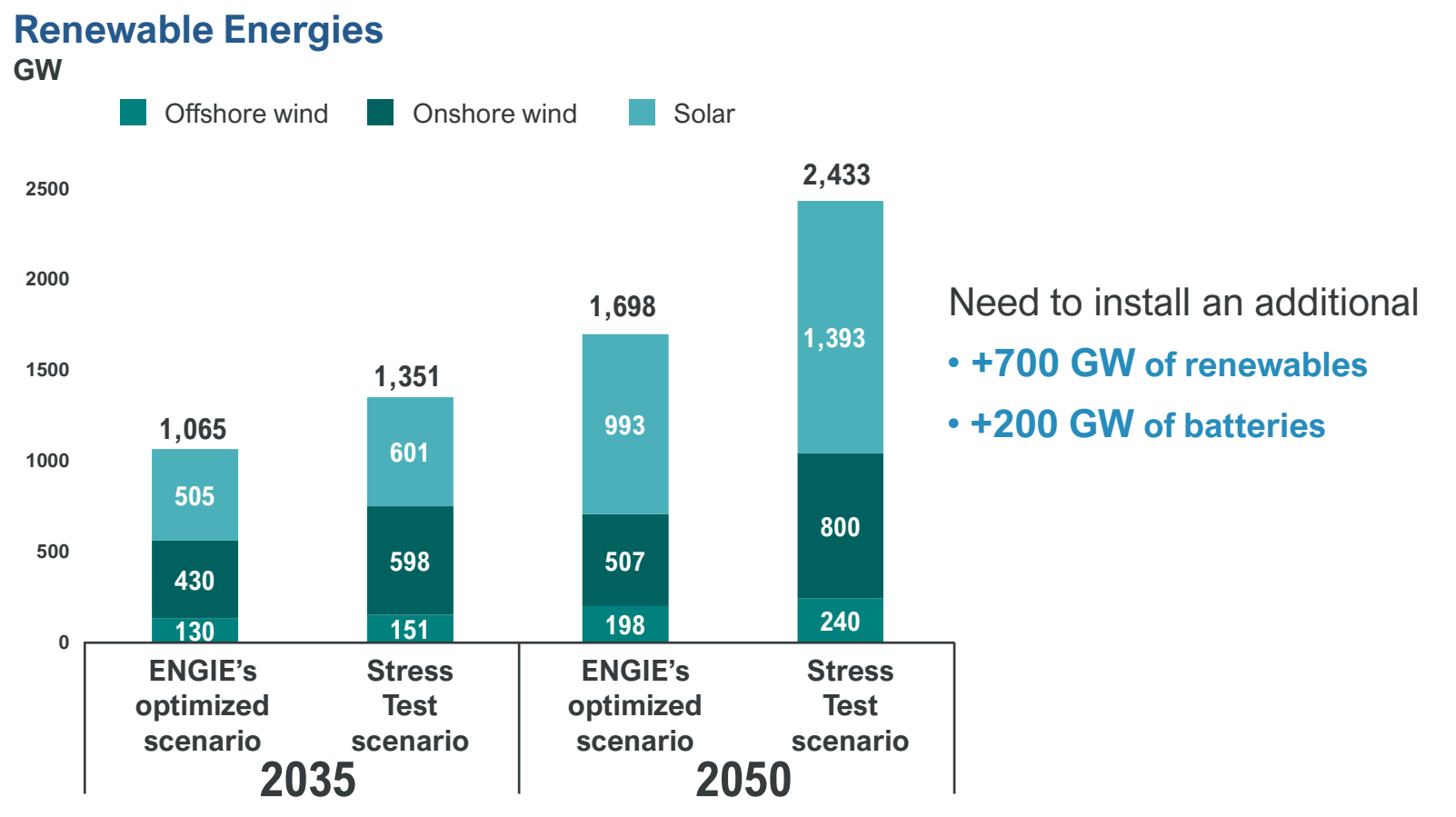


STRESS TEST

No additional development of decarbonized thermal (105GW)



