



Wind Power

Technology Trends, Economic and Environmental Issues

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21st Nov 2023

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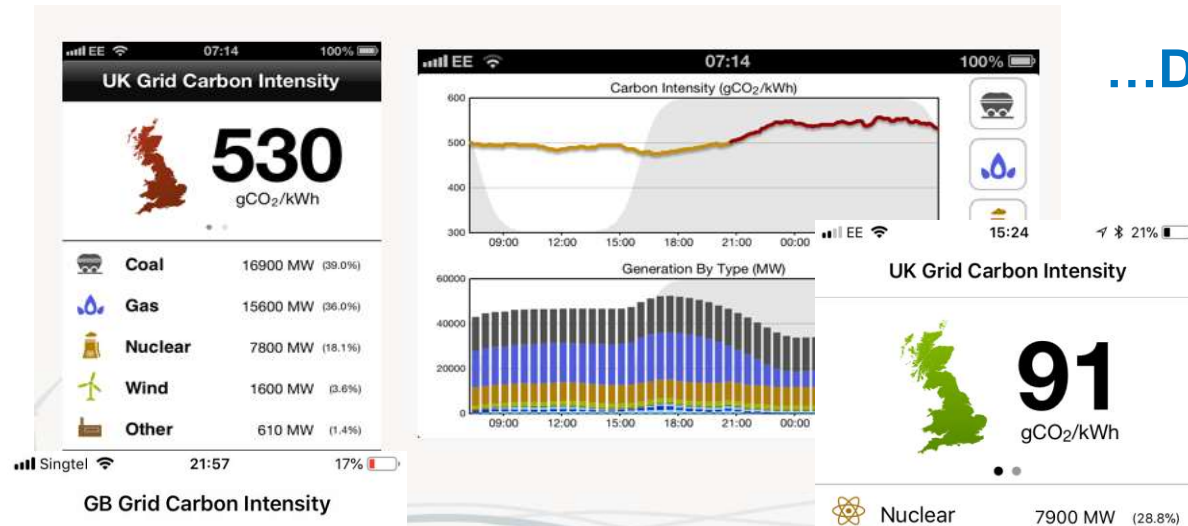
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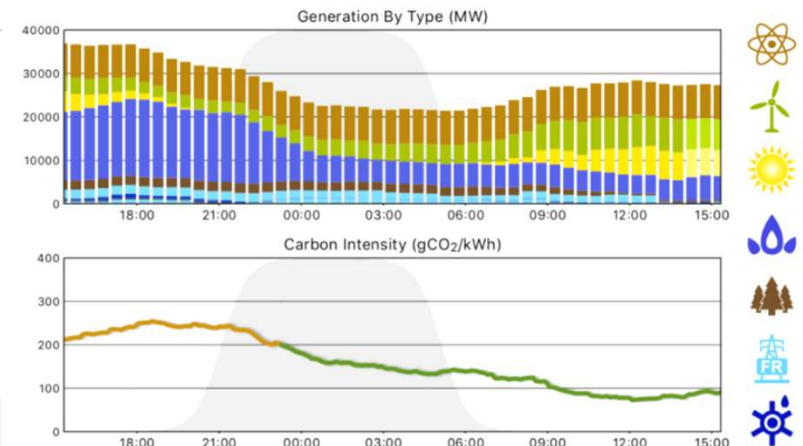
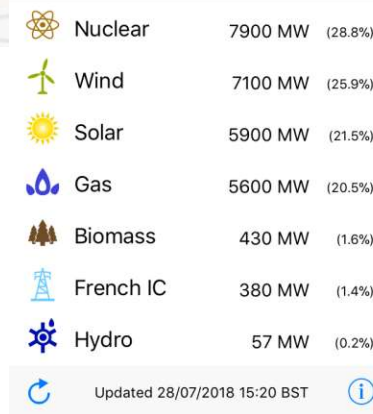
UK POWER MARKET



