EMR Delivery Body Consultation - De-Rating Factor Methodology for Renewables' Participation in the CM

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Scene Setting

- The EMR Delivery body has been tasked to derive a methodology for de-rating renewables should they be allowed to participate in the Capacity Market (CM)

- The scope of this consultation is around input assumptions to the modelling and the methodology for derating renewables in the CM that rewards participants fairly and also ensures value of money for consumers

- The workshop relates to both wind power and solar PV renewable resources
  - Based on feedback from our last consultation on Limited Duration Storage we are consulting this time on both the methodology and the indicative results

- Any policy questions should be directed to BEIS and will be covered at a later policy consultation stage, we will deal with issues of technical concern here

- In developing this proposal we have, in addition to our own thinking, held discussion with some industry stakeholders, academics, and other international system operators which has given us confidence that our approach is both robust and fair

- We have also discussed the proposal with BEIS, Ofgem and BEIS' independent Panel of Technical Experts (PTE) who have endorsed the approach

- Hence although this proposal has involved significant thought, our final position can still be informed by your response, and we welcome any additional insight, data sources or views from industry

Timeline of Next Steps

- Your feedback on the methodology and reliability modelling issues raised here today is welcome - please send any comments via email by 5.00pm on January 31st to:

  emrmodelling@nationalgrid.com

- Note that any policy related feedback or concerns should be sent to BEIS directly – the EMR Delivery Body is consulting on the renewables de-rating factor methodology only
- We will publish a response to this consultation by the end of February on our EMR Delivery Body Portal, feeding in to the final methodology agreed with BEIS and Ofgem
- That consultation response will summarise the feedback from industry, the final methodology proposal and any further details of the numerical assessments
- BEIS/Ofgem policy/rules consultations will proceed at a later date, after which the new proposed methodology for renewable de-rating factors could be written in to the CM rules
- The numerical de-rating factors indicated here should be taken as indicative
  - Renewables participation in the CM requires additional policy and rules consultation efforts and given the time requirements for both, then the resultant de-rating factors that would apply may be on the basis of later EMR modelling studies with the most up to date data and assumptions at the time
- Today's slides containing the consultation questions will be posted on the EMR Delivery Body Portal tomorrow

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Introduction

Consultation Overview

- ❑ Summary of key methodology design issues
- ❑ Stakeholder engagement
- ❑ Definitions of Equivalent Firm Capacity (EFC)
- ❑ Wind turbine and Solar PV power curves
- ❑ Weather and demand data sources
- ❑ EMR Base Case assumptions and modelling studies overview
- ❑ Key results and sensitivities
- ❑ Indicative T-1/T-3/T-4 De-Rating Factors for Wind and Solar PV
- ❑ Summary and next steps
- ❑ Annex

Key Methodology Questions for Consideration

- ❑ **Should we have separate CM technology sub-categories for onshore and offshore wind turbines?**

- ❑ **How to calculate the contribution of wind and solar PV resources to security of supply in a technology-neutral manner using Equivalent Firm Capacity (EFC)?**

- ❑ **Should we use ‘Average’ or ‘Incremental’ EFCs as the basis for the de-rating factors?**

- ❑ **What are the interactions, if any, with duration-limited storage on the system?**

- ❑ **Which EFC statistical risk metric makes most sense for wind and solar – unserved energy (EEU) or loss of load hours (LOLE)?**

- ❑ **How do all of these trends and issues change as the penetrations of the resources increase in future, and how can we design a robust methodology?**

❑ EFC = Equivalent Firm Capacity, LOLE = Loss of Load Expectation, EEU = Expected Energy Unserved

Stakeholder Engagement

- Accounting for the contribution of wind (as a non-CM-participant) to security of supply has featured in our Winter Consultation and Winter Outlook assessments for many years

- Some differences are required in the treatment for renewables participation in the CM

- In addition to this formal industry consultation, we have thus engaged widely on the technical aspects of the methodology derivation for derating wind and solar PV resources
  - We have consulted with BEIS and Ofgem, and the BEIS Panel of Technical Experts who have endorsed the approach
  - We have been advised by our own independent academic consultants at the University of Edinburgh (Dr. Chris Dent, Dr. Stan Zachary and Dr. Amy Wilson), on matters relating to risk modelling with renewables
  - We have taken expert advice and data input on weather modelling from Dr. Daniel Drew, from University of Reading, who is on sabbatical with us at National Grid ESO at the moment
  - We have shared experience with other system operators, academics, and industry representatives in Europe via a collaborative research paper presented at the 2018 Wind Integration Workshop in Stockholm
  - We have also engaged with US based industry representatives via the IEEE Loss of Load Expectation (LOLE) Working Group, at the Summer 2018 General Meeting