IMPLICATIONS



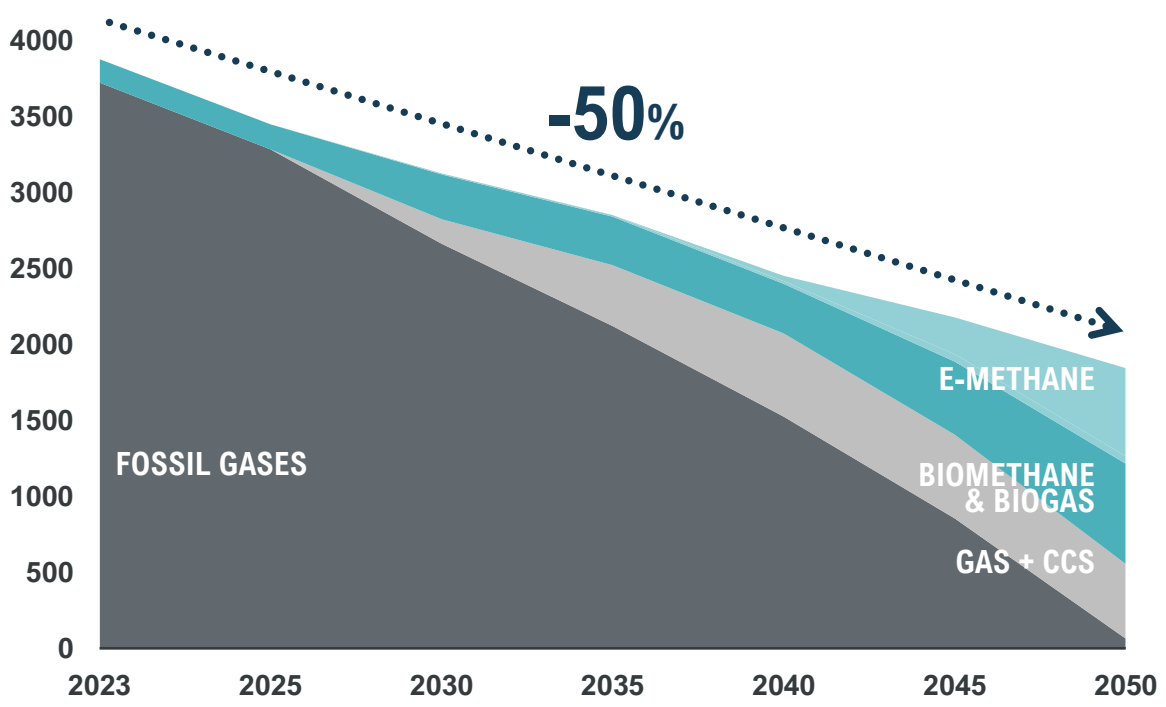
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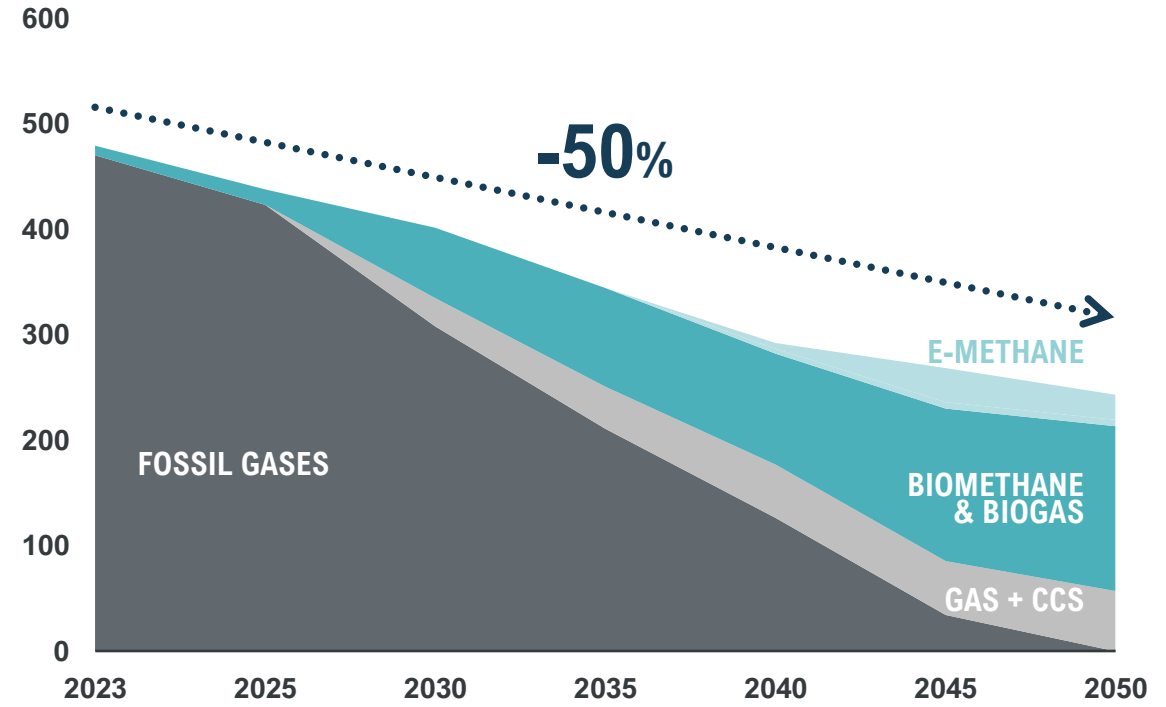


