



Future European electricity scenarios

A project with FortyEight Brussels and Oxera

OCTOBER 2025 – ANNEX TO THE REPORT “EUROPEAN ELECTRICITY INFRASTRUCTURE IN THE ENERGY TRANSITION AGE”

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Agenda

1. Context and goal of the document

2. Flexible demand and RES are key for a competitive and resilient system
 3. Central system coordination and distributed flexibility integration can drive further improvements
- Annex



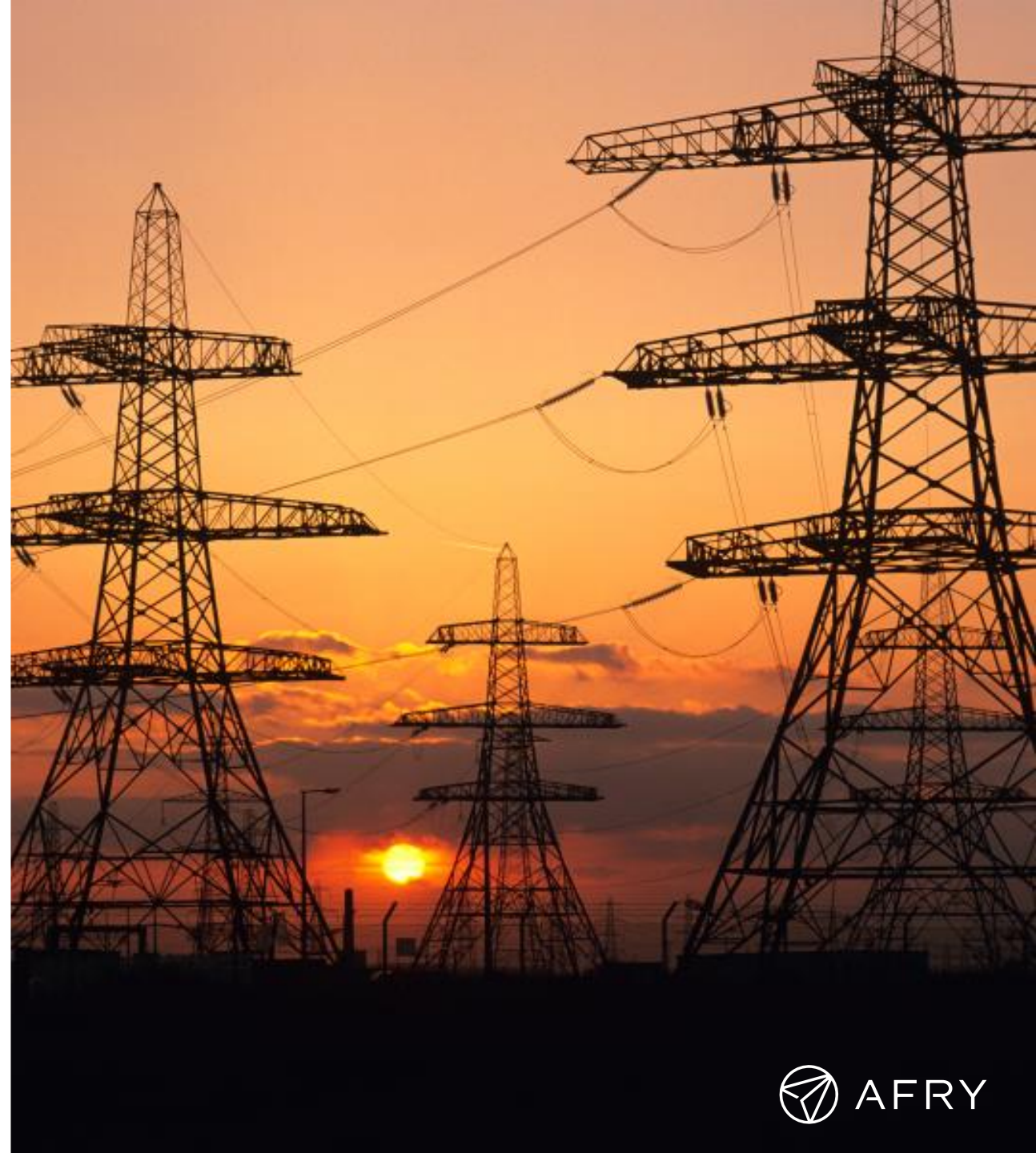
AFRY has developed dedicated power market scenarios to assess impacts of different investment pathways

CONTEXT

- Forty Eight Brussels and Intesa Sanpaolo (together, “the Clients”) commissioned the study “European electricity infrastructure in the energy transition age” which addresses a critical question for European policymakers and investors: how do different investment pathways shape the speed, cost, and resilience of our electricity system transformation?
- The Clients have asked AFRY to develop a number of scenarios to showcase the potential benefits stemming from a particular set of policies that can be promoted and implemented at European level

GOAL OF THE DOCUMENT

- Within this context, AFRY has developed and modelled a number of power market scenarios and sensitivities starting from the TYNDP scenarios and performing appropriate optimizations, and has quantified the benefits of the different set-ups
- This document illustrates the overarching storyline that links the optimized scenarios, and presents the benefits resulting from each. Moreover, short methodological descriptions are given
- This document is an Annex to the report “European electricity infrastructure in the energy transition age” dated 15/12/2025



Electricity demand in Europe has remained almost flat over the last 10 years, increasing by only +2% in the 2013-2023 period

ELECTRICITY DEMAND IN EUROPE

Year	Electricity demand (TWh)	Demand/GDP (kWh per inflation adjusted €1000)	Renewable generation (TWh)	% on total demand	Renewable power (GW)	Renewable Load factor
2013	2360	180	700	29,7%	400	20,0%
2014	2340	175	720	30,8%	420	19,6%
2015	2400	177	770	32,1%	450	19,5%
2016	2450	175	820	33,5%	480	19,5%
2017	2480	173	880	35,5%	520	19,3%
2018	2470	168	900	36,4%	560	18,3%
2019	2480	165	950	38,3%	600	18,1%
2020	2385	160	1000	41,9%	620	18,4%
2021	2570	165	1080	42,0%	650	19,0%
2022	2485	156	1080	43,5%	670	18,4%
2023	2410	150	1100	45,6%	705	17,8%

COMMENTS

- Electricity demand increased by just 2% from 2013 to 2023, with year-to-year fluctuations but no sustained upward trend
- Electricity demand per unit of GDP declined by nearly 17%, indicating that Europe is generating more economic output with less electricity
- Renewable generation rose by 57% over the decade, increasing its share of total electricity demand from 30% to nearly 46%
- Installed renewable power capacity grew by 76%, while the average load factor decreased from 20.0% to 17.8%, reflecting the integration of more variable renewable sources and possible curtailment or grid constraints

Source: IMI CIB analysis on Eurostat, Entso-E, Ember data

The demand stagnation has coincided with a plateau in the electricity share in Europe and US at ~20%, while China's share has continued to rise to 30%

ELECTRICITY SHARE OF FINAL ENERGY CONSUMPTION



COMMENTS

- **Electrification is a global trend**—countries are competing to increase the share of electricity in their final energy consumption
- **The transition to electricity is essential** for both competitiveness (staying ahead in the global energy transition) and affordability (as electrification can lead to cost reductions and efficiency gains)
- **China is leading** the global race towards electrification, maintaining a steady upward trajectory that has already brought its electricity share to 30%—well ahead of other major economies



Considerable potential still remains for the US and Europe to further increase their electricity share

Source:

RMI.org on Energy Institute, IEA EV outlook , IEA World Energy Balance, BNEF Energy Transition Investment Trends, IEA World Energy Outlook (WEO)

The US has recognized these challenges and already announced its intention to enhance the reliability and security of the electric grid

US GOV. EXECUTIVE ORDER

COMMENTS



- The US government has taken decisive action to address grid reliability and security challenges
- This will ensure the grid can accommodate future surges in electricity demand, driven by rapid technological advancements (e.g. AI data centers) and increased domestic manufacturing
- This will be achieved through a more centralized, federally coordinated planning and intervention in the electric grid

Source: [Whitehouse.org](https://www.whitehouse.org)

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Annex



Starting from a Baseline scenario, additional sensitivity analyses were carried out to examine the value of the green flexible demand and rising gas prices

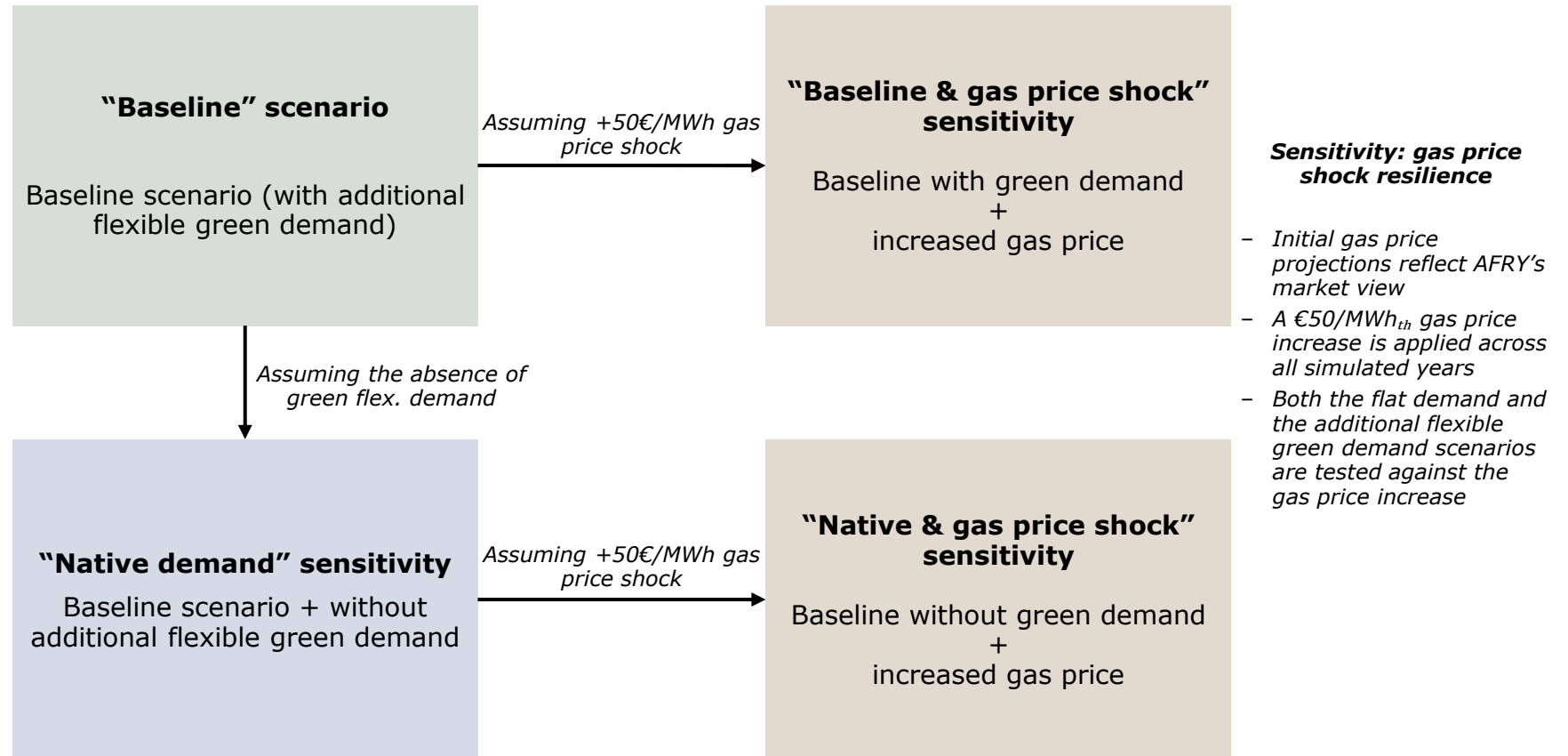
SENSITIVITY METHODOLOGY

Baseline scenario: with additional flexible green demand

- Native and EV demand annual values and profiles follow TYNDP NT for 2030 and GA for 2035 and 2040
- An additional flexible component of green demand was incorporated to account for sources specifically requiring green energy. This component reflects a degree of flexibility in how these demands can be satisfied

Sensitivity: the value of green flexible demand

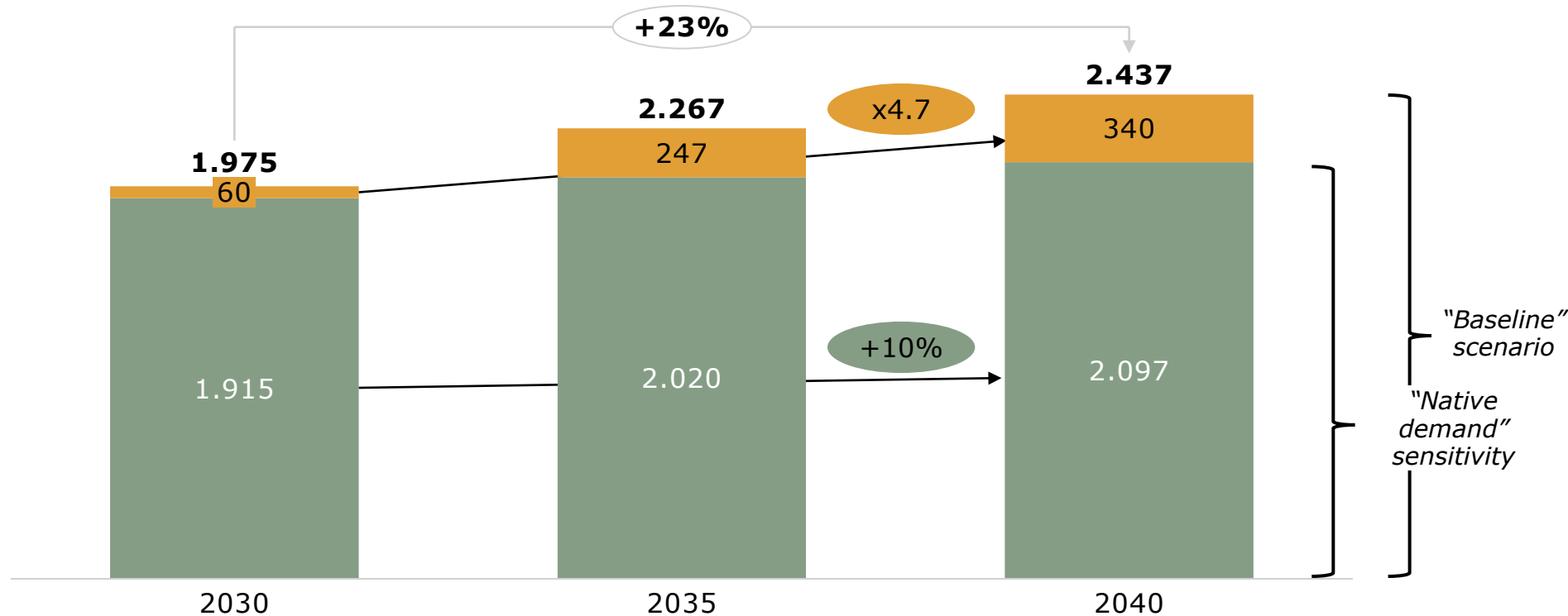
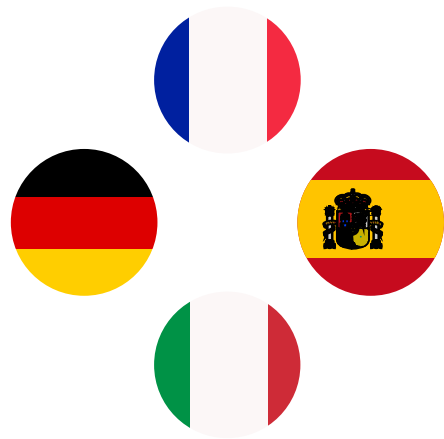
- Only native and EV demand, whose annual values and profiles are based on TYNDP NT for 2030 and GA for 2035 and 2040