- As a result of these stakeholder engagement efforts, we are confident that we are proposing a methodology that is representative of the state of the art in this area

Equivalent Firm Capacity (EFC) Definitions

Equivalent Firm Capacity (EFC) Definitions

- Equivalent Firm Capacity is a very useful construct to normalise the security of supply contribution of non-conventional adequacy resources
  - An EFC is defined essentially as *"for a penetration of that resource, what is the amount of perfectly reliable firm capacity it can displace while maintaining the exact same risk level (as defined by a suitable statistical risk metric)"*
  - It exists already as a concept in the GB system via the contribution of wind to security of supply in our Winter Outlook – also the non-CM participant wind power EFC reduces the amount of CM procurement in the Electricity Capacity Report
  - It has also been recently used as the basis to de-rate duration-limited storage upon it's entry to the CM

- An indication of the broad methodology to calculate an EFC for a non-conventional resource would be as follows:
  - Set up a base case with a credible supply portfolio, for the given CM target horizon year, with a specific baseline reliability level - there may be some subjectivity in the choice of base case, and target reliability level
  - Add the resource to the study case, and recalculate the improved adequacy level via reliability model simulation
  - Assess the level of perfectly firm capacity, that when added to the same base case, would give the same change in the adequacy risk level
  - That firm capacity shift is deemed the EFC of the resource in question
  - Note that the EFC can be defined with respect to either the LOLE or the EEU risk metric

- Note also that there are some important distinctions required between:
  - The "incremental" EFC of a small amount (e.g. 100MW) of the resource added to the margin of the base case
  - The "average" EFC of the entire fleet of that resource type in the base case
  - The "combined" or total EFC of a set of fleets of different technology types which may exhibit some interactions

Weather Data and Power Curves Assumptions

Weather and Demand Data Sources

- Wind and solar PV power are clearly variable renewable resources, with power availability based on the fluctuations of the underlying weather patterns at any given time

- As the CM targets a specific level of reliability, and that reliability level (3 hours LOLE/year) is defined by a statistical risk metric, then it is important that we capture as best as possible the "long run average contribution" of these weather dependent resources to security of supply

- We therefore need to include a relatively long time series of wind and solar data in order to capture their range of possible variations, and also possible correlations with GB system demand

- We use the NASA MERRA atmospheric reanalysis dataset to represent the GB weather variations over the same time-coincident period that we have for GB system demand data
  - These weather files contain hourly records of wind speed and solar insolation at different spatial and altitude definitions over the entire globe, and are freely available for download from the NASA website

- Using the known GB wind farm fleet GPS locations and hub height records, we can then translate this weather data in to estimated historical wind power output, for the capacity adequacy analysis

- For the solar PV representation, we also use the MERRA weather data source in a similar manner, as well as data obtained from the Sheffield Solar Innovation Project which measures/estimates in real-time the availability of solar PV on the GB system

- These data sources allow us 12 years of time coincident wind, solar and demand data, so that the interactions between each can be captured and integrated consistently for the GB system risk study

Wind Turbine Power Curves

- A key assumption in understanding the contribution of wind power to security of supply, is the conversion of wind speed from the MERRA data source above, to wind power output for subsequent inclusion in the risk modelling studies

- We are aware that wind turbine capacities are increasing, that turbine hub-heights heights are getting higher, and that the turbine control designs are evolving to be ever more sophisticated
  - Therefore there may be a diversity of performance of the range off turbines across the existing fleet

- However, the assumptions that we use in the de-rating factor analysis should be evidence based, as opposed to idealised curves based on e.g. manufacturer data

- As we need to be as technology-neutral as possible, this philosophy is in keeping with the general principles of the CM de-rating factor approach for other technologies e.g.
  - Using the last 7 years of MEL data to derive the availability of conventional plant for their de-rating factors
  - The grouping of other CM participant sites in to overall technology-type categories, regardless of the age/capability of individual units