METHANE: DEMAND IS HALVED AND MET BY DECARBONIZED SOURCES BY 2050

Methane demand
TWh



- 450 TWh of low-carbon gas needed to reach “Fit-for-55” targets by 2030
- Imports will be 25% below current levels

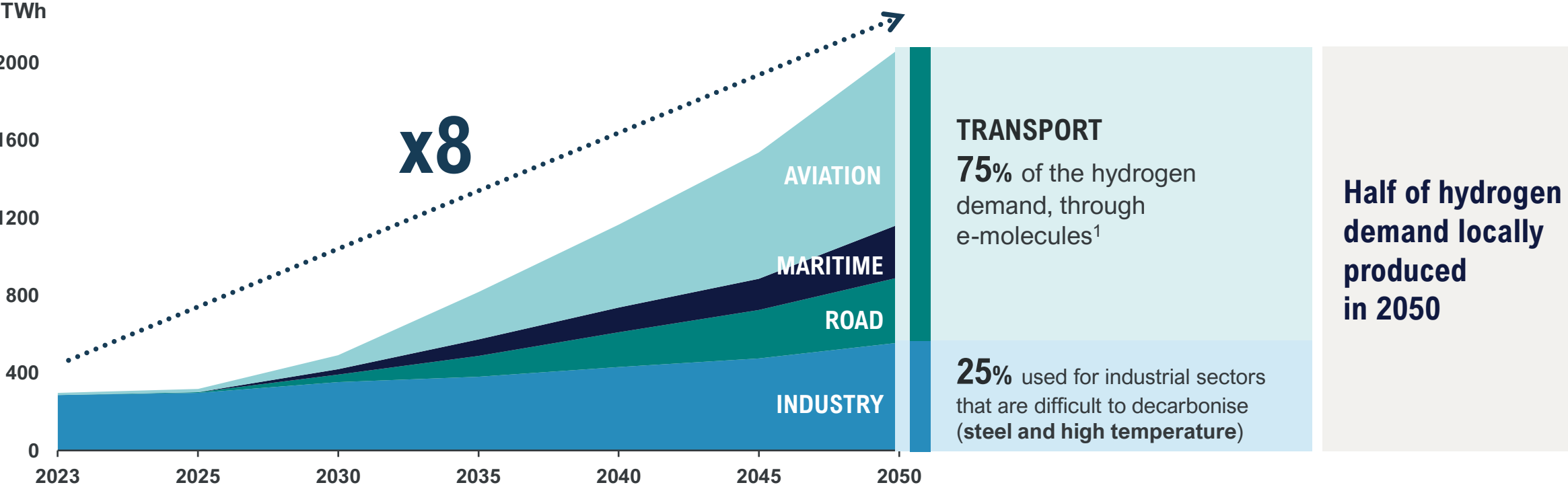


- 245 TWh demand for fully decarbonized gas by 2050
- Biomethane plays a key role (two-thirds of the demand in 2050)



