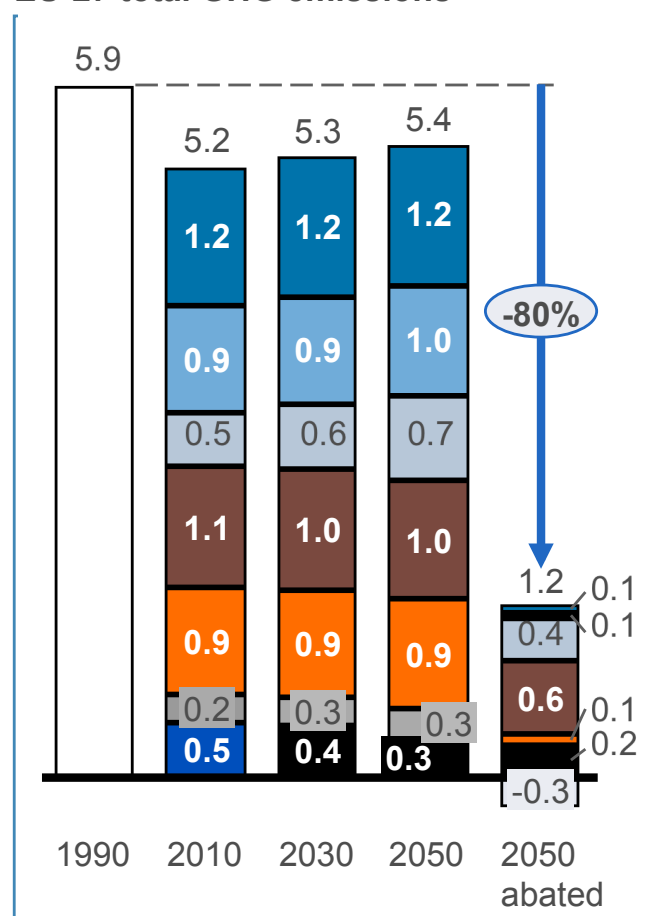


80% by 2050 only possible with zero-carbon power supply

GtCO₂e per year

EU-27 total GHG emissions



Sector	Abatement	Within sector ^{1, 2}	Fuel shift
Power	95% to 100%	>95%	
Road transport	95%	20%	75% (electric vehicles, biofuels and fuel cells)
Air & sea transport	50%	30%	20% (biofuels)
Industry	40%	35% (CCS ³)	5% (heat pumps)
Buildings	95%	45% (efficiency and new builds)	50% (heat pumps)
Waste	100%	100%	
Agriculture	20%	20%	
Forestry	-0.25 GtCO ₂ e	Carbon sinks	