- In the modelling of non-CM-participant wind power to date, we have used different turbine power curves for onshore and offshore wind farms, based on their different power production patterns

- The methodology takes historical metered wind power output, as well as historically measured wind speeds, and creates a best-fit curve between the two datasets to derive an empirical power curve

- As part of this project, we have also updated these power curves with the most up to date information

Updating the Wind Turbine Power Curves Project - Results

- Objective of the work: To review and update wind turbine speed to power output curves
  - The offshore wind turbine power curve was last reviewed in 2016
  - The onshore wind turbine power curve was last reviewed in 2015

- This year's analysis (conducted in October 2018):
  - Half-hourly metered power output and wind speed data for winter 2017/18 (Nov '17 to March '18)
  - Offshore: 9 wind farms (with 12 data sets) were used in analysis for offshore wind power curve(s).
  - Onshore: 18 wind farms were used in analysis for onshore wind power curve(s).
  - Sample wind farms were selected from a range of different makes and turbine sizes, where possible.

- Methodology steps applied:
  - Assess data quality of the selected wind farms' data and clean as required
  - Calculate the best fit s-curve by individual wind farms by minimizing the residual squared error
  - The final wind turbine curves were produced by combining or aggregating all cleansed data together and calculating the curves thereafter
    - We considered developing these averaged curves by turbine size, however this led to minimal differences and thus we reverted to the original approach of one offshore and one onshore curve

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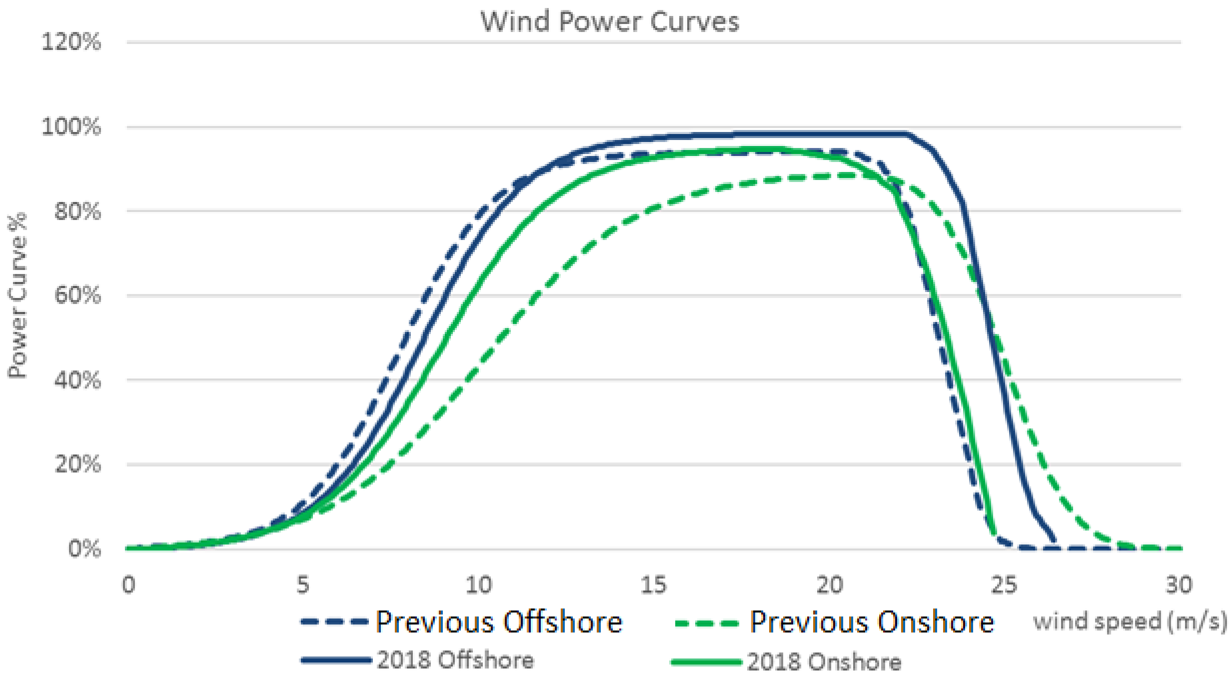
Updating the Wind Turbine Power Curves Project - Results

- The graph below indicates the updated wind power curves compared to the previous ones



