Roadmap 2050: a practical guide to a prosperous, low-carbon Europe

Costs and barriers

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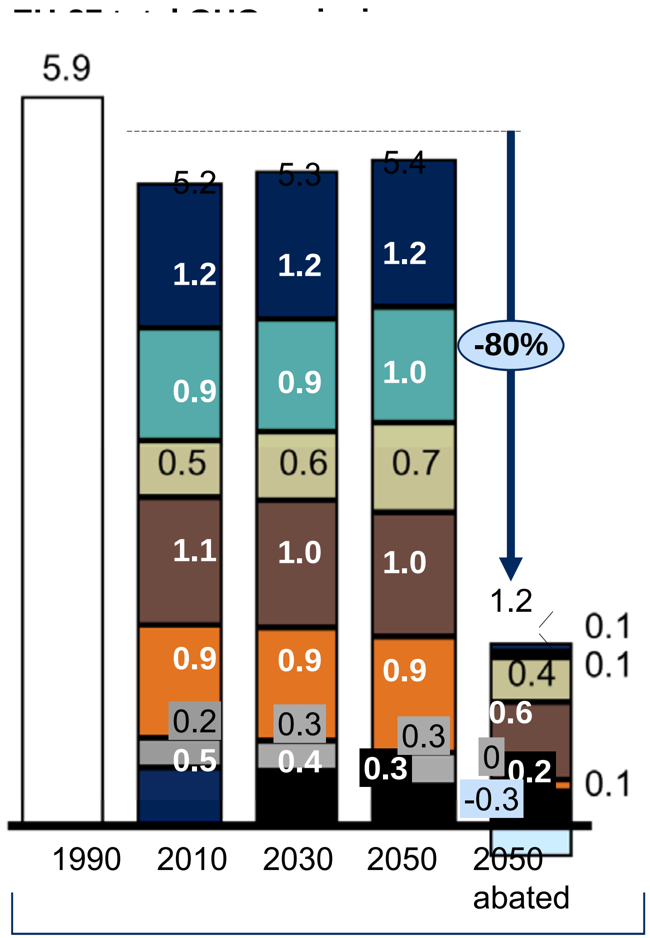
http://www.inforse.org/europe/seminar_2010_BXL.htm

80% decarbonization overall means nearly full decarbonization in power, road transport and buildings

GtCO$_2$e per year



Sector	Total abatement	Abatement within sector[1, 2]	Abatement from 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% (effi-ciency, CCS[3])	5% (heat pumps)
Buildings	**95%**	45% (efficiency)	50% (heat pumps)
Waste	**100%**	100%	
Agriculture	**20%**	20%	
Forestry	**-0.25 GtCO$_2$e**	Carbon sinks	

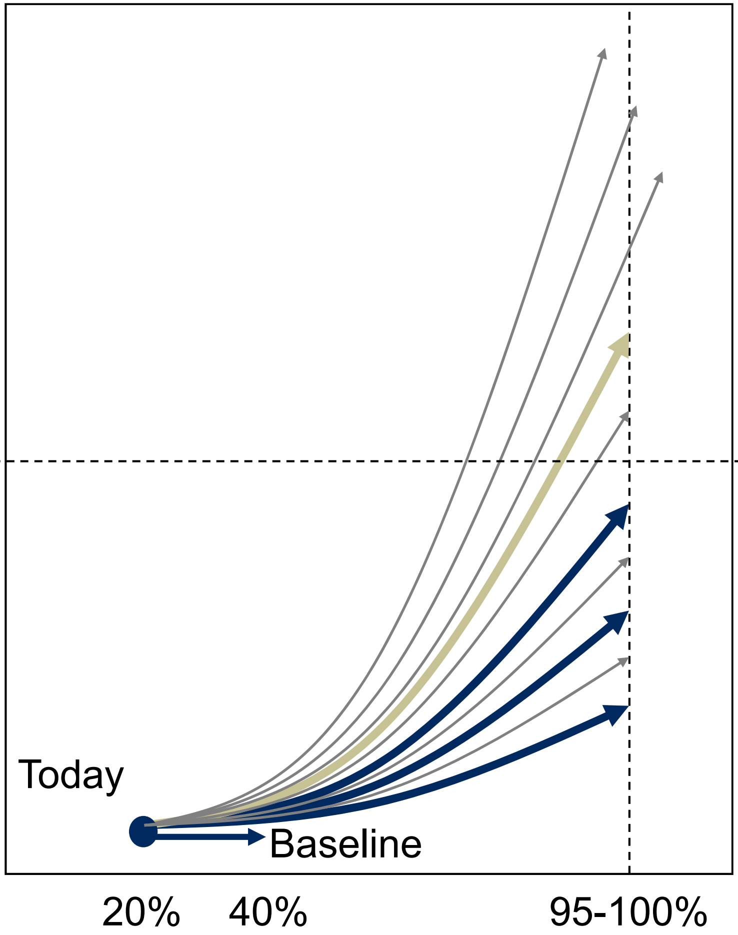
1 Abatement estimates within sector based on the McKinsey Global GHG Cost Curve
2 Large efficiency improvements are already included in the baseline based on the IEA WEO 2009, especially for industry
3 CCS applied to 50% of large industry (cement, chemistry, iron and steel, petroleum and gas, not applied to other industries)