...Dec 2013

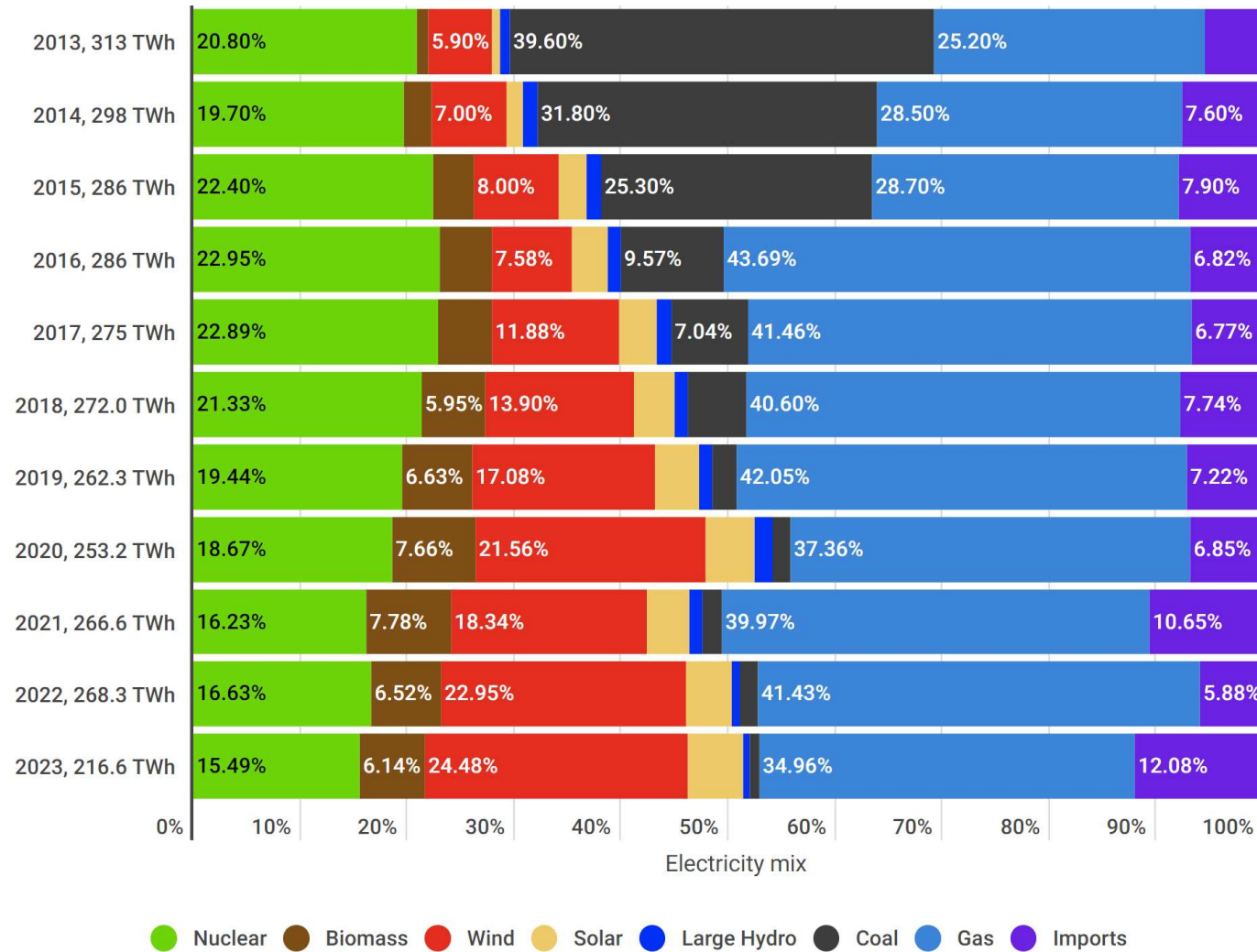
...July 2018

...Aug 2019

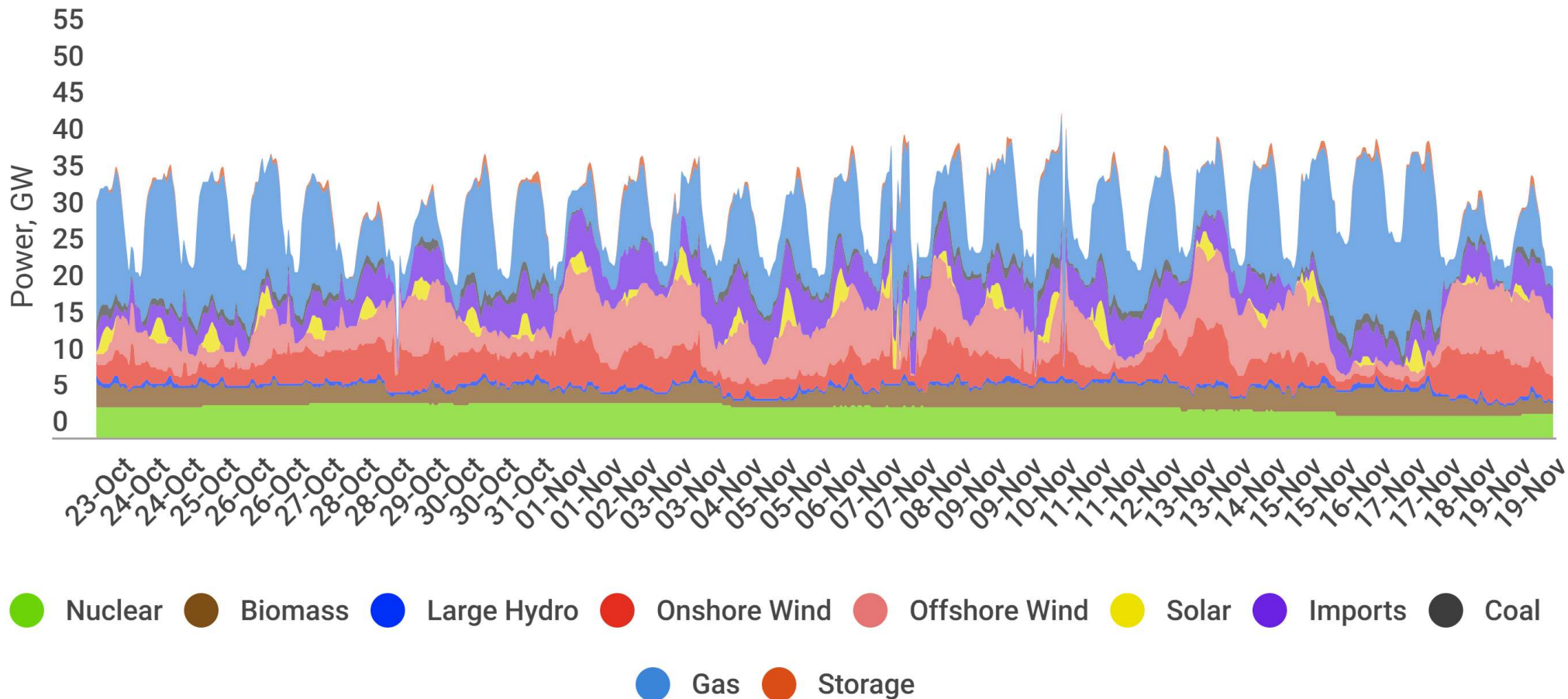


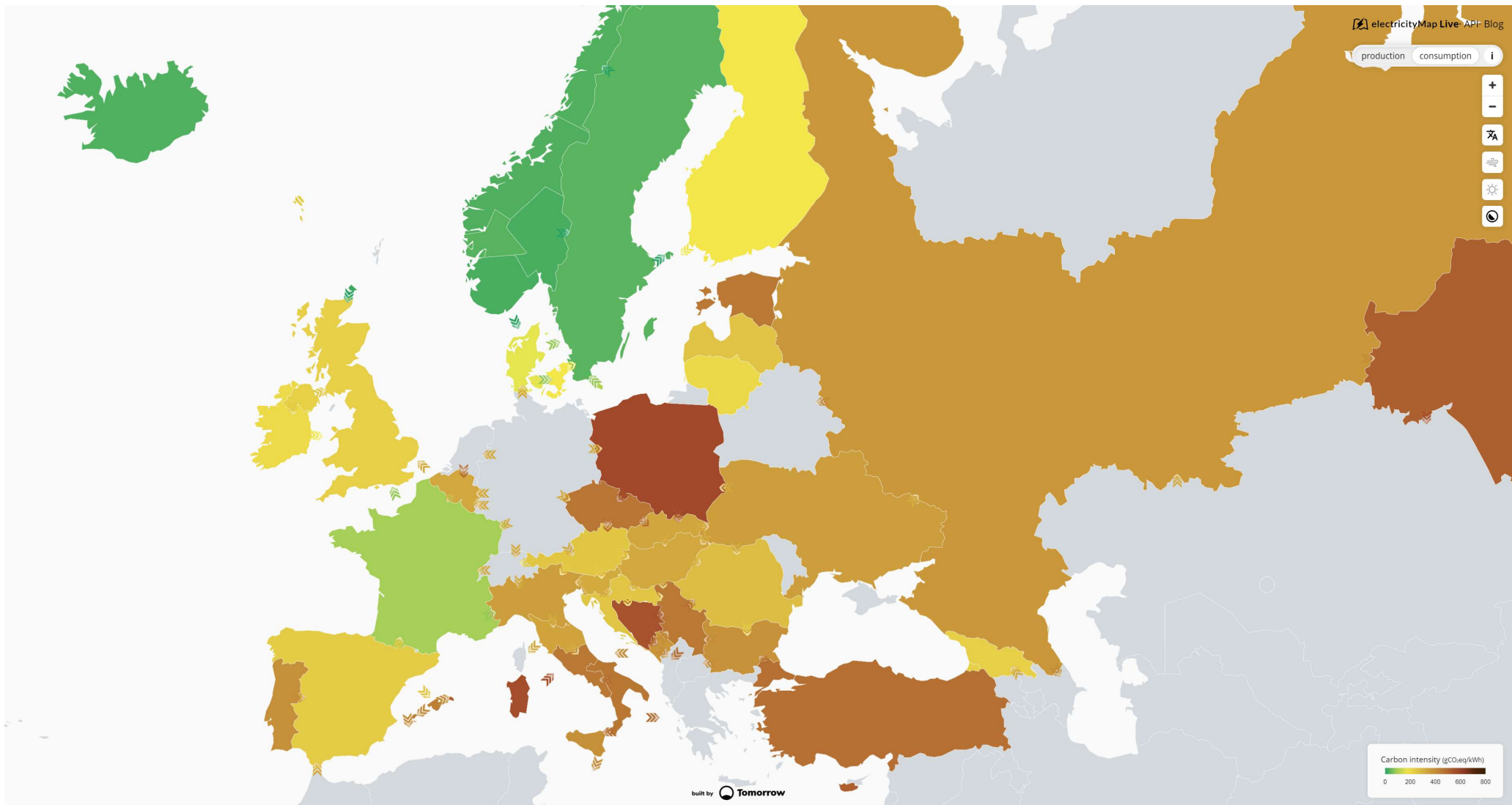
GRID decarbonisation well underway...