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

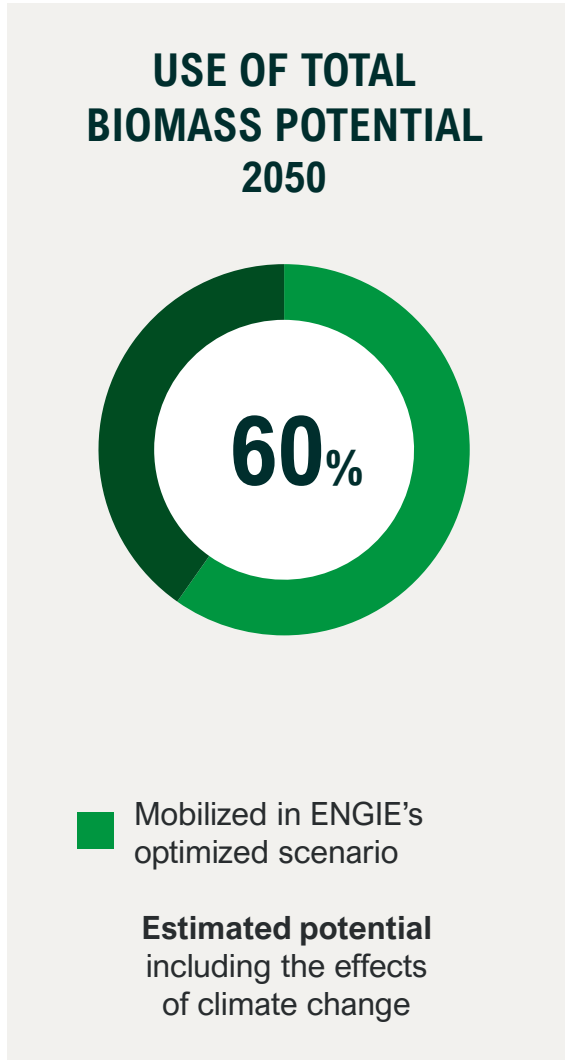
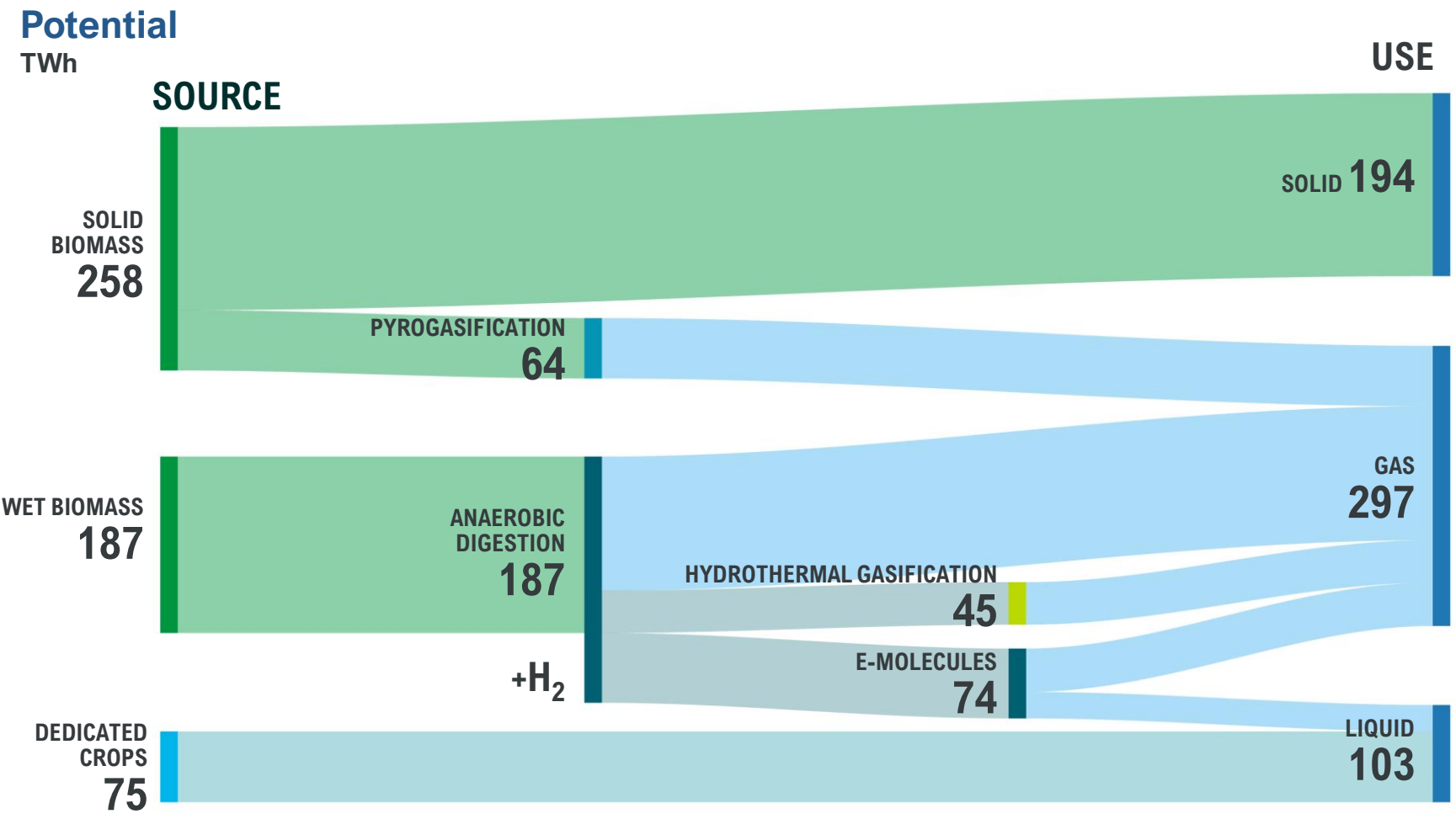
Sectors of the hydrogen economy



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



BIOMASS: SUFFICIENT RESOURCES EXIST TO MEET PROJECTED NEEDS



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

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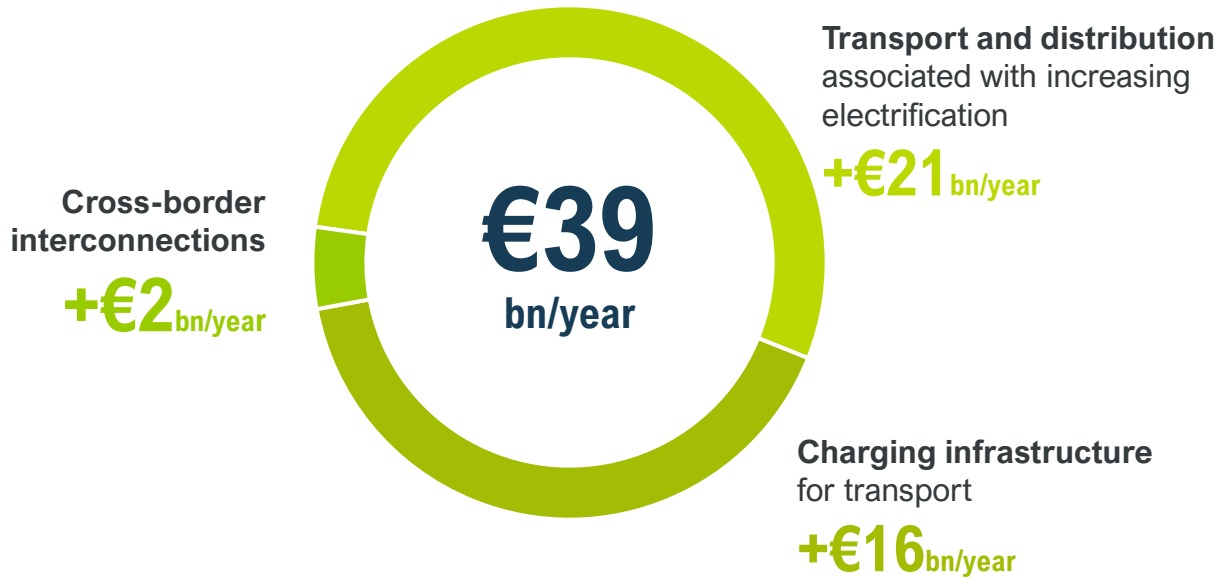


ENERGY INFRASTRUCTURE: AN ESSENTIAL LEVER FOR SUCCESSFUL DECARBONIZATION



ELECTRICITY

Investments significantly increase until 2040



METHANE & HYDROGEN

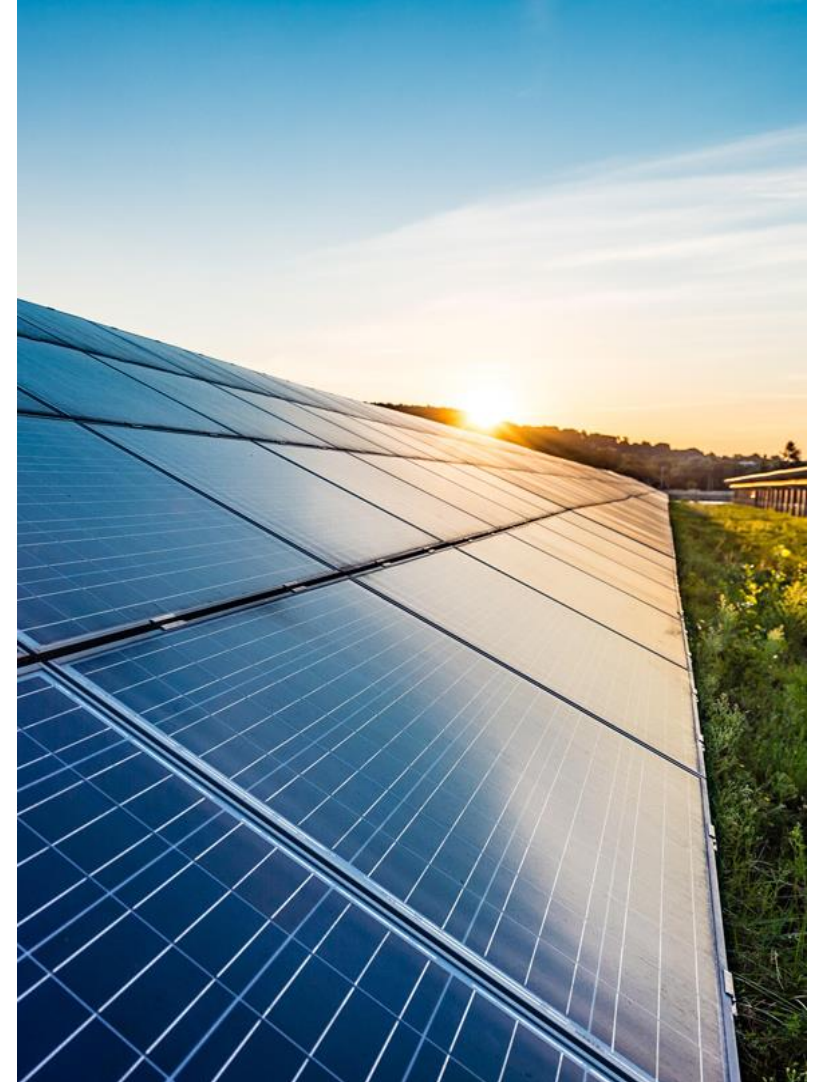
Rely on existing infrastructure



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

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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

SOME CONCRETE BARRIERS MUST BE ADDRESSED

ACCELERATION OF RENEWABLE POWER AND GAS

- Stabilize the **investment framework**
- Facilitate and speed up network **connections** and **permitting**

DEVELOPMENT OF HYDROGEN by taking action throughout the value chain

- Finalize the **European regulatory framework**
- Ensure that **appropriate public funding** is granted quickly and that H₂ **conversion** of gas infrastructure is financed

MAXIMIZING BIOMETHANE POTENTIAL by activating all levers

- Ensure effective **production support mechanisms** (prices and inputs) in France and in Europe

DEVELOPMENT OF FLEXIBILITY TECHNOLOGIES

- Develop **suitable remuneration models** (load management, batteries, decarbonized CCGT, etc.)
- Speed up **permitting**

DECARBONIZATION OF THE BUILDINGS SECTOR by supporting all solutions

- Accelerate development of **green heating networks**, including geothermal energy
- **Prioritize the use of biomethane** for buildings and **hybrid solutions** (heat pump, hybrid heat pump, boiler replacement, etc.)
- Simplify access to **housing aid** with a one-stop shop grouping current mechanisms

DECARBONIZATION OF INDUSTRY

- **Step up the use of waste energy** (guarantee fund and threshold reduction)
- Maintain **funding** over time (BCIAT fund in France)
- Maintain **local biomass** as an RE

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