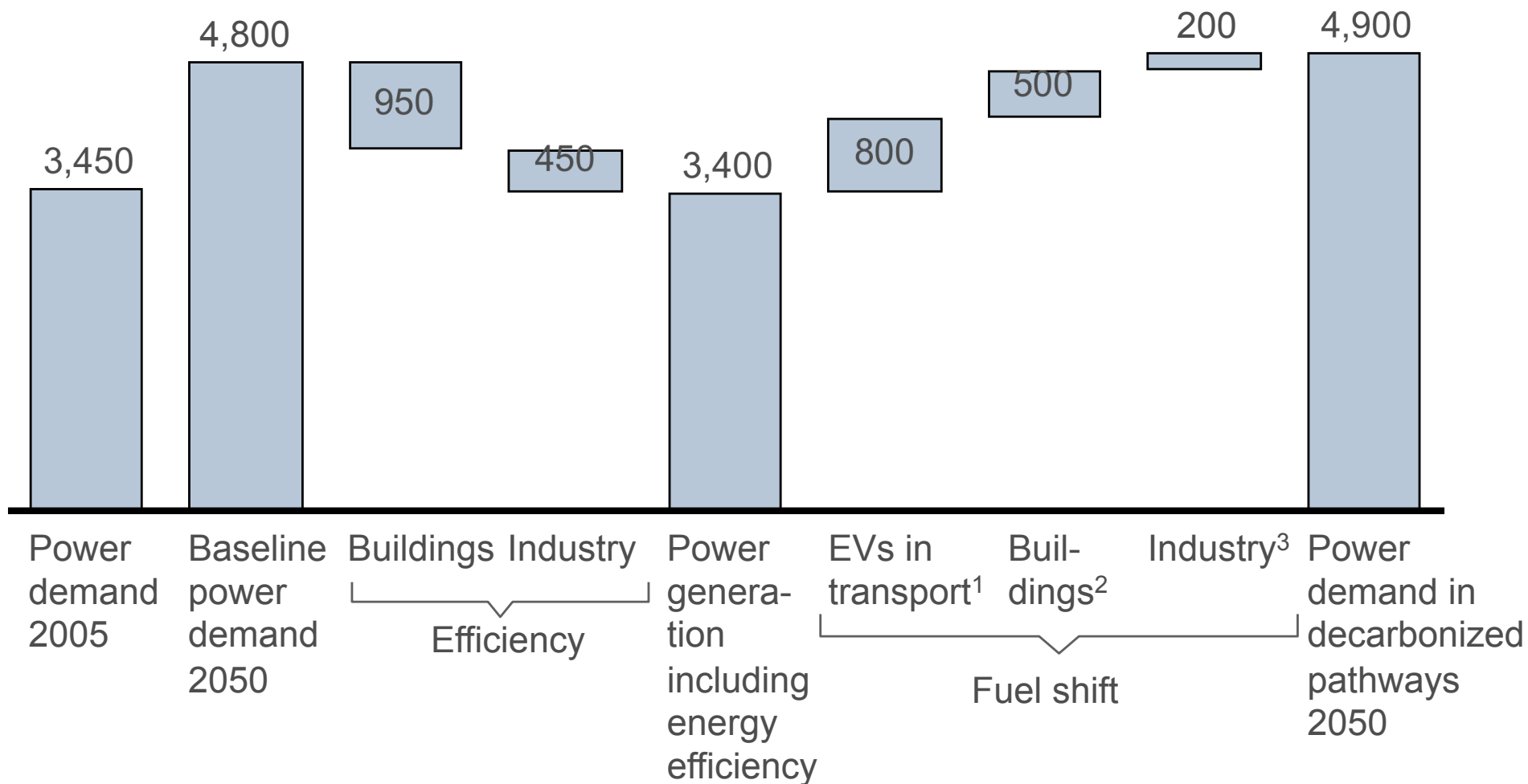
1 Based on the McKinsey Global GHG Cost Curve

2 Large efficiency improvements are already included in the baseline, especially for industry

3 CCS applied to 50% of industry (cement, chemistry, iron and steel, petroleum and gas, not applied to other industries)

Power generation will go down due to higher efficiency and up due to additional demand from fuel shift