SOURCE: McKinsey Global GHG Abatement Cost Curve; IEA WEO 2009; US EPA; EEA; Team analysis

The 3 pathways are only a few examples of many potential options

Including other regions and technologies

Focus on EU-27 and existing technologies



Level of decarbonization of the power sector

Pathways containing, e.g., tidal, nuclear fusion, algae and power from Iceland or Russia are not assessed

A 100% renewable scenario that includes CSP[1] from North Africa and EGS[2] is assessed technically

Three pathways with varying shares of renewable, nuclear and CCS[3] are assessed both technically and economically

1 Concentrated Solar Power (thermal, not photo voltaic) 2 Enhanced Geothermal Systems 3 Carbon Capture and Storage

SOURCE: Team analysis

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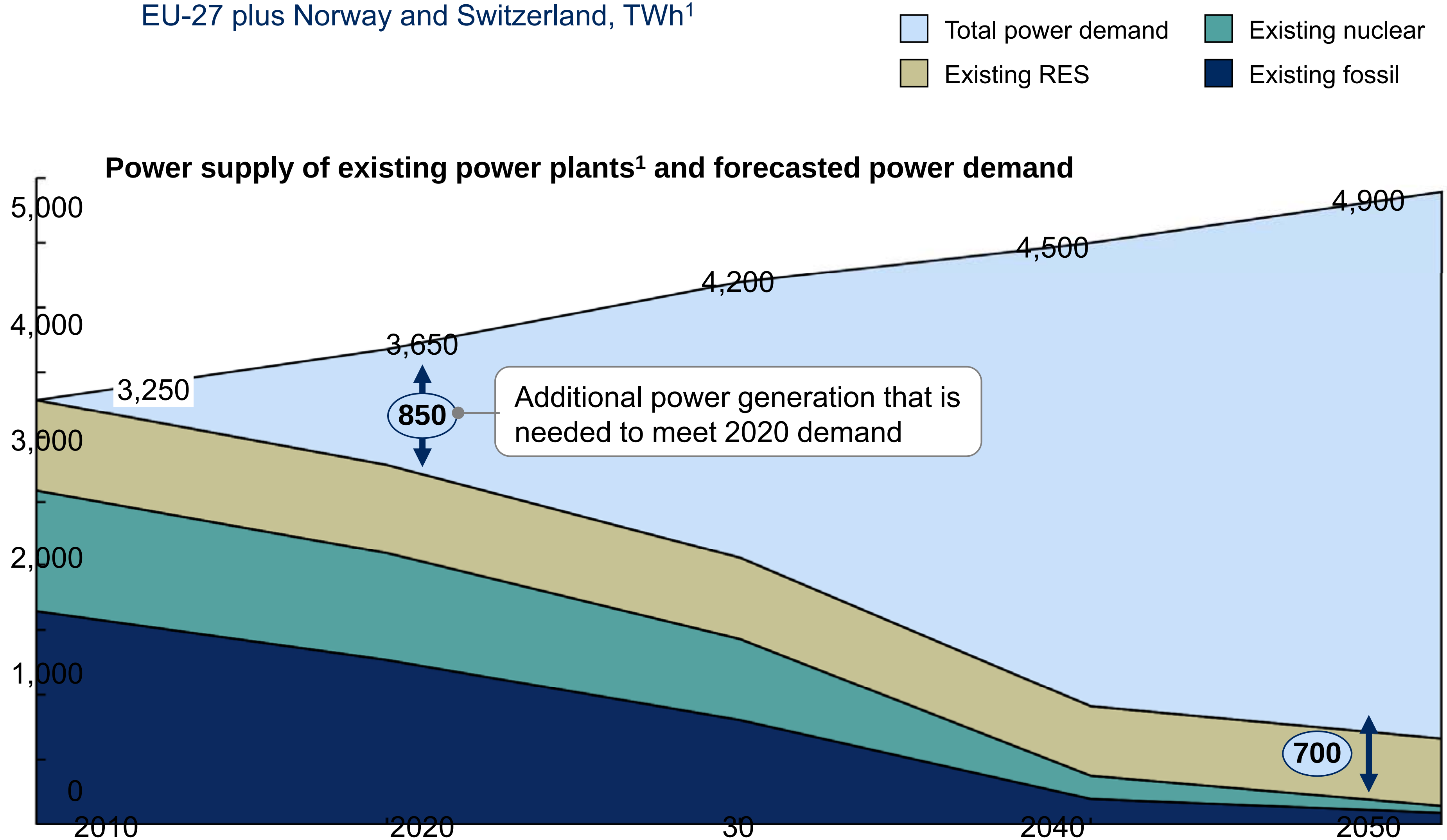
Additional 850 TWh per year of production is required by 2020