Solar PV Power Curve

- The approach taken for the solar PV power curve comes about from a recent NIA Project carried out between National Grid ESO and University of Reading

- This project sought (amongst other things) to develop a single power curve for all GB solar PV resources by developing an empirical relationship between past soar PV power measurements (from the Sheffield Solar monitoring project) and the NASA MERRA solar PV irradiance data set

- There are also parameters in the curve based on the temperature (which can affect panel performance), as well as control variables for the season of the year and diurnal time of the day

- The resultant solar PV curve is therefore a multiple linear regression statistical approach, with general format as per the following equation

$$PV(t) = \alpha_1 + \alpha_2(GB\ Irr\ (t)) + \alpha_3(GB\ Temp\ (t)) + \sum_{k=4}^{6} \propto_k SEASON(t) + \sum_{i=7}^{11} \propto_i TIME(t)$$

where PV(t) is the GB-aggregated solar capacity factor at time t, GB Irr is the capacity weighted mean solar irradiance (in Wm^{-2}), GB Temp is the capacity weighted mean air temperature. The α's are regression coefficients. α_2 and α_3 correspond to the coefficients for meteorological drivers of solar PV generation; solar irradiance and temperature. α_4 to α_{11} are coefficients of binary values accounting for the season and time of day.

Modelling Studies and Base Case Assumptions

Base Case and Sensitivity Analysis Details (1)

- We have updated the LCP Unserved Energy Model (UEM) to be able to calculate the
  - "*Incremental*" EFCs of wind (offshore/onshore), and solar PV
  - "*Average*" EFCs the [entire wind], or [entire solar PV], or [entire storage] fleets considered individually
  - "*Combined*" EFC of all [wind plus storage plus solar PV] resources considered together

- These EFCs are calculated with either LOLE or EEU risk metric, various storage coordination algorithms, when the Base Case is at the GB reliability standard of 3 hours LOLE/year

- We have carried out the EFC analysis on both the T-1 (2020/21), the T-3 (2022/23) and the T-4 (2023/24) EMR Base Case years

- We have also assessed a large number of sensitivities on the T-3 Base Case looking at
  - Individually increasing penetrations of wind or solar, assuming zero storage, for both EEU and LOLE
  - Collectively increasing penetrations of wind and solar together, assuming zero storage, for EEU
  - Individually increasing penetrations of wind or solar, with various penetrations of storage, for EEU
  - Collectively increasing penetrations of wind, solar and storage all together for EEU and LOLE
  - A credible future GB scenario level of wind, storage and solar at different base reliability levels, for EEU
  - A credible future GB scenario level of wind, storage and solar with different MW sizes of the incremental wind and solar EFC units applied to the margin, for EEU
  - Impact of the new updated wind turbine power curves on wind EFC calculations

Base Case and Sensitivity Analysis Details (2)

- The solar PV, onshore/offshore wind and storage penetration levels in the Base Cases and Sensitivities are listed in the Table below – these broadly correspond to the 2018 EMR 5 Year Base Case assumptions

- Note that the Base Cases have ~ 2.7GW of long duration pumped storage, the rest being made up of a variety of shorter duration battery storage.

- For the 'Medium' and 'High' storage Sensitivities, then the pumped storage level was kept constant and the duration-limited battery storage durations doubled or trebled in MW size respectively compared to the T-3 case

Base Case and Sensitivity Wind, Storage, Solar PV Capacity Assumptions (MW)

Base Cases	Onshore Wind	Offshore Wind	All Wind	Storage	Solar PV
T-1 2020/21	12784	9990	22774	3786	14379
T-3 2022/23	13005	11740	24745	4415	15569
T-4 2023/24	13022	13960	26982	4464	16356
Sensitivities					
"Medium" Case	15000	15000	30000	6086	22500
"High" Case	20000	20000	40000	7757	30000

Results and Sensitivity Analysis Implications

Indicative T-1, T-3 and T-4 De-Rating Factors

- The table below lists the incremental, average and combined EFC results for the T-1, T-3 and the T-4 de-rating factor assessments – using EEU as the EFC risk metric, with new wind turbine power curves

	Incremental EFCs (%)				Average EFCs (MW)					Difference	Combined EFC (MW)
Base Cases	Onshore Wind	Offshore Wind	Solar PV	Storage 0.5h	Onshore Wind	Offshore Wind	All Wind	Storage	Solar		All
T-1 2020/21	8.98%	14.65%	1.17%	17.19%	1590	2043	5050	2864	366	-203	8076
T-3 2022/23	8.40%	12.89%	1.76%	15.04%	1438	2166	5130	3088	469	-204	8483
T-4 2023/24	8.20%	12.11%	1.56%	15.04%	1413	2497	5513	3104	504	-247	8874

- Note that in the results tables, the "Diff" column implies the result of the "Combined" EFC – (All Wind EFC + Storage EFC + Solar EFC)

- **Important observations are:**
  - Wind incremental EFCs are lower than the (~15-20%) average EFC that is typically seen in Winter Outlooks. This is because wind becomes less valuable the more of it you have on the system. With 15 year contracts available in the CM, we need to properly reflect the incremental value of the next new project to the system
  - Offshore wind turbines are bigger, taller and have better wind regime – hence they would appear to require a separate treatment compared to onshore wind farms
  - Solar has a small but non-zero incremental value to the system. This is primarily due to the interaction with duration limited storage, where solar availability on peak demand days allows battery storage to be discharged later in the evening than would otherwise be the case. The effect is relatively small (for now).
  - The combined EFC of [wind, storage, solar] together is slightly distinct from the sum of individual average EFCs – this is due to statistical interactions of all three resources. The effect is relatively small (for now).

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- Note that we are consulting on renewables derating factors here, however we include the 0.5 hour duration limited storage incremental EFC results as well as a general indication of the impacts on duration limited storage of renewables. The final CM auction storage derating factor is the EFC above multiplied by the storage technical availability number of ~ 95%

Other Observations From Sensitivity Analyses (1)

- **Which risk metric to use for the EFC of renewables?**
  - To date we have usually used LOLE as the risk metric for wind power, and EEU for storage.
  - When calculating incremental EFCs for wind using LOLE, then we note from the table below that the value differs based on which coordination algorithm you assume storage operates with during stress events. With EEU as the risk metric the incremental wind EFC value is far more stable
  - The solar EFC comes about from a diurnal interaction with storage, and as we have used EEU for storage de-rating factors already, hence we may need consistency of risk metric to assess both together
  - Hence EEU seems to have distinct advantages as the risk metric applied for all incremental EFC de-rating factors

			Incremental EFCs (%)			
Case Detail	Risk Metric	Storage Coordination	Onshore Wind	Offshore Wind	Solar	Storage - Duration 0.5
T-3 EEU	eeu	1	6.8%	15.8%	1.6%	15.6%
	eeu	2	6.6%	15.6%	1.6%	15.8%
	eeu	3	7.0%	16.4%	2.0%	14.8%
	eeu	4	6.6%	15.2%	1.4%	16.0%
T-3 LOLE	lole	1	6.3%	22.9%	3.1%	50.0%
	lole	2	6.3%	14.1%	1.2%	20.6%
	lole	3	4.7%	17.2%	1.4%	48.4%
	lole	4	11.0%	17.6%	1.6%	17.3%

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- Note that the results in this table were run with the older wind turbine power curves due to project time limitations, but the conclusions hold regardless

Other Observations From Sensitivity Analyses (2)

- **Solar PV and storage interactions are additive**
  - Without any duration-limited storage, then the solar PV EFC would be almost negligible
  - Combined with wind and storage, the net demand shape changes gives an indirect EFC value to solar PV
  - The solar PV EFC may grow in time if there is big expansion in battery storage on the system

- Increasing solar in a case with no storage and no wind:

				EEU Risk Metric						
Case Details							Average and Combined EFCs (MW)			
Storage	Solar	Onshore Wind	Offshore Wind	Storage Coordination	Solar	Storage - Duration 0.5	Storage	Solar	Diff. Sum of Averages	Combined
no storage		no onshore	no offshore							
	0GW			1	0.4%	32.7%	0	0	0	0
	10GW			1	0.1%	33.3%	0	26	0	26
	20GW			1	0.0%	33.5%	0	33	0	33
	30GW			1	0.0%	33.7%	0	38	0	38

- Increasing solar in a case with high level of storage and no wind:

				EEU Risk Metric						
Case Details							Average and Combined EFCs (MW)			
Storage	Solar	Onshore Wind	Offshore Wind	Storage Coordination	Solar	Storage - Duration 0.5	Storage	Solar	Diff. Sum of Averages	Combined
high storage	base solar	zero wind	zero wind	1	1.4%	13.3%	4382	422	-385	4420
high storage	medium solar	zero wind	zero wind	1	0.8%	14.5%	4462	502	-460	4504
high storage	high solar	zero wind	zero wind	1	0.3%	15.3%	4505	547	-501	4551

- Note that the results in this table were run with the older wind turbine power curves due to project time limitations, but the conclusions hold regardless

Other Observations From Sensitivity Analyses (3)

- **‘Combined’ EFC interactions are small for now, but are complex, and may grow**
  - Solar and storage have a clear positive additivity effect, as per the learnings from the storage de-rating project last year
  - Wind and storage have a slight negative additivity effect, due to (we think) wind making stress events a tiny bit longer
  - Wind and solar have a slight positive additivity again (we think) due to wind making stress events longer
  - When all three are considered together, they have a slightly net-positive additivity effect
  - These effects are small for now (~ < 250MW de-rated capacity in the T-4 Base Case, and well within other EMR modelling tolerances e.g. demand forecast error), though we need to be mindful that they may grow in time in the future GB system

Other Observations From Sensitivity Analyses (4)

❑ Impact of the Base Case Margin on the incremental EFC de-rating factors

- ❑ All EFC de-rating factor results in the CM are provided for Base Case at 3 hours LOLE - we propose to be consistent with this for wind and solar participation
- ❑ As per previous observations in Winter Outlook analyses, then the tighter the margin (higher LOLE), then the higher the wind and solar PV EFCs will be, as they can make a better contribution to more and deeper stress events
- ❑ As per previous observations in the storage consultation last year, then the tighter the margin (higher LOLE), then the lower the duration-limited storage EFCs will be as stress events tend to be longer
- ❑ These trends are evident in the table below

				Incremental EFCs (%)				Average and Combined EFCs (MW)						
Case Detail		Risk Metric	Storage Coordination	Onshore Wind	Offshore Wind	Solar	Storage - Duration 0.5	Onshore Wind	Offshore Wind	All Wind	Storage	Solar	Diff. Sum of Averages	Combined
Plausible "Medium" future case with different GB margin starting levels - EEU	LOLE 0.1 hrs/yr	eeu	1	4.7%	10.9%	0.8%	17.2%	785	2715	4618	3964	254	-168	8668
	LOLE 1 hrs/yr	eeu	1	5.5%	11.9%	1.4%	14.1%	1003	2878	5343	3740	705	-441	9348
	LOLE 2hrs/yr	eeu	1	5.9%	13.1%	1.7%	13.3%	1085	3026	5645	3643	742	-401	9630
	LOLE 3hrs/yr	eeu	1	6.3%	13.5%	1.8%	13.1%	1143	3137	5855	3584	792	-408	9824
	LOLE 4hrs/yr	eeu	1	6.5%	14.2%	2.0%	12.4%	1192	3233	6024	3531	837	-414	9978
	LOLE 5hrs/yr	eeu	1	6.7%	14.6%	2.2%	11.8%	1240	3326	6179	3486	875	-416	10123

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❑ Note that the results in this table were run with the older wind turbine power curves due to project time limitations, but the conclusions hold regardless

Other Observations From Sensitivity Analyses (5)

- **Impact of the size of the marginal EFC unit**
  - This assumption does not seem to make much impact on the incremental EFCs derived with EEU as the risk metric – hence we propose to continue with the use of 20MW incremental sized unit to be consistent with the approach used for duration-limited storage EFC calculation to date

				Incremental EFCs (%)				Average and Combined EFCs (MW)						
Case Detail		Risk Metric	Storage Coordination	Onshore Wind	Offshore Wind	Solar	Storage - Duration 0.5	Onshore Wind	Offshore Wind	All Wind	Storage	Solar	Diff. Sum of Averages	Combined
Plausible "Medium" future case with different size of incremental EFC units - EEU	20MW inc unit	eeu	any	6.3%	13.7%	1.8%	13.1%	1143	3137	5855	3584	792	-408	9824
	50MW inc unit	eeu	any	6.3%	13.6%	1.8%	13.1%	1143	3137	5855	3584	792	-408	9824
	100MW inc unit	eeu	any	6.3%	13.5%	1.8%	13.1%	1143	3137	5855	3584	792	-408	9824
	200MW inc unit	eeu	any	6.2%	13.5%	1.8%	13.0%	1143	3137	5855	3584	792	-408	9824
	500MW inc unit	eeu	any	6.2%	13.4%	1.8%	12.9%	1143	3137	5855	3584	792	-408	9824

- Note that the results in this table were run with the older wind turbine power curves due to project time limitations, but the conclusions hold regardless

Other Observations From Sensitivity Analyses (6)

❑ Effect of updating the wind turbine power curve

- The 2018 wind turbine power curve update makes the onshore wind EFC a little better (~ 2 %) and the offshore wind EFC a little worse (~ 3%) compared to the previous curves used
- The respective incremental EFCs for onshore/offshore will change as a result
- However the overall wind fleet 'average' EFC remains almost the same as the changing onshore/offshore effects largely balance each other out, so the effects on the combined EFC are relatively small.
- We will propose to use the updated 2018 wind power curve for the analyses henceforth

Updated Wind Turbine Power Curves

Case Details	Incremental EFCs - %				Average EFCs - MW						Combined EFCs - MW
	Onshore	Offshore	Solar	Storage - Duration 0.5h	Onshore Wind	Offshore Wind	All Wind	Storage	Solar	Diff.	Combined
T-3 2022/23	8.4%	12.9%	1.8%	15.0%	1438	2166	5129	3091	470	-204	8486

Old Wind Turbine Power Curves

Case Details	Incremental EFCs - %				Average EFCs - MW						Combined EFCs - MW
	Onshore	Offshore	Solar	Storage - Duration 0.5h	Onshore Wind	Offshore Wind	All Wind	Storage	Solar	Diff.	Combined
T-3 2022/23	6.8%	15.8%	1.6%	15.6%	1124	2751	5252	3119	439	-199	8610

Difference

Case Details	Incremental EFCs - %				Average EFCs - MW						Combined EFCs - MW
	Onshore	Offshore	Solar	Storage - Duration 0.5h	Onshore Wind	Offshore Wind	All Wind	Storage	Solar	Diff.	Combined
T-3 2022/23	1.6%	-2.9%	0.2%	-0.6%	314	-586	-123	-27	31	-4	-123

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Indicative Future Trends in EFC De-Rating Factors

- The table below indicates changes from the Base T-3 2022/23 year, to the “Medium” and “High” Sensitivities, to illustrate how these issues may evolve in future

			Incremental EFCs (%)				Average and Combined EFCs (MW)						
Case Detail	Risk Metric	Storage Coordination	Onshore Wind	Offshore Wind	Solar	Storage - Duration 0.5	Onshore Wind	Offshore Wind	All Wind	Storage	Solar	Diff. Sum of Averages	Combined
Base T-3 Case	eeu	1	6.8%	15.5%	1.8%	15.3%	1097	2697	5168	3086	445	-171	8528
"Medium" Sensitivity	eeu	1	6.3%	13.5%	1.8%	13.1%	1143	3137	5855	3584	792	-408	9824
"High" Sensitivity	eeu	1	5.5%	11.4%	1.9%	11.4%	1335	3624	6875	4009	1266	-748	11402

- Some observations
  - Wind incremental EFC %s reduce slightly,
  - Solar incremental EFC %s increase slightly
  - Short duration storage EFC %s continue to degrade
  - The “non-additivity” difference between the ‘Combined’ EFC and the sum of individual ‘Average’ EFCs becomes more appreciable, indicating that the interactions become more complex in the future system

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- Note that the results in this table were run with the older wind turbine power curves due to project time limitations, but the conclusions hold regardless
- The final CM auction storage derating factor is the EFC above multiplied by the storage technical availability number of ~ 95%

Indicative Stress Event Supply/Demand Balance Profiles

Indicative Stress Event Profiles

- The following slide gives an indicative stress event shape as simulated in the LCP Unserved Energy Model in one of the sensitivity analyses conducted

- These trends show the overall supply and demand balance (including renewables) as it evolves over a single day with a stress event, as well as a view of how duration-limited storage could be applied

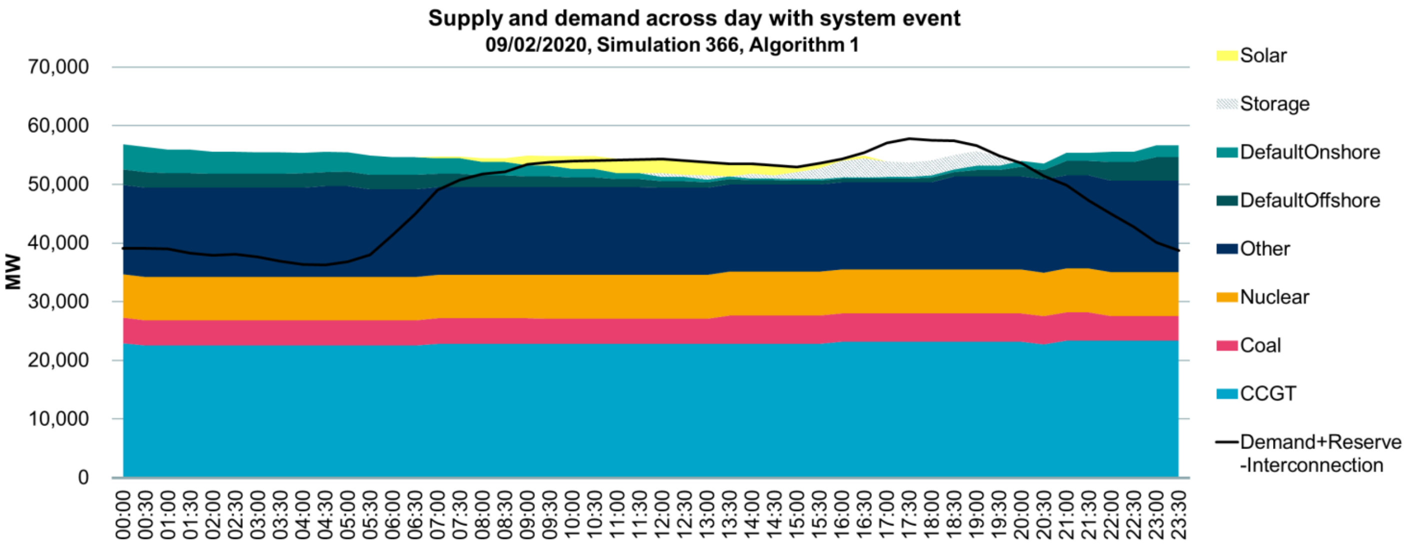
- The stress event in this example is caused by a coincidence of high demand, low wind, and some conventional plants on forced outage at the same time

- It must be remembered that no two simulated stress events are exactly the same, and <u>this is just one particular example for indicative purposes</u>

- However, one can imagine the interactions of wind, solar and duration-limited storage more broadly across the year from this indicative example case though

- Crucially, wind is generating very little during the stress event, and day-time solar generation mostly precedes the onset of the stress event, and some of the storage runs out

Indicative Stress Event Supply/Demand Balance Profile



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Conclusions and Indicative Recommendations for T-1, T-3, and T-4 De-Rating Factors

Key Methodology Issues – Proposed Directions

- **Should we have separate CM technology sub-categories for onshore and offshore wind turbines?**
  - Yes it seems the higher offshore wind speeds deserve a better CM de-rating factor – arguably we could sub-divide even further (geographical, hub height, etc) but this could lead to too much admin complexity

- **Should we use 'Average' or 'Incremental' EFCs as the basis for the de-rating factors?**
  - Incremental EFC makes more sense as the capacity value of renewables depends on the build out rate

- **What are the interactions with duration-limited storage on the system?**
  - There are some minor interactions between the various individual EFCs of wind, solar and storage which we can capture by calculating the EFC of the combined [wind + storage +solar] fleets together

- **Which risk metric makes most sense for wind and solar – EEU or LOLE?**
  - EEU seems to be more robust to capture any effects related to storage coordination assumptions during stress events, and better links to the VoLL v CONE trade-off basis of the CM procurement anyways

- **How do all of these trends change as the penetrations of the resources increase in future?**
  - Incremental EFCs of renewables generally fall slightly with increasing penetrations, though solar and storage have a mutually beneficial interaction as their penetrations grow

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- EFC = Equivalent Firm Capacity, LOLE = Loss of Load Expