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Ökonomie und Politik der weltweiten Energiewende

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Toblacher Gespräche 2018: Wo bleibt das solare Zeitalter?
30. September 2018

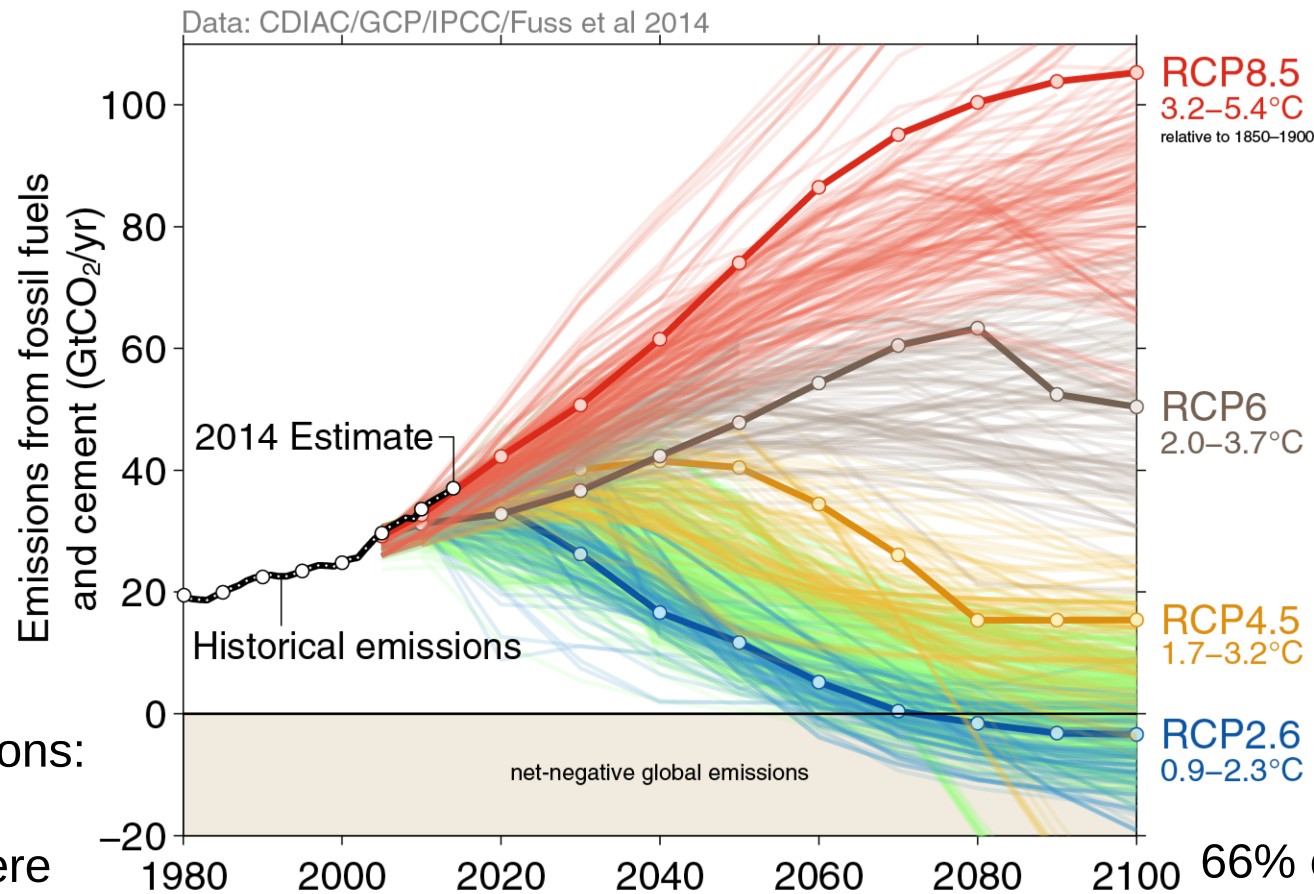
Paris Agreement on Climate Change

- adoption of the Paris Agreement at COP21 December 2015
- entered into force after ratification by at least 55 countries and by countries representing at least 55% of global emissions (legally binding, 4 Nov 2016) - 197 signed, 180 ratified
- Paris long-term temperature goal: holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels (increase of ambitions via global stocktake - IPCC special report on 1.5 C)
- bottom-up approach as a valid starting point
  - strongly emphasizes sovereignty
  - facilitates monitoring, reporting, and verification
  - burden sharing for enhanced commitments („2°C gap")

IPCC Transformation Pathways

- long-term scenarios assessed in IPCC AR 5, WGIII (Chapter 6) (2014) generated primarily by large-scale, integrated assessment models that link many important human systems (e.g., energy, agriculture, land use, economy) with physical processes associated with climate change (e.g., the carbon cycle)
- limiting warming to 2° C involves substantial technological, economic and institutional challenges: require unprecedented emission reductions between 2030 and 2050 of about 3% per year globally and a rapid scale up of low carbon energy
- but even much less ambitious mitigation scenarios require fundamental deviation from baseline (global mean surface T increases in 2100 from 3.7 to 4.8 C compared to pre-industrial)
- delaying emissions reduction increases the difficulty and narrows the options for mitigation (6% per year after 2030)

IPCC Transformation Pathways



negative emissions: take carbon out of the atmosphere

66% change, global temp increase < 2C above pre-ind

Source: Peters (2015)

http://www.cicero.uio.no/en/posts/news/a-journey-from-5c-to-2c

IPCC Transformation Pathways

if i) all countries of the world ii) begin mitigation immediately, with iii) single global carbon price, and iv) technologies are available
→ 2 degree target has low economic costs

feasibility even then unclear: fast decarbonisation necessary, large scale application of BECCS (availability, scale up)

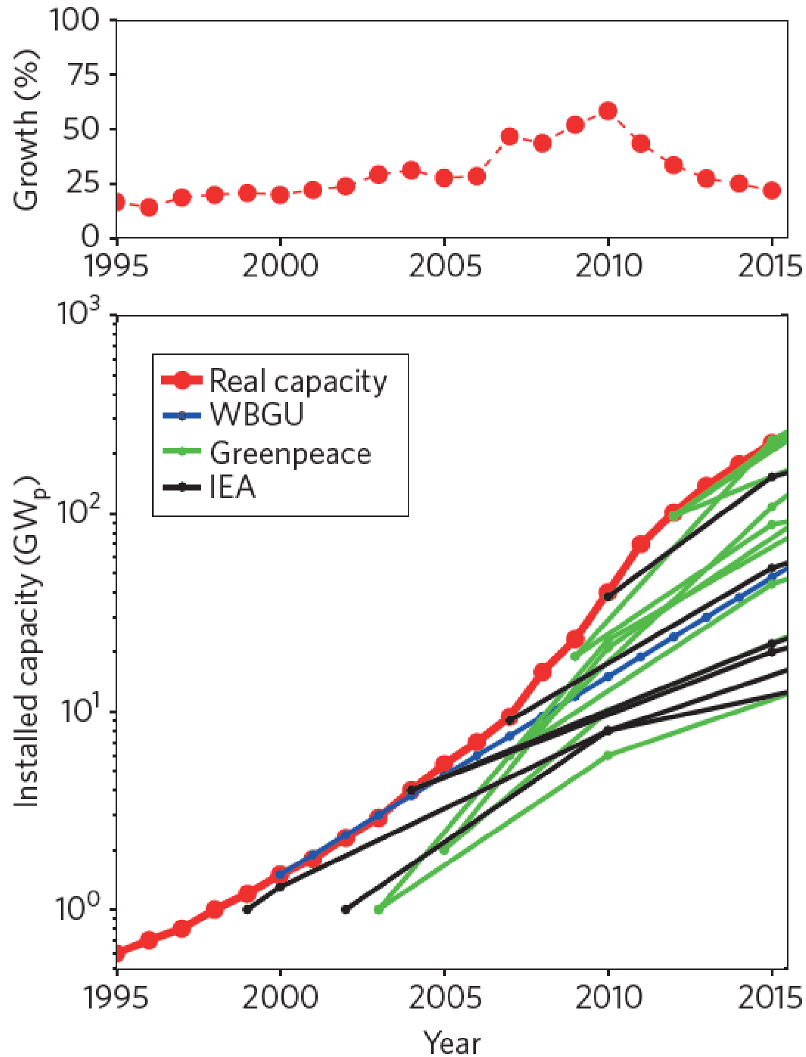
if technologies not available due to political or technological constraint, especially CCS & bioenergy, costs might be 4x as high

delayed action as with current pledges reduces feasibility and increases costs further

i) unilateral policies and iii) inefficient implementation

What about solar energy?

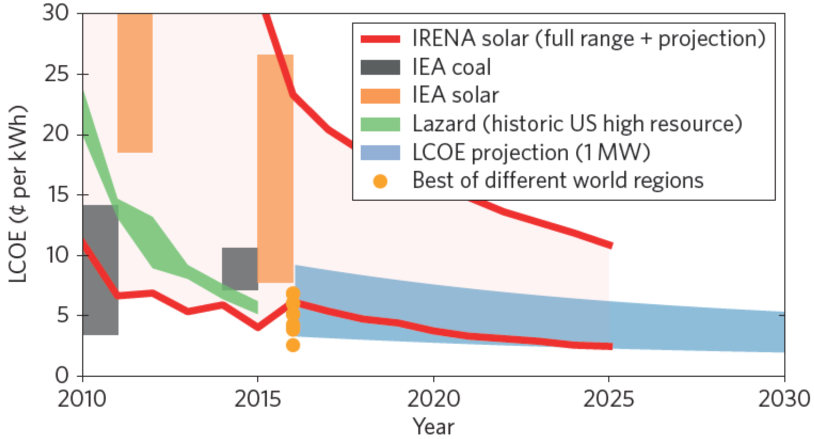
- Solar energy: technical potential 1.500 –50,000 EJ, global energy demand 2050 1,000 EJ
- PV has consistently exceeded expectations (40% p.a. growth vs. 16-30%)
- Key factors
  1. Regulation (FIT Germany)
  2. Technology learning (22,5% for each doubling in cum. production capacity)
  3. Costs of other technologies (CCS, nuclear, CO_2 price)

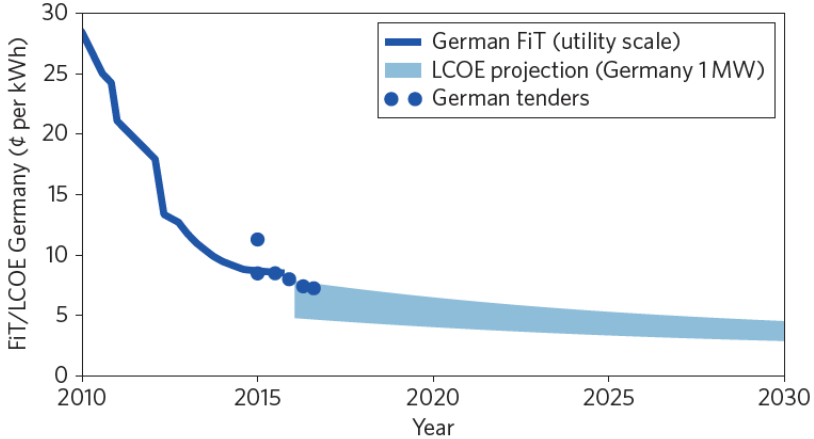


Source: Creutziget al. (2017)

What about solar energy?