The scenarios envisage an electricity demand where the flexible green component drives total growth by 23% over 10 years in the focus countries

ELECTRICITY DEMAND¹ - TWH

■ Native Demand + EV ■ Additional flexible demand

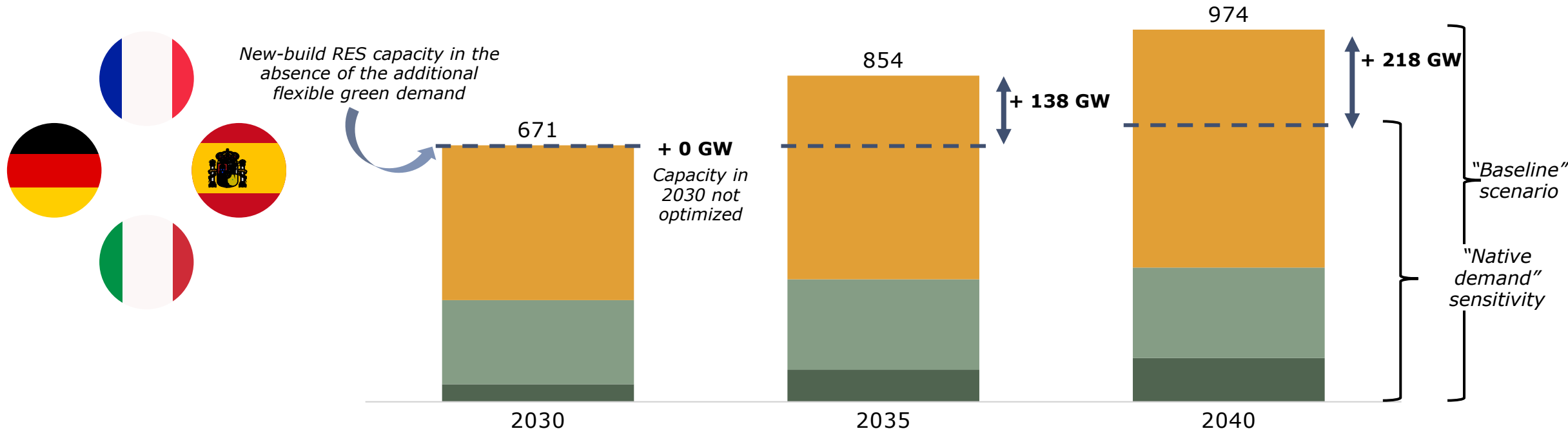


The growth in green flexible demand triggers a significant increase of +218GW RES capacity by 2040...

TOTAL RES CAPACITY BY YEAR – GW

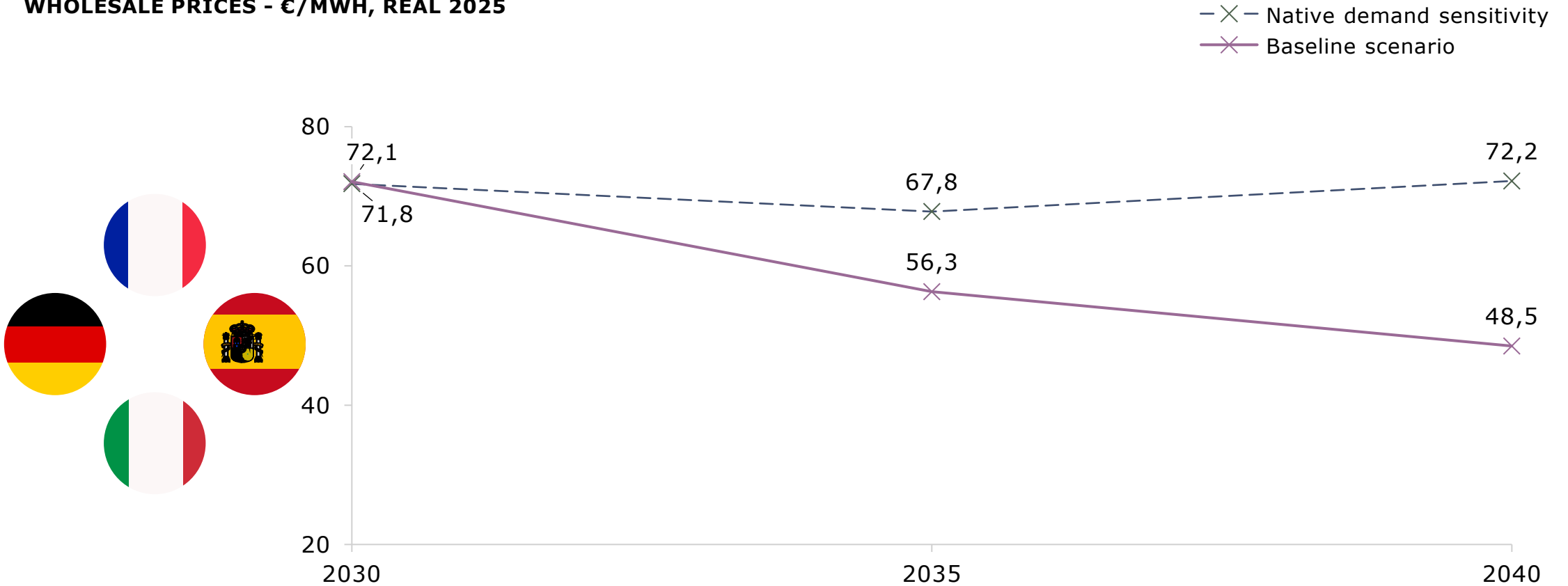
Offshore Wind Onshore Wind PV

+218 GW more RES capacity due to higher demand



...achieving a large price reduction of -23€/MWh on average at 2040 for a cheaper and more competitive system in the focus countries...

WHOLESALE PRICES - €/MWH, REAL 2025



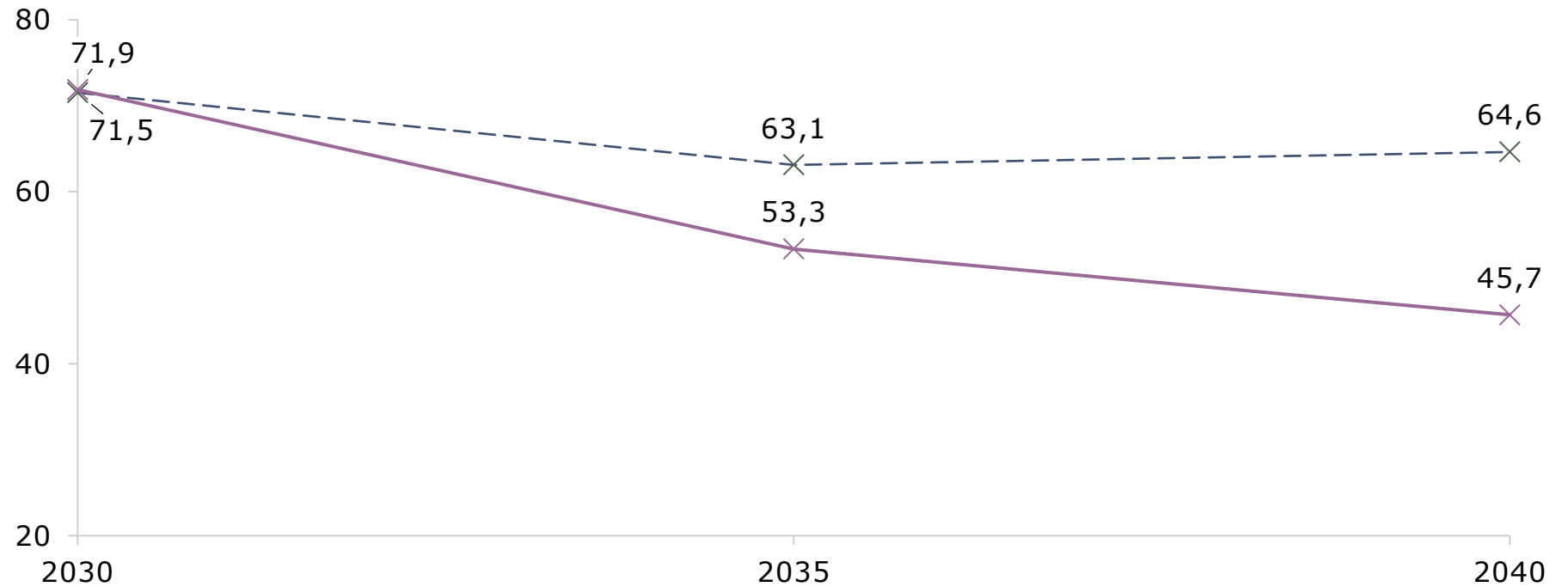
Notes: Standard gas price: in 2030 is 28.7 €/MWh, in 2040 is 32.8 €/MWh. CO2 price: in 2030 is 122.5 €/ton, in 2040 is 171 €/ton. Real 2025 money values

12 03/11/2025 COPYRIGHT AFRY | EUROPEAN ELECTRICITY INFRASTRUCTURE IN THE ENERGY TRANSITION AGE - ANNEX **Note:** Wholesale prices indicated as «Native demand» represent a sensitivity and should be considered indicative

...as well as at European level where the price reduction is -18.9 €/MWh on average at 2040

WHOLESALE PRICES - €/MWH, REAL 2025

—X— Native demand sensitivity
—X— Baseline scenario

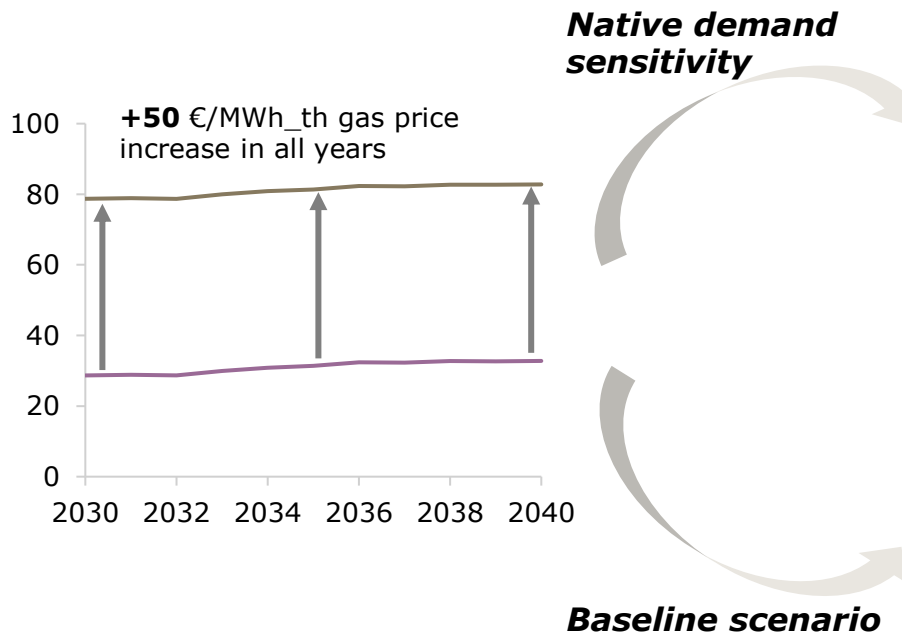


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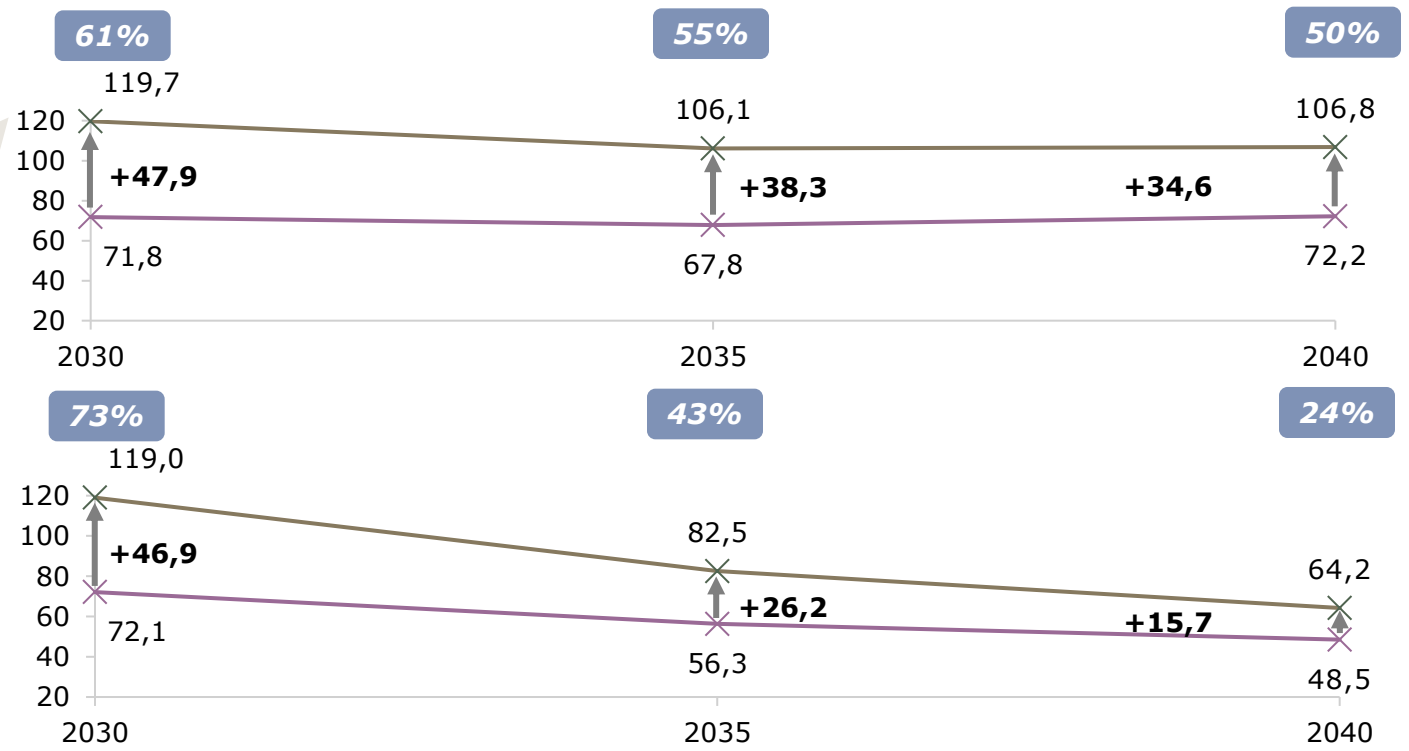
13 03/11/2025 COPYRIGHT AFRY | EUROPEAN ELECTRICITY INFRASTRUCTURE IN THE ENERGY TRANSITION AGE - ANNEX **Note:** Wholesale prices indicated as «Native demand» represent a sensitivity and should be considered indicative

Up to 55% of the effect of a gas price shock of +50 €/MWh in 2040 is absorbed by the resilience of the system and not reflected in the wholesale price

GAS PRICE [€/MWH_TH, REAL 2025]



WHOLESALE PRICES [€/MWH, REAL 2025]



— Without gas shock — With gas shock

% % Hours with CCGT as the price-setting technology (in the standard gas price scenario)