EU-27 plus Norway and Switzerland, TWh[1]

Power supply of existing power plants[1] and forecasted power demand



1 Assumes no change in reserve margin from 2010 to 2050
2 Existing capacity includes new builds until 2010

SOURCE: McKinsey Power Generation Model

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On top of the baseline, up to 165 GW of interregional transmission and up to 255 GW of back-up capacity could be required

2050, GW

Transmission & generation capacity requirements

Pathways	DR	Transmission	Back-up and balancing	RES curtailment[1] %
Baseline	0%	2	120	
Requirements on top of the baseline				
100% RES 0% CCS 0% nuclear	0%	329	211	5
	20%	213	94	2
80% RES 10% CCS 10% nuclear	0%	165	255	3
	20%	125	150	2
60% RES 20% CCS 20% nuclear	0%	100	205	2
	20%	85	120	1
40% RES 30% CCS 30% nuclear	0%	55	150	2
	20%	50	70	2

Excluding NA-EU link (refers to the 100% RES transmission figures)

1 In percentage of total renewable energy production

SOURCE: KEMA; Imperial College; McKinsey

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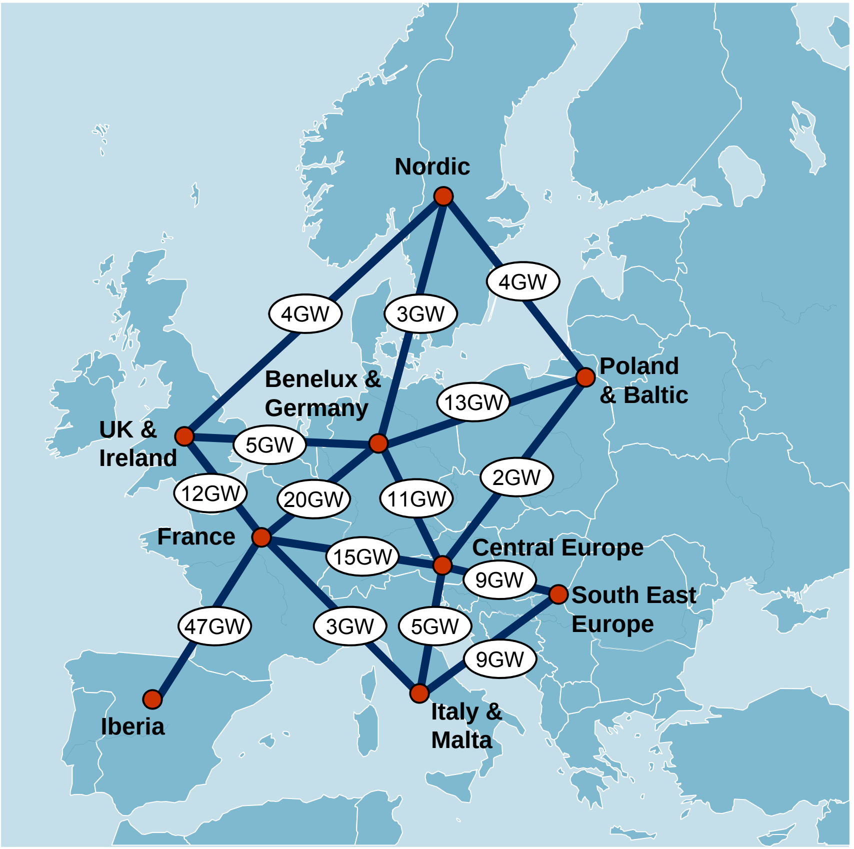
80% RES: DR reduces transmission requirements with 24%

● Centre of gravity

Total net transfer capacity requirements
GW (existing + additional)



Interconnection	Capacity additional (existing) [GW]	Annual utilization [%]
UK&Ireland-France	10 (2)	78
UK&Ireland-Nordic	4 (0)	90
UK&Ireland-Benelux&Germany	5 (0)	81
France-Iberia	46 (1)	74
France-Benelux&Germany	14 (6)	77
France-Central-Europe	12 (3)	89
France-Italy&Malta	0 (3)	92
Nordic-Benelux&Germany	0 (3)	85
Nordic-Poland&Baltic	3 (1)	72
Benelux&Germany-Central-EU	7 (4)	68
Benelux&Germany-Poland&Baltic	12 (1)	82
Central-Europe-Poland&Baltic	0 (2)	72
Central-South East EU	7 (2)	76
Central-Europe-Italy&Malta	0 (5)	69
South East EU-Italy&Malta	8 (1)	74
Total	**127 (34)**	