- Rapid decline in costs
  1. LCOE residential-scale PV below price of retail grid electricity (soon even systems with battery storage)
  2. Large PV projects selling power at less than US$0.03 per kWh (in Dubai, Mexico and Chile) or at US$0.06 per kWh (Rajasthan, India and Zambia)



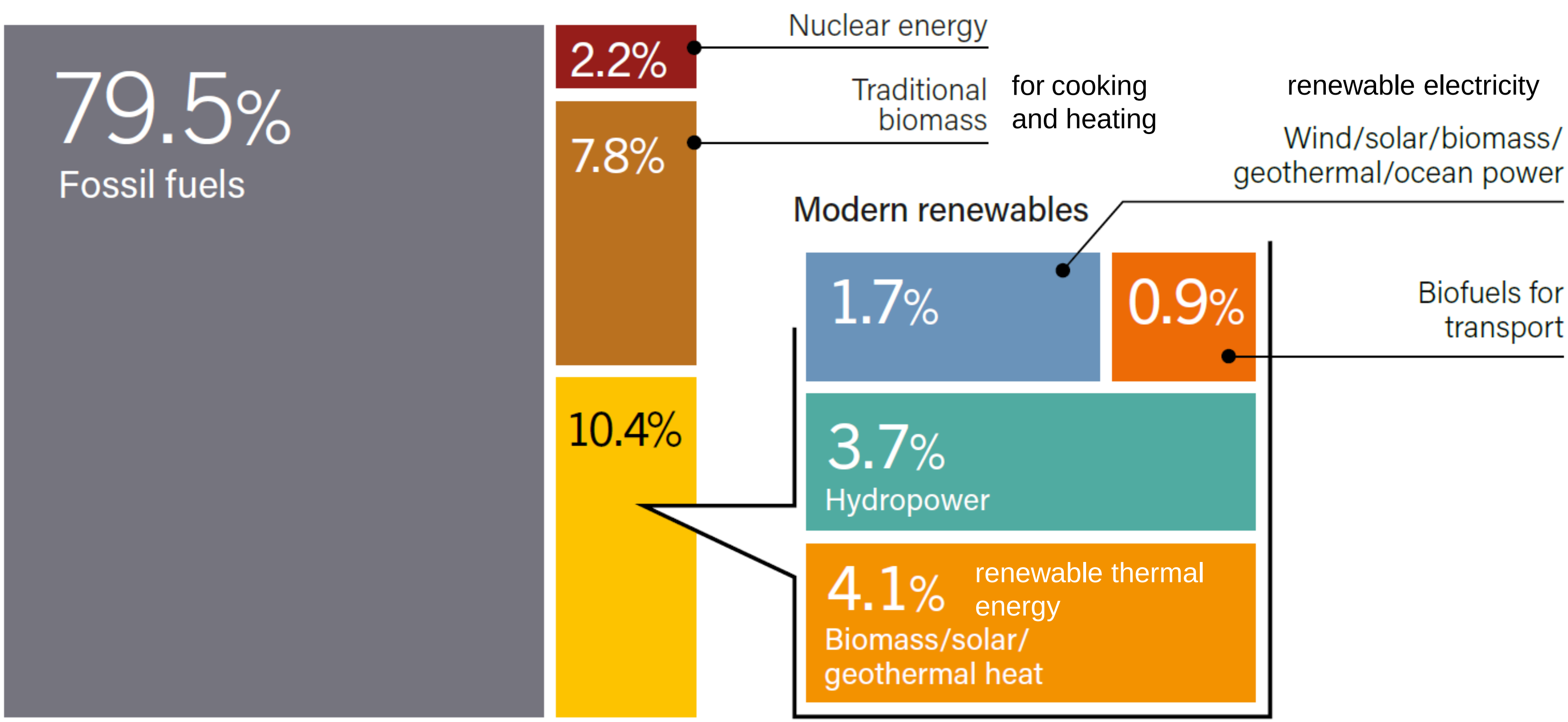


Key factors for technology learning: R&D, industry-scale production & skills, financing and regulation

Source: Creutziget al. (2017)

Global renewable energy indicators

Estimated Renewable Share of Total Final Energy Consumption in 2016

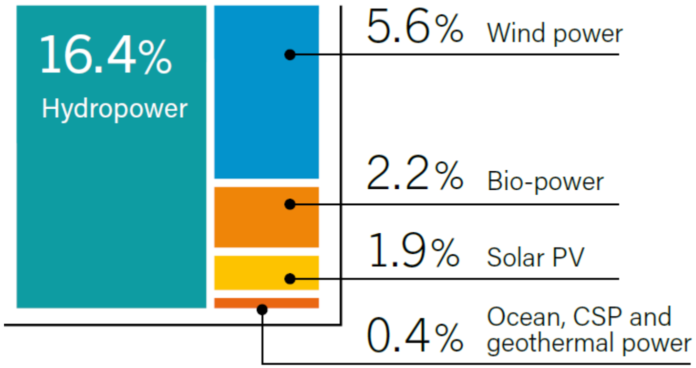


Source: REN21 (2018)

Global renewable energy indicators

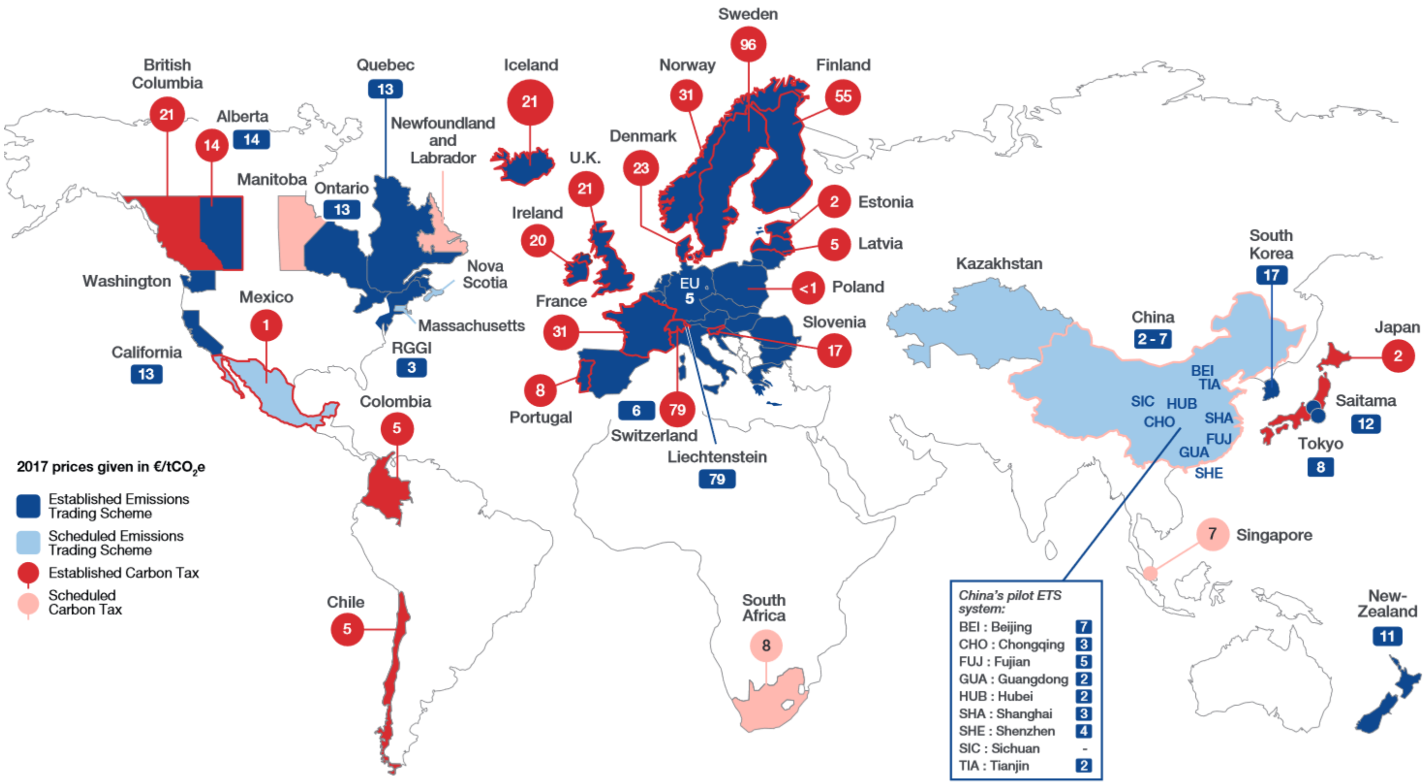
		2016	2017
INVESTMENT			
New investment (annual) in renewable power and fuels[1]	billion USD	274	**279.8**
POWER			
Renewable power capacity (including hydro)	GW	2,017	**2,195**
Renewable power capacity (not including hydro)	GW	922	**1,081**
Hydropower capacity[2]	GW	1,095	**1,114**
Bio-power capacity	GW	114	**122**
Bio-power generation (annual)	TWh	501	**555**
Geothermal power capacity	GW	12.1	**12.8**
Solar PV capacity[3]	GW	303	**402**
Concentrating solar thermal power (CSP) capacity	GW	4.8	**4.9**
Wind power capacity	GW	487	**539**
Ocean energy capacity	GW	0.5	**0.5**
HEAT			
Solar hot water capacity[4]	GW_{th}	456	**472**
TRANSPORT			
Ethanol production (annual)	billion litres	103	**106**
FAME biodiesel production (annual)	billion litres	31	**31**
HVO production (annual)	billion litres	5.9	**6.5**

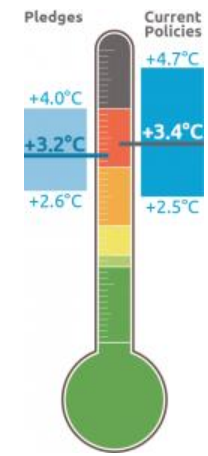
Global renewable electricity
26.5% in 2017



Source: REN21 (2018)

Status quo: international CO2-prices in 2017





https://climateanalytics.org/

Quelle: I4CE (2017): Global panorama of carbon prices in 2017

Climate Protection as a Social Dilemma

- economic incentives for sovereign states to reach international environmental agreements
- climate change mitigation is a global public good
  → costs are carried by individual countries, benefits are shared
  → free-riding incentives lead to an under-provision of the public good and potentially low (not zero) willingness-to-pay (WTP) for abating CO_2 individually
- other perspective: climate targets have to be acceptable to voters
  → empirical evaluation of people's demand for climate protection and willingness to pay (WTP) crucial for prospects of climate mitigation

comment

China's emissions trading takes steps towards big ambitions

China recently announced its national emissions trading scheme, advancing market-based approaches to cutting greenhouse gas emissions. Its evolution over coming years will determine whether it becomes an effective part of China's portfolio of climate policies.

Frank Jotzo, Valerie Karplus, Michael Grubb, Andreas Löschel, Karsten Neuhoff, Libo Wu and Fei Teng

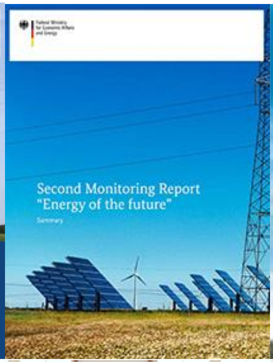
NATURE CLIMATE CHANGE | VOL 8 | APRIL 2018 |

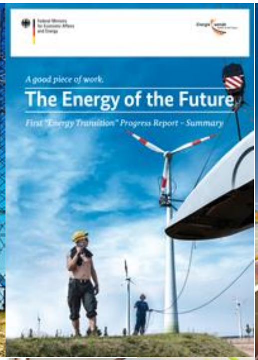
An inconvenient truth

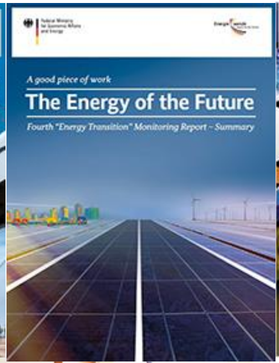
- if people in Germany are asked to give up real money, WTP for climate protection is lower than in hypothetical studies
- overall low WTP for climate protection based on framed field experiments (mean: 12€ per tCO_2, median: 0€ per tCO_2)
- this is indeed an "inconvenient truth" from a political economy perspective
- different incentives and specific interventions might increase provision of climate mitigation (matching and price rebates, **co-benefit of local mitigation**, non monetary incentives like altruistic behaviour, "warm glow", image motivation, moral norms)

Prof. Dr Andreas Löschel (Chair)
Prof. Dr Georg Erdmann
Prof. Dr Frithjof Staiß
Dr Hans-Joachim Ziesing

Monitoring the Energy Transition
http://www.bmwi.de/Redaktion/EN/Artikel/Energy/monitoring-implementation-of-the-energy-reforms.html







Status of the German Energy Transition

Principal goals of the energy transition	Reduction of greenhouse gas emissions (lead indicator)	🔴
	Phase-out of nuclear power (lead indicator)	🟢
Renewables	Increase of the share of renewables in gross final energy consumption (lead indicator)	🟢
	Increase of share of renewables in gross electricity consumption	🟢
	Increase of the share of renewables in heat consumption	🟡
	Increase of renewables in transportation	🔴
Energy efficiency	Reduction of primary energy consumption (lead indicator)	🔴
	Final energy productivity	🔴
	Reduction of heat consumption in buildings	🟡
	Reduction of final energy consumption in transportation	🔴

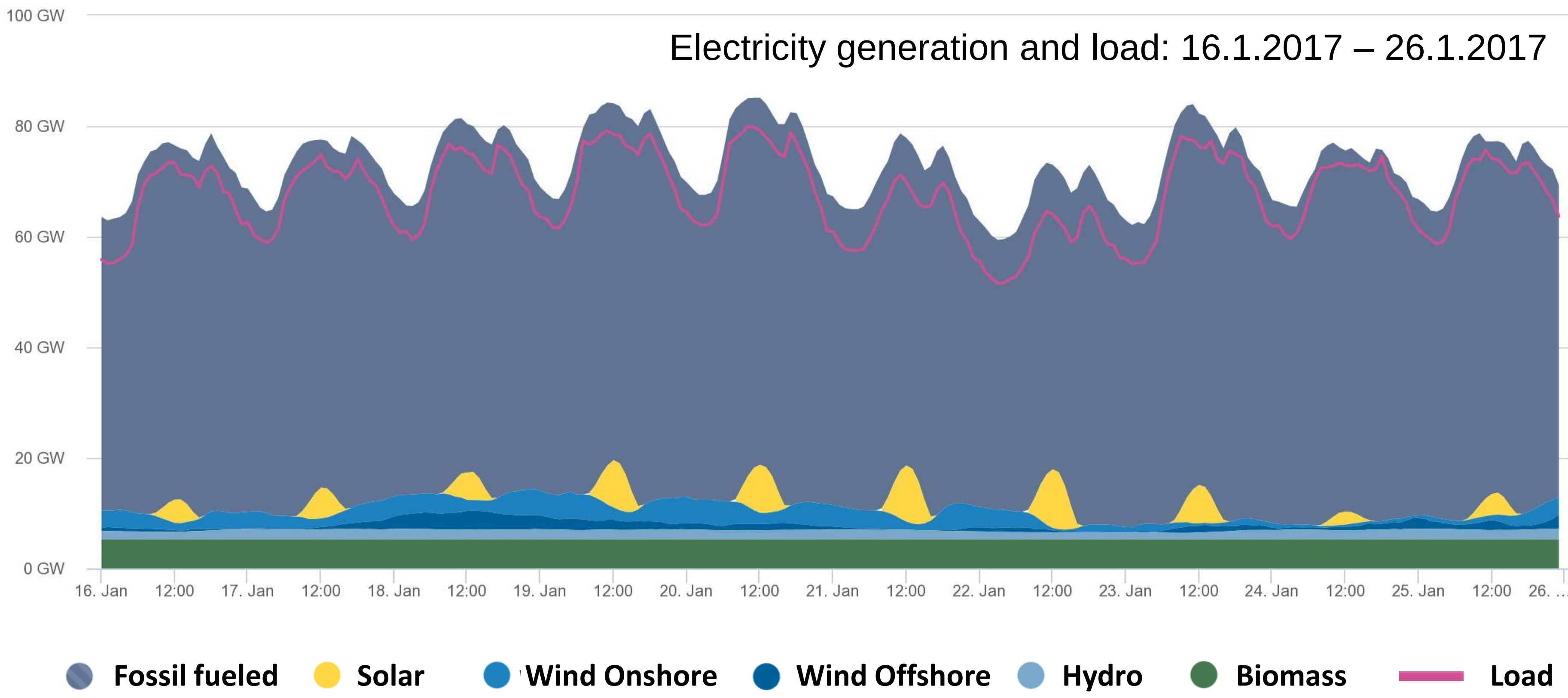
Probability of target attainment: 🟢 Probable 🟡 Uncertain 🔴 Improbable