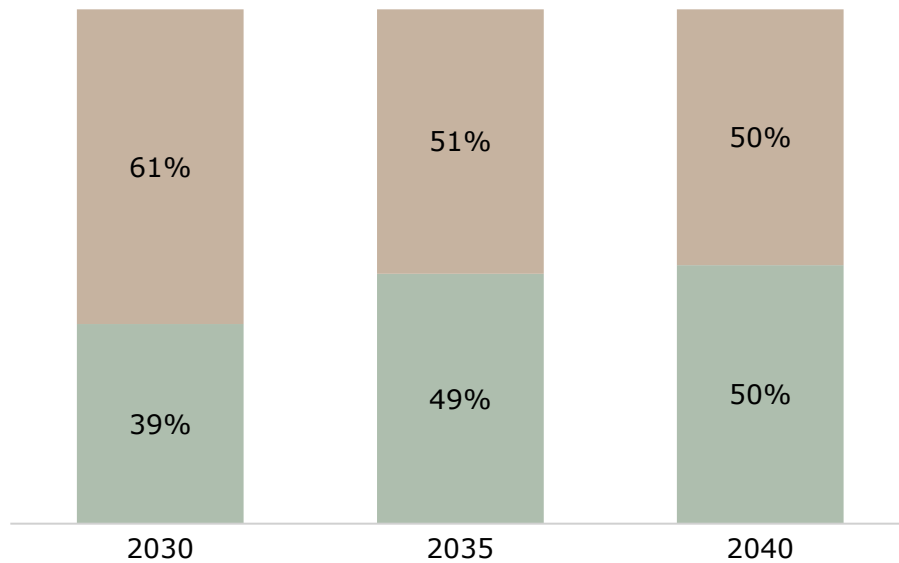
Notes: Values refer to 4 focus countries: France, Germany, Italy and Spain



Additional green generation increases renewable price-setting, displacing gas-fired generation from the merit order

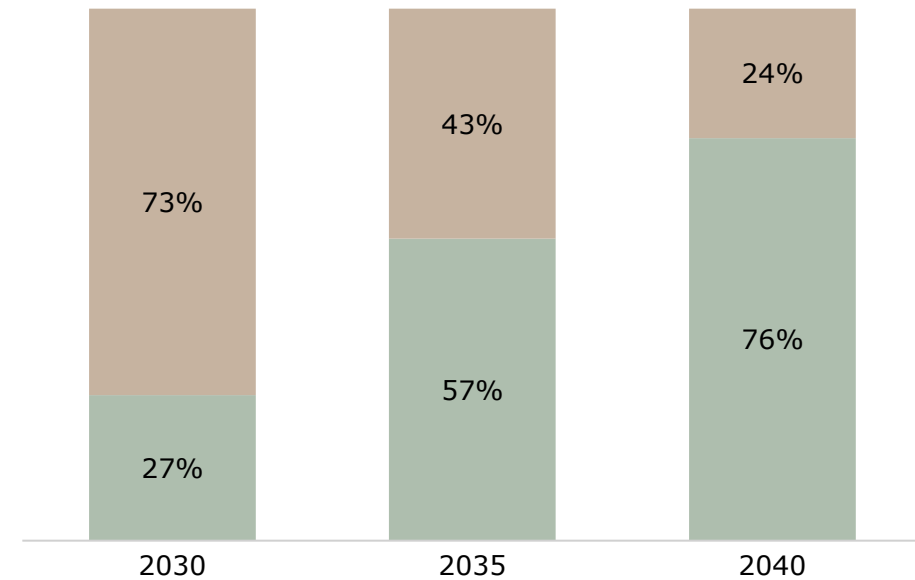
HOURS CCGT SETTING THE PRICE [%] - NATIVE DEMAND SENSITIVITY

Under as-is conditions with "flat" demand and CCGTs still being majority price setters, gas price still strongly influences the power price



HOURS CCGT SETTING THE PRICE [%] - BASELINE SCENARIO

The additional RES capacity driven by the flexible green demand displaces CCGTs from the merit order, thereby decoupling the power price from the gas price



■ CCGT ■ Other technologies

Notes: Values refer to 4 focus countries: France, Germany, Italy and Spain

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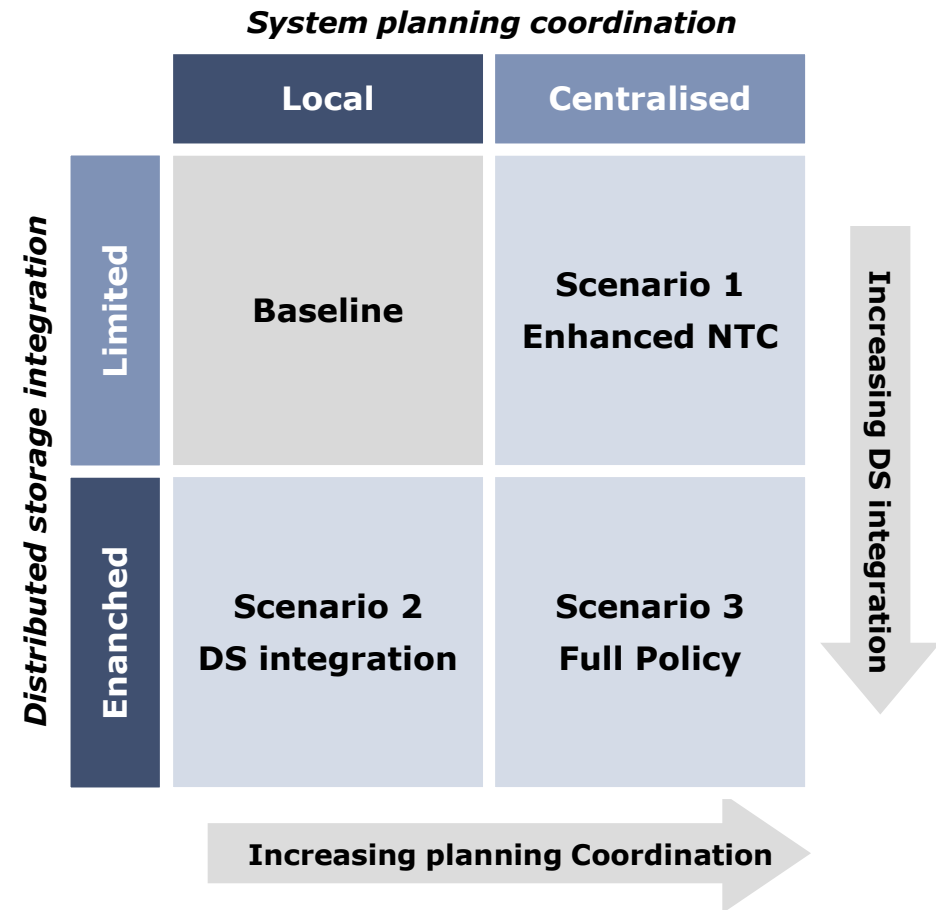
3. Central system coordination and distributed flexibility integration can drive further improvements

Annex



Starting from Baseline, we have developed 3 additional scenarios based on varying degrees of TSO coordination and distributed storage integration

SCENARIO MATRIX



SCENARIO DESCRIPTION

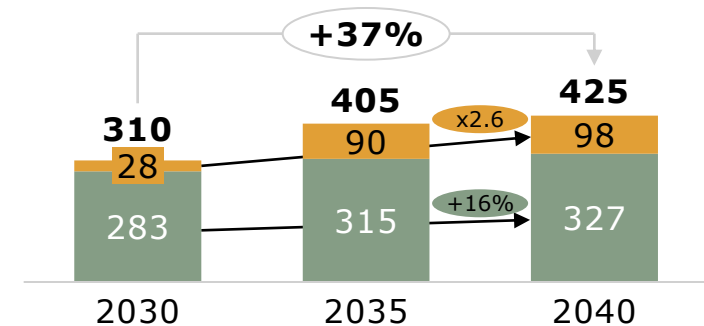
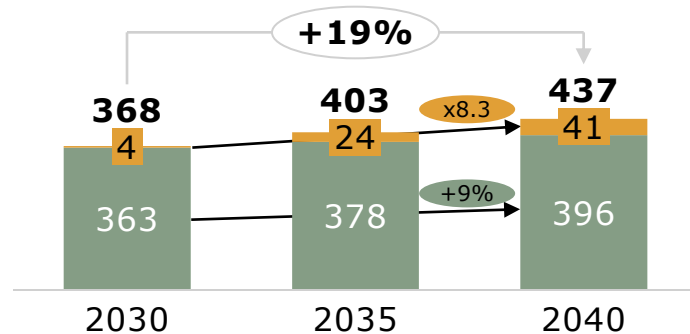
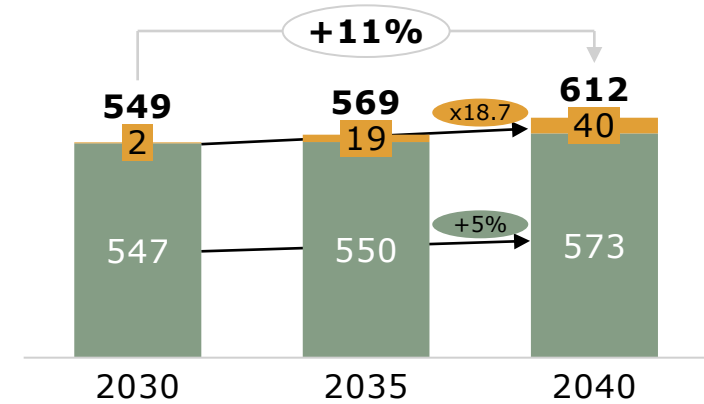
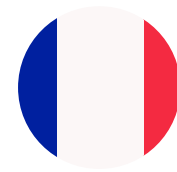
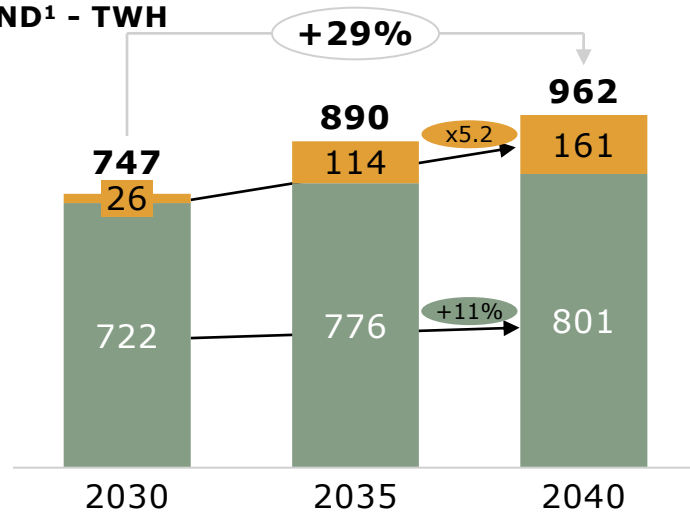
BASELINE	<ul style="list-style-type: none"> Starting from TYNDP NT for 2030, GA for 2035 and 2040 NTC evolution from TYNDP i(i.e. disjointed national grid plans) Capacity mix (BESS, RES, CCGT) re-optimized for 2035 and 2040
SCENARIO 1 «Enhanced NTC»	<ul style="list-style-type: none"> NTCs are optimized at European level for 2035 and 2040 Consequently, capacity mix (BESS, RES, CCGT) is re-optimized
SCENARIO 2 «DS integration»	<ul style="list-style-type: none"> Improved integration of DS considering, as a proxy a 25-40% CAPEX reduction for BESS¹, and -20% OPEX reduction NTC evolution from TYNDP as for Baseline scenario Capacity mix (BESS, RES, CCGT) re-optimized for 2035 and 2040
SCENARIO 3 «Full Policy»	<ul style="list-style-type: none"> Improved integration of DS assumed as for Scenario 2 NTCs are optimized at European level for 2035 and 2040 Consequently, capacity mix (BESS, RES, CCGT) is re-optimized

Note: 1) The BESS capex reduction is calculated considering a discount of -25% in 2030 and -40% in 2040 with a linear interpolation in between

The scenarios envisage an electricity demand where the flexible green component drives growth by 23% over 10 years in the 4 focus countries