DECARBONISATION - UK

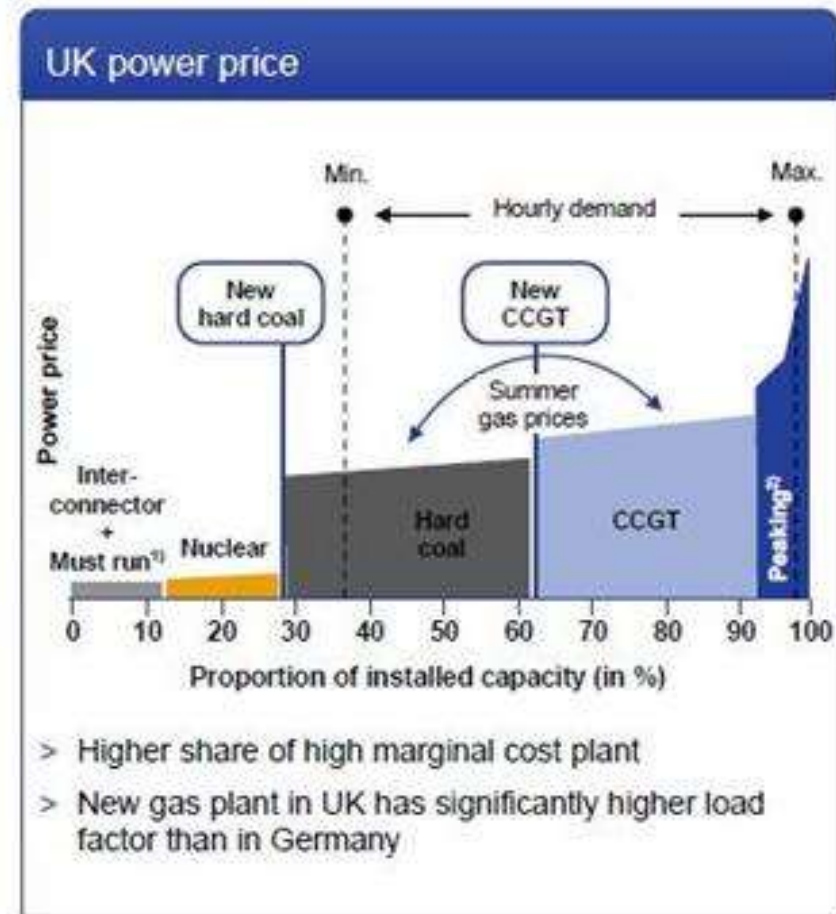
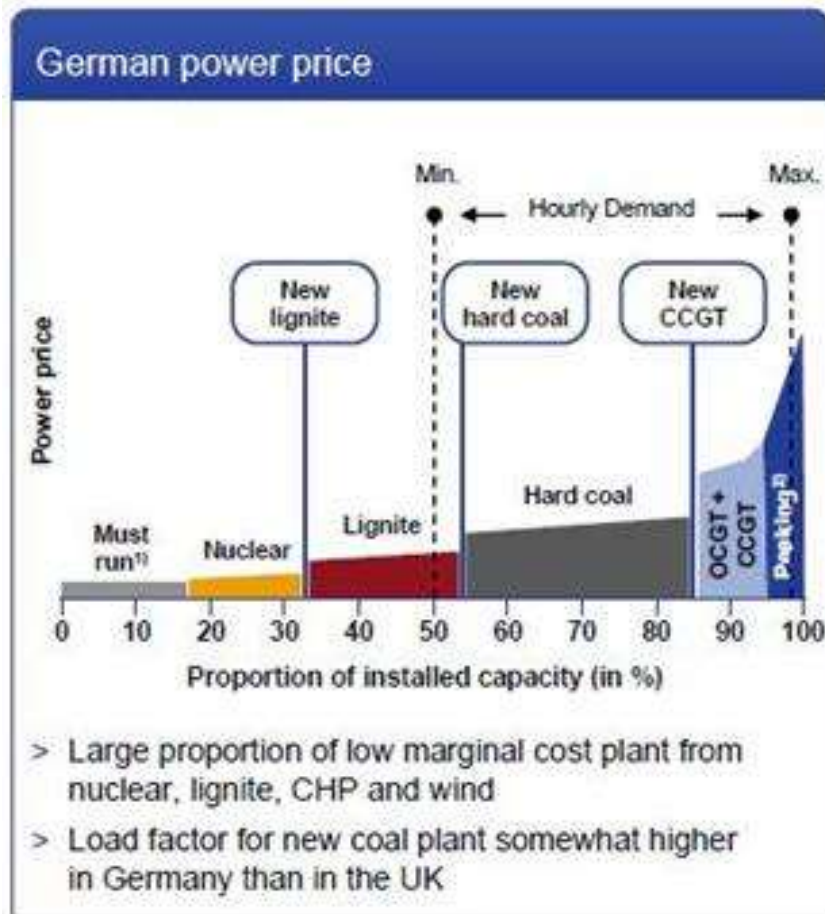