Status of the German Energy Transition

Security of supply	Transmission grid expansion (lead indicator)
	Redispatch measures
	System Average Interruption Duration Index SAIDI power & gas
Affordability	Final consumer expenditures for electricity in GDP (lead ind.)
	Final consumer expenditures for heating services
	Final consumer expenditures in road transport
	Real unit electricity costs in industrial sector (int. comparison)
	Energy cost burden on households
Acceptance	General approval of the Energiewende (lead ind.)
	Approval of implementation of Energiewende
	Approval based on degree of being personally affected

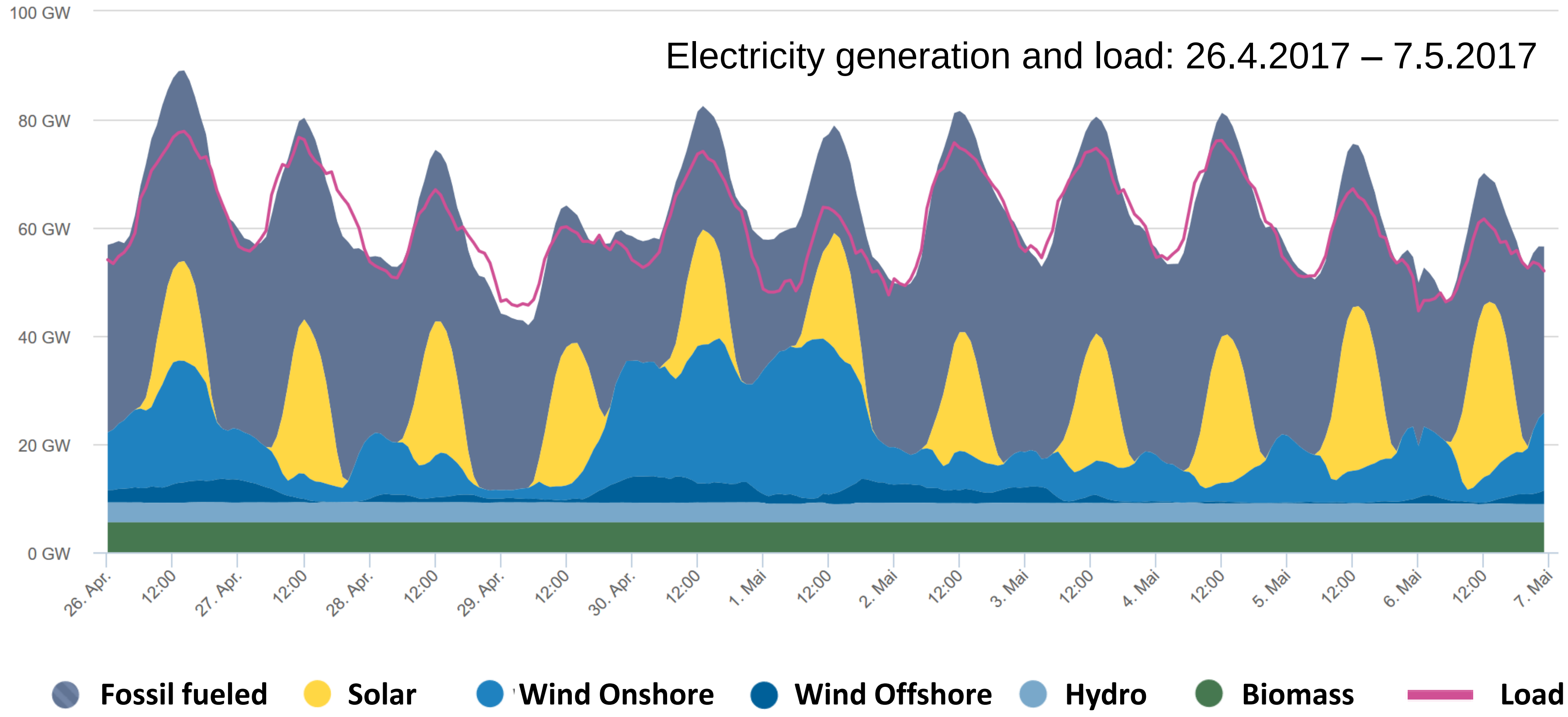
Probability of target attainment: Probable Uncertain Improbable

Integrating renewables in Germany



Source: Agora Energiewende Stand 5.2.2017

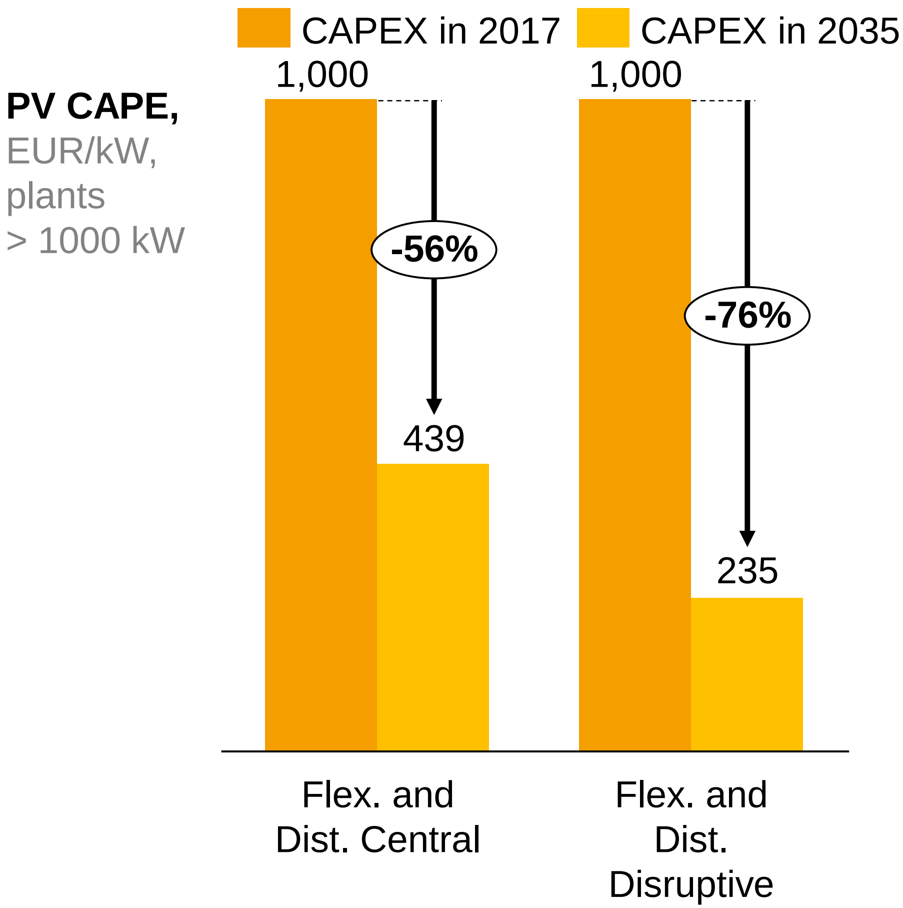
Integrating renewables in Germany



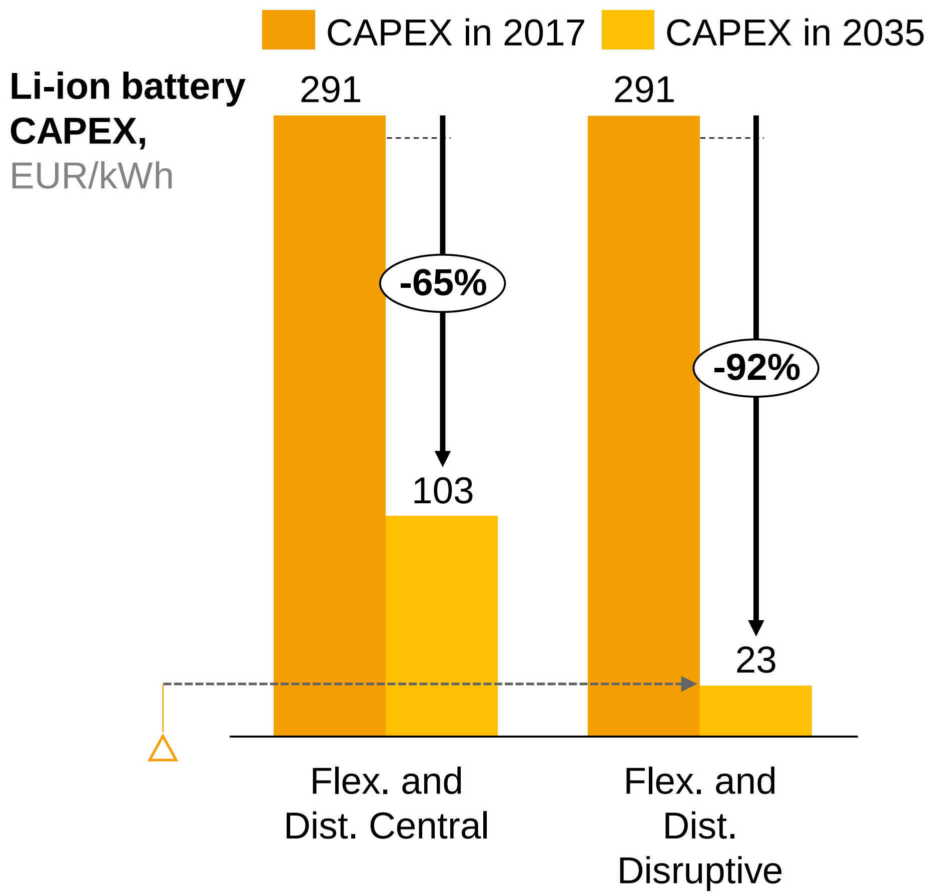
Source: Agora Energiewende Stand 29.9.2018

A (desruptive) scenario for Germany

cost decline of 76% would only require 15% of global final energy consumption met by solar (17.250 GW cum. built capacity)