EU-27 plus Norway and Switzerland power demand, TWh per year

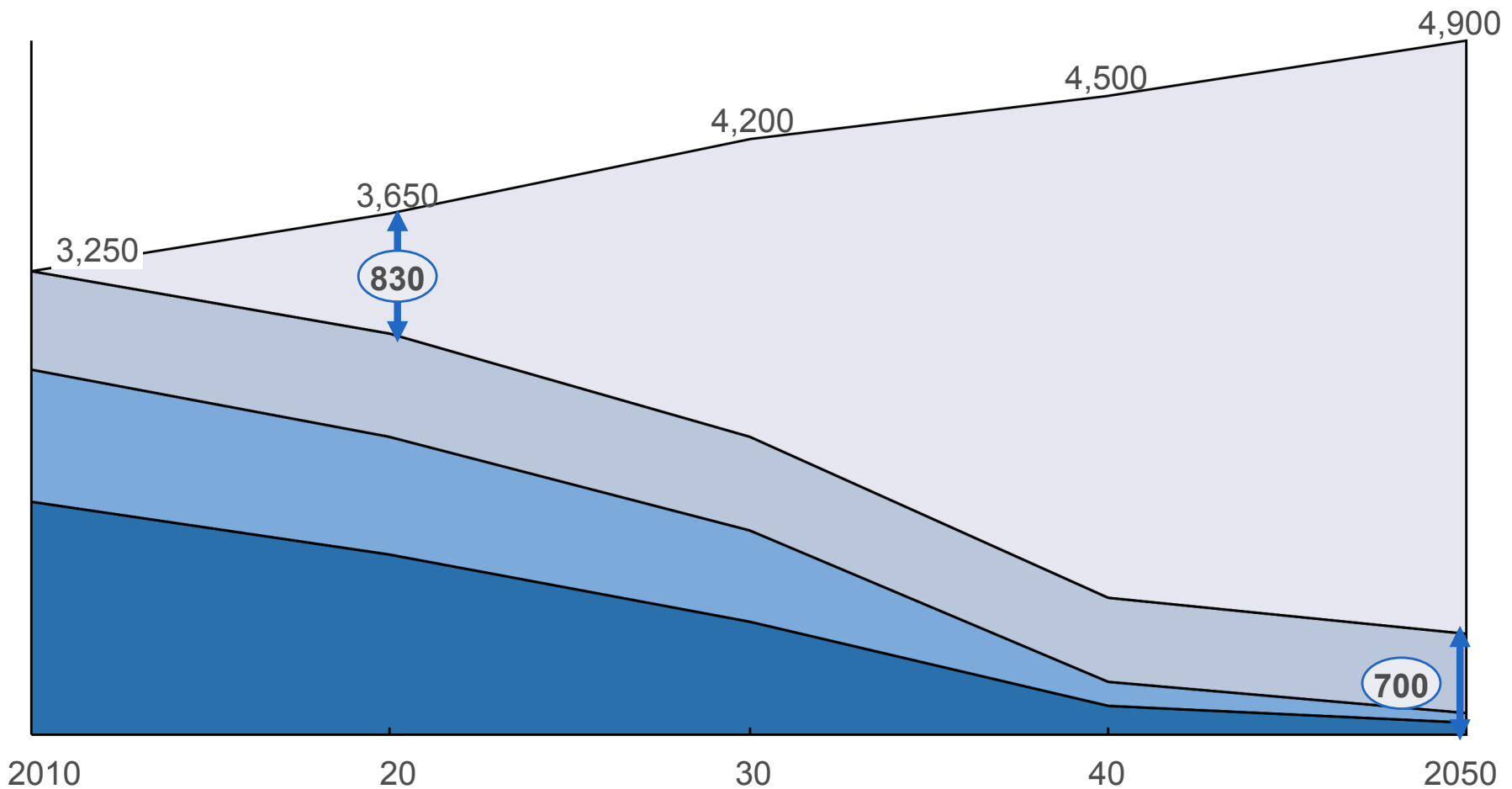


1 Electrification of 100% LDVs and MDVs (partially plug-in hybrids); HDVs remain emitting ~10% while switching largely to biofuel or hydrogen fuel cells
 2 90% of remaining primary energy demand converted to electricity (heating/cooling from heat pumps); assumed 4 times as efficient as primary fuel
 3 10% of remaining primary energy demand for combustion converted to electricity (heating from heat pumps); assumed 2.5 times as efficient as primary fuel

Only 700 TWh of today's existing and planned production capacity is assumed to still be operating in 2050

Power supply by existing and currently planned power plants and forecasted power demand, TWh

- Total power demand
- Existing nuclear
- Existing RES¹
- Existing fossil



¹Existing RES Production remaining in 2050 is nearly all from existing hydro

The pathways cover a wide range of technology mixes

Decarbonization pathways

**40% RES¹
30% Nuclear
30% CCS**

**60% RES
20% Nuclear
20% CCS**

**80% RES
10% Nuclear
10% CCS**

100% RES

- RES share close to currently legally committed by the EU and the IEA baseline
 - Sensitivities on a high nuclear share and a high thermal / CCS share are included
- }
- RES mix based on current deployment (minimum), aim for a broad mix of technologies and theoretical deployment (maximum)
 - Equal shares for nuclear and thermal / CCS
- }
- Same shares for RES as the 80% pathway
 - Includes more potential for enhanced geothermal and the use of CSP from Africa