SOURCE: Imperial College; KEMA

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Reserve sharing between regions reduces total reserve requirements by ~40%

Maximal reserve requirement[1], GW

Region	Baseline	20% RES	30% RES	40% RES
UK & Ireland	8	42	28	15
France	2	31	21	9
Iberia	7	40	27	10
Nordic	3	20	15	10
Benelux & Germany	13	44	28	10
Central-Europe	2	29	20	8
Poland & Baltic	2	18	12	5
South East Europe	2	18	12	4
Italy & Malta	2	40	27	10
Total EU27	42	28	191	80
Benefit of reserve sharing	20	98	66	32
Total with reserve sharing between regions	22	183	125	48
	-47%	-35%	-35%	-40%

1 Reserve refers to reserve required at four hour ahead of real-time. This is required to manage the larger changes in generation (due to plant outages and expected uncertainty in intermittent output) expected over that four hour period that could require starting additional (or switching off) generation

SOURCE: Imperial College, KEMA, team analysis

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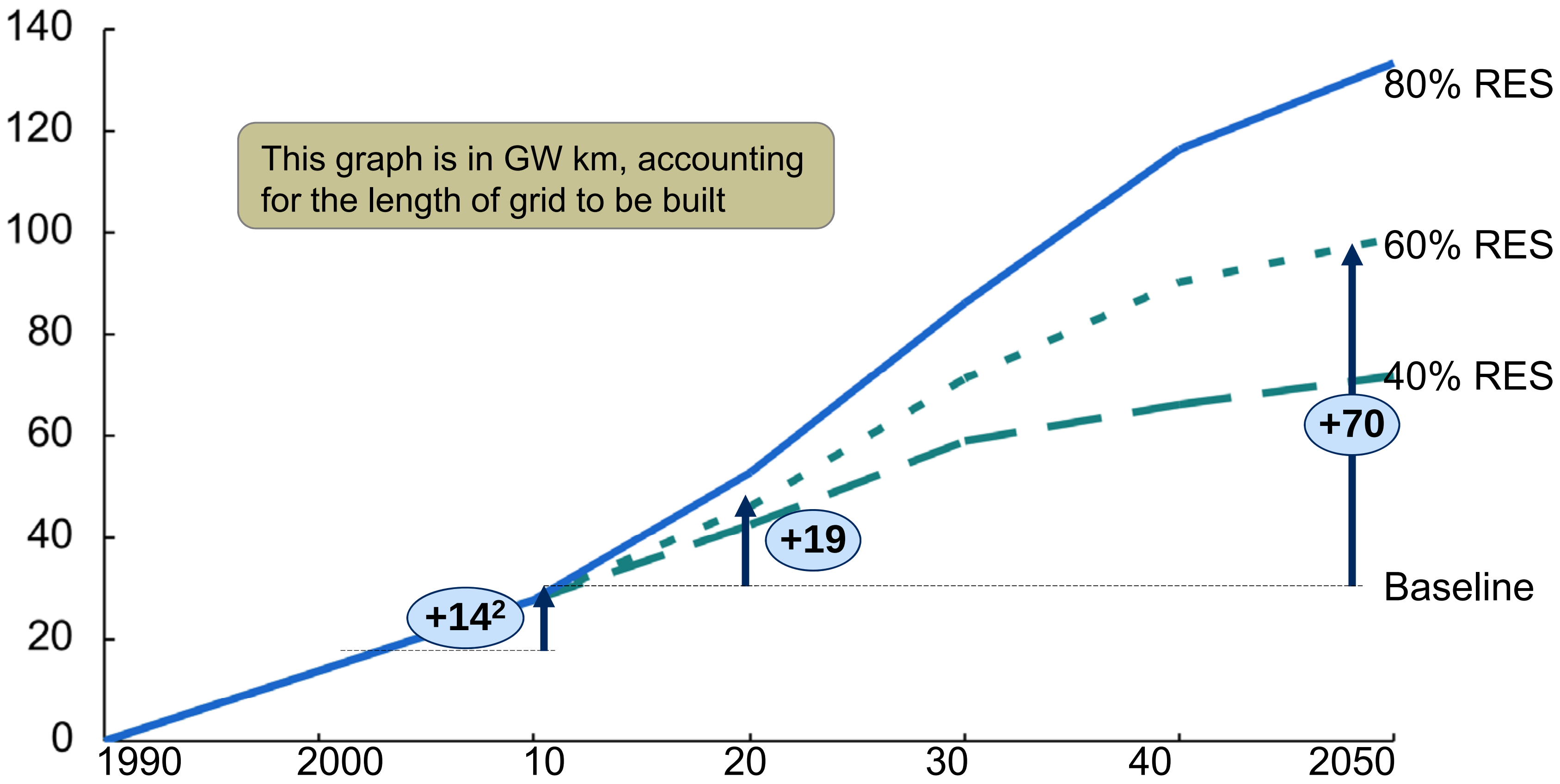
To reach the required transmission grid length, the current rate of construction has to increase by 25% for the 60% pathway

20% DR

Development of transmission grid capacity[1], thousand GW km, EU-27 including Norway and Switzerland



1 Development of grid is assumed to be driven by the penetration of intermittent power sources (solar PV, wind onshore and wind offshore)
2 This assumes a linear build up of grid capacity in thousand GW km between 1990 and 2010, starting at zero, although some grid has been built even before 1990, i.e. UK-France and much of the Central European interconnections

SOURCE: KEMA, team analysis

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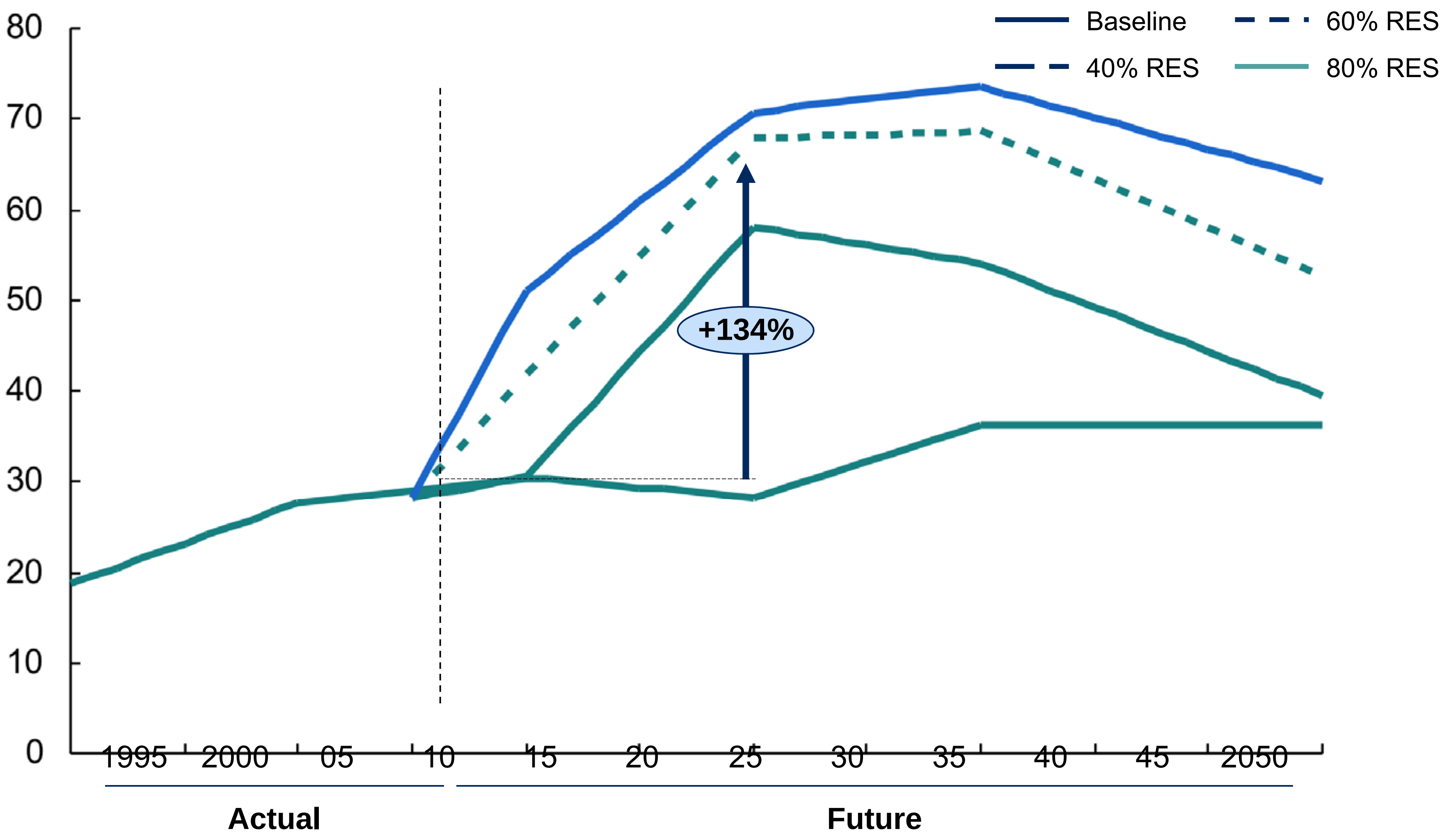
A doubling of capital spent would be required over the next 15 years

Annual capex development per pathway, € billions per year

GENERATION ONLY



SOURCE: Team analysis

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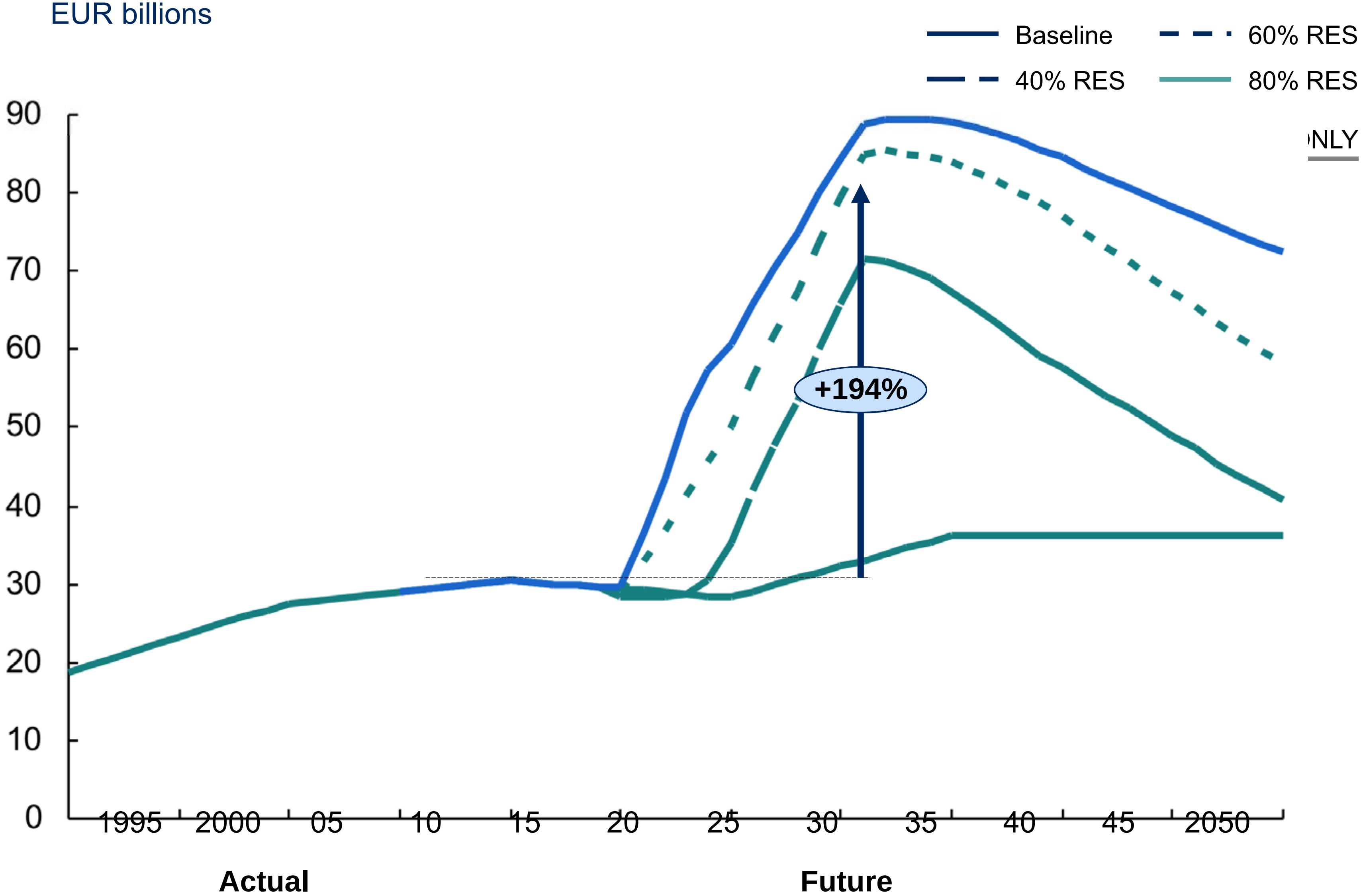
Delayed by 10 years, the annual capex would be up by almost 200%

EUR billions



SOURCE: Team analysis

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Grid costs

The 2050 Roadmap capital investment estimates for grid expansion (including connecting offshore wind) are:

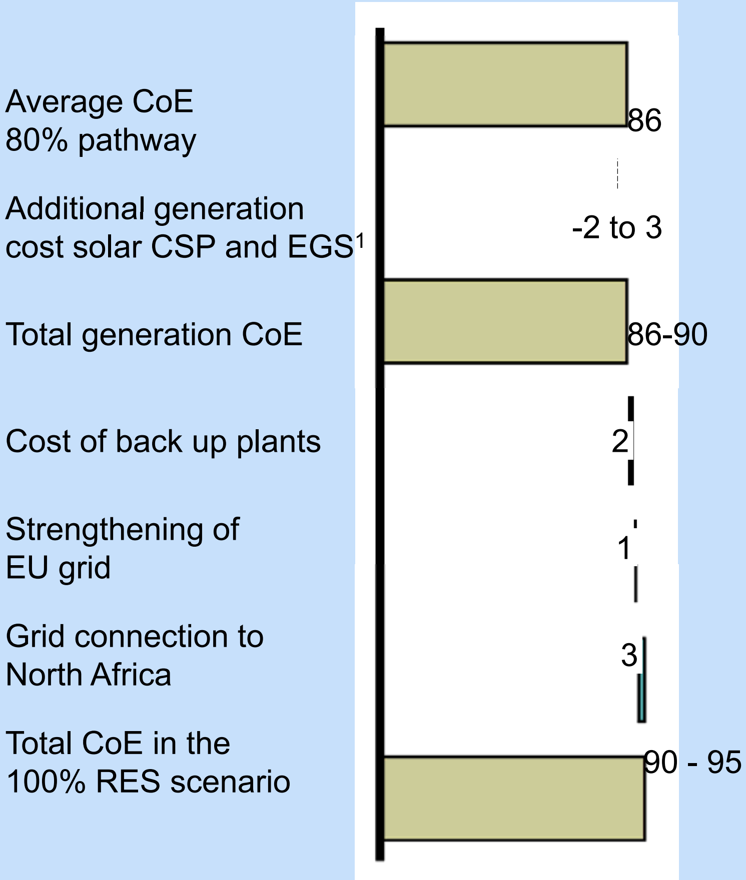
- €53 billion (40% RES)
- €102-135 billion (60% RES)
- €148-182 billion (80% RES)
- Up to €355 billion (100% RES) – depending on which bits of grid you count.

This compares to other reports and initiatives:

- €209 billion to 2050 (Greenpeace/EREC ‘Renewables 24/7’)
- €45 billion to 2050 for HVDC connections for North African solar (DLR ‘trans-CSP’ study 2006)
- €34 billion for a North Sea grid (Friends of the Supergrid)
- €23-28 billion to 2020 (ENTSO-E Ten Year Network Development Plan)

100% RES could be about €10 per MWh more costly and relies on 15% import of power from North Africa

Average CoE of new builds from 2010 to 2050, EUR/MWh



Conditions

- Technical and economic viability of geothermal
- Technical and economic viability of CSP
- Political viability of power import from North-Africa

- Back up plants produce 144 TWh/yr at 20%DR

- Additional transmission lines

- HVDC cables from North Africa to South Europe

1 Coal (5%), gas (5%) and nuclear power (10%) replaced by 15% solar CSP from North-Africa (~700-800 TWh (similar as Desertec) and 5% enhanced geothermal (assumed to be spread over the region relative to the estimated potential). CSP CoE assumes 75% improved irradiation compared to Iberia

SOURCE: KEMA, Desertec, team analysis

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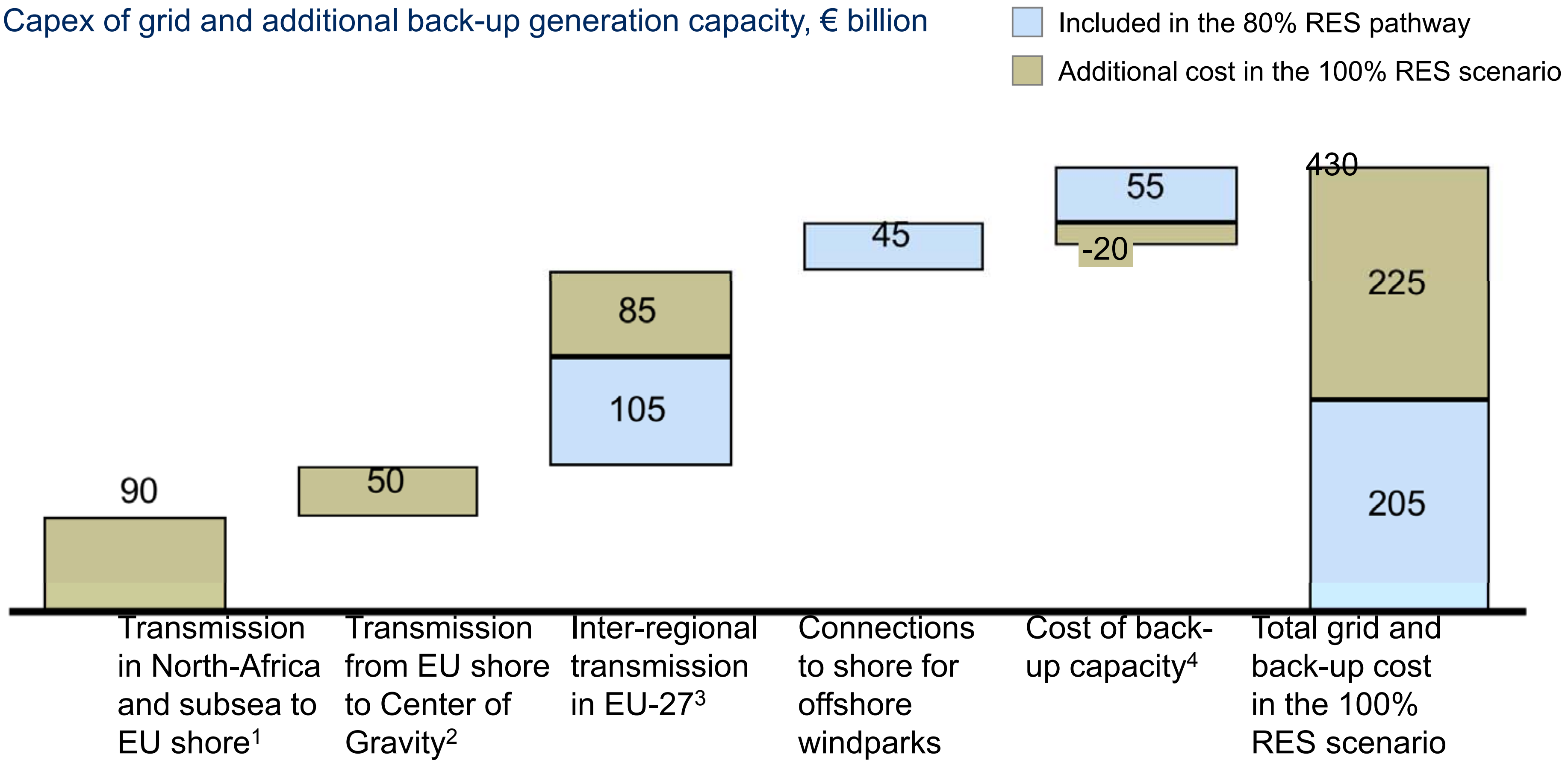
Adding stable renewable energy sources makes 100% RES possible at additional investment cost ~ € 225 billion

Capex of grid and additional back-up generation capacity, € billion



1 North African onshore transmission requirements and subsea connections to the European continent, all HVDC
2 All HVDC transmission with 20% cable and 80% overhead line
3 Requirements in transmission reinforcements to spread the electricity across the various regions from the Centers of Gravity in Southern Europe
4 With higher transmission in Europe, back-up requirements with demand response are lower in the 100% RES pathway, with 75 GW, compare to 95 GW in the 80% RES pathway

SOURCE: KEMA, Desertec, team analysis

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Policy implications – key issues

- Step change in energy efficiency
- Technology commercialisation
- Creating strategic EU power network
- The future of ETS, complementary measures & market reform

Policy implications - solutions

- Step change in energy efficiency
- Technology commercialisation
- Creating strategic EU power network
- The future of ETS, complementary measures & market reform

EU level:

- Convert non-binding 2020 efficiency goal into a firm requirement to deliver
- Updated framework of standards and regulations

MS level:

- Sustained political commitment
- Broad portfolio of measures designed to take advantage of local circumstances

Policy implications - solutions

- Step change in energy efficiency
- Technology commercialisation
- Creating strategic EU power network
- The future of ETS, complementary measures & market reform

EU level:

- Request MSs to come forward with long term deployment strategies for key renewable technologies and CCS

MS level:

- Consider deployment strategies and whether these need to be co-ordinated at EU level

Policy implications - solutions

- Step change in energy efficiency
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EU level:

- Expand ACER/ENTSO-E mandate
- Create strategic inter-connection plan out to 2050
- Policy framework to promote pan-European resource optimisation

MS /regional level:

- Long term indicative energy mix
- Reform regulators' mandates
- Regionally integrated planning/operations
- Design, execute smart grid pilots

Policy implications - solutions

- Step change in energy efficiency
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- Creating strategic EU power network
- The future of ETS, complementary measures & market reform

EU level:

- Develop complementary measures to EU ETS which create business case for low carbon generation and avoid carbon price distortions
- Strengthen reduction targets

MS/regional level:

- Review market framework to:
  - Create business case for low carbon investment
  - Provide clear signals not to invest in high carbon assets
  - Support market integration