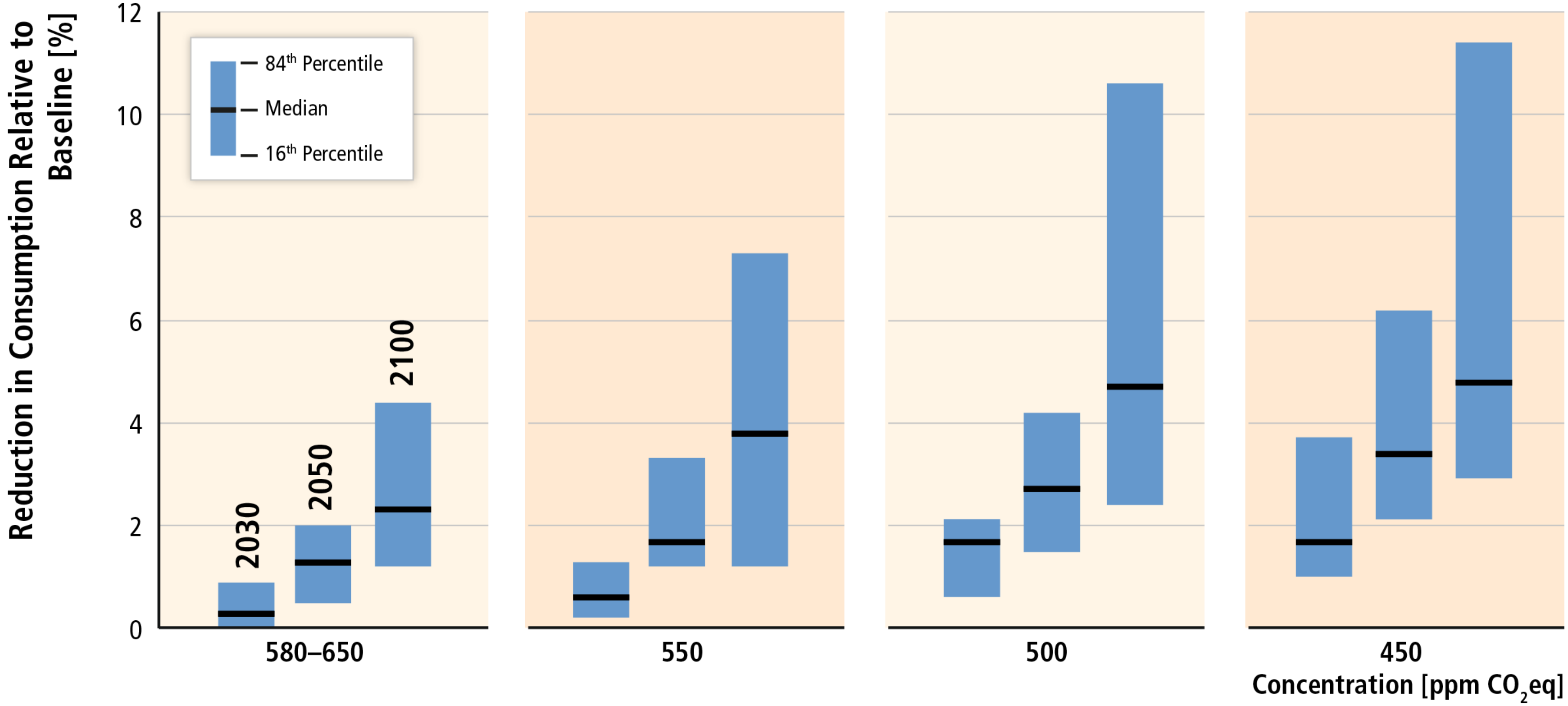
worldwide diffusion of electric vehicles would trigger disruptive decline in Li-ion battery cost (cum. built capacity 49,000 GWh w 55% of veh., today 50 GWh)



Economics and Politics of Global Transition

- Paris targets extremely difficult to achieve (and very costly)
- Political and technological constraints (CCS, bioenergy)
- Unilateral policies raise competitiveness concerns
- Inefficient implementation
- Climate policy as a public good with free riding incentives makes strong policy responses unlikely (support unclear)
- Renewables are going to increase steadily, but depend on regulation (support), technology learning, prices of competitors (esp. CO_2 price)
- German energy transition with problems esp. to reduce CO_2 emissions and increase efficiency
- renewable build out effective, but not efficient
- integration of renewable next challenge

Global costs rise with the ambition of the mitigation goal.

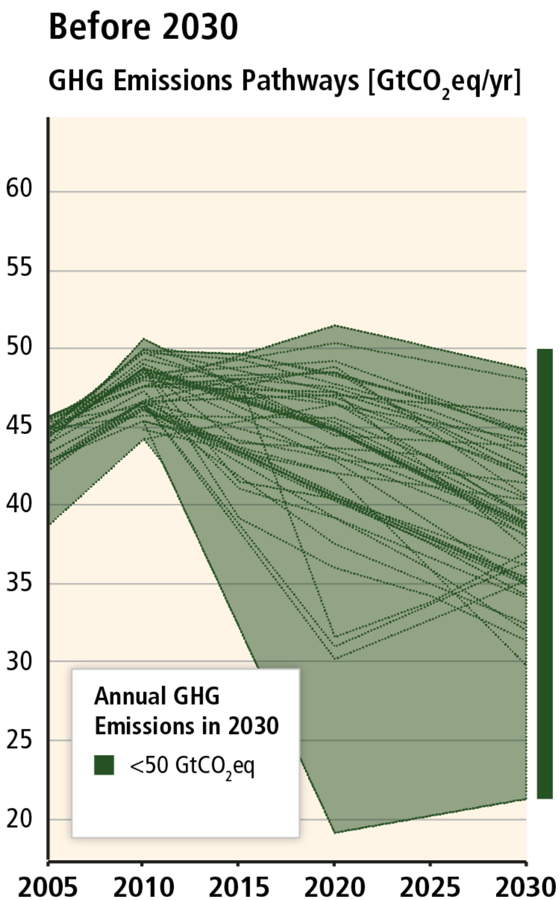


Percentage Point Reduction in Annualized Consumption Growth Rate over 21st Century			
0.03 (0.01-0.05)	0.04 (0.01-0.09)	0.06 (0.03-0.13)	0.06 (0.04-0.14)

Based on Table SPM.2

ASSUMPTIONS: i) all countries of the world ii) begin mitigation immediately, there is iii) a single global carbon price, and iv) all key technologies are available

Immediate action

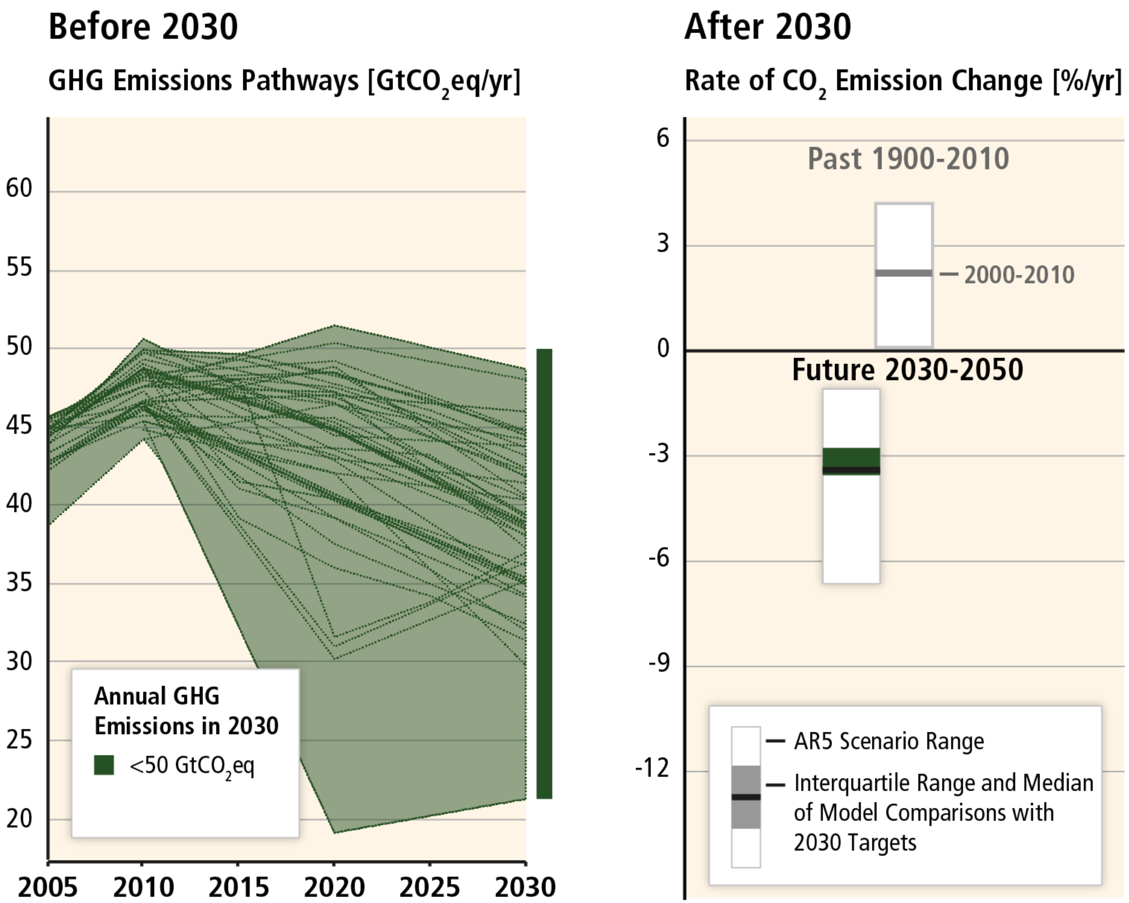


"Immediate Action"

Based on Figure SPM.5

- scenarios broadly consistent with 2 degree goal not growing beyond today's level of roughly 50 Gt CO_2eq. They are typically characterized by annual GHG emissions in 2030 of roughly between 30 $GtCO_2$eq and 50 $GtCO_2$eq.

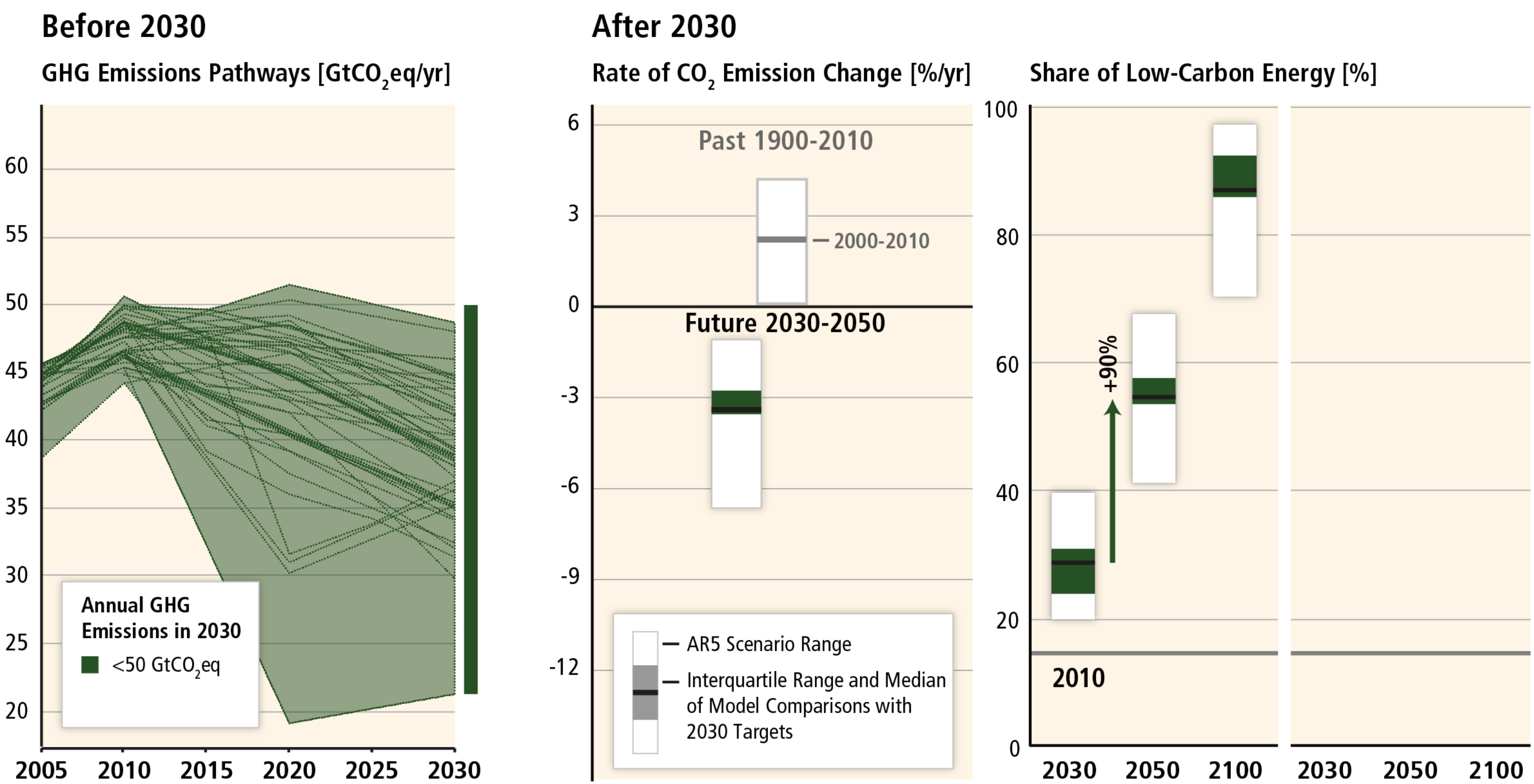
Still, between 2030 and 2050, emissions would have to be reduced at an unprecedented rate...



Based on Figure SPM.5

scenarios require emission reductions between 2030 and 2050 of about 3% per year globally

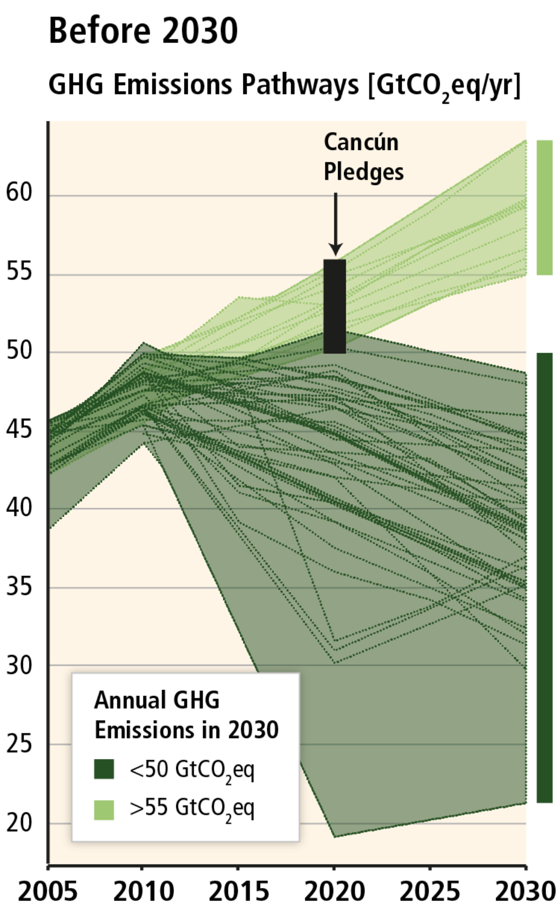
...implying a rapid scale-up of low-carbon energy.