¹ Renewable energy sources

40% RES: Transmission requirements are substantial, even after thorough optimization

● Centre of gravity

Total net transfer capacity requirements GW (existing + additional)



Interconnection	Capacity additional (existing) [GW]	Annual utilization [%]
UK&Ireland-France	12 (2)	80
UK&Ireland-Nordic	0 (0)	0
UK&Ireland-Benelux&Germany	0 (0)	0
France-Iberia	16 (1)	80
France-Benelux&Germany	11 (6)	94
France-Central-Europe	2 (3)	98
France-Italy&Malta	0 (3)	92
Nordic-Benelux&Germany	0 (3)	65
Nordic-Poland&Baltic	4 (1)	72
Benelux&Germany-Central-EU	0 (4)	45
Benelux&Germany-Poland&Baltic	4 (1)	79
Central-Europe-Poland &Baltic	0 (2)	73
Central-South East EU	0 (2)	53
Central-Europe-Italy	0 (5)	31
South East EU-Italy	6 (1)	81
Total	56 (34)	

80% RES: Transmission requirements are significant, even after thorough optimization

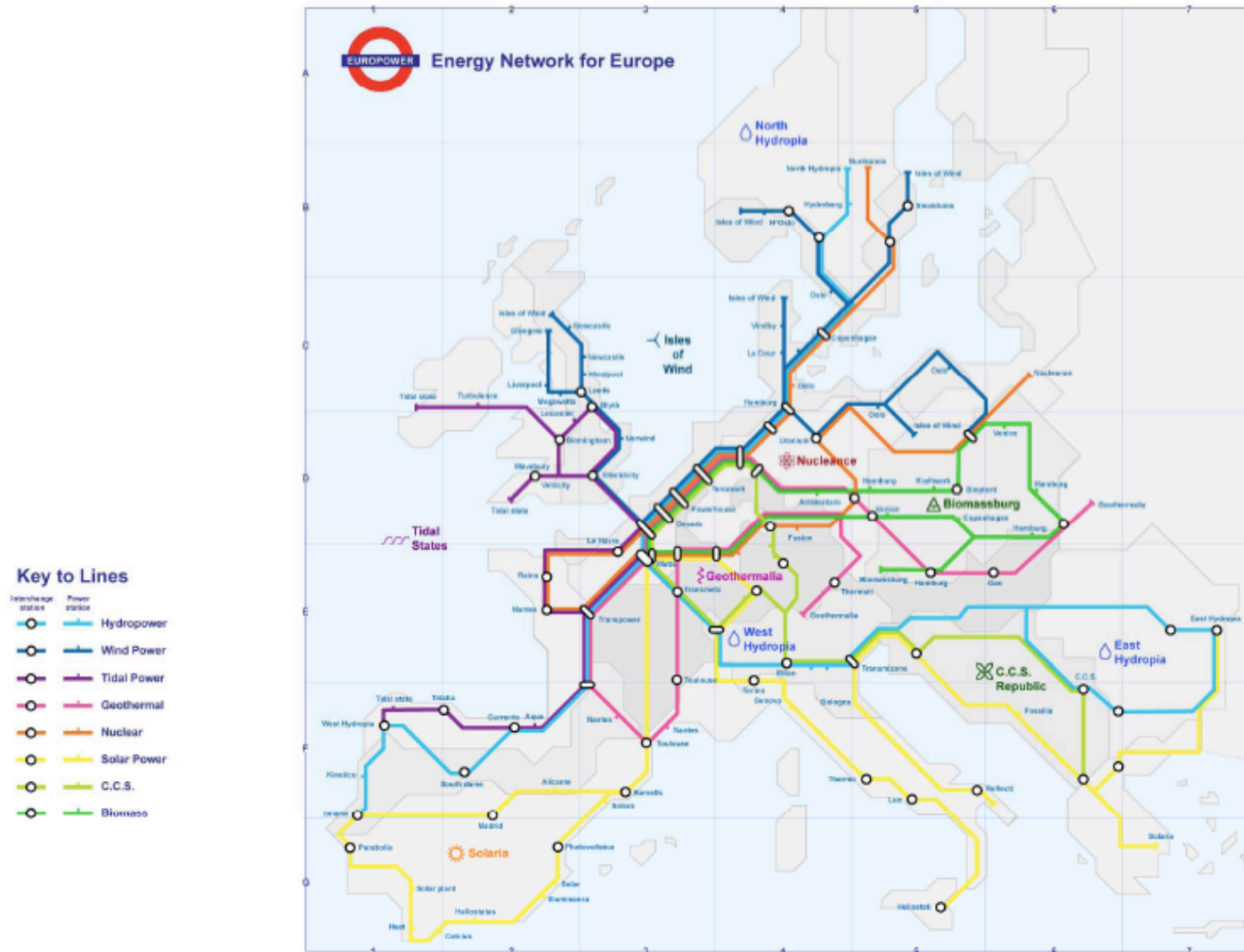
● Centre of gravity

Total net transfer capacity requirements GW (existing + additional)



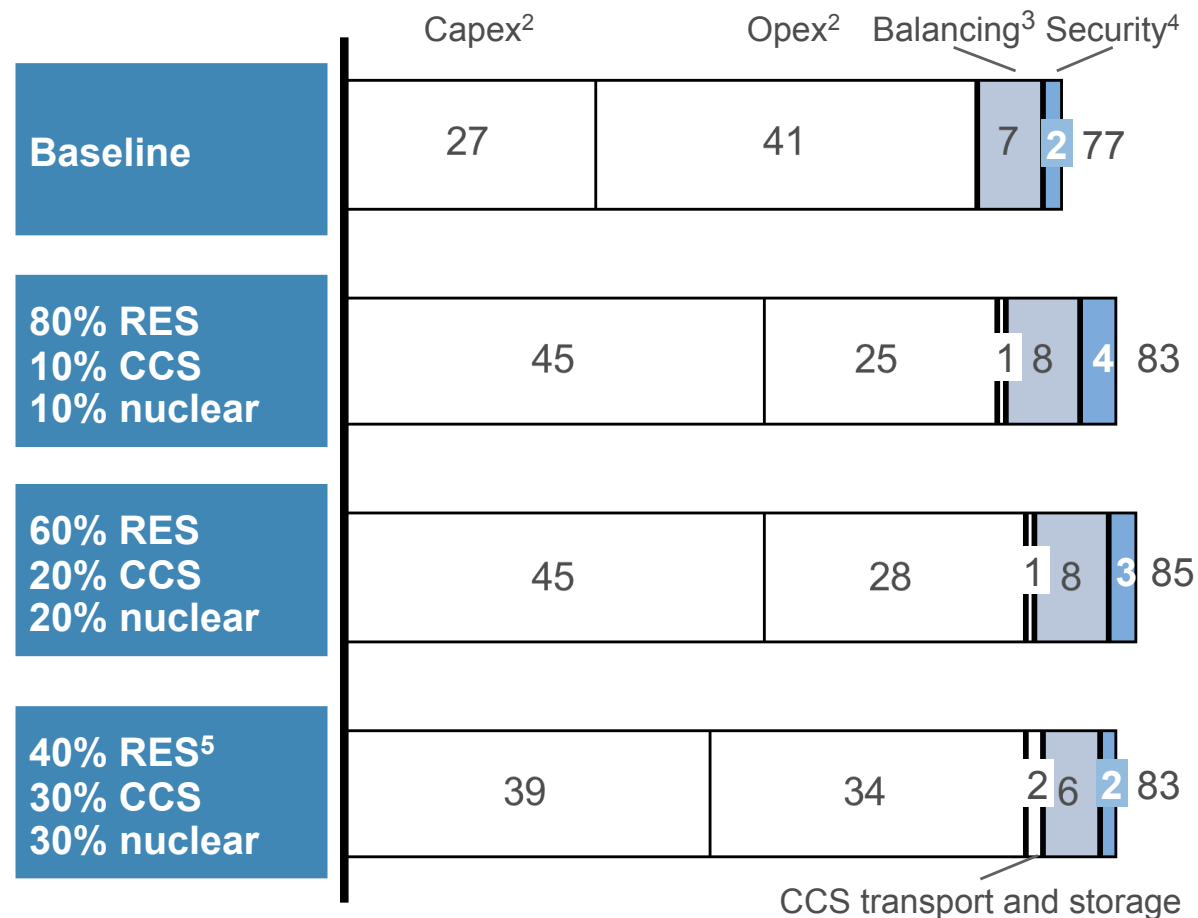
Interconnection	Capacity additional (existing) [GW]	Annual utilization [%]
UK&Ireland-France	19 (2)	57
UK&Ireland-Nordic	9 (0)	74
UK&Ireland-Benelux&Germany	5 (0)	61
France-Iberia	52 (1)	61
France-Benelux&Germany	23 (6)	54
France-Central-Europe	11 (3)	70
France-Italy&Malta	6 (3)	77
Nordic-Benelux&Germany	0 (3)	67
Nordic-Poland&Baltic	5 (1)	62
Benelux&Germany-Central-EU	7 (4)	56
Benelux&Germany-Poland&Baltic	13 (1)	72
Central-Europe-Poland&Baltic	0 (2)	52
Central-South East EU	5 (2)	62
Central-Europe-Italy	0 (5)	47
South East EU-Italy	11 (1)	57
Total	166 (34)	

What REAL energy security looks like....



All pathways can deliver power with roughly the same cost and reliability as the baseline with carbon price $\leq \text{€}50/\text{tCO}_2$

Average new built CoE from 2010 to 2050¹, EUR/MWh (real terms)



1 Weighted average based on the CoE in each 10-year time frame (2010, 2020, 2030, 2040, 2050)

2 Generation only

3 Cost related to non optimal plant use, system dispatch cost for secure operation, running backup plants, storage losses, reserve and response cost

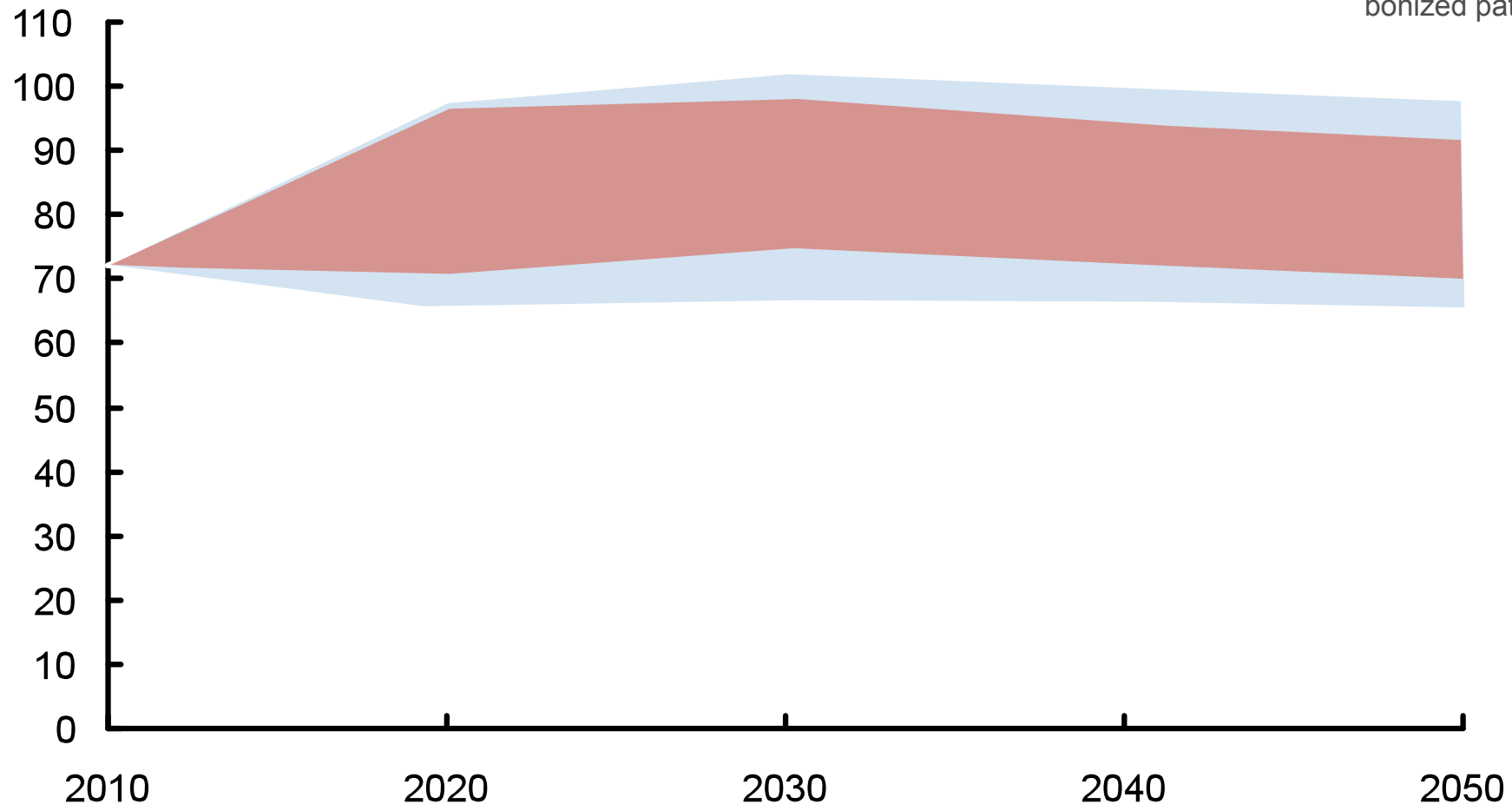
4 Transmission and additional generation capex as well as fixed opex for transmission and backup

5 Grid not modeled by KEMA yet, impact estimated by interpolation from the other pathways

The cost of electricity is similar in the baseline and in the decarbonized pathways

Ranges of the levelized cost of electricity of new builds¹,
€ per MWh (real terms)

Baseline
Average of decarbonized pathways



¹ Based on a WACC of 7% (real after tax), computed by technology and weighted across technologies based on their production; including grid. COE ranges are based on: Carbon price from €0 to 35 per tCO₂e; Fossil fuel prices: IEA projections +/- 25%; Learning rates: default values +/- 25%

SOURCE: Team analysis

A reminder of the policy changes needed to decarbonise the EU power system:

- A step change in energy efficiency
- Credible plans for technology commercialisation, including for CCS
- A strategic EU power network (with wide-area integration + demand-side activation + CO₂ transportation and storage included)
- Ensure the future of ETS + complementary measures and market reform

Conclusion: CCS policies are part of a framework of critical measures

Policy implications split between EU wide and Member State specific level

Key policy implications

EU level

MS level

Energy Efficiency

- Make targets binding

- Implement measures designed to take advantage of local circumstances

Technology commercialisation

- Strong enforcement of requirement for member state deployment strategies
- Expand SET plan to include deployment

- Develop and execute on appropriate regional deployment strategies

EU power network

- Expand mandate of ENTSO-E and ACER
- Create long-term view on EU-wide grid expansion

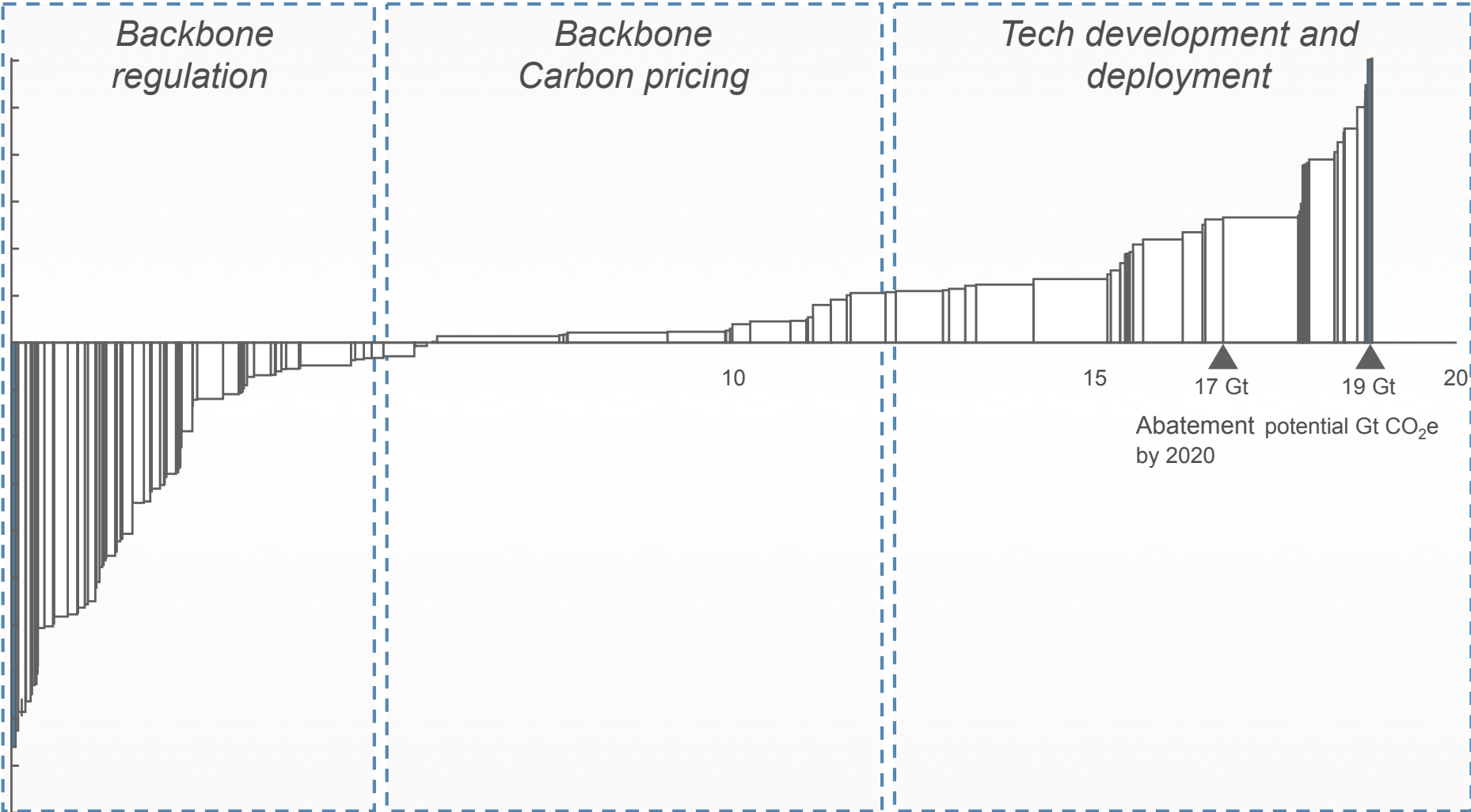
- Reform regulators' mandates
- Create regionally integrated planning / operations
- Execute smart grid pilots

ETS & complementary measures

- Strengthen role of ETS in power sector
- Develop complementary measures alongside ETS

- Address market barriers/gaps in a low carbon supply future
- Provide clear direction on no new high-carbon investment retirement of existing assets

Re-cap – different policies needed to capture different decarbonisation opportunities



Positives

- Groundbreaking NER 300 financing for a European CCS demonstration programme – first round tender announced November 2010, slow but sure progress.
- UK CCS competition – likely to announce first winner soon.
- Dutch CCS taskforce driving two centres of CCS excellence in the Netherlands.
- Potential Emissions Performance Standards (EPSs) in Ireland, the UK and Holland.

Negatives

- Germany has yet to pass a CCS law.
- Uncertainty around CCS finance after the demonstration phase.