DECARBONISATION - UK



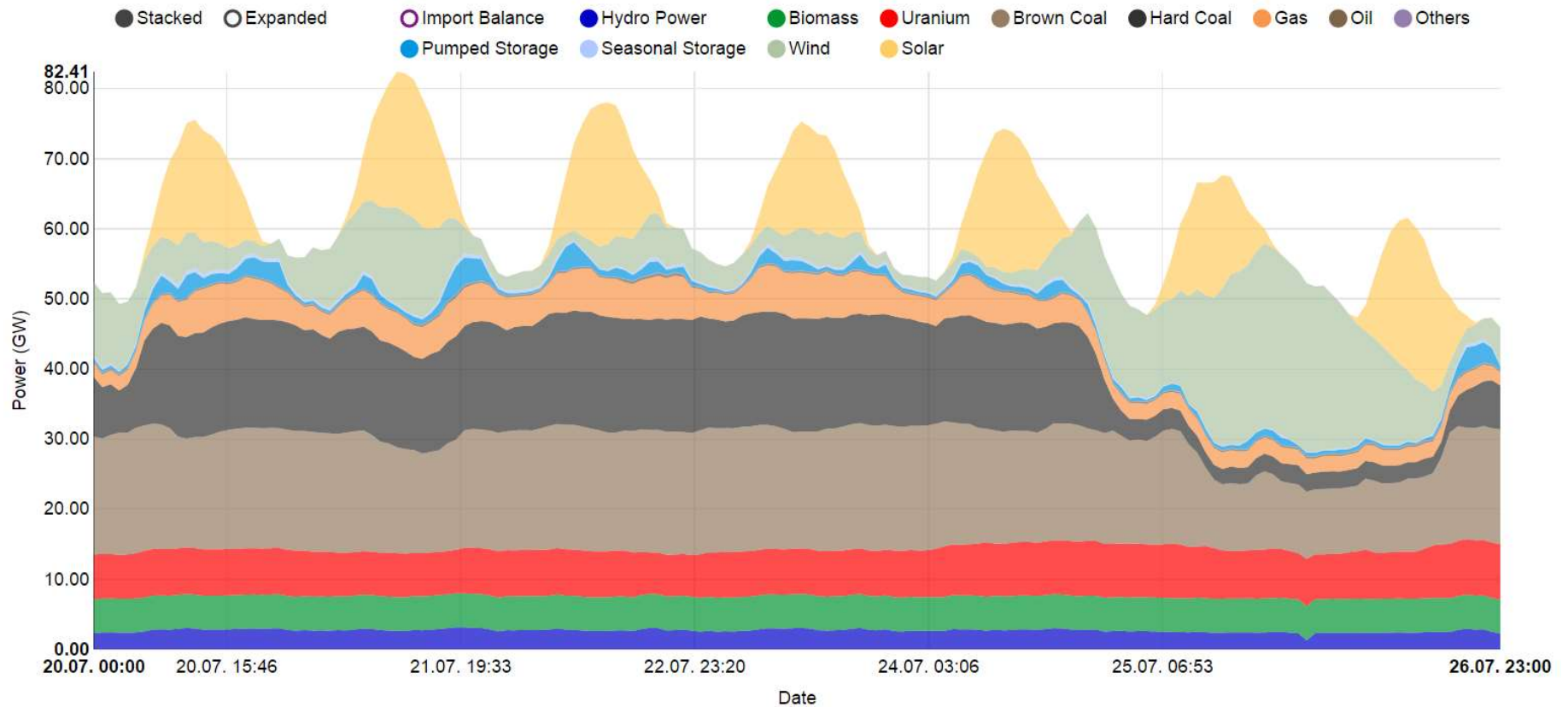


MERIT ORDER



DECARBONISATION - GERMANY

Electricity production in Germany in week 30 2015



last update: 28 Jul 2015 13:18

Source: <https://energytransition.org/2015/07/renewables-covered-78percent-of-german-electricity/>

NEGATIVE POWER PRICES



[Home](#) / [News & Insight](#) / [News Article](#)

UK sees longest period of negative power prices

7 Jun 2017, 3.28 pm GMT

London, 7 June (Argus) — System prices in the power balancing market traded negative for five consecutive hours this morning, the longest sustained period of negative system prices in the UK market since records began, as the grid was oversupplied owing to high wind generation during off-peak hours of low demand.

Energy industry
The Observer

Record levels of green energy in UK create strange new world for generators

As renewables play a greater role in the British market, they are making the price of power increasingly unstable

9233 341



NEGATIVE POWER PRICES



Factsheet

05 Jan 2018 | Sören Amelang, Kerstine Appunni

The causes and effects of negative power prices

#Cost & Prices #Electricity market

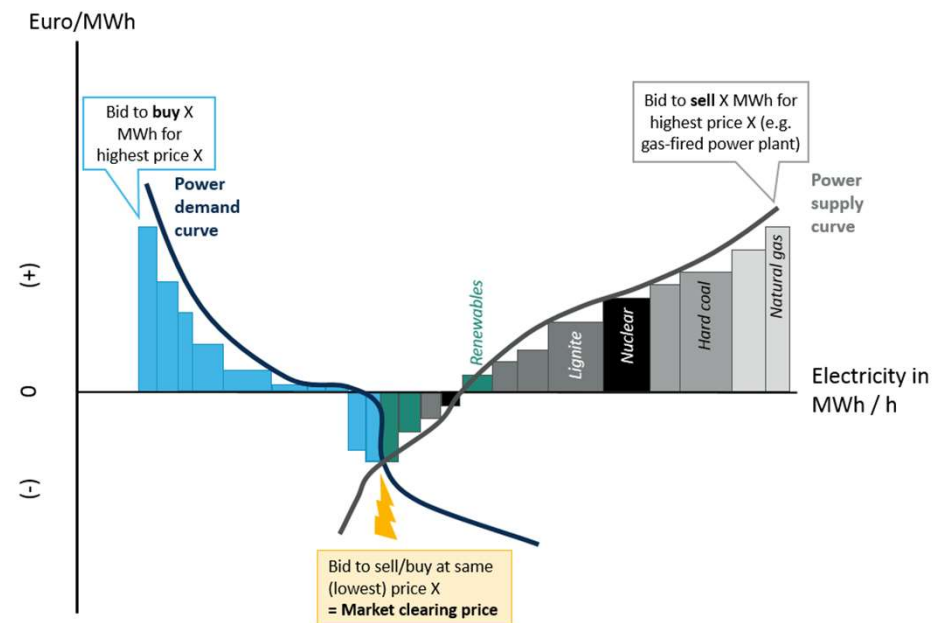
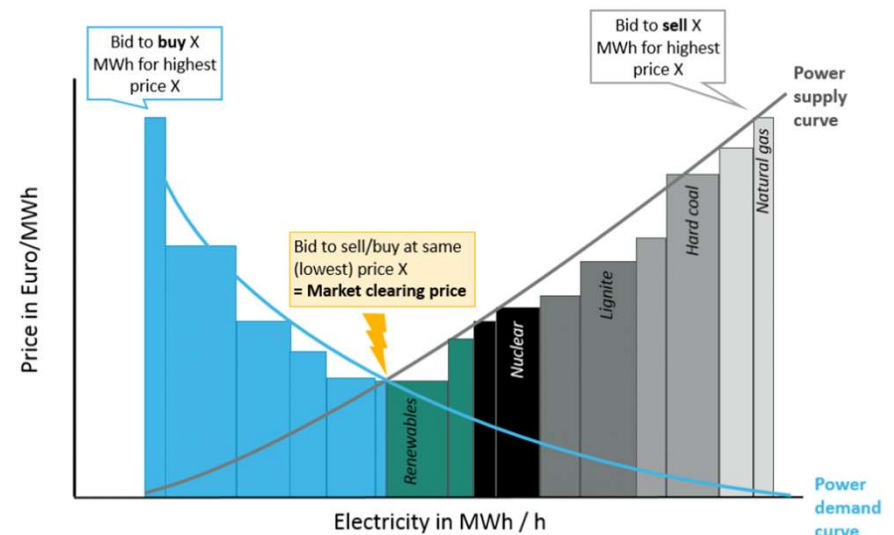
When power prices on the electricity exchange fall below zero, power suppliers have to pay their wholesale customers to buy electric energy. The phenomenon is on the rise in Germany with an increasing number of renewable sources feeding into the grid. This factsheet explains how and why negative power prices arise, what the effects on consumer power prices are, what can be done to prevent them, and whether Germany loses out by exporting power at negative prices. [UPDATES throughout with new data, additional information]

Renewables have made negative prices increasingly common

The rising share of renewable power has made power prices much more volatile in Germany and negative prices have become a fairly common phenomenon.

In 2017, electricity reached its lowest average price on 29 October, when a combination of strong wind power output and low demand pushed the daily average down to minus 52 euros per megawatt-hour. This contrasts with a peak of 102 euros on 24 January, when renewable production was very low and demand strong, according to figures by energy think tank Agora Energiewende*.

This Factsheet





Levelised Cost

WHAT IS A WINDFARM WORTH ?

$$\text{Value} = -\text{DEVEX} - \text{CAPEX} + \sum_{25 \text{ years}} (\text{REVENUE} - \text{OPEX} - \text{Cost of Capital})$$

Where:

DEVEX = Σ (Team, Engagement & Consultation, Lease, Consent application + ...)

CAPEX = Σ (Cost of Turbines + Balance of Plant + Transmission + O&M Base + ...)

REVENUE (£) = YIELD (MWh) x CFD Strike Price (£/MWh)

YIELD (MWh) = Capacity (MW) x Capacity factor (~0.4) x Time (h)

OPEX = Cost of running windfarm (£/year)

Cost of Capital = Debt finance (bank) or Opportunity cost (balance sheet)



CAPEX COST TRENDS

Irrational Exuberance

Early Mover Advantage

Early Losses

Cautious approach to pricing

Turbine competition with onshore
(and pricing to the market)

Vessel competition with Oil and Gas

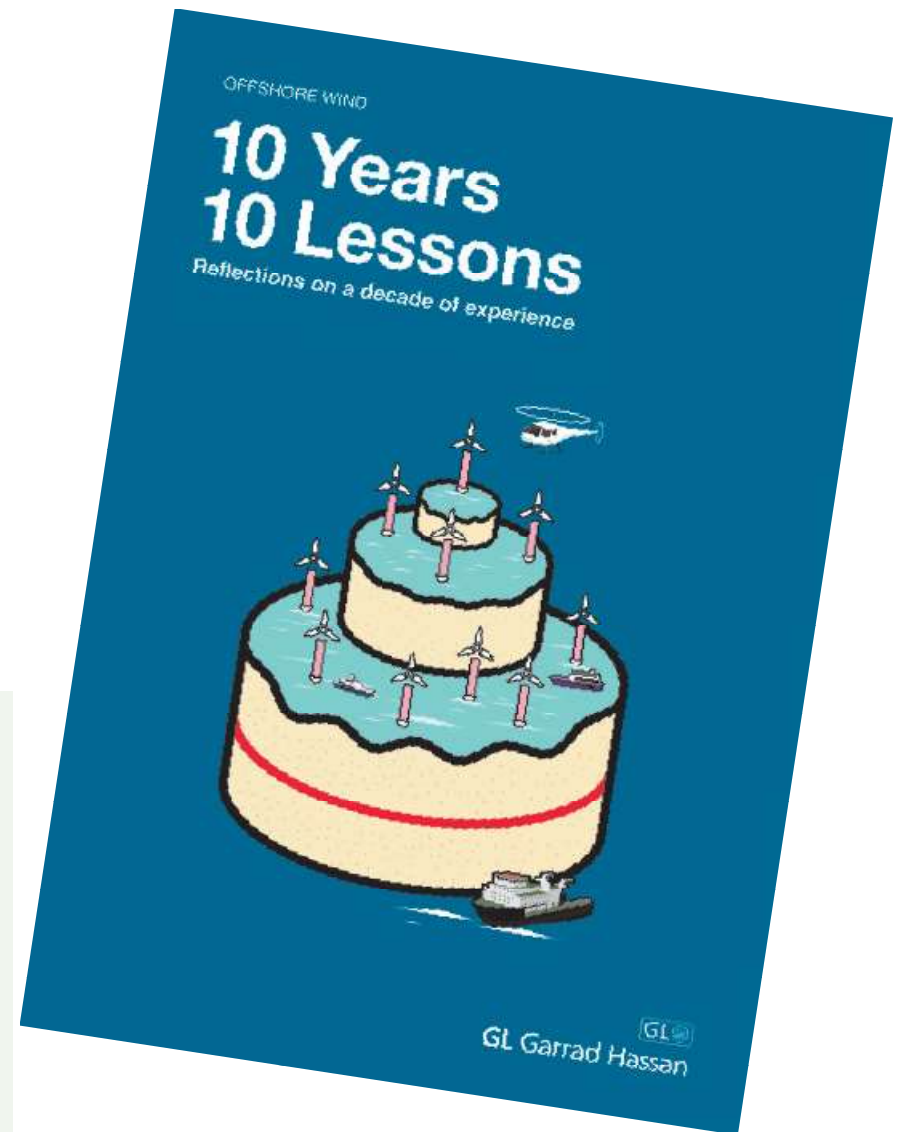
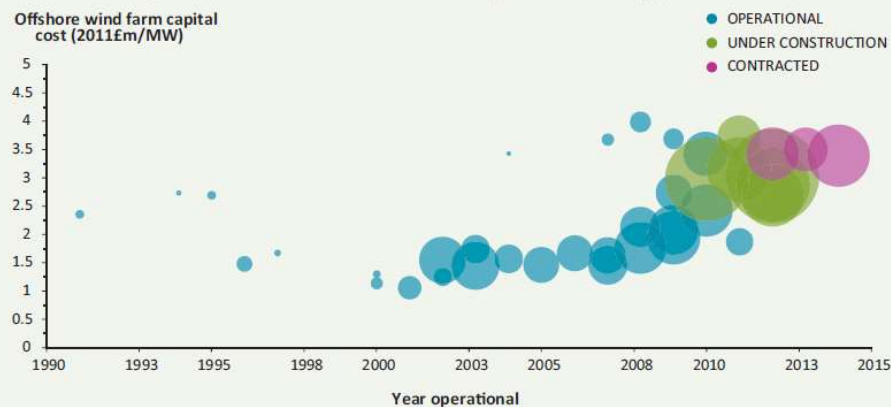


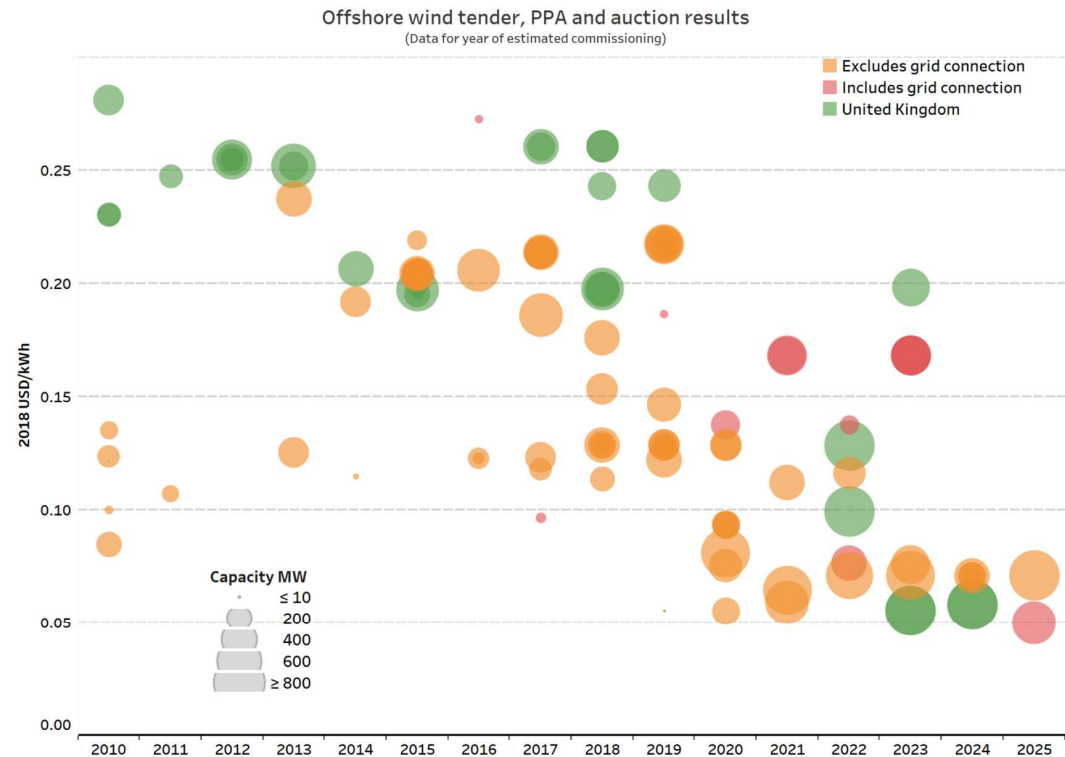
Exhibit 3.2 European offshore wind farm capital costs by year



Note: Bubble diameter proportion to wind farm capacity. The values utilised for the chart are based on published information – typically contractor or developer press releases and / or guidance from the relevant project owner through direct consultation. The values have been adjusted for currency, inflation and scope differences. Adjustment for scope differences has been made in cases where grid connection including offshore substation have been provided by a third-party. In addition, reductions have been made in cases where Warranty, Operational and Maintenance costs have been included in the published value. The values exclude developmental and operational expenditure.

