



Offshore wind in Europe – transition to subsidy free buildout

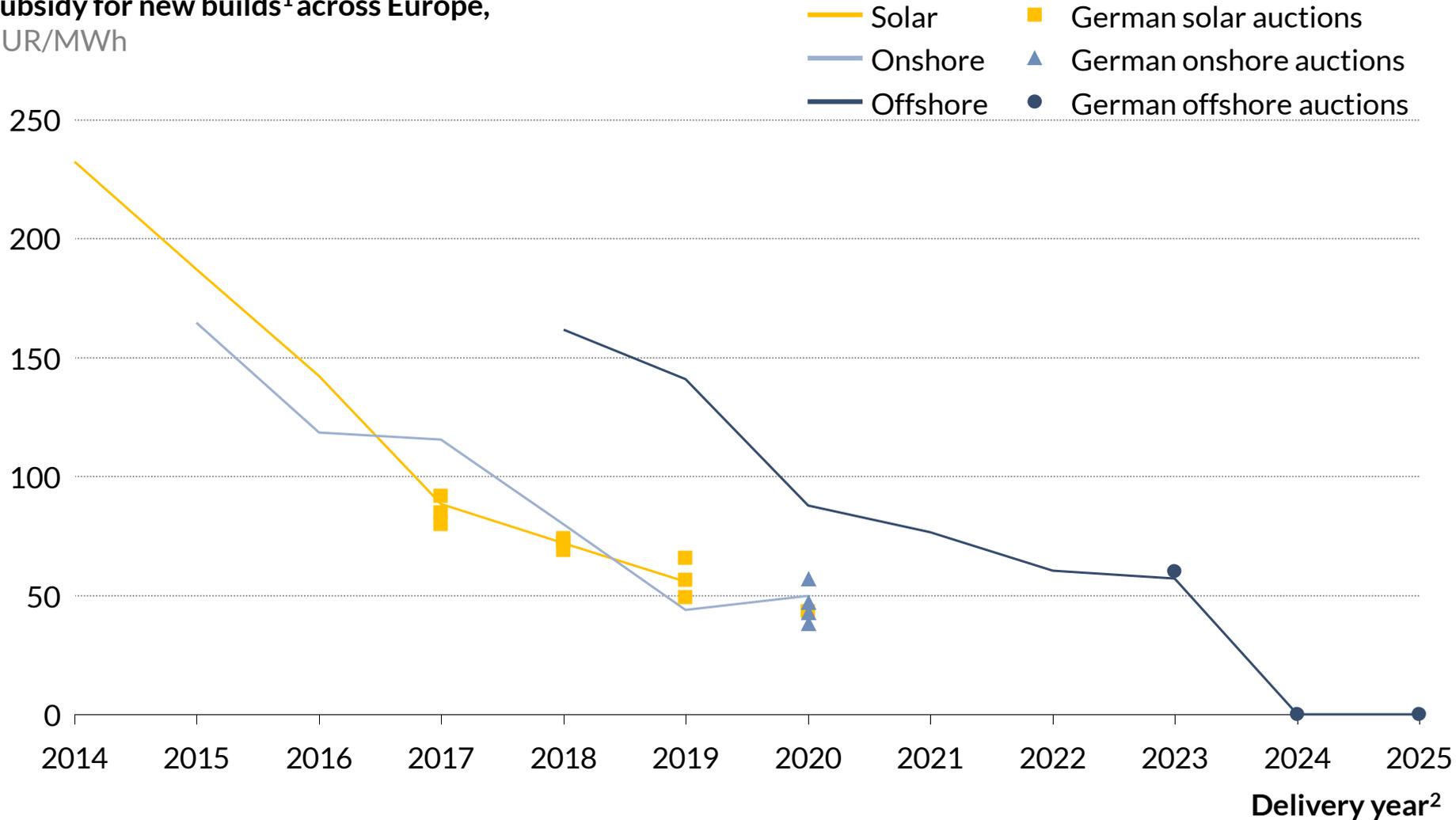
Dr. Manuel Köhler

Offshoretage in Warnemünde, March 2nd 2018



Subsidies for renewables are under pressure, driven by falling technology cost and competitive auctions

Subsidy for new builds¹ across Europe, EUR/MWh



1) Developers bid for an “average location”, paid subsidy is adjusted for local wind yield by correction factor. Most successful bids were at below average locations and will thus receive higher payments. 2) 2017 German onshore auctions gave special provisions to citizen energy projects, including a longer build-out deadline

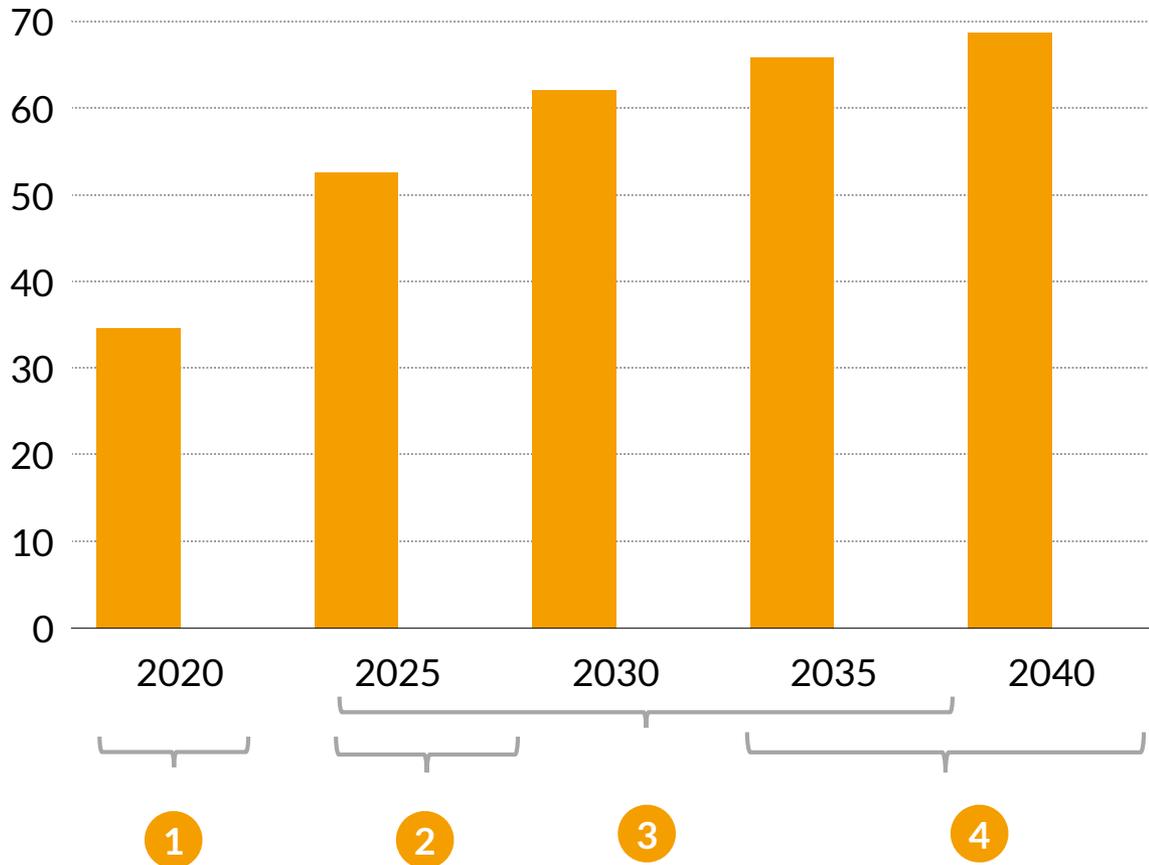
Shrinking baseload, more renewables and rising commodity prices will shape wholesale power markets across the EU

Area	Details
Coal Phase-out	 The new coalition government intends to close all Dutch coal plants by 2030
	 UK will phase out remaining coal fleet by 2025 (13 GW)
Nuclear Phase-out	 Belgium decided to phase out nuclear by the end of 2025 (6 GW)
	 France is reviewing a reduction of nuclear capacities.
Renewables Build out	 2030 EU climate & energy target sets a target of 27% share of renewable energy
	 Energieakkoord sets onshore wind targets of 6 GW until 2020 and offshore wind targets of 4.5 GW by 2023, with further increases of 1 GW p.a. 2023 - 2030
	 New coalition agreement increases 2030 target to 65% generation by renewables
Carbon Price Floor & EU ETS	 Market Stability Reserve and phase IV reform is likely to increase prices in the long run
	 In 2013 UK implemented a carbon price floor to support the switch from coal to less carbon intensive gas. In 2020 the total cost of carbon in the UK will be ~22 GBP/t
	 New coalition government intends to introduce a carbon price floor from 2020 on
Fuel prices	 European gas price are expected increase as LNG market rebalances
Electrification of transport	 Increasing number of European countries are debating a ban for new IC engines
	 Dutch governments states that by 2030 all new cars should be emission-free



Consequently, Aurora expects power prices to rise in the mid- to long-term

German electricity base price EUR/MWh (2016 real)



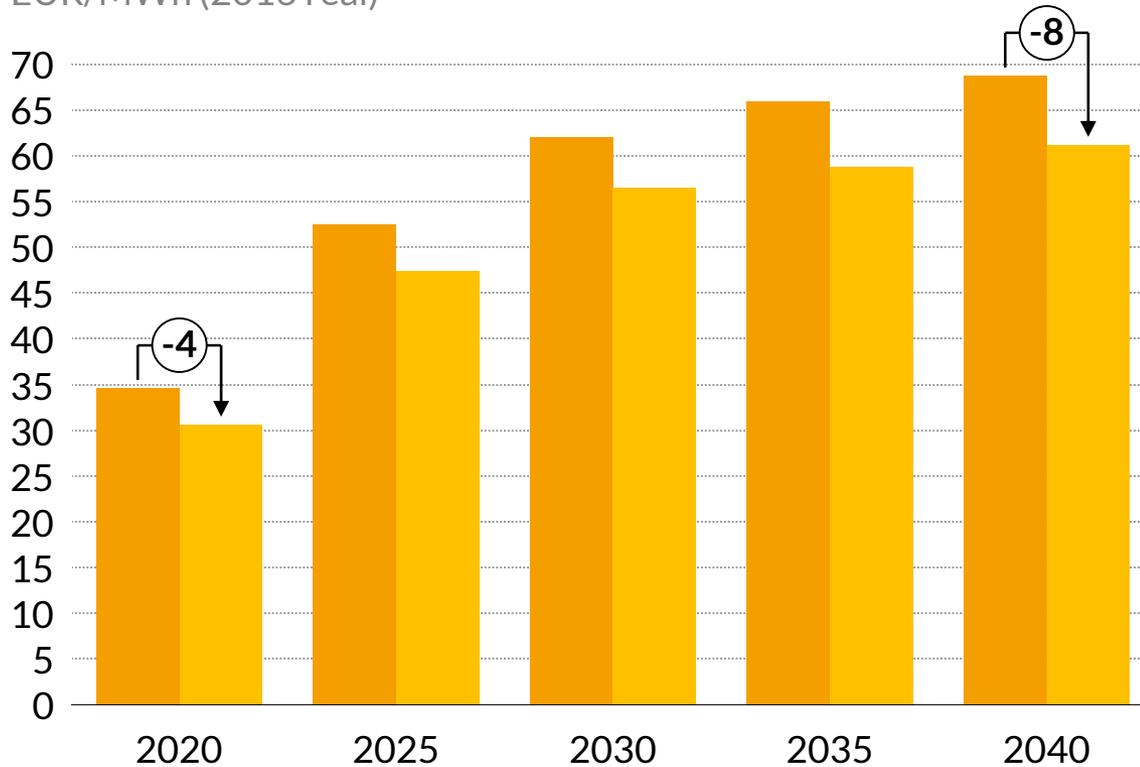
Key drivers of Central scenario

- 1 Rising gas prices, but falling coal prices lead to broadly constant power prices
- 2 Power prices increase due to exit of nuclear and coal capacity
- 3 Rising EUA and fuel prices, as well as increasing power demand induce a steady growth of power prices
- 4 Faster market-driven renewable build-out across Central Europe puts downward pressure on prices



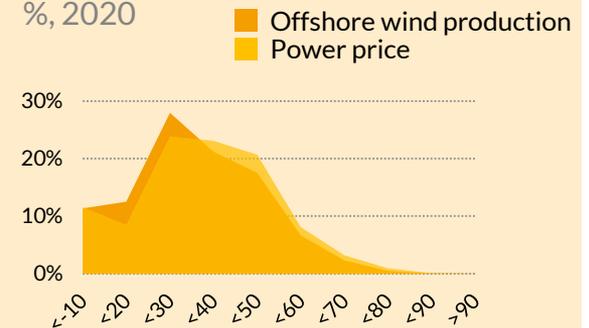
Offshore capture prices double even though gap to baseload prices increase as more wind enters the market

Wholesale price and offshore wind capture prices, EUR/MWh (2016 real)



■ Baseload price
■ Offshore wind capture price

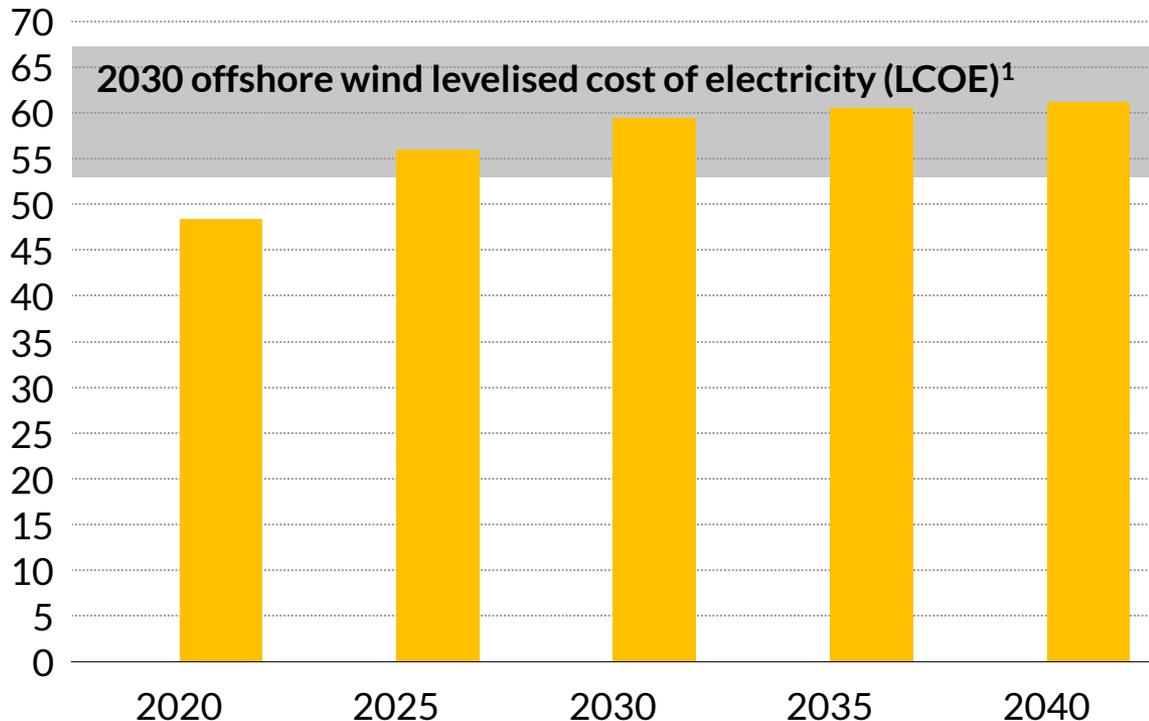
Distribution of power price and offshore wind production, %, 2020



- Less expensive technologies set the price in periods with high wind production and vice versa
- With higher wind penetration production pattern shifts further to low price periods due to strong correlation of wind patterns across Europe's offshore coast

As cost fall and power prices rise, subsidy free offshore deployment will become the norm over the next decade

20 year forward rolling average of German offshore wind capture prices, EUR/MWh (real 2016)



- Higher turbine ratings, design improvements and more efficient O&M reduce cost and improve load factors of offshore wind
- As levelized cost of electricity fall below prices that offshore can capture on the market, subsidy free buildout becomes viable
- Subsidy free buildout will likely become the norm for asset with COD from the late 2020s on

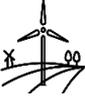
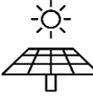
1) Levelised cost of electricity of individual assets vary substantially depending on site conditions, technology and capital cost

In an subsidy free market, offshore wind directly competes with other renewables technologies

Sensitivity analysis of capture price on additional deployment of renewables technologies

There is fierce competition between onshore and offshore

Impact on capture price in 2035

	Capture price in Aurora Central 2035, EUR/MWh, real 2016	+100 TWh onshore wind 	+100 TWh offshore wind 	+100 TWh large-scale PV 	+100 TWh BTM ² PV with batteries 
Onshore Wind	52	-23	-21	-5	-5
Offshore Wind	59	-24	-24	-1	-1
Large-scale PV	59	-8	-7	-26	-30
Behind-the-meter PV	Household price ¹ : 296	-12 household price	-12 household price	-6 household price	-6 household price

When moving to a subsidy free world it is crucial to understand the competition among the technologies

1) Household price is wholesale price plus taxes, levies and charges, whereas VAT is neglected. 2) Behind-the-meter

Key risks to power price recovery are a fast renewables cost decline and low commodity prices

Overview of uncertainties with high likelihood / high impact	Likelihood & power to influence by region						Indicative impact on North-European offshore capture price in 2035

Future of generation fleet

▪ Mandated coal exit until 2040	●	◐	-	-	-	◐	+ 2- 5 EUR/MWh
▪ Higher renewable targets supported by continued subsidies	◐	◐	◐	◐	◐	◐	-(12 - 18) EUR/MWh
▪ Faster cost decline of established solar & wind technologies (30% faster than in Central by 2035)	-----●-----						-(12 - 18) EUR/MWh

Commodity prices

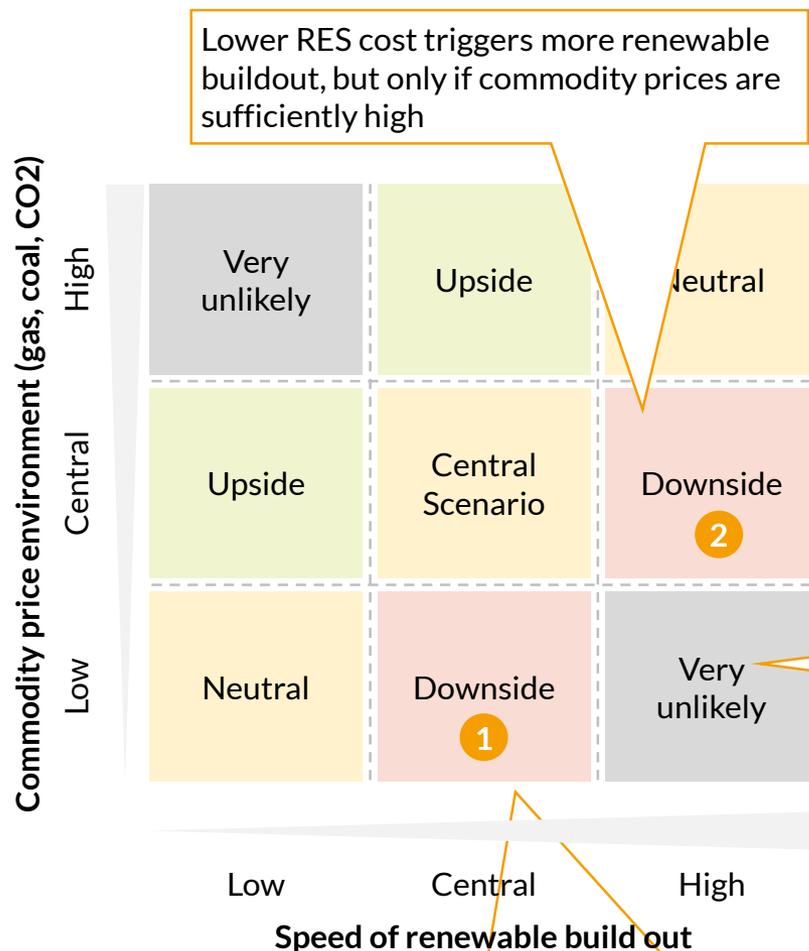
▪ Low gas price environment and relatively high coal price (in 2035 -12 EUR/MWh vs. Central)	-----●-----						-(10 - 15) EUR/MWh
▪ Failure of EU ETS Phase 4 reform to enact higher prices (~12 EUR/t)	-----●-----						-(12 - 18) EUR/MWh

Power demand

▪ Fast shift to Electric Vehicles and electrification of heating	-----●-----						+ 6 - 10 EUR/MWh stabilizes low price periods
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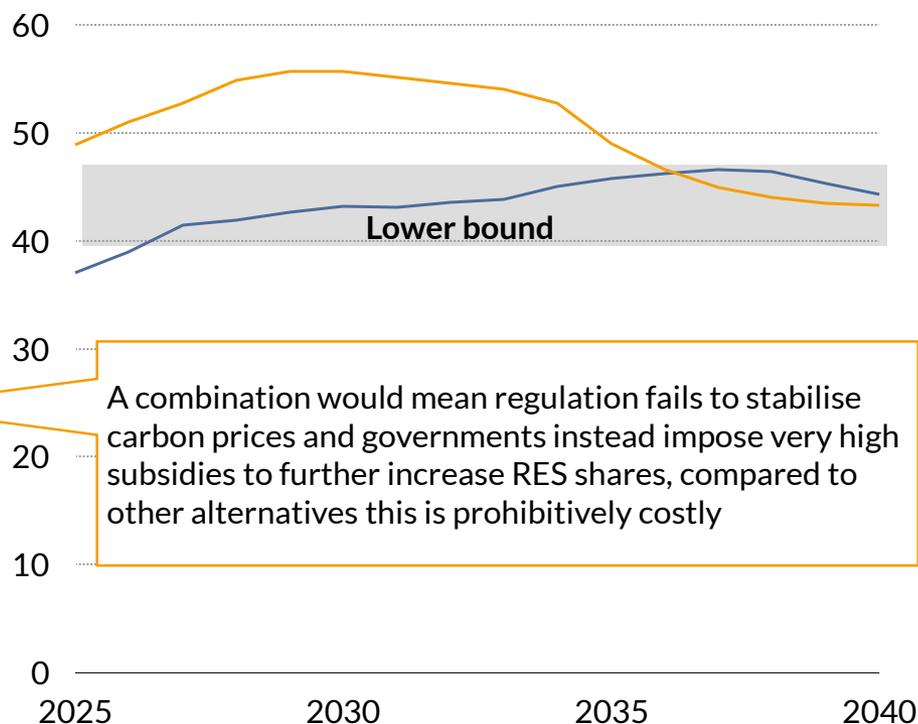
However these two risks need to be seen as alternatives not additives, which provides a lower bound on prices



Decrease in commodity prices depresses power prices and thus slows down/stops subsidy free renewable buildout which stabilising prices

- 1 — Low Commodity scenario
- 2 — Fast renewable innovation scenario

Offshore capture price
EUR/MWh (real 2016)

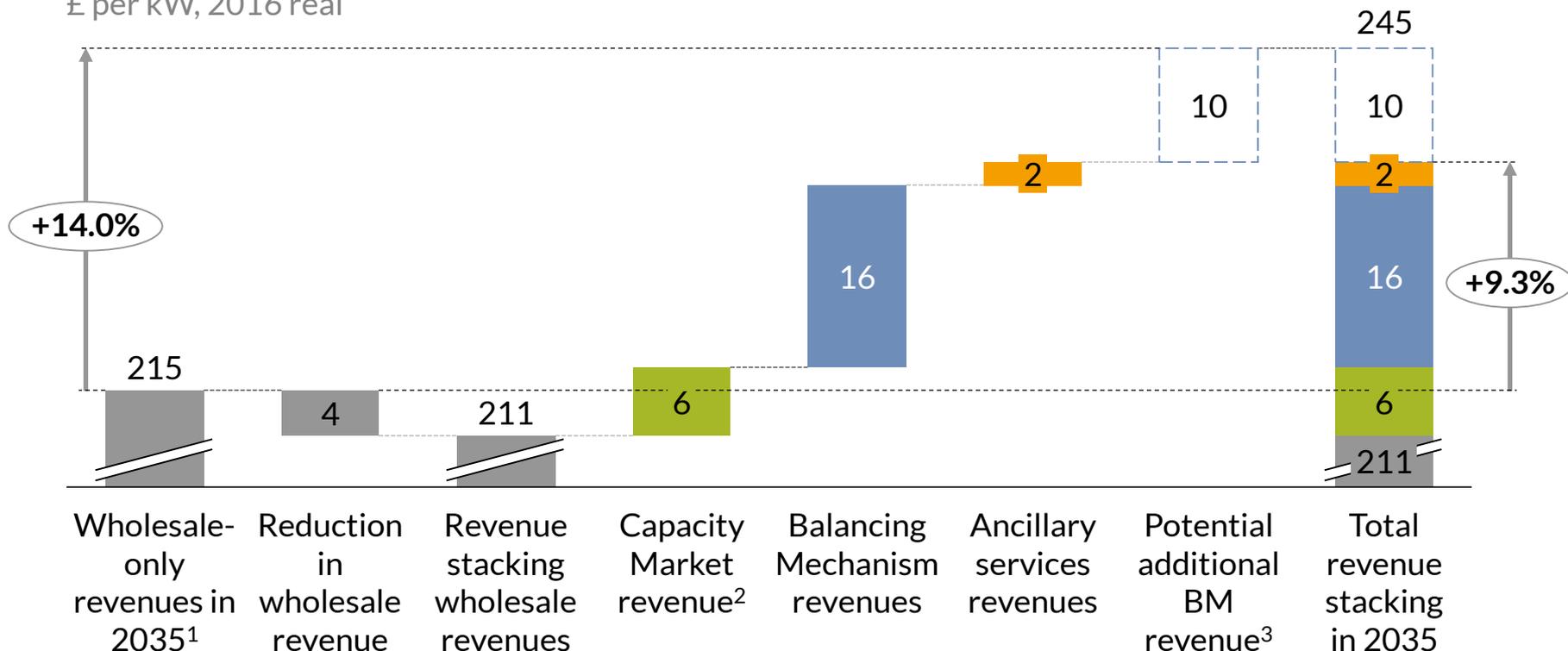




GB study shows that subsidy free offshore wind can provide services beyond pure merchant power generation

- Potential additional BM revenue
- Ancillary services
- Balancing Mechanism
- Capacity market
- Wholesale market

Revenues in 2035 for revenue-stacking model, £ per kW, 2016 real



1) Wholesale-only model does not build endogenously within model until late 2030s 2) Assumes a capacity de-rating factor of 25% 3) Potential additional BM revenue dependent on bidding strategy in BM and operating strategy between wholesale and Balancing Mechanism

Also other EU markets are already considering wind participation in balancing and ancillary services



- The **FP7 TWENTIES** project successfully tested the controlled provision of voltage control and secondary reserve by wind farms connected to the transmission network
- The **REserviceS** project assessed the technical possibilities of wind farms and concluded that capabilities for certain voltage and frequency services are already incorporated in existing wind turbine technology or can be installed if required



- TSO is testing of reserve services provision (negative tertiary reserve) with regionally distributed onshore wind farms¹



- NUON is testing provision of frequency and reactive power provision in the 122 MW onshore wind farm Zuidlob¹



- TSO Elia has tested provision of downward secondary frequency services in the 77 MW onshore wind farm in Estinnes¹



- Under the DS3 Programme, EirGrid is implementing a wind dispatch tool to maintain the security of the system²

1) Based on a summary provided by TKI Wind op Zee on "Ancillary services from offshore windfarms in the Netherlands" (2015). 2) Based on information found on EirGrid's website. 3) Based on "International Review of Frequency control adaptation" by DGA Consulting (2016). 4) Based on S&C Electric Company submission to the Interim Report on System Security Market Frameworks

4 key points to take away!

▶ **Market transition:** Shrinking baseload, more renewables and rising commodity prices will shape wholesale power markets across the EU

▶ **Prices:** By 2035 offshore capture prices double. Key risk scenarios provide a lower bound on long-term prices of ~45 EUR/MWh (real terms).

▶ **Renewables future:** As technology cost fall and wind capture prices rise, renewables build towards the end of the 2020 will be merchant. Onshore and offshore farms directly compete with each other.

▶ **Revenue-stacking:** Several examples show that offshore wind has the capability to provide services beyond the pure merchant power generation, adding ~14% of revenue.