Based on Figure SPM.5

share of low carbon energy (RES, nuc, CCS, BECCS) needs to be roughly doubled, decarbonisation at unprecedented rates

Relax ii): Delaying emissions reductions increases the difficulty and narrows the options for mitigation.



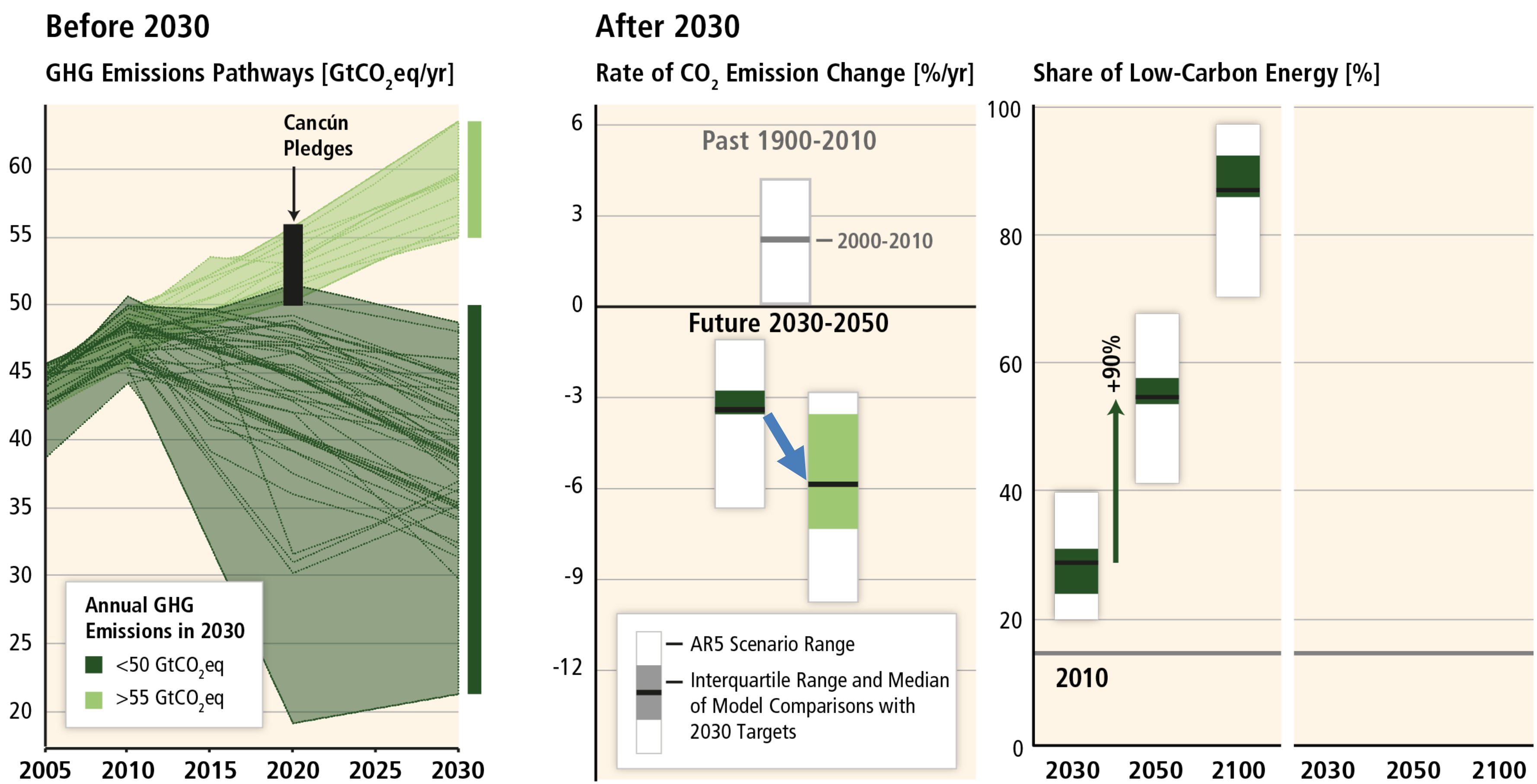
"Delayed Mitigation"

"Immediate Action"

Based on Figure SPM.5

scenarios are typically characterized by 2030 emission levels of more than 55 Gt CO_2eq/yr

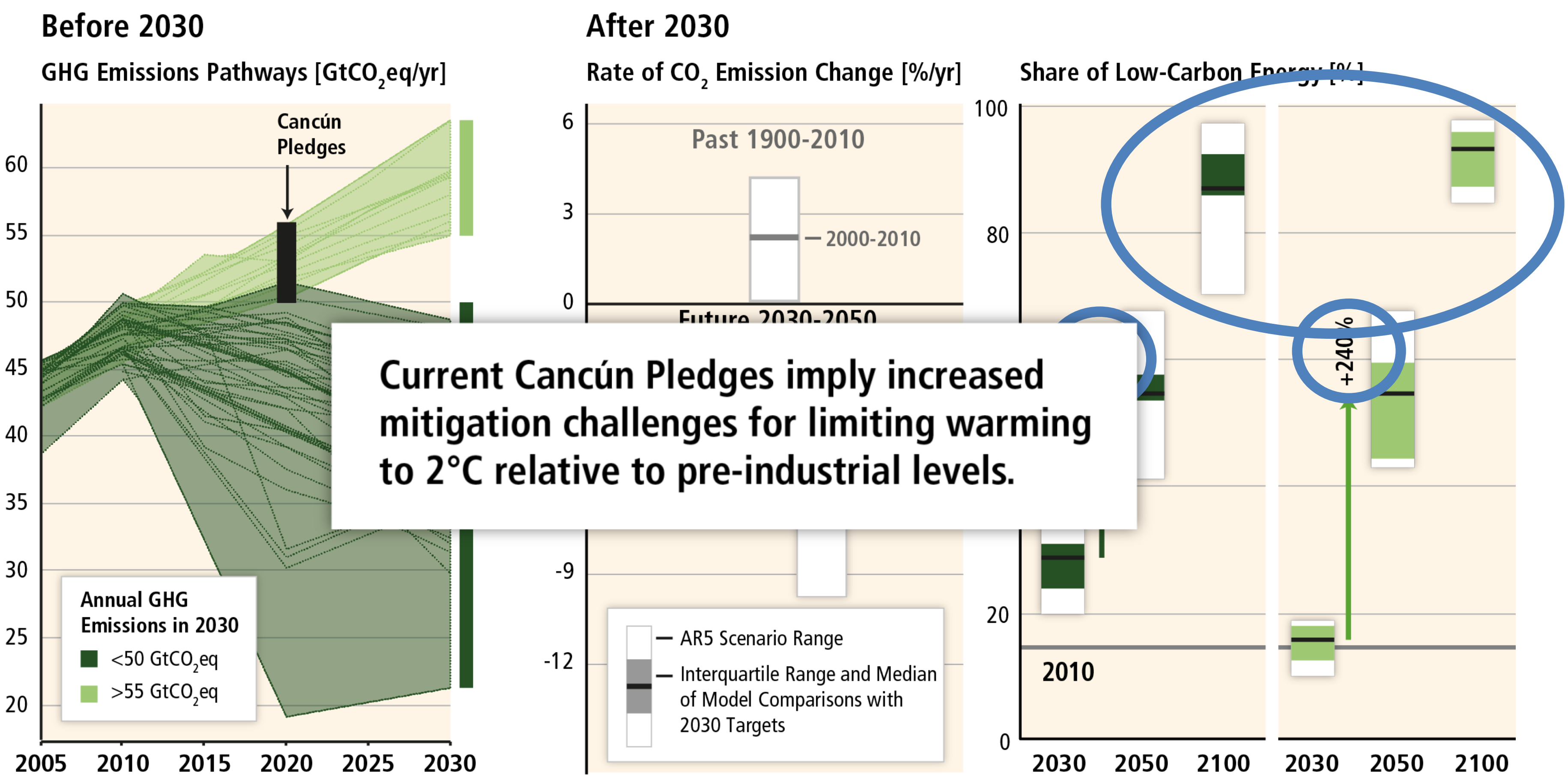
Delaying emissions reductions increases the difficulty and narrows the options for mitigation.



Based on Figure SPM.5

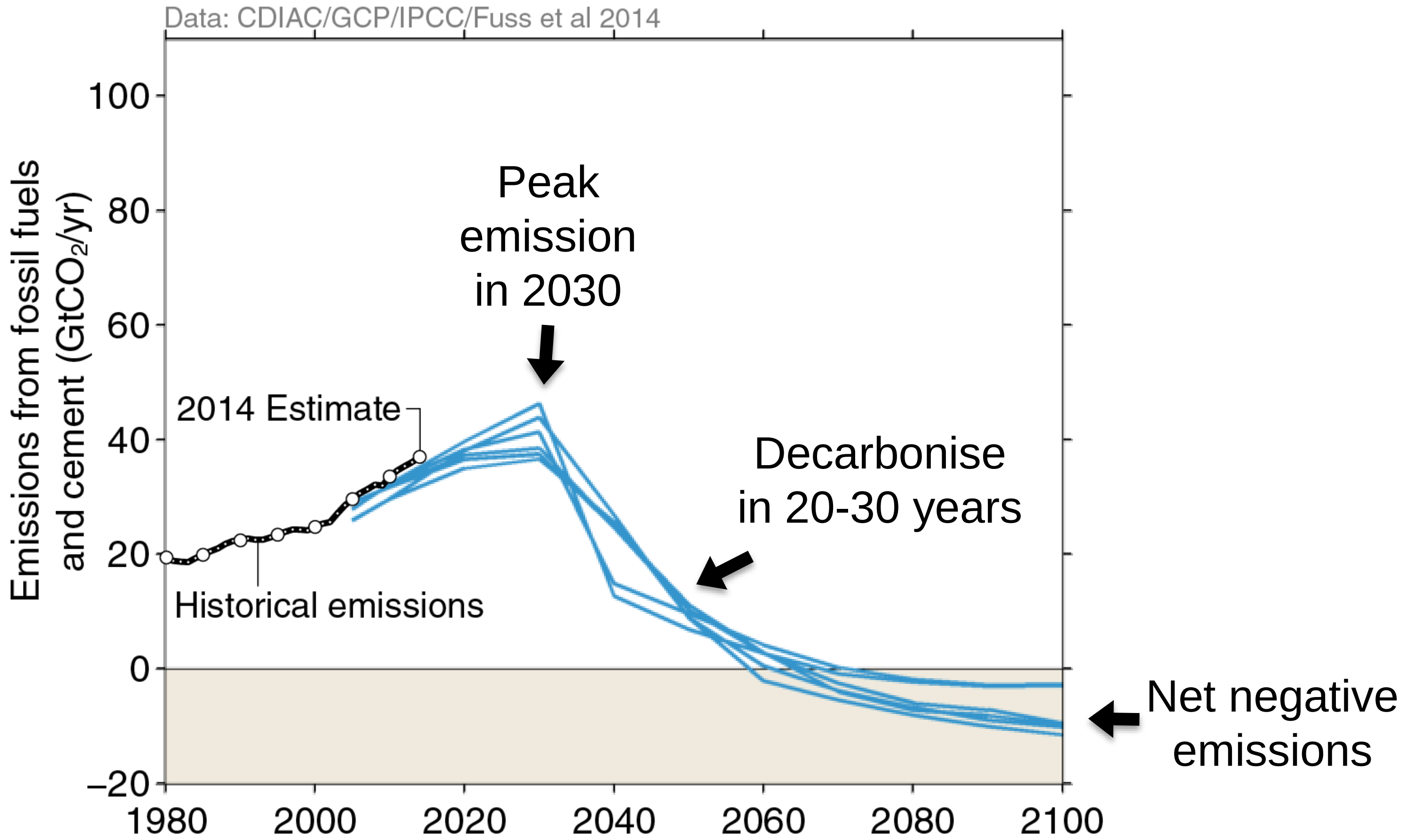
Instead of required global emission reductions of 3%/yr, emissions are reduced by 6% per year in these scenarios, GLOBALLY.

Delaying emissions reductions increases the difficulty and narrows the options for mitigation.