Source: GL - Garrad Hassan

COST REDUCTION PATHWAYS



Cost of electricity generation for offshore wind projects around the world (2018\$/kWh) and starting to operate in years between 2010 and 2025. Each circle represents a single project, tender or auction round, with the size being proportional to its capacity. UK projects and auctions are shown in green, with results from other countries shown in red and orange depending on whether their costs include a connection to the electricity grid. PPAs are power purchase agreements signed between a developer and large electricity consumers. Source: [IRENA renewable cost database](#).

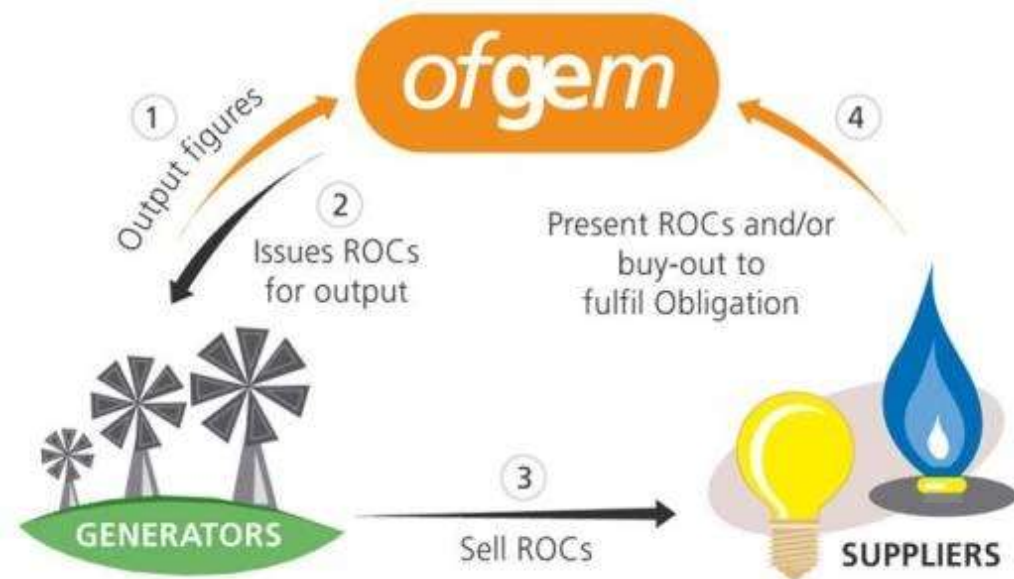


Support Mechanisms

SUPPORT MECHANISMS - HISTORIC

Band	Technologies	Level of support ROCs/MWh
Established	Sewage gas; landfill gas; co-firing of non-energy crop (regular) biomass	0.25
Reference	Onshore wind; hydro-electric; co-firing of energy crops; EfW with combined heat and power; other not specified	1.0
Post-demonstration	Offshore wind; dedicated regular biomass	1.5
Emerging technologies	Wave; tidal stream; advanced conversion technologies (anaerobic digestion, gasification and pyrolysis); dedicated biomass burning energy crops (with or without CHP), dedicated regular biomass with CHP; solar photovoltaics; geothermal	2.0

Historically ~£42/MWh



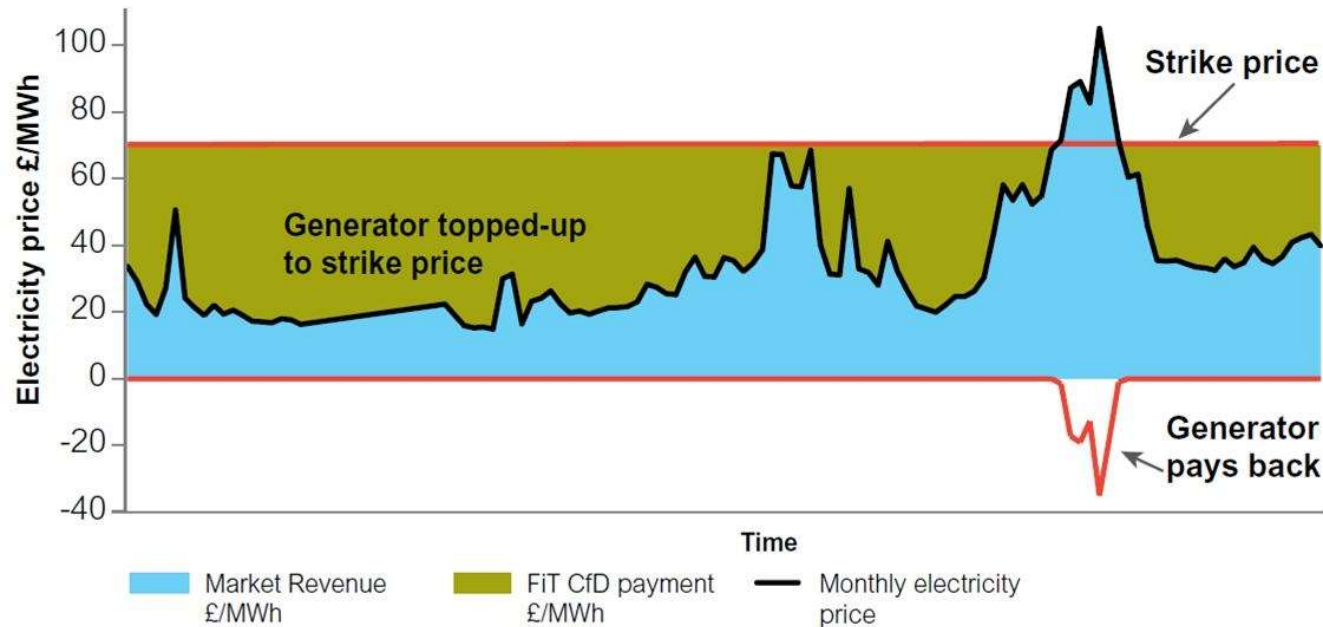
ELECTRICITY MARKET REFORM

EMR White Paper - July 2011

- **Contracts for Difference** (Strike Price) + Capacity Mechanism replace ROCs
- Creates revenue certainty for developers
- Transfers wholesale price volatility risk from private investors to the taxpayer.
- Support capped via the **Levy Control Framework**.



CfD - STRIKE PRICE



Strike prices with Over 1 Gigawatt of Potential Deployment

Renewable Technology	Draft Strike prices (£/MWh) (2012 prices)					Potential 2020 Deployment Sensitivities (subject to Vfm and cost reduction) (GW) ¹
	2014/15	2015/16	2016/17	2017/18	2018/19	
Biomass Conversion ²	105	105	105	105	105	1.2 – 4
Hydro ³	95	95	95	95	95	c. 1.7
Offshore Wind	155	155	150	140	135	8 – 16
Onshore Wind	100	100	100	95	95	9 – 12
Large Solar Photo-Voltaic	125	125	120	115	110	2.4 – 3.2

(see drafting notes for full list of technologies and notes to accompany this table)

Draft strike prices - 2012

ALLOCATION ROUND I – Feb '15

Contracts for Difference (CFD) Allocation Round One Outcome

DECC has today 26 February 2015 at 7AM published the outcome of the first allocation round to coincide with when National Grid notifying applicants of the outcome of the round.

(A) Information on the successful applicants, as follows – strike prices are in 2012 prices:

<i>Project Name</i>	<i>Developer</i>	<i>Technology</i>	<i>MW</i>	<i>Strike Price (£)</i>	<i>Delivery Year</i>
BHEG Walsall	BH EnergyGap (Walsall) Ltd	Advanced Conversion Technologies	26	114.39	2018-2019
Energy Works (Hull)	Energy Works (Hull) Limited	Advanced Conversion Technologies	25	119.89	2017-2018
Enviroparks Hirwaun Generation Site	Enviroparks Operations Ltd	Advanced Conversion Technologies	11	119.89	2017-2018
Wren Power and Pulp	Gent Fairhead & Co. Ltd	Energy from Waste with CHP	49.75	80.00	2018-2019
K3 CHP Facility	K3CHP Ltd	Energy from Waste with CHP	45	80.00	2018-2019
EA 1	Scottishpower Renewables (UK) Limited	Offshore Wind	714.00	119.89	2017-2018 ¹
Near na Gaoithe	Near na Gaoithe Offshore Wind Limited	Offshore Wind	448	114.39	2018-2019
Dorenell Wind Farm	Dorenell Limited	Onshore Wind	177	82.50	2018-2019
Kype Muir Wind Farm	Banks Renewables (Kype Muir Wind Farm) Limited	Onshore Wind	104	82.50	2018-2019
Clocaenog Forest Wind Farm	RWE Innogy UK Limited	Onshore Wind	96	82.50	2018-2019
Middle Muir Wind Farm	Banks Renewables (Middle Muir Wind Farm) Limited	Onshore Wind	60	82.50	2018-2019
Brenig Wind Farm - Brenig Wind	Brenig Wind Limited	Onshore Wind	45	79.23	2016-2017

¹ EA1 will be built in three phases; 2017/18 is the delivery year for phase 1

1,162MW Offshore / 305MW Onshore

ALLOCATION ROUND 2 – Sep '17

Contracts for Difference Second Allocation Round Results

BEIS has today on 11 September 2017 at 7AM published the outcome of the second Contracts for Difference (CFD) allocation round to coincide with National Grid notifying qualifying applicants of the outcome of the round.

(A) Information on the successful applicants – strike prices are in 2012 prices.

Project Name	Developer	Technology Type	Capacity (MW)	Strike Price (£/MWh)	Delivery Year	Homes Powered	Region
Drakelow Renewable Energy Centre	Future Earth Energy (Drakelow) Limited	Advanced Conversion Technologies	15.00	74.75	2021/22	27,190	England
Station Yard CFD 1	DC2 Engineering Ltd	Advanced Conversion Technologies	0.05	74.75	2021/22	90	Wales
Northacre Renewable Energy Centre	Northacre Renewable Energy Limited	Advanced Conversion Technologies	25.50	74.75	2021/22	46,220	England
IPIF Fort Industrial REC	Legal and General Prop Partners (Ind Fund) Ltd	Advanced Conversion Technologies	10.20	74.75	2021/22	18,490	England
Blackbridge TGS 1 Limited	Think Greenenergy TOPCO Limited	Advanced Conversion Technologies	5.56	74.75	2021/22	10,080	England
Redruth EFW	Redruth EFW Limited	Advanced Conversion Technologies	8.00	40.00	2022/23	14,500	England
Grangemouth Renewable Energy Plant	Grangemouth Renewable Energy Limited	Dedicated Biomass with CHP	85.00	74.75	2021/22	148,880	Scotland
Rebellion	Rebellion Biomass LLP	Dedicated Biomass with CHP	0.64	74.75	2021/22	1,120	England
Triton Knoll Offshore Wind Farm	Triton Knoll Offshore Wind Farm Limited	Offshore Wind	860.00	74.75	2021/22 ¹	893,690	England
Hornsea Project 2	Breesea Limited	Offshore Wind	1,386.00	57.50	2022/23 ²	1,440,300	England
Moray Offshore Windfarm (East)	Moray Offshore Windfarm (East) Limited	Offshore Wind	950.00	57.50	2022/23 ³	987,220	Scotland

3,196MW Offshore / 0MW Onshore

CfD COST TRENDS



Project	Strike Price	Term	Decommissioning
Hinkley Point	£92.50/MWh	35years	Excluded
Offshore Wind	£57.50/MWh	15years	Included

ALLOCATION ROUND 3 – Sep'19

1 of 3

Contracts for Difference Allocation Round 3 Results – Published by BEIS on 20 September 2019

(A) Information on the successful applicants – strike prices are in 2012 prices.

Project Name	Developer	Technology Type	Capacity (MW)	Strike Price (£/MWh)	Delivery Year	Homes Powered	Region
Bulwell Energy Limited	Bulwell Energy Limited	Advanced Conversion Technologies	27.50	39.650	2023/24	50,980	England
Small Heath Bio Power Limited	Small Heath Bio Power Limited	Advanced Conversion Technologies	6.10	41.611	2024/25	11,310	England
Costa Head Wind Farm	Costa Head Wind Farm Limited	Remote Island Wind	16.32	39.650	2023/24	15,750	Scotland
Druim Leathann Windfarm Limited	Druim Leathann Windfarm Limited	Remote Island Wind	49.50	41.611	2024/25	47,760	Scotland
Hesta Head Wind Farm	Hesta Head Wind Farm Limited	Remote Island Wind	20.40	39.650	2023/24	19,680	Scotland
Mualtheabhal Wind Farm	Uisenis Power Limited	Remote Island Wind	189.00	39.650	2023/24	182,340	Scotland
Doggerbank Creyke Beck A P1	DoggerbankOffshoreWindFarm Project1ProjcoLimited	Offshore Wind	1200.00	39.650	2023/24 ¹	1,505,330	England
Doggerbank Creyke Beck B P1	DoggerbankOffshoreWindFarm Project2ProjcoLimited	Offshore Wind	1200.00	41.611	2024/25 ¹	1,505,330	England
Doggerbank Teeside A P1	DoggerbankOffshoreWindFarm Project3ProjcoLimited	Offshore Wind	1200.00	41.611	2024/25 ¹	1,505,330	England
Forthwind	Forthwind Limited	Offshore Wind	12.00	39.650	2023/24	15,050	Scotland
Seagreen Phase 1	Seagreen Wind Energy Limited	Offshore Wind	454.00	41.611	2024/25 ¹	569,520	Scotland
Sofia Offshore Wind Farm Phase 1	Sofia Offshore Wind Farm Limited	Offshore Wind	1400.00	39.650	2023/24 ¹	1,756,220	England

5,466MW Offshore / 259MW Onshore

ALLOCATION ROUND 4 – 2021

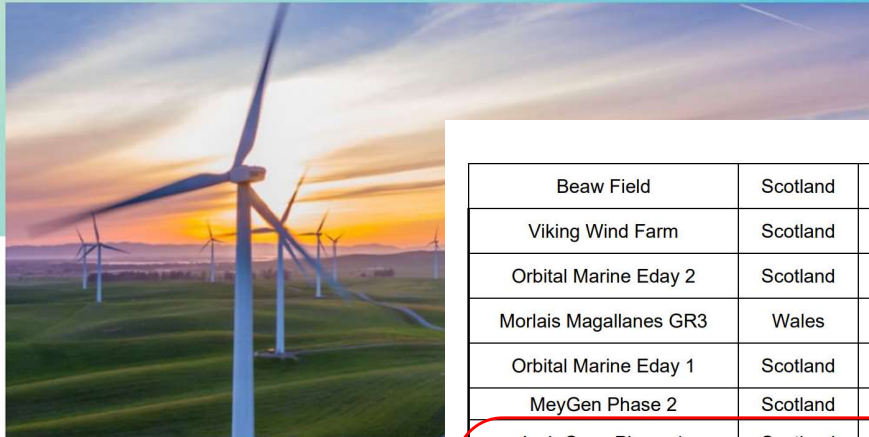
Contracts for Difference (CfD) Allocation Round 4 resource portal [Home](#) [About](#) [News](#) [Events](#) [Timelines](#) [Contact](#) [FAQs](#) [Publications](#) [Subscribe](#)

Contracts for Difference

Welcome to the Contracts for Difference Allocation Round 4 (CfD AR4) portal.

The portal aims to provide a central resource for applicants to navigate the fourth CfD allocation round.

[Learn more](#)



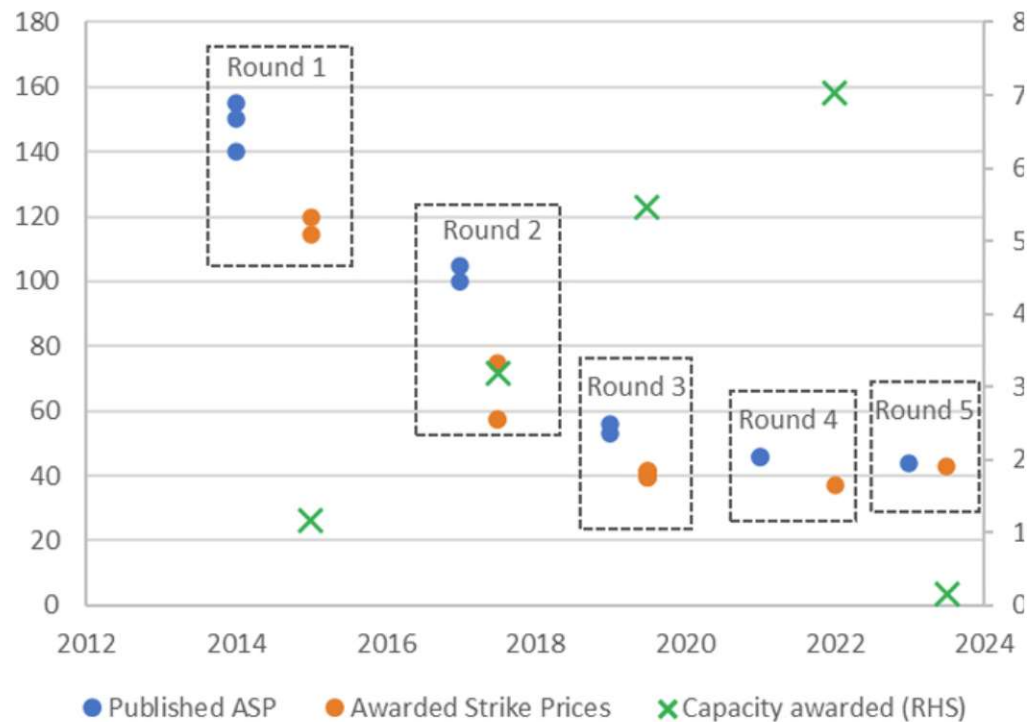
The CfD AR4 portal is a collaborative effort between partners: the Department for Business, Energy & Industrial Strategy, the Low Carbon Contracts Company, and the Energy Networks Association.

High Water Mark?

Beaw Field	Scotland	PEEL NRE WIND FARMS (YELL) LIMITED	Remote Island Wind (RIW)	72.00	46.39	2026/27	1	2
Viking Wind Farm	Scotland	Viking Energy Wind Farm LLP	Remote Island Wind (RIW)	220.00	46.39	2026/27	1	2
Orbital Marine Eday 2	Scotland	ORBITAL PROJECTS 4 LIMITED	Tidal Stream	4.80	178.54	2026/27	1	2
Morlais Magallanes GR3	Wales	MAGALLANES TIDAL ENERGY LTD	Tidal Stream	5.62	178.54	2025/26	1	2
Orbital Marine Eday 1	Scotland	ORBITAL PROJECTS 3 LIMITED	Tidal Stream	2.40	178.54	2026/27	1	2
MeyGen Phase 2	Scotland	MeyGen PLC	Tidal Stream	28.00	178.54	2026/27	1	2
Inch Cape Phase 1	Scotland	INCH CAPE OFFSHORE LIMITED	Offshore Wind	1080.00	37.35	2026/27 ¹	3	3
EA3, Phase 1	England	EAST ANGLIA THREE LIMITED	Offshore Wind	1372.34	37.35	2026/27 ¹	3	3
Norfolk Boreas (Phase 1)	England	NORFOLK BOREAS LIMITED	Offshore Wind	1396.00	37.35	2026/27 ¹	3	3
Hornsea Project Three Offshore Wind Farm	England	ORSTED HORNSEA PROJECT THREE (UK) LIMITED	Offshore Wind	2852.00	37.35	2026/27	1	3
Moray West Offshore Wind Farm	Scotland	MORAY OFFSHORE WINDFARM (WEST) LIMITED	Offshore Wind	294.00	37.35	2026/27	1	3

6,994MW Offshore / 32MW Floating / 887 Onshore / 598 RIW / 41MW Tidal

ALLOCATION ROUND 5 – 2023



The maximum strike price has been increased by 66% for offshore wind projects, from £44/MWh to £73/MWh, and by 52% for floating offshore wind projects, from £116/MWh to £176/MWh ahead of Allocation Round 6 (AR6) next year.

Non Price Factors?

WORKED EXAMPLE... MORAY WINDFARM

$$\text{Value} = -\text{DEVEX} - \text{CAPEX} + \sum_{25 \text{ years}} (\text{REVENUE} - \text{OPEX} - \text{Cost of Capital})$$

Where:

DEVEX = Maybe £50m

CAPEX = 950 MW x £2.5m/MW = £2,375m

YIELD (MWh) = 950 MW x ~0.4 x 8750 (h) = 3,328,800 MWh/year

REVENUE (£) = 3,328,800 MWh x 57.5 £/MWh = £191.4m/year

OPEX = £10/MWh = £33m/year

Cost of Capital = 25year term 3% interest = £71m/year

VALUE = - £240m (before decommissioning!!)



Thanks for listening

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