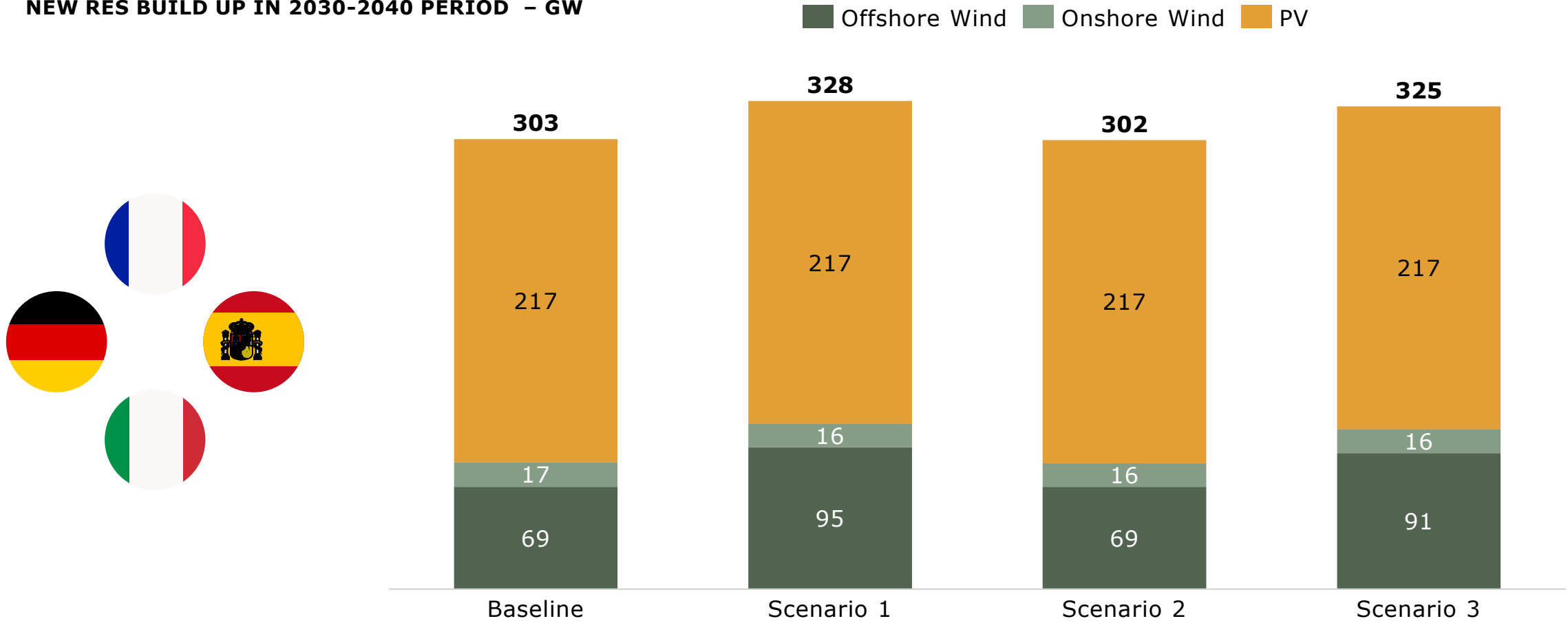
ELECTRICITY DEMAND¹ - TWH

■ Native Demand + EV ■ Additional flexible demand



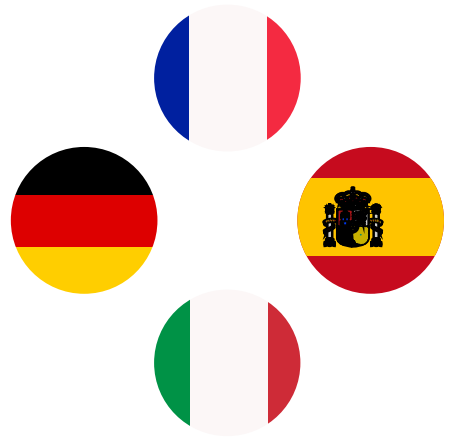
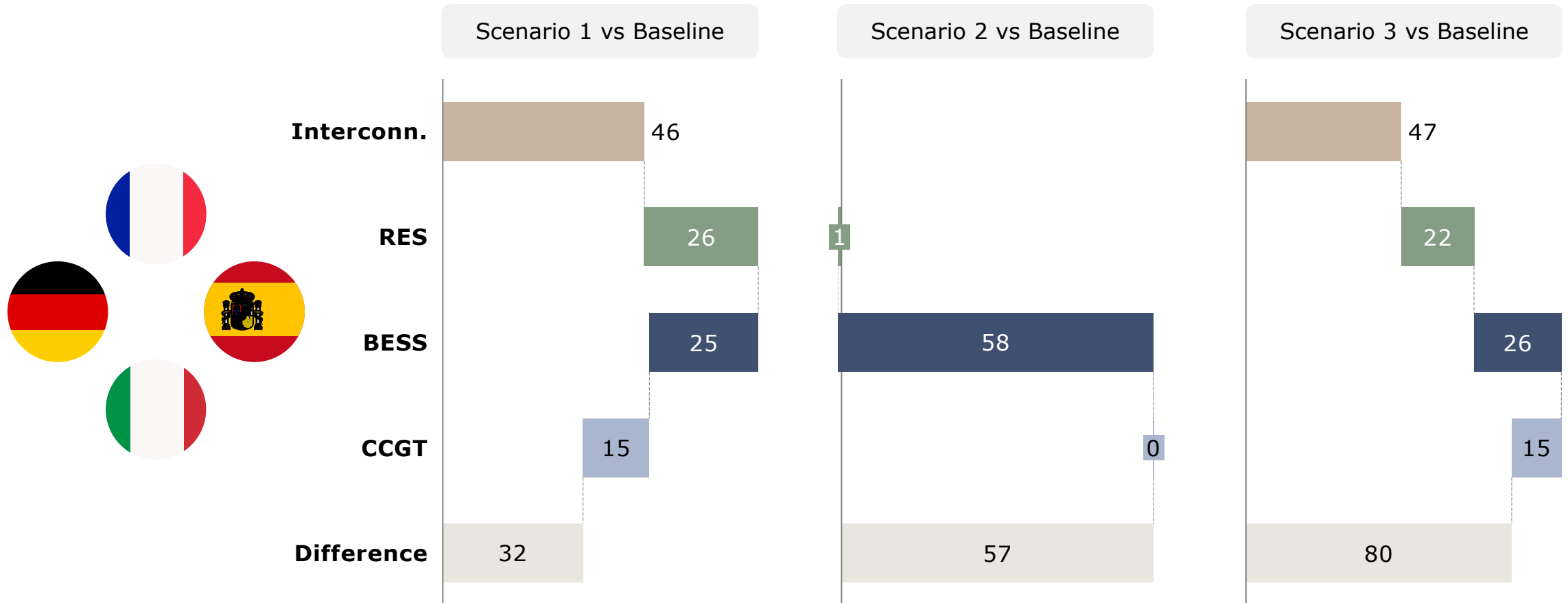
In all scenarios, RES are the most competitive response to the increase of demand

NEW RES BUILD UP IN 2030-2040 PERIOD – GW



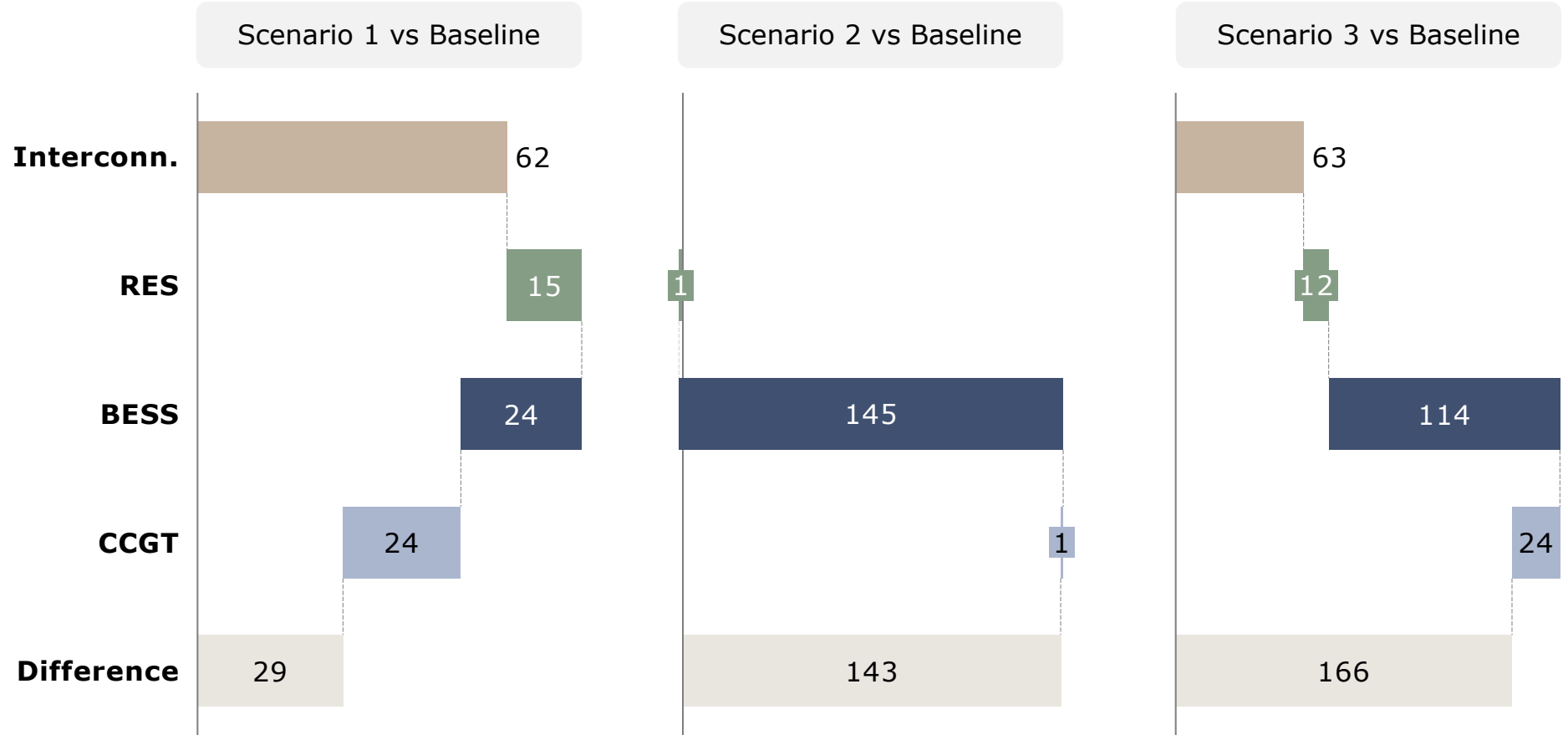
The possibility to further leverage on interconnection and flexibility allows for additional optimization in the future generation mix in the focus area...

CAPACITY DIFFERENTIAL IN 2040 – GW



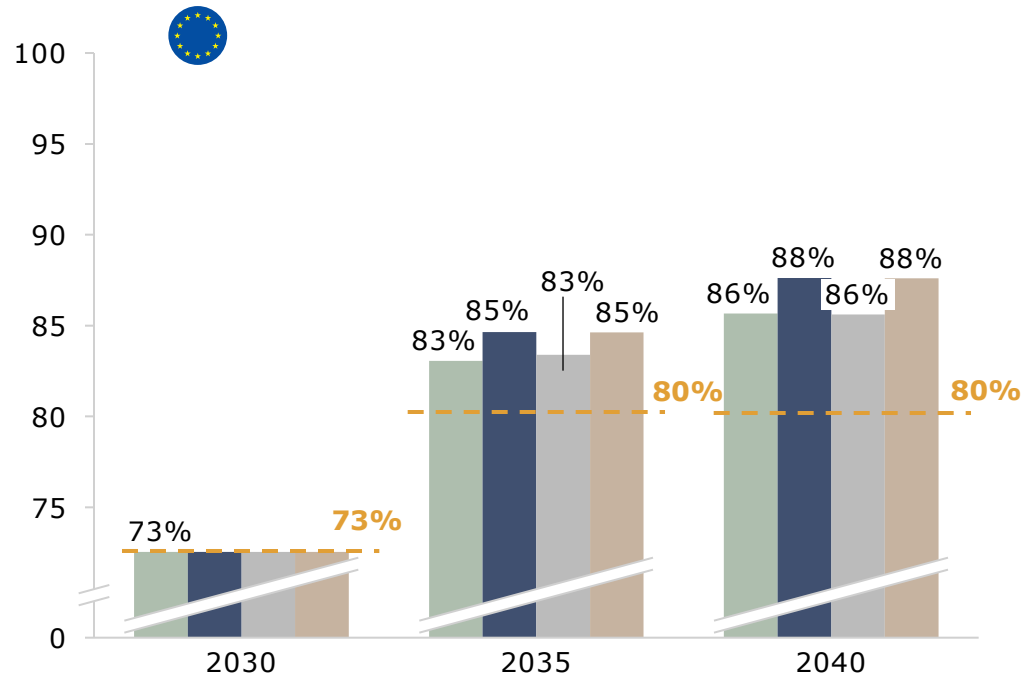
...as well as in the entire European modelled perimeter...

CAPACITY DIFFERENTIAL IN 2040 – GW

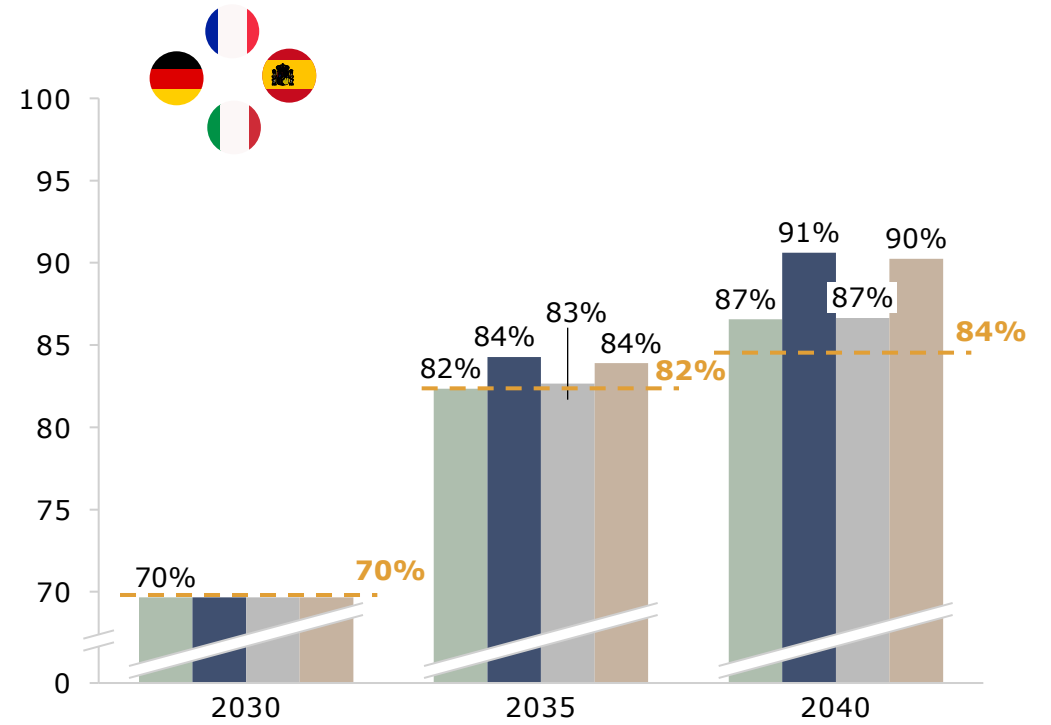


... and driving higher RES penetration even above the one envisaged in the TYNDP...

RES PENETRATION [%]



RES PENETRATION [%]



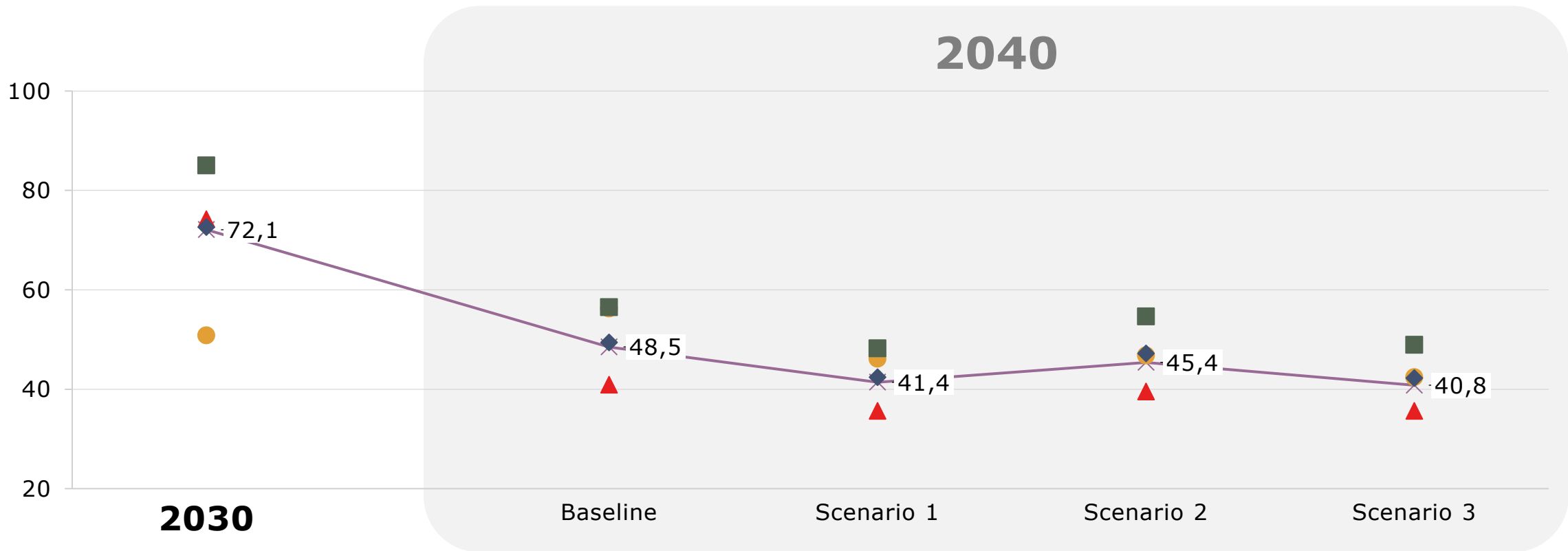
■ Baseline
 ■ Scenario 1
 ■ Scenario 2
 ■ Scenario 3
- - - RES Penetration Policy

Note: RES penetration (on demand) as per TYNDP scenarios NT30, GA35, GA40

... and decreasing the electricity price up to -8€/MWh on average at 2040 with full policy implementation

WHOLESALE PRICES - €/MWH, REAL 2025

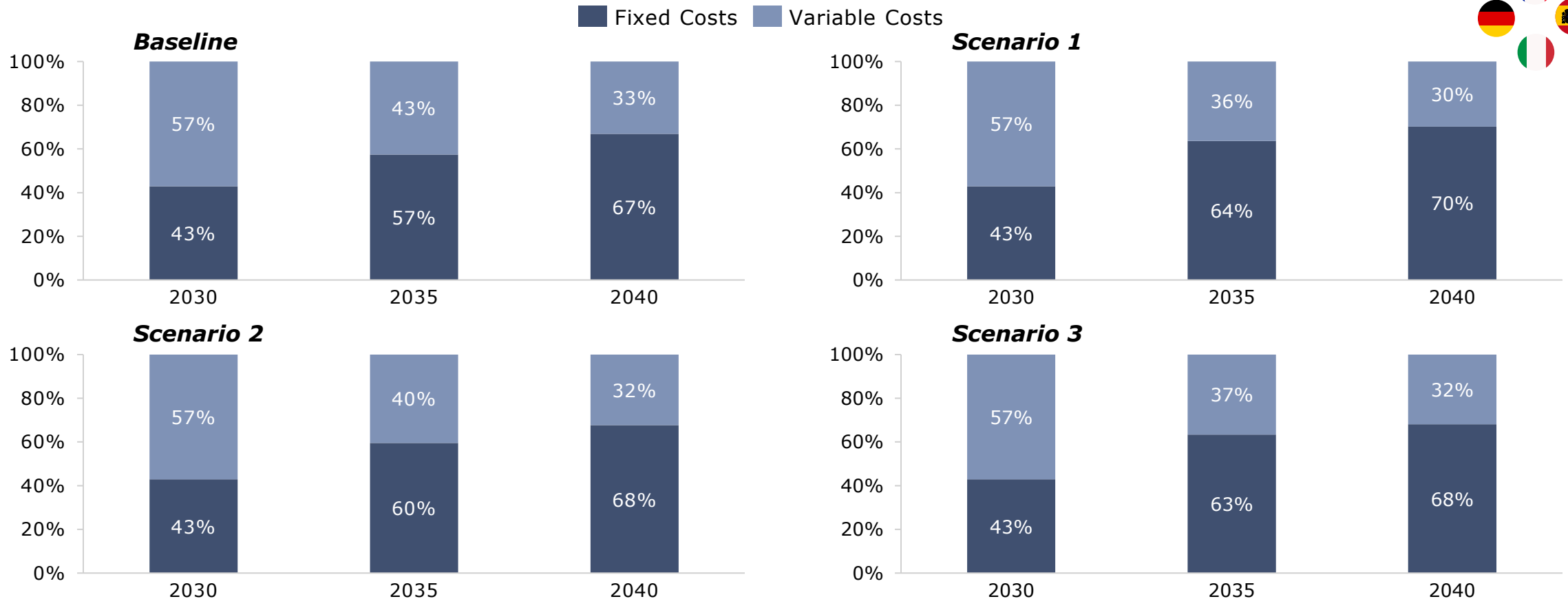
▲ Germany ● Spain ◆ France ■ Italy ✕ Average



Notes: Gas price: in 2030 is 28.7 €/MWh, in 2040 is 32.8 €/MWh. CO2 price: in 2030 is 122.5 €/ton, in 2040 is 171 €/ton. Real 2025 money values

The wholesale price formation evolves from being primarily driven by variable costs to being largely determined by fixed costs in all scenarios

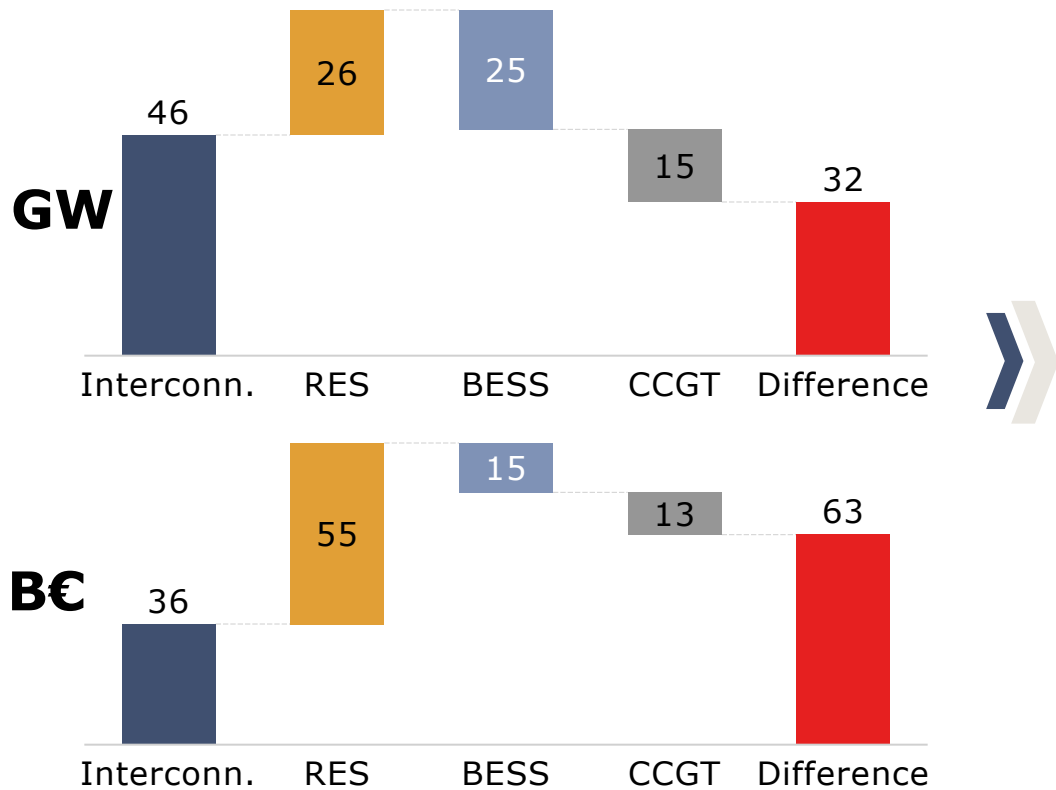
WHOLESALE PRICE DEPENDENCE ON VARIABLE AND FIXED COSTS¹



Note: 1) The cost structure reflects the evolution of price-setting technologies over time, and the decomposition of their costs between fixed and variable

A centralized coordination of electricity systems development would bring benefits¹ for around 57 Bln€

GENERATION MIX CHANGE (SCENARIO 1 VS BASELINE) – CUMULATIVE OVER 2030-2040



SYSTEM BENEFITS (SCENARIO 1 VS BASELINE) – CUMULATIVE OVER 2030-2040

Cheaper system:
-49 B€ end user costs
-2 B€ ancillary services and redispatch costs

Better RES integration and security:
+488 TWh RES
 Increased system security*

Accelerated decarbonisation and social benefits:
-38 Mt_{CO2}
-5.6 B€ CO2 social costs

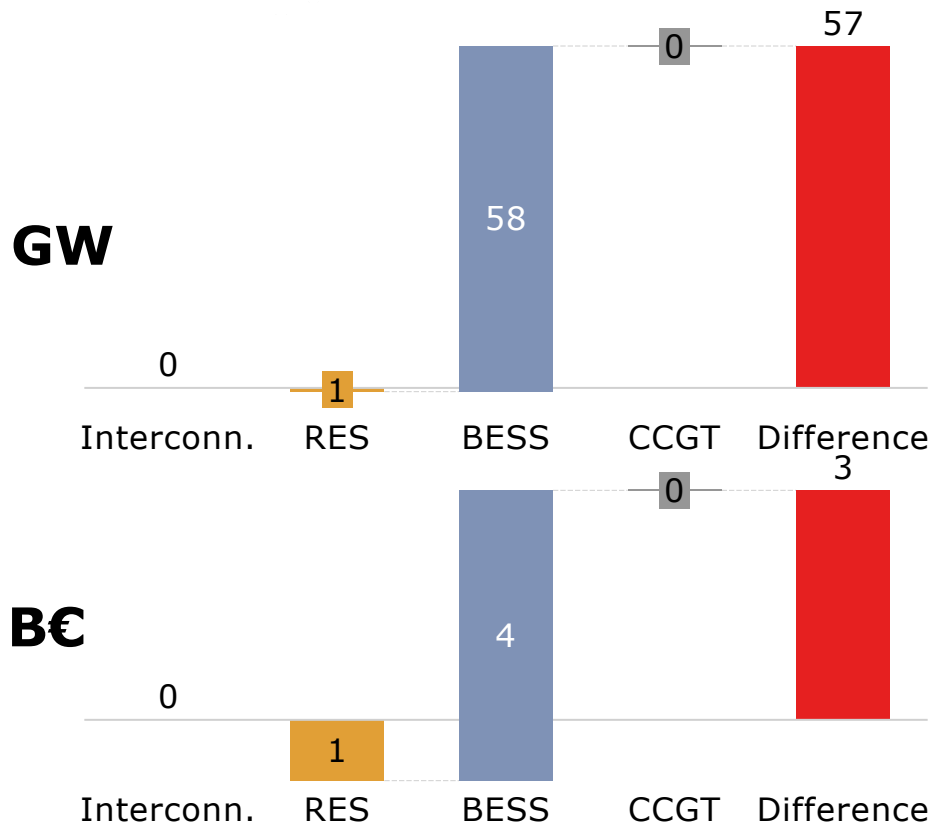
Positive impacts on strategic independence and trade balance:
-19 bcm imported gas
-83 B€ imports (gas and technologies) already accounted in end-user cost

Note: *) see slide 25 for details

Note: 1) Cumulative values over the period 2030-2040, referring to the Focus Countries: France, Germany, Italy, Spain

A policy shift towards integrating more distributed flexibility would bring benefits¹ for around 14 Bln€, with minimum additional investments

GENERATION MIX CHANGE (SCENARIO 2 VS BASELINE) – CUMULATIVE OVER 2030-2040



SYSTEM BENEFITS (SCENARIO 2 VS BASELINE) – CUMULATIVE OVER 2030-2040

Cheaper system:

- 12 B€ end user costs
- 0.3 B€ ancillary services and redispatch costs

Better RES integration and security:

- +88 TWh RES
- No relevant loss of system security*

Accelerated decarbonisation and social benefits:

- 9 Mt_{CO2}
- 1.3 B€ CO2 social costs

Positive impacts on strategic independence and trade balance:

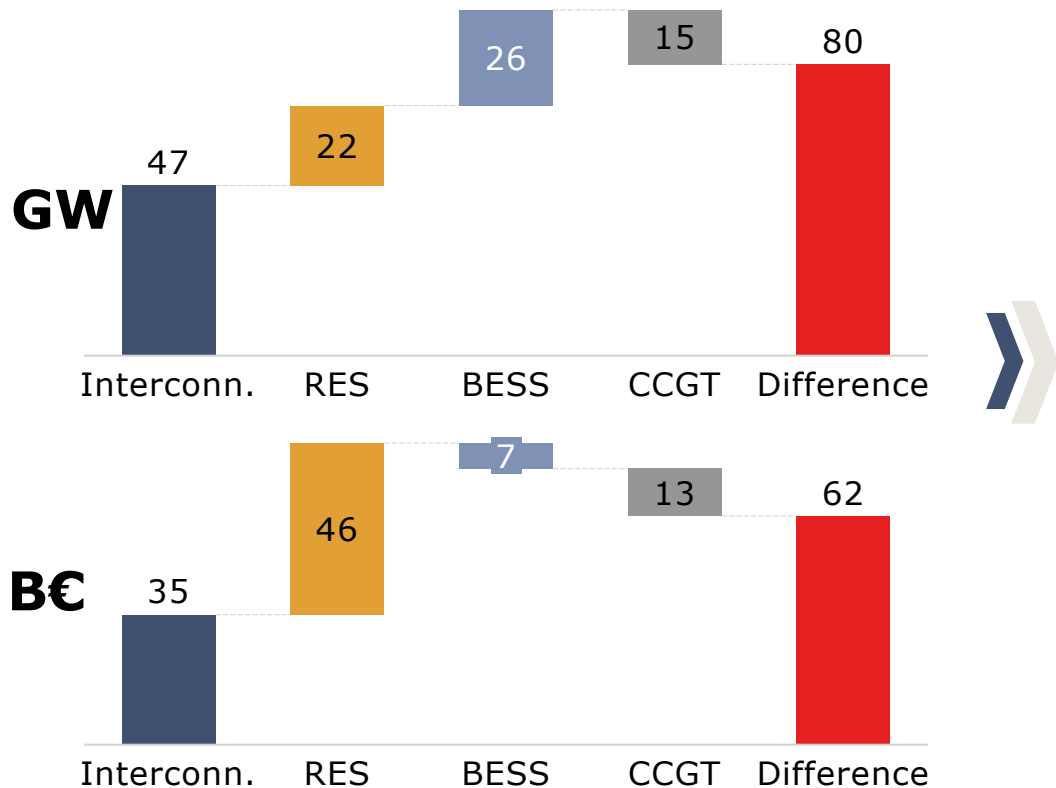
- 4 bcm imported gas
- 0.7 B€ imports (gas and technologies) already accounted in end-user cost

Note: *) see slide 25 for details

Note: 1) Cumulative values over the period 2030-2040, referring to the Focus Countries: France, Germany, Italy, Spain

Combining centralized coordination with the promotion of distributed flexibility would bring benefits¹ for around 71 Bln€

GENERATION MIX CHANGE (SCENARIO 3 VS BASELINE) – CUMULATIVE OVER 2030-2040



SYSTEM BENEFITS (SCENARIO 3 VS BASELINE) – CUMULATIVE OVER 2030-2040

Cheaper system:
-64 B€ end user costs
-1 B€ ancillary services and redispatch costs

Better RES integration and security:
+426 TWh RES
 Increase of system security*

Accelerated decarbonisation and social benefits:
-41 Mt_{CO2}
-5.9 B€ CO2 social costs

Positive impacts on strategic independence and trade balance:
-20 bcm imported gas
-75 B€ imports (gas and technologies) already accounted in end-user cost

Note: *) see slide 25 for details

Note: 1) Cumulative values over the period 2030-2040, referring to the Focus Countries: France, Germany, Italy, Spain

Agenda

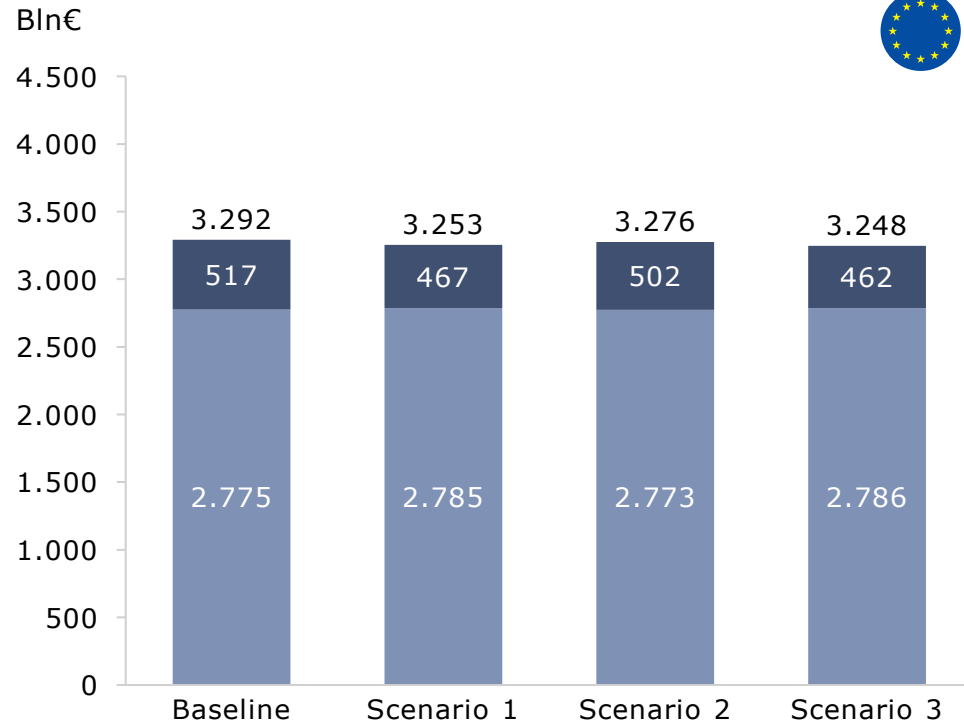
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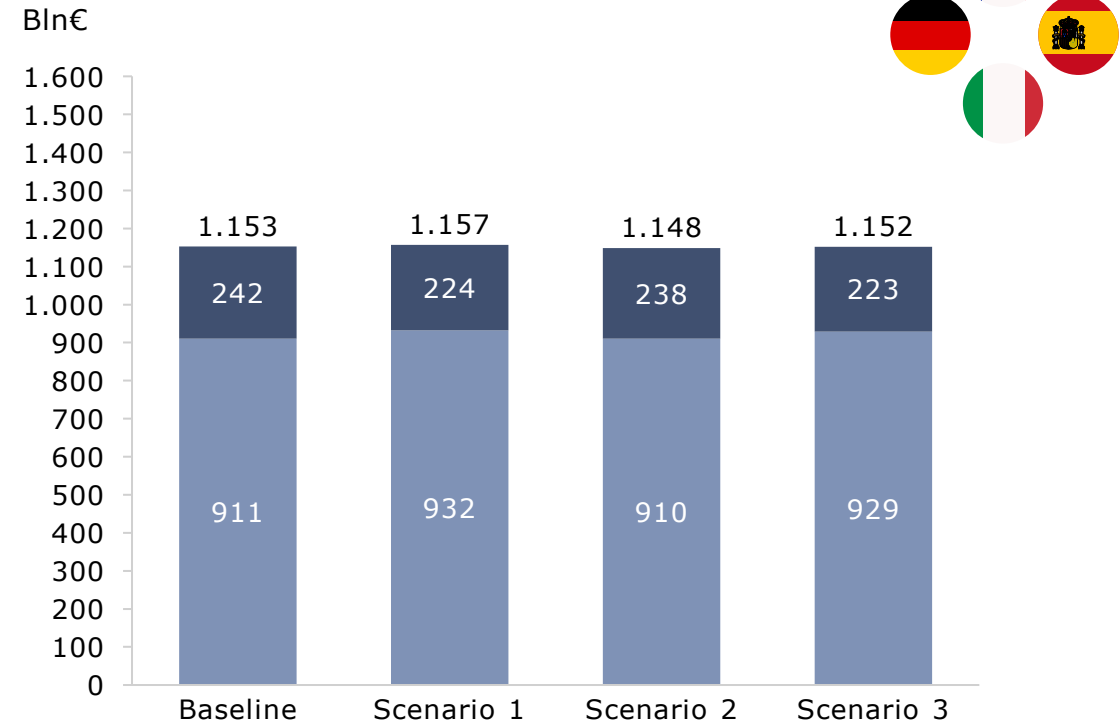


Scenarios 1 and 3 show the largest reduction of total system costs, due to the additional degrees of freedom in the European-wide optimization

**TOTAL SYSTEM COSTS - ALL EUROPE
CUMULATIVE OVER 2030-2040**



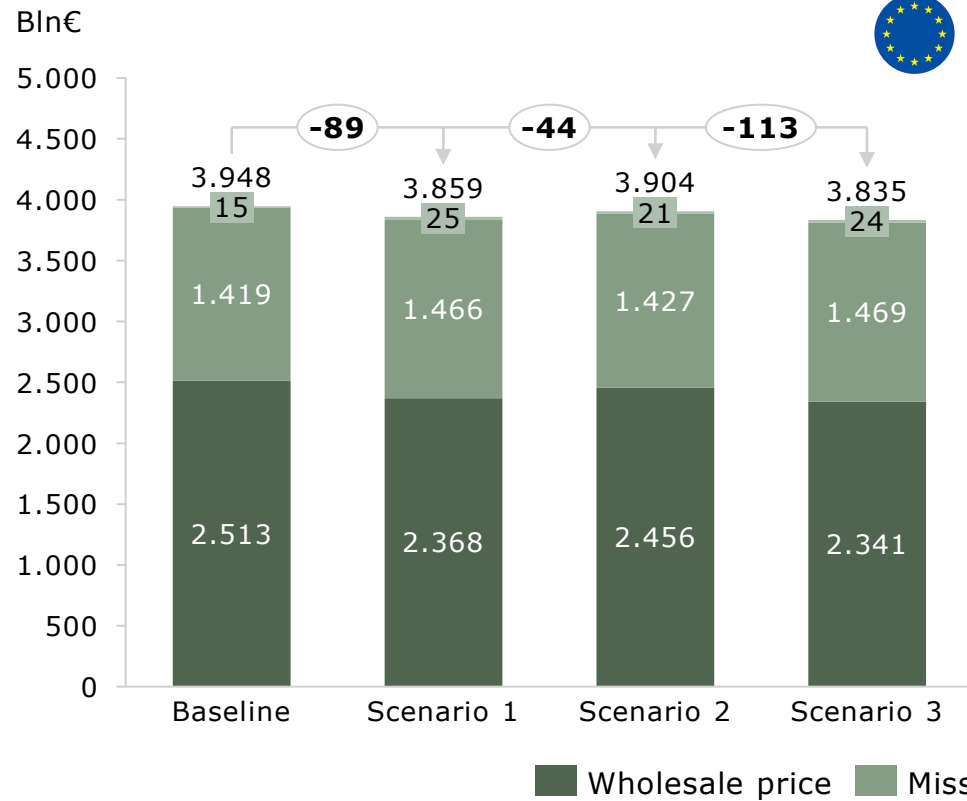
**TOTAL SYSTEM COSTS - CORE COUNTRIES
CUMULATIVE OVER 2030-2040**



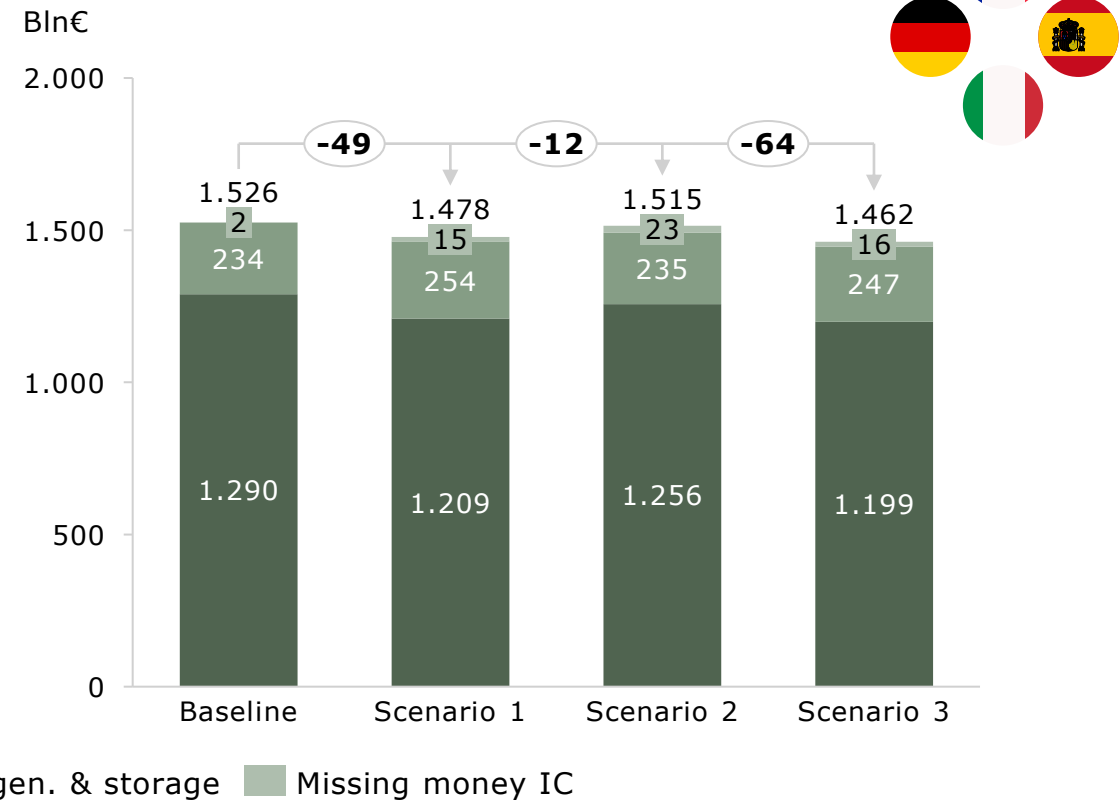
■ Variable generation costs
■ New build levelized Capex and fixed costs

The savings in end-user costs are larger in Scenarios 1 and 3, primarily due to the reductions in wholesale prices

**END-USER COSTS - ALL EUROPE
CUMULATIVE OVER 2030-2040**

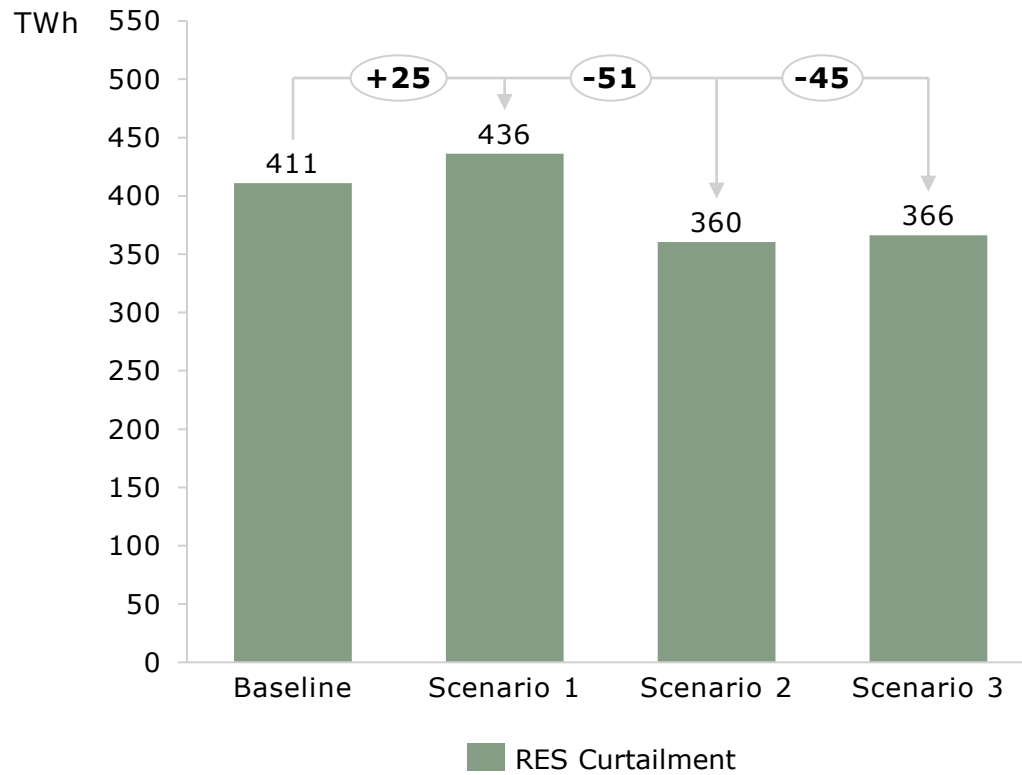


**END-USER COSTS - CORE COUNTRIES
CUMULATIVE OVER 2030-2040**

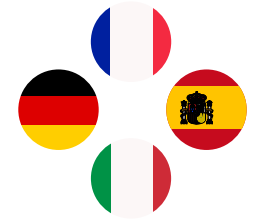


A better integration of RES is possible without losing system security

RES CURTAILMENT – CUMULATIVE OVER 2030-2040



SAFE HOURS (%)

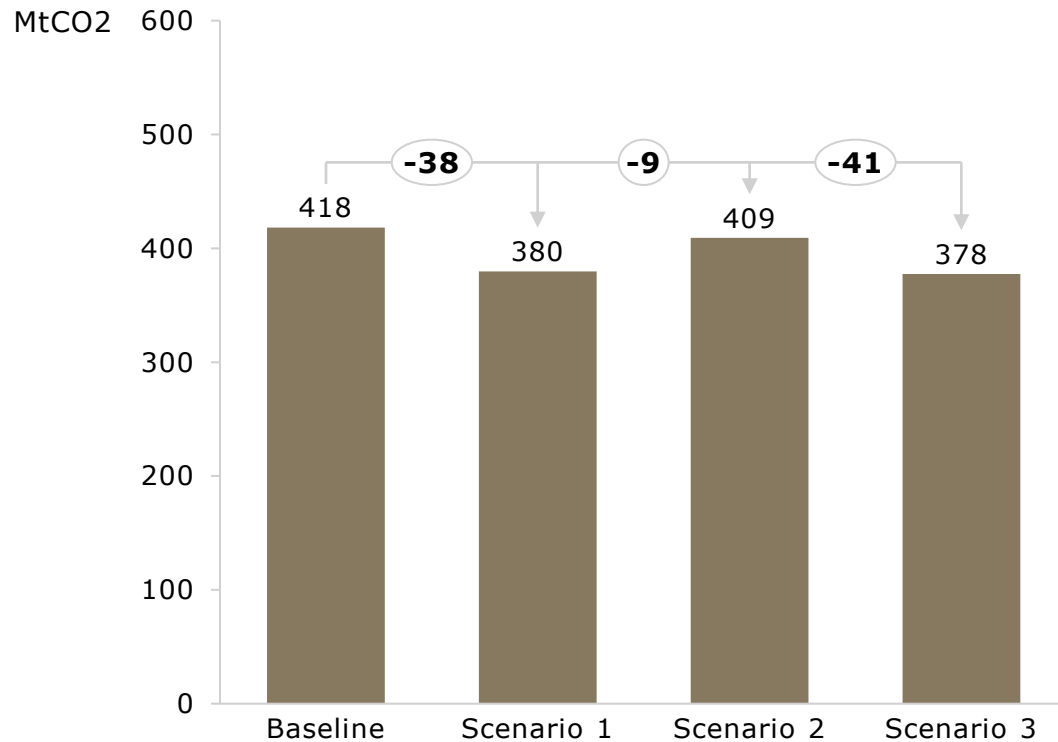


	2030	2040	Avg.
Baseline	78%	76%	77%
Scenario1	83%	83%	83%
Scenario2	78%	75%	76%
Scenario3	82%	82%	82%

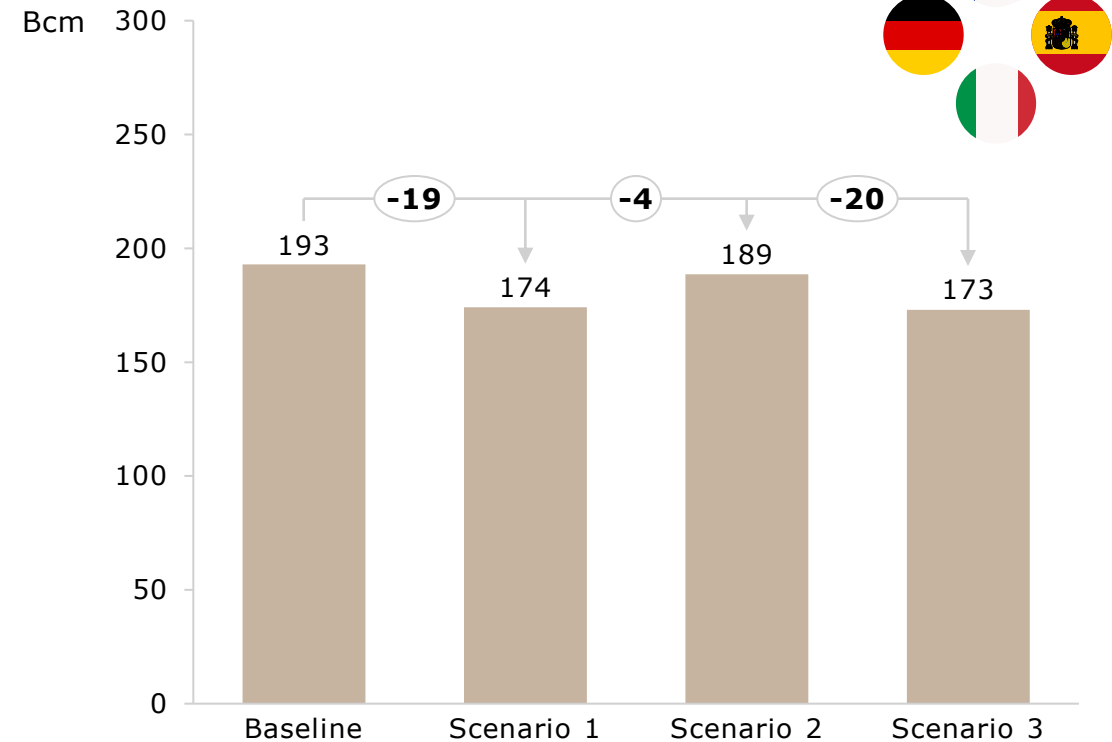
Note: «safe hours” are defined as hours in which programmable generation, including the contribution from interconnectors, is greater than 10% of the overall local generation

Although decarbonization is not the primary focus of the scenarios, an effective system cost management also supports decarbonization objectives

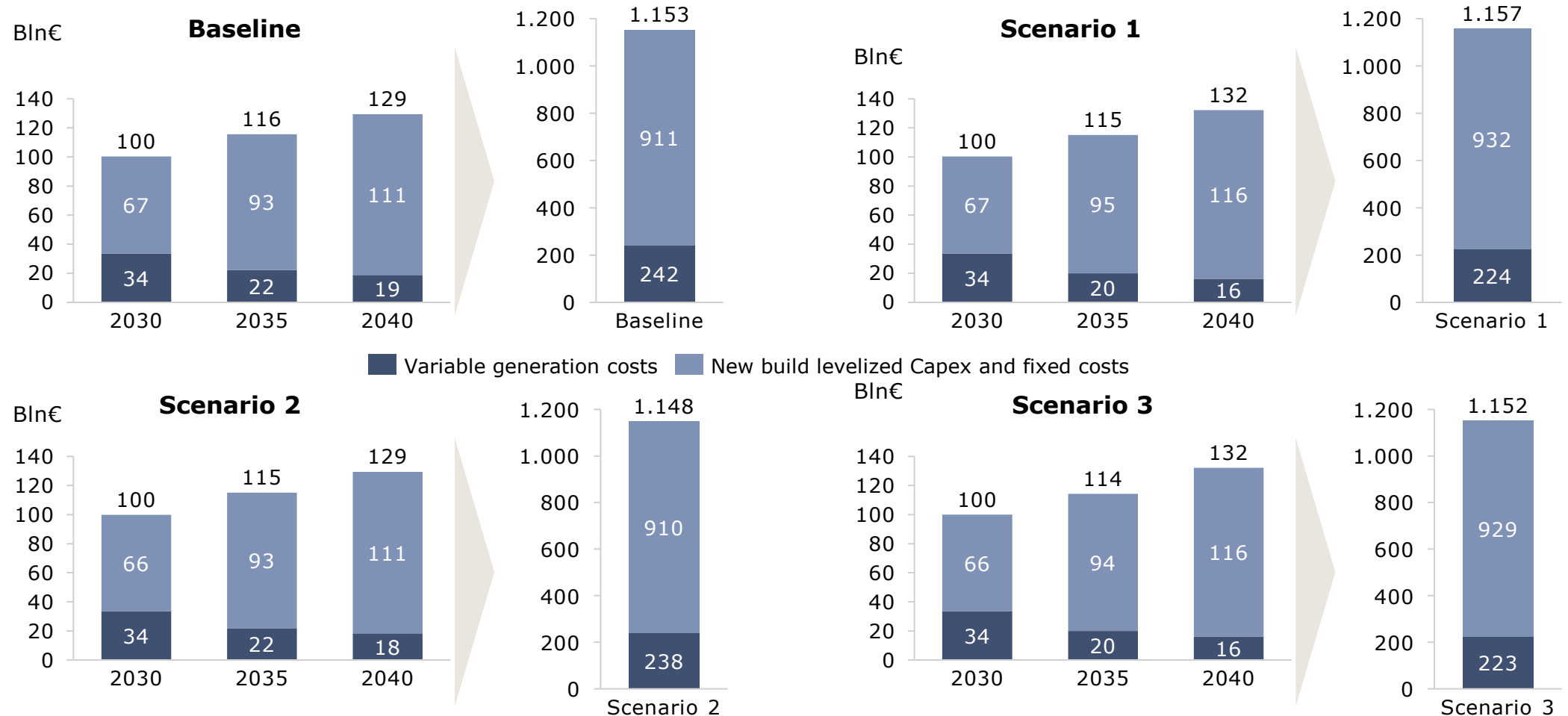
CO2 EMISSIONS – CUMULATIVE OVER 2030-2040



GAS CONSUMPTION – CUMULATIVE OVER 2030-2040

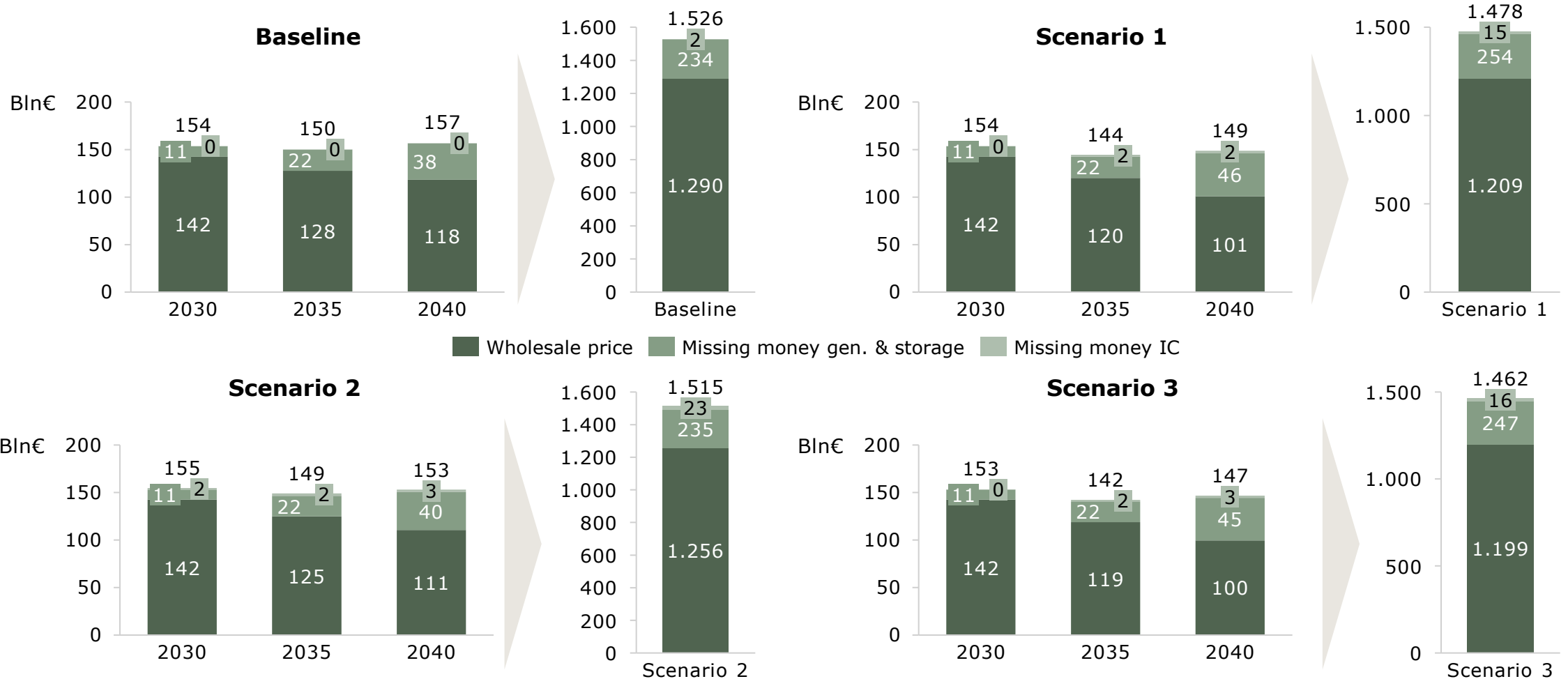


The levelized Capex component increases over time and represents the largest part of the Total System Cost

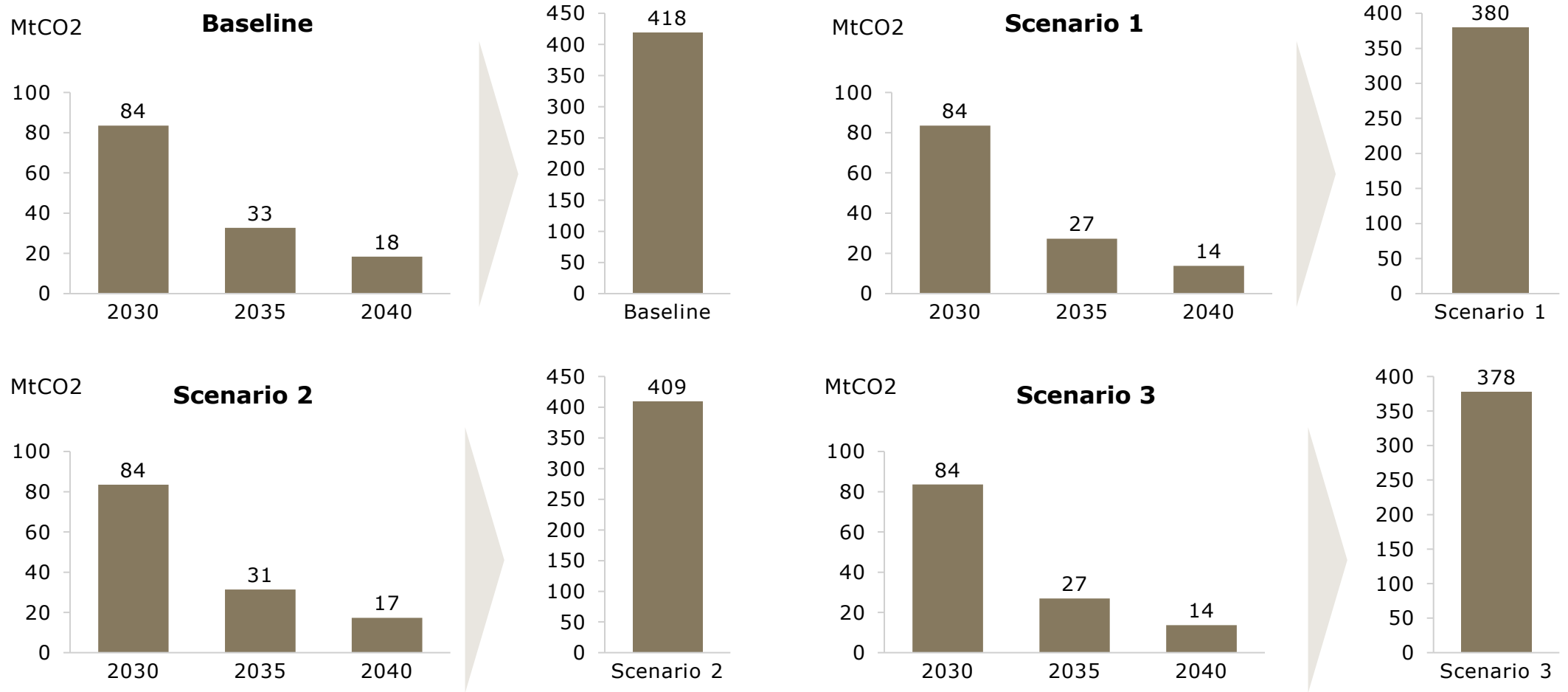


Note: Cumulative means: at 2030 the value is cumulated with respect to 2025, at 2035 the value is cumulated with respect to 2025, at 2040 the value is cumulated with respect to 2025. Levelised means: dividing the capex over the lifetime assuming a discount factor (20 years lifetime with 8% discount for generation plants, 40 years lifetime with 6% discount for interconnectors). Therefore the value represented in each year represents the capex which needs to be covered in that year for all the cumulative investments until then

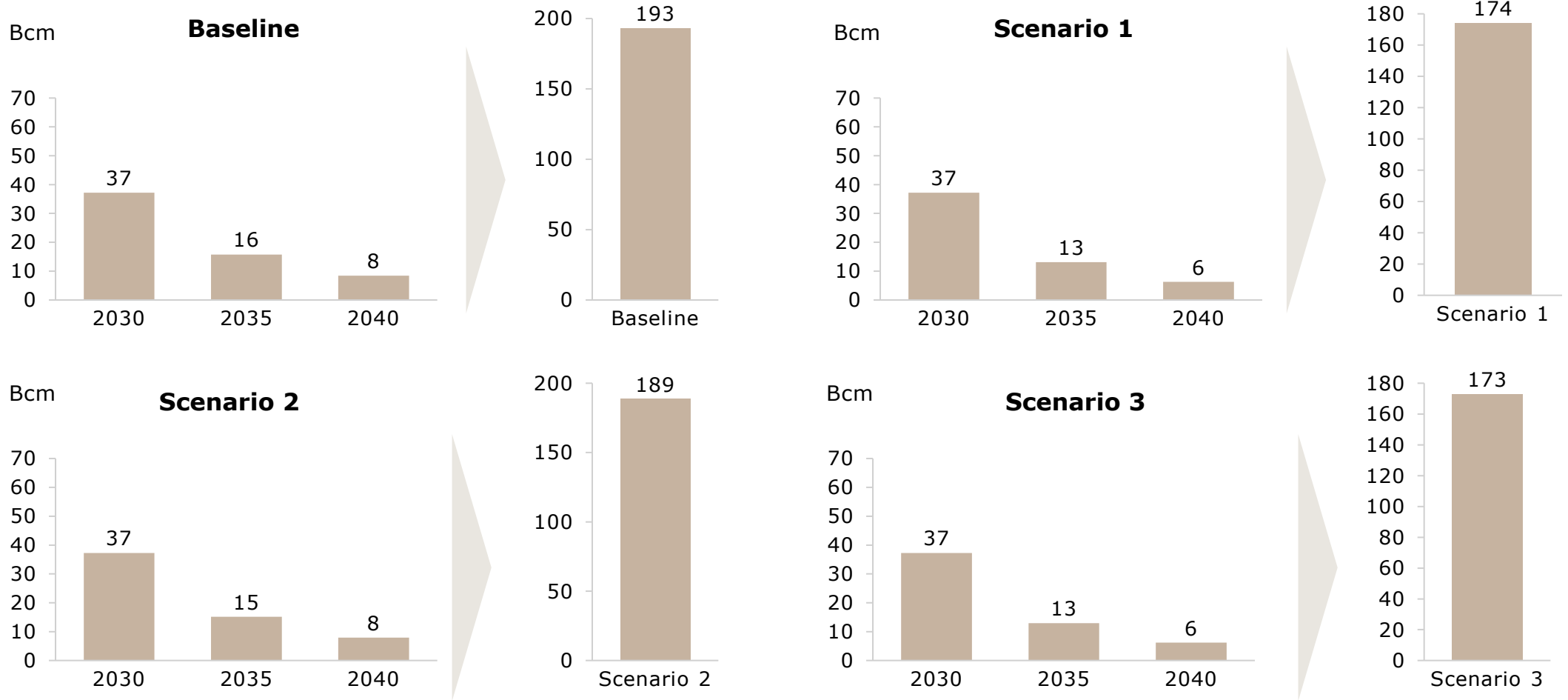
The majority of end-user costs are due to the wholesale price, since all investments before 2030 are currently treated as sunk costs



CO2 emissions decrease over time in all scenarios due to the changes in the generation mix

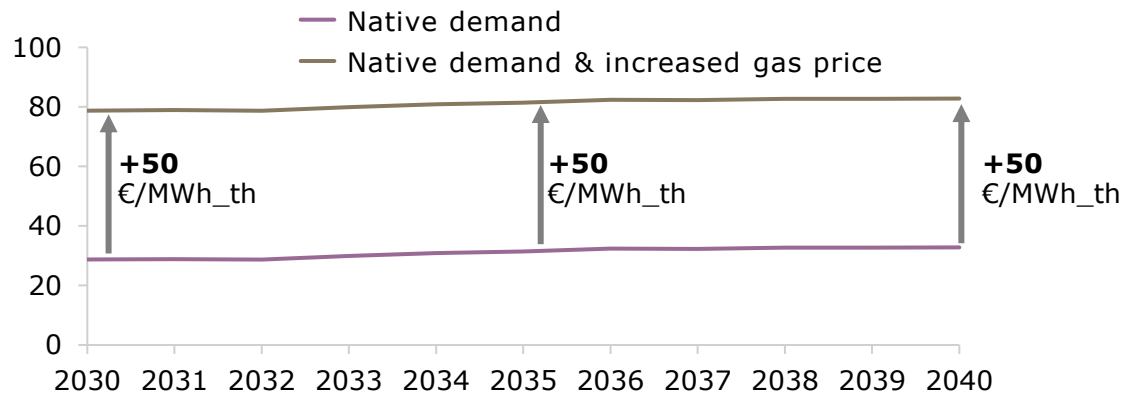


Gas consumption decreases over time in all scenarios due to the changes in the generation mix

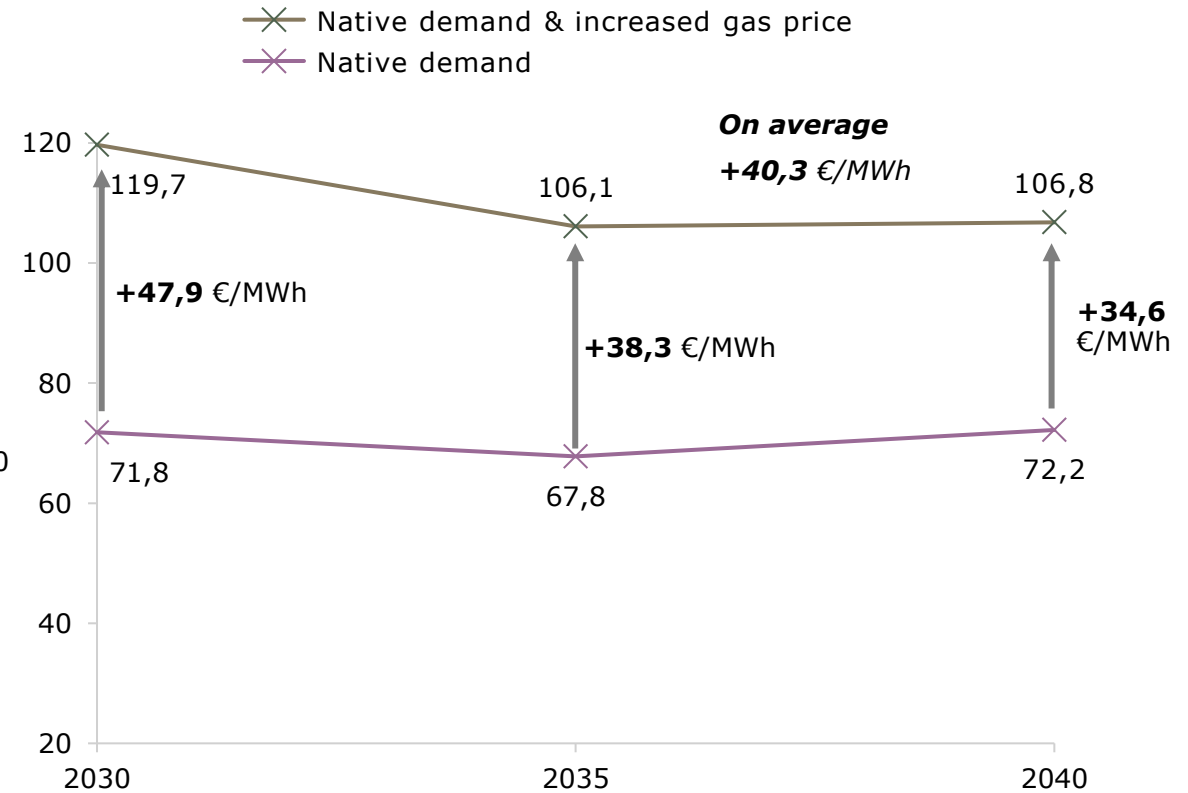


The system also turns out to be more resilient; for example, a gas price shock of +50€/MWh would have led to a price increase of +35€/MWh in 2040...

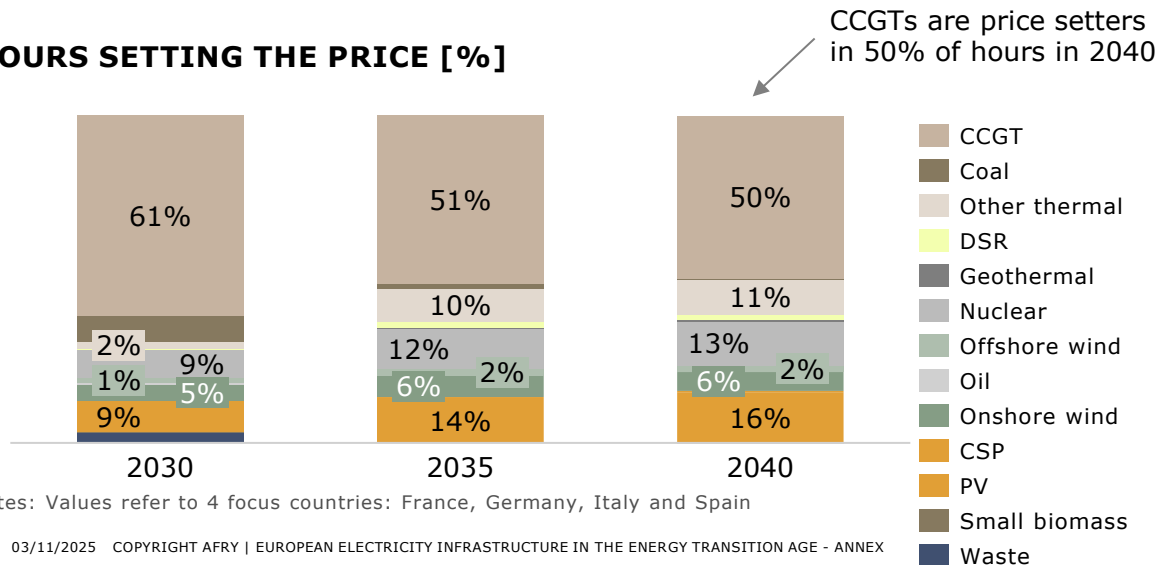
GAS PRICE [€/MWH_TH, REAL 2025]



WHOLESALE PRICES [€/MWH, REAL 2025]



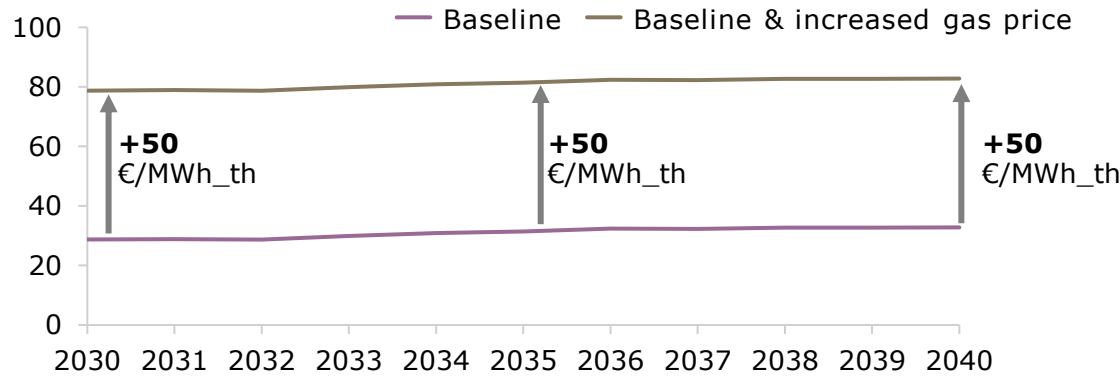
HOURS SETTING THE PRICE [%]



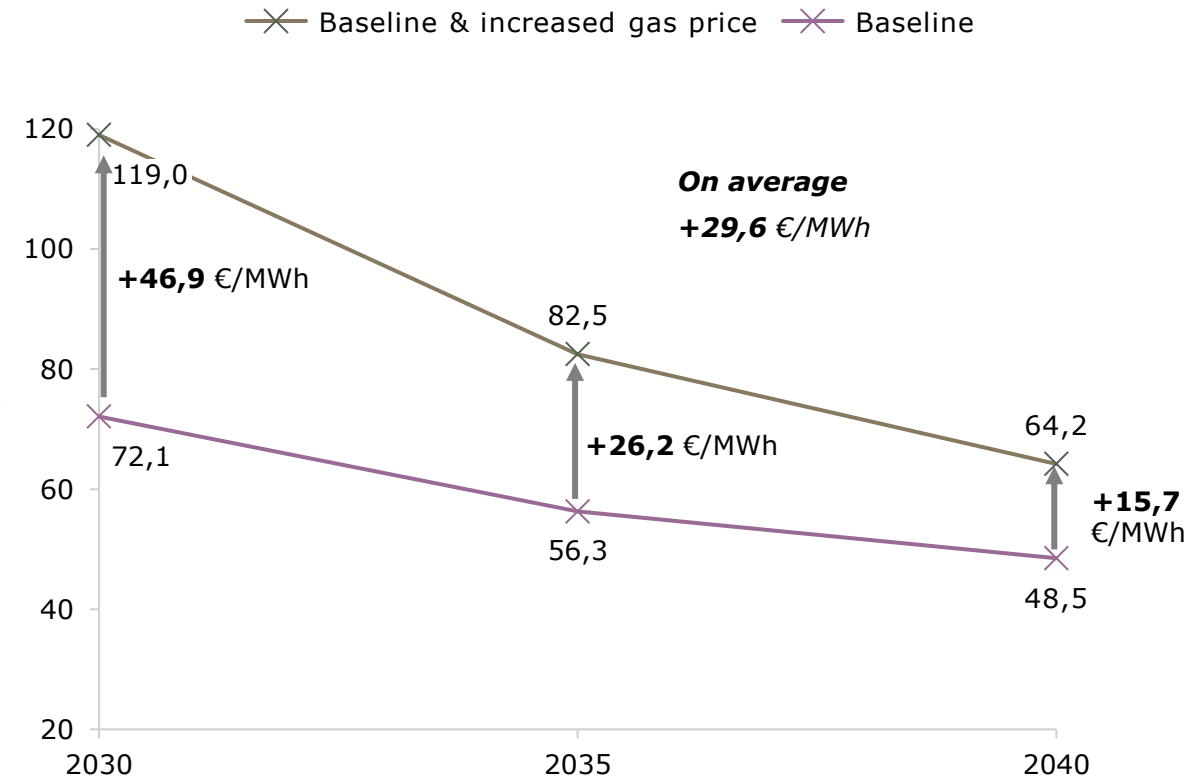
Notes: Values refer to 4 focus countries: France, Germany, Italy and Spain

...but if flexible green demand is present, such impact drops to +15€/MWh in 2040, since gas-fired generators are increasingly less marginal

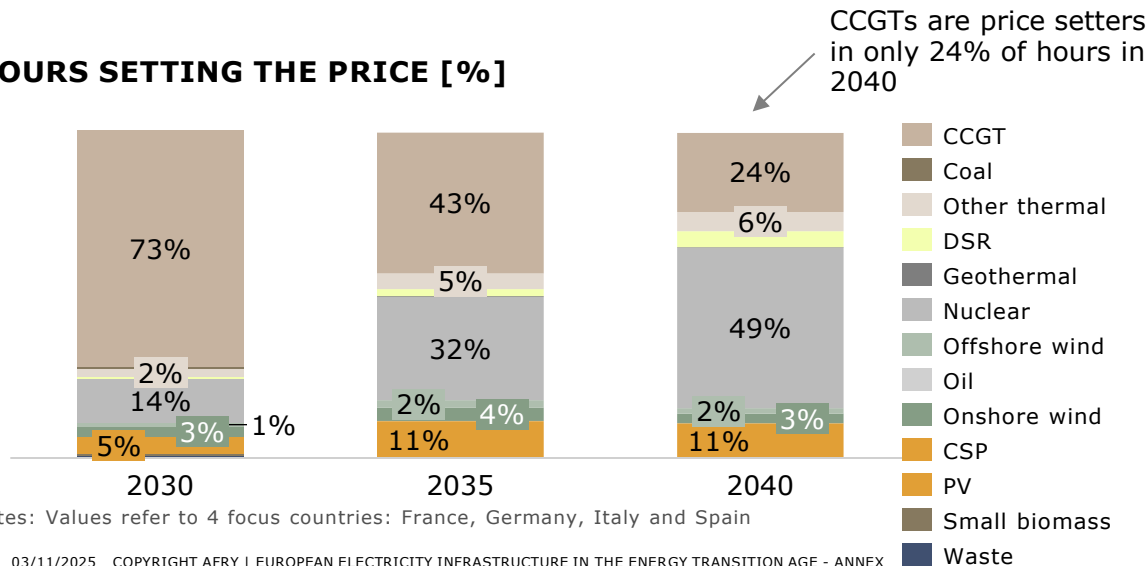
GAS PRICE [€/MWH_TH, REAL 2025]



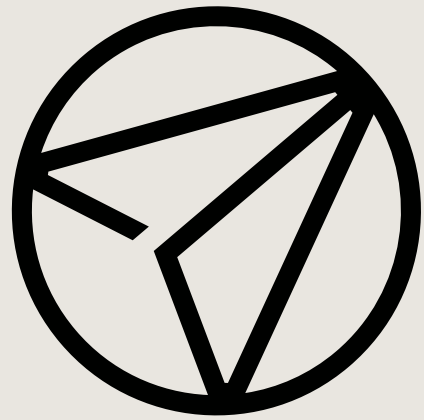
WHOLESALE PRICES [€/MWH, REAL 2025]



HOURS SETTING THE PRICE [%]



Notes: Values refer to 4 focus countries: France, Germany, Italy and Spain



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