Based on Figure SPM.5

- much more rapid scale-up of low carbon energy necessary (3x instead of 2x between 2030 and 2050)
- delayed pathway more economically costly, higher reliance on CDR technologies



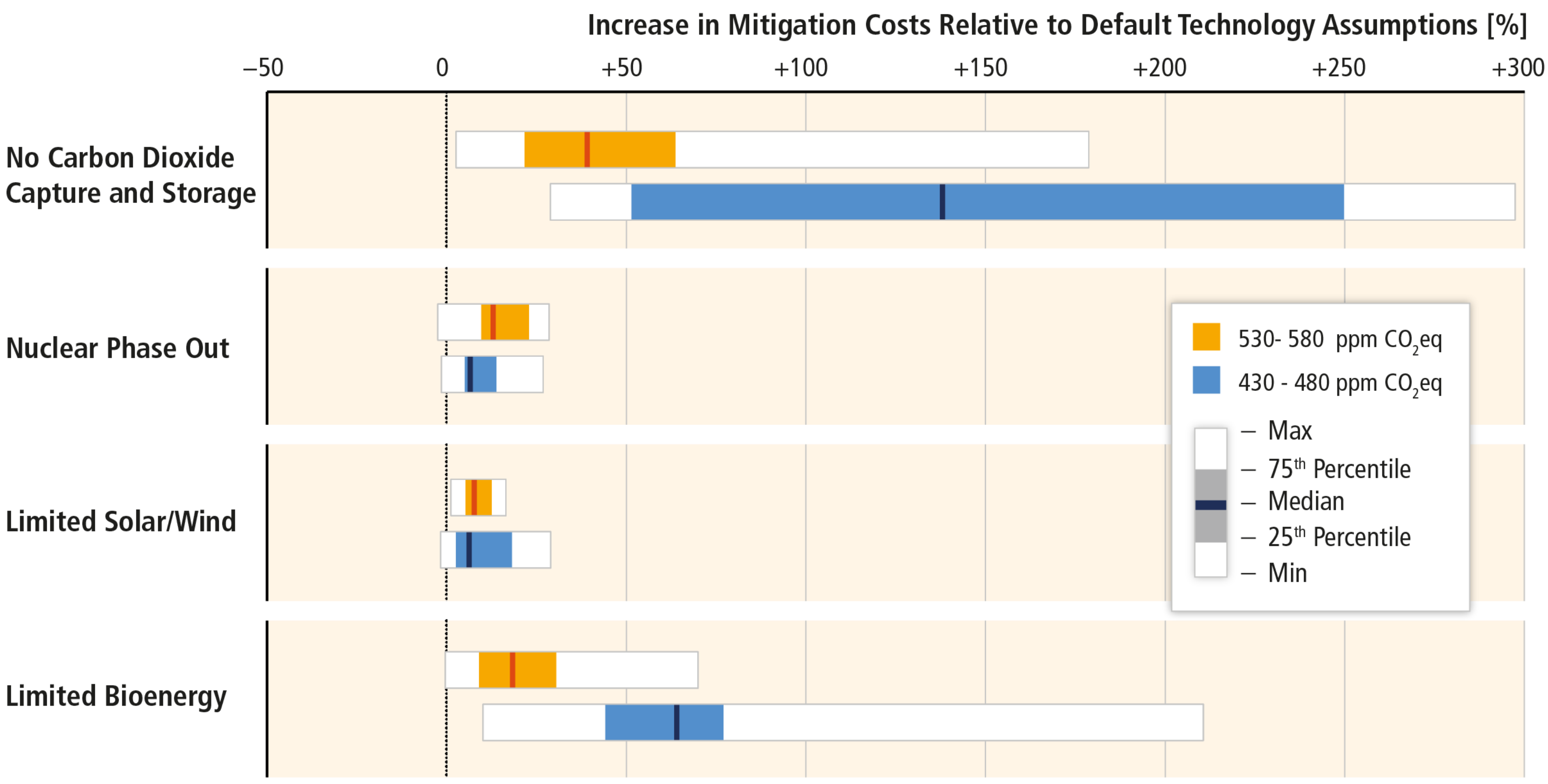
Is 2° C possible without a global agreement until 2030? → difficult

Source: Peters (2015)

http://www.cicero.uio.no/en/posts/news/a-journey-from-5c-to-2c

Relax iv): all technologies available

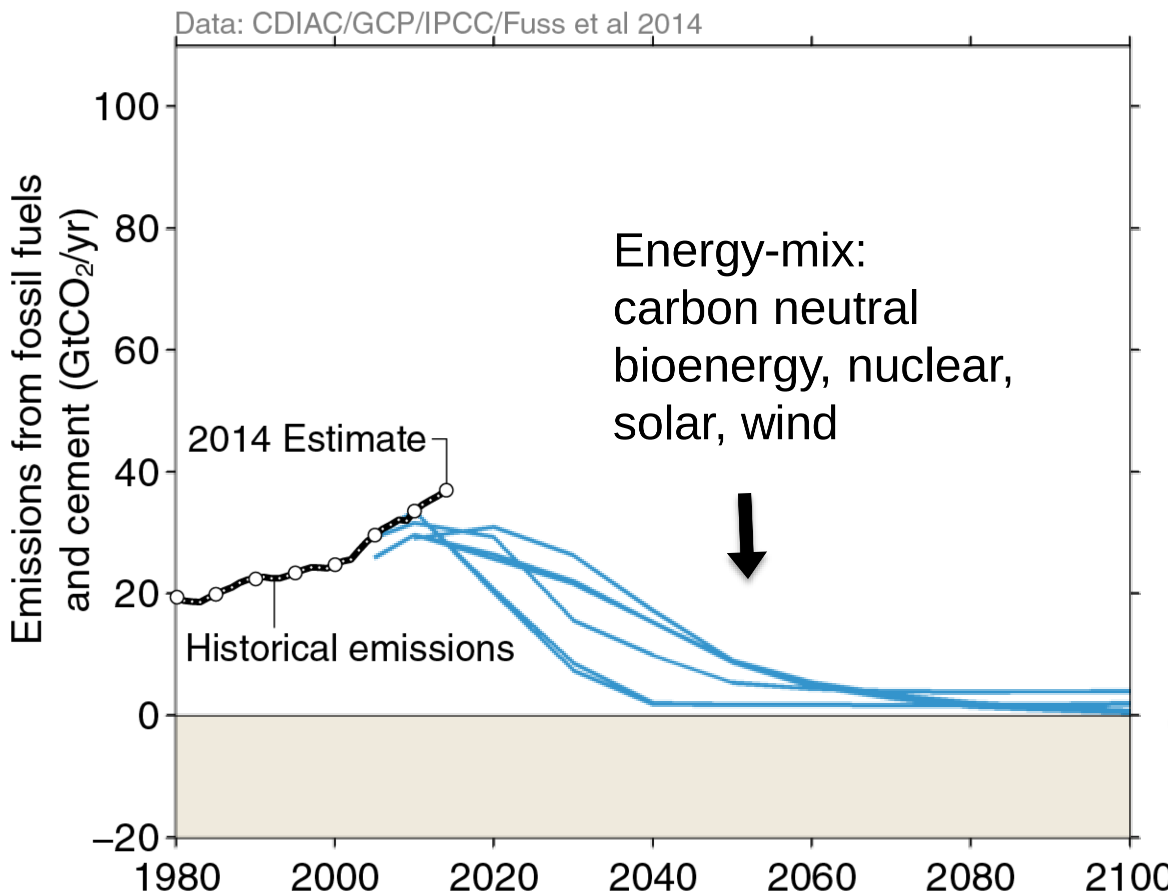
Technological limitations can increase mitigation costs.



Based on Figure 6.24

- Many models could not achieve concentration levels of 450 ppm CO_2eq by 2100 if additional mitigation is considerably delayed or under limited availability of key technologies, such as bioenergy, CCS, and their combination (BECCS).

Without “negative emissions” (6 scenarios)



Negative emissions offset previous emissions

No negative emissions, no fossil fuels

Source: Peters (2015)

http://www.cicero.uio.no/en/posts/news/a-journey-from-5c-to-2c

Renewables in Germany

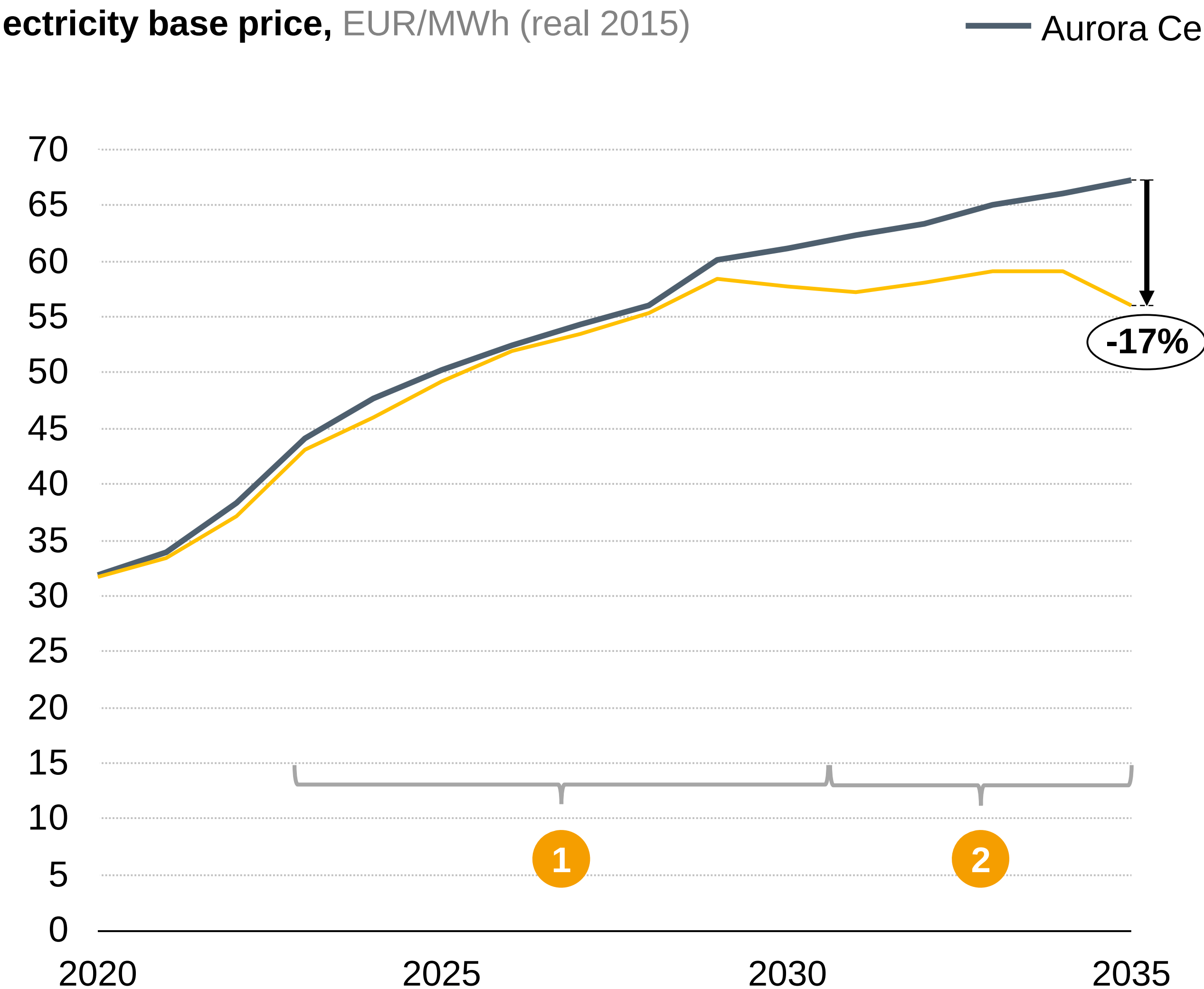
- PV corridor of 2.500 MW (gross) - 2015 only 1.444 MW (but more wind)
- Auctions (600 MW/a): large scale PV & rooftop > 100 kW
  1. round 2015: 9,17ct/kWh, 5. round: avg 7,25ct/kWh
- FIT for rooftop < 100 kW with cost reductions 10-15ct/kWh
- Outside EEG < 15%
  23TWh on exchange (hydro, waste biomass)
  2TWh self-consumption of PV electricity
  (in comparison 35-40 TWh CHP self-consumption)
- preferable treatments for self-consumption
  guaranteed grid connection, no additional system cost, feed-in privilege (40% FiT)

Renewables in Germany

- Renewable integration is the real challenge:
  LCOE are lower, but system integration costs crucial
- high shares of PV supply and demand diverge more:
  value of generated electricity reduced by 50-70% for 30% PV
- Storage becomes important (short term storage for diurnal cycle - battery-electric storage)
- Grid extension for pooling
- Virtual power plants with PV, wind (variable renewables)
- Flixible demand and DSM: pricing, smart grid
- Market barriers and market design: shorter duration and smaller size of products, flexible products
- Electrification of other sectors

A scenario for Germany

Electricity base price, EUR/MWh (real 2015)

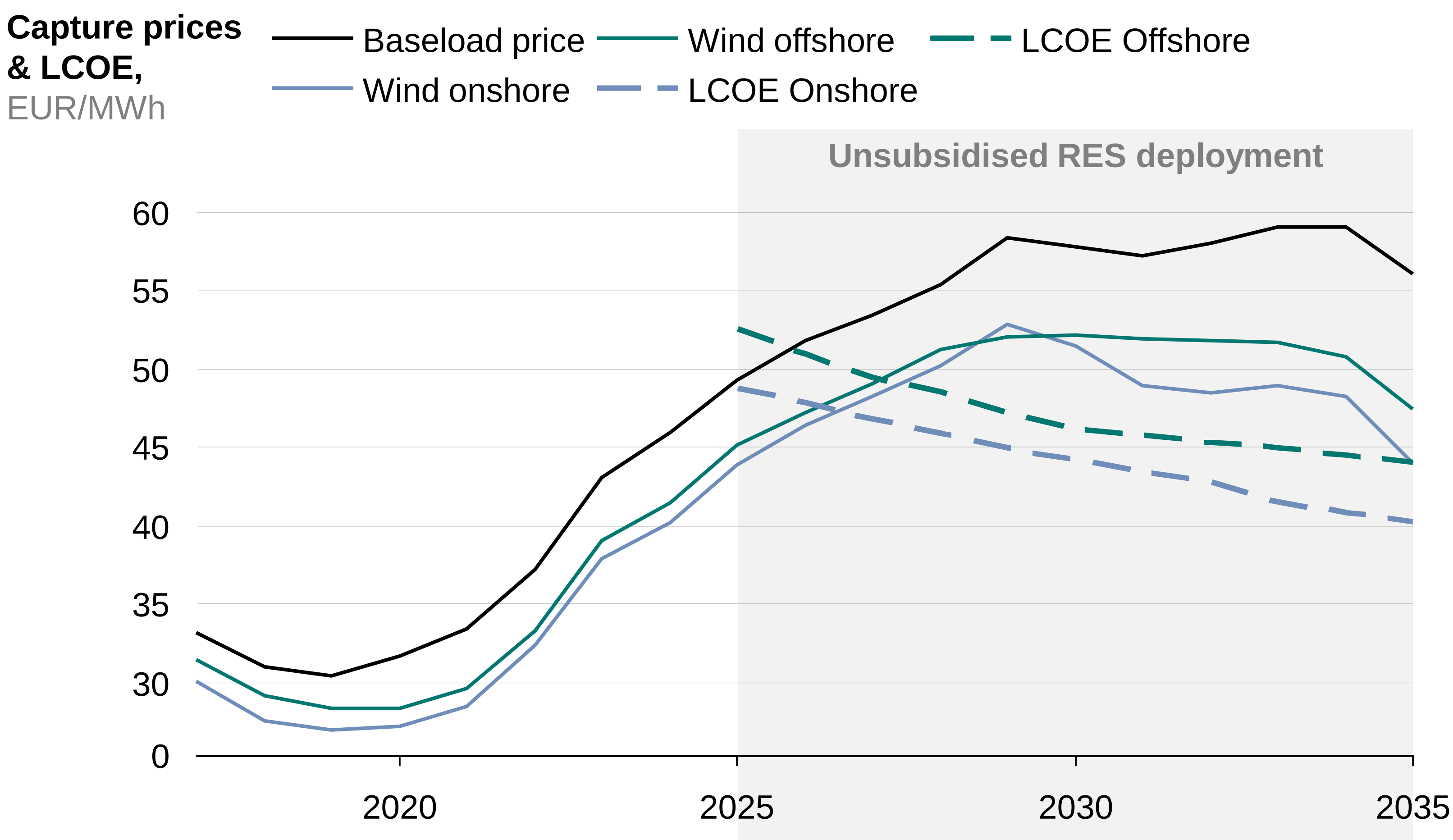


1 ~39 GW of rooftop PV is added behind the meter

2
- Further uptake of rooftop PV
- 64 GW of unsubsidised wind and 43 GW of unsubsidised large-scale PV are added in Germany
- Significant uptake of RES across Europe
- Germany becomes a net importer

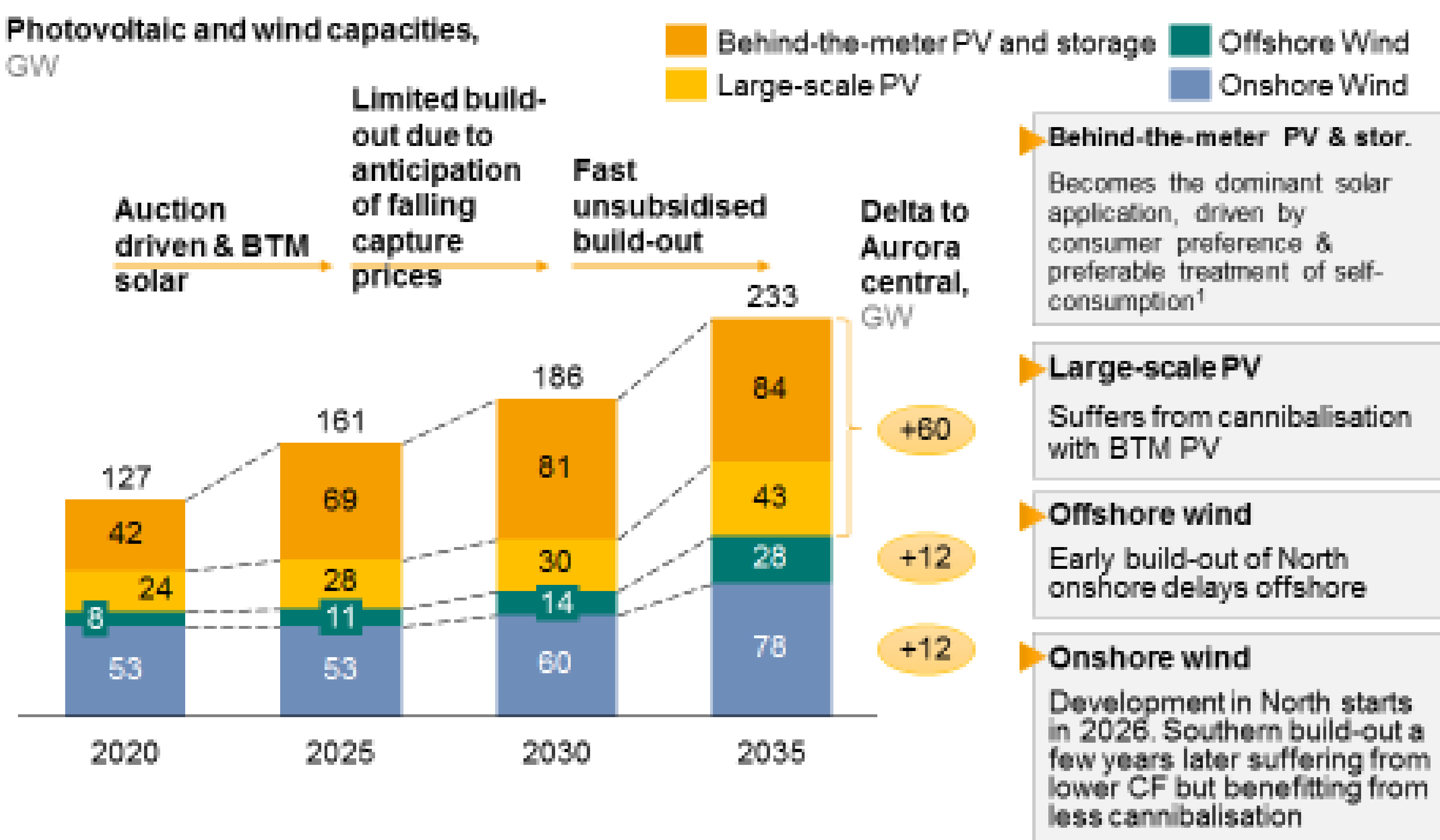
A scenario for Germany

- In the long run capture prices approach LCOEs of own or competing technology unless build-out limits are imposed - **cannibalisation**



A scenario for Germany

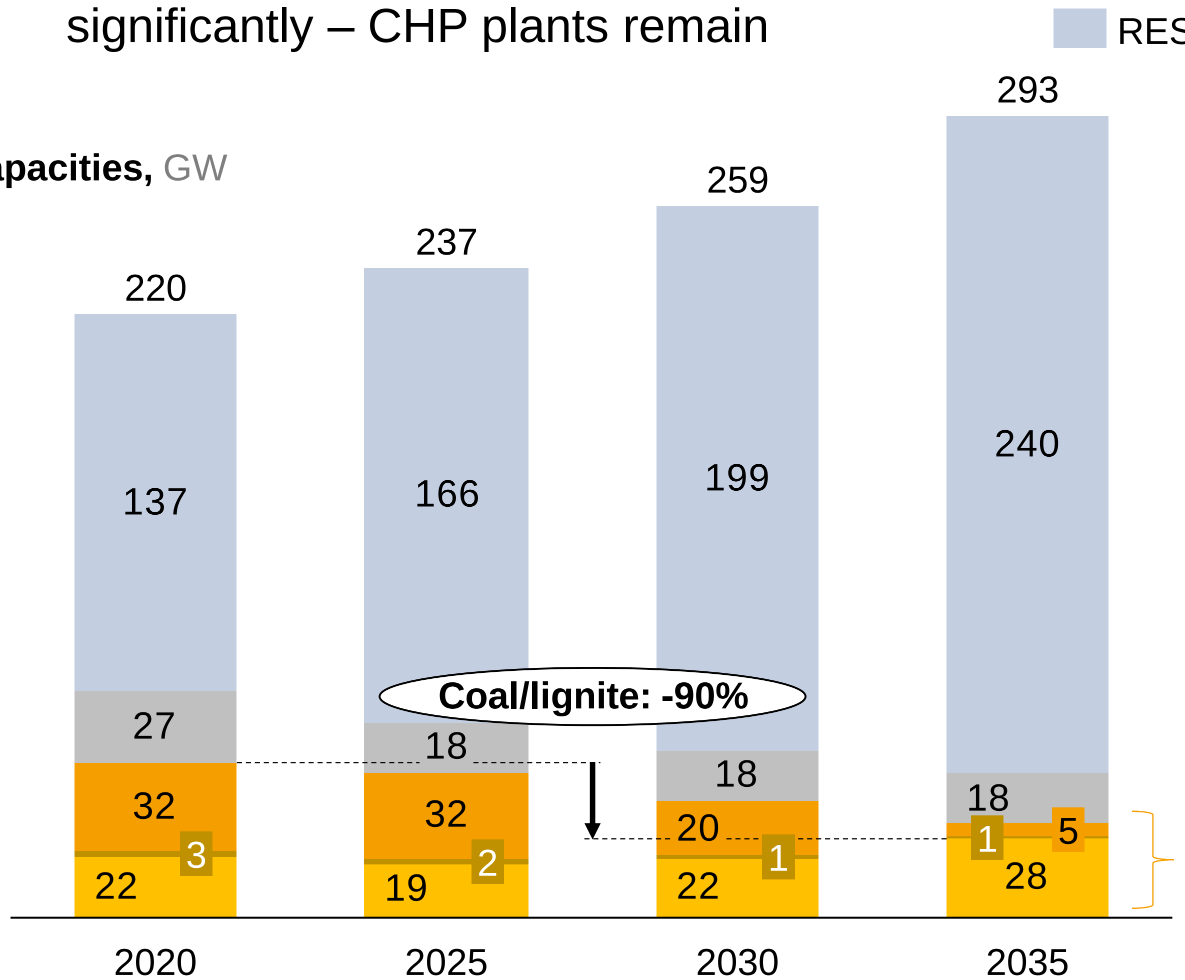
large PV	LCOE (€/MWh)		87 (2017) → 41 (2035)
	CAPEX (€/kW)		743 (2025) → 439 (2035)
	OPEX (€/kW/a)		11 (2025) 8 (2035)



A scenario for Germany

As prices start to decrease thermal plant retire at scale, especially coal is hit significantly – CHP plants remain

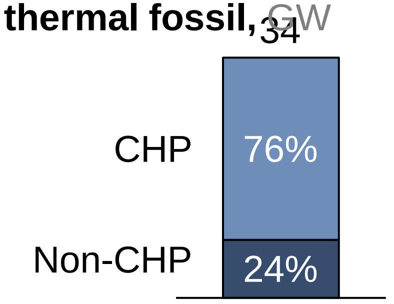
Capacities, GW



Emission reduction post 2035 requires decarbonisation strategy for heat sector

- 76% of remaining fossil capacities run in cogeneration
- Non-CHP capacities are mostly gas peakers

Share of CHP of 2035 thermal fossil, GW

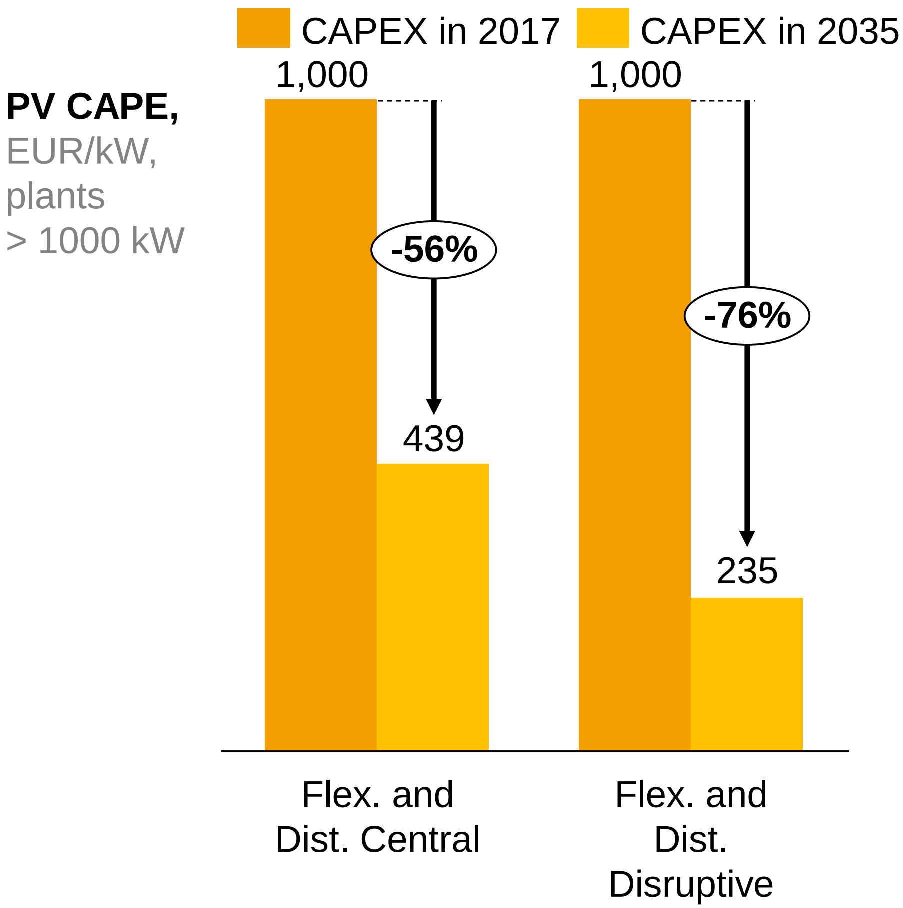


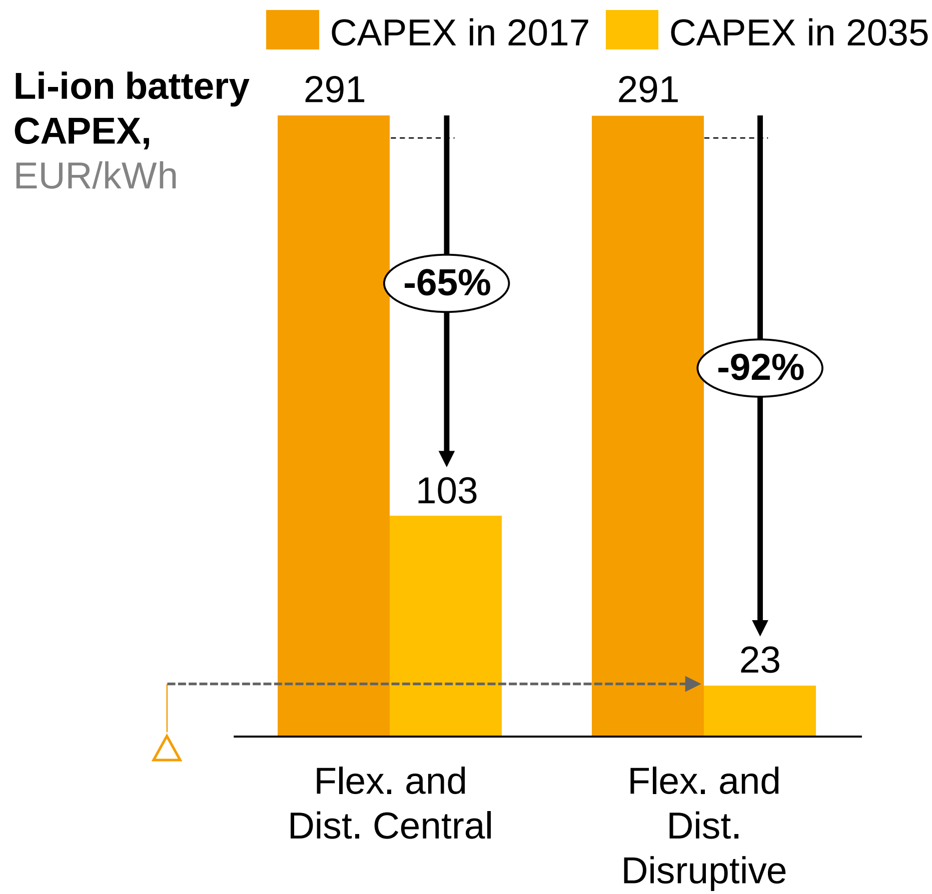
1) Other include nuclear, DSR, waste, pumped storage, other storage and other fossil generation plants

A (desruptive) scenario for Germany

cost decline of 76% would only require 15% of global final energy consumption met by solar (17.250 GW cum. built capacity)

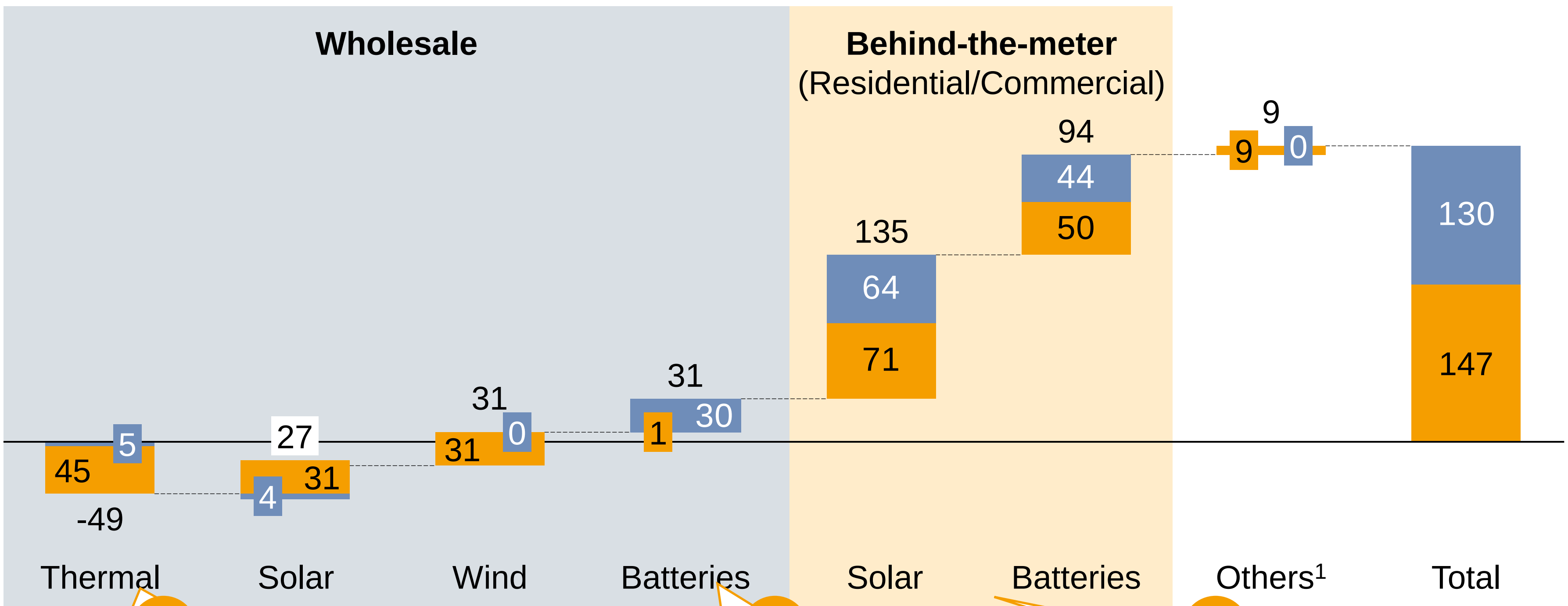
worldwide diffusion of electric vehicles would trigger disruptive decline in Li-ion battery cost (cum. built capacity 49,000 GWh w 55% of veh., today 50 GWh)





A (desruptive) scenario for Germany

In disruptive flexible & distributed scenario, baseload prices remain broadly constant from 2025 onwards at wholesale market prices in 2035 around 50 - 55 EUR/MWh



C
In the Disruption scenario, only 5 GW more thermal capacities exit – reflecting the fact that thermal capacities continue to be needed when the sun doesn't shine

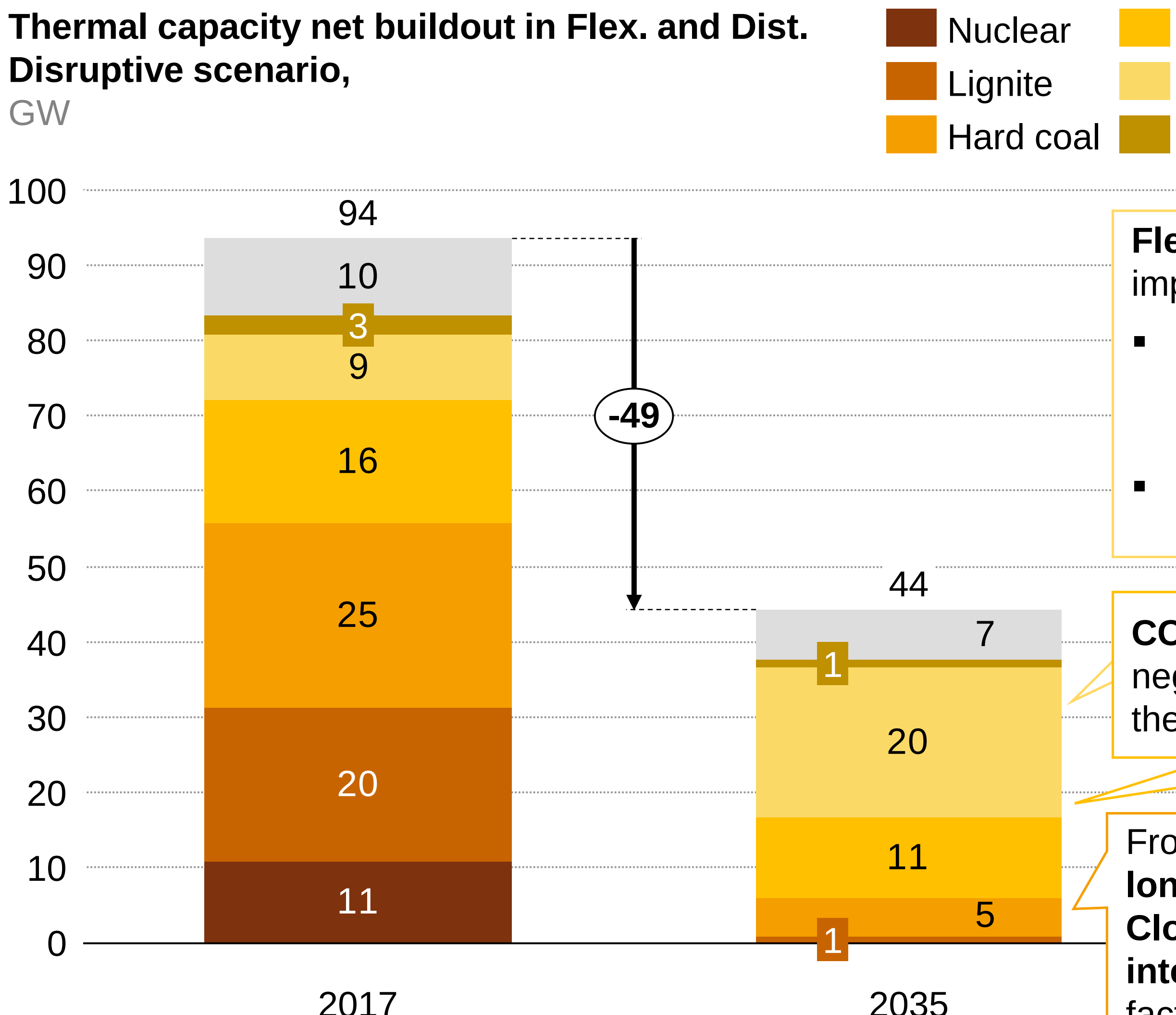
D
Grid-scale batteries become investible in the wholesale market at CAPEX below 100 EUR/kWh

E
Behind-the-meter solar and batteries displace grid-scale solar due to self-consumption privileges

1) Includes small-scale CHP, applications in the industry sector (Batteries, DSR) and for ancillary services

A (desruptive) scenario for Germany

Coal plants become unprofitable and retire; only flexible gas plants are added



Flexible gas plants gain in importance:

- Inflexible coal CHP plants are replaced by **flexible gas CHP plants**
- 4.5 GW **gas peaking plant** replace retiring thermal capacities

CCGT newbuilds remain NPV-negative; retiring capacities are therefore not replaced

From 2030, most **coal plant no longer cover their fixed costs. Close even without government intervention**, due to declining load factors and rising EUA prices

A scenario for Germany

Renewables perspective:

- Falling cost of renewables have a high chance to result in significant unsubsidised build-out across Europe post 2025.
- Wholesale power price start stagnating post 2026 at 55 – 60 EUR/MWh and in particular capture prices are put under pressure, which over time approach LCOE of technology or competing technology i.e. onshore/offshore
- We see a role for all four key renewables models, given variation in weather and regional constraints, yet correlation between asset cluster needs to be assessed to avoid unforeseen cannibalisation effects in the future

Fossil perspective:

- At this pathway, 90% of the German coal/lignite fleet is closing until 2035, turning Germany into a net importer

Policy perspective:

- Technological progress alone is not sufficient to meet 2030 targets, leaving government with the role to ensure long-term certainty on carbon pricing to be above 40 EUR/t or a coal phase-out
- Security of supply becomes increasingly an issue post 2030. High IC capacity and renewables penetration creates cluster risk of correlated demand and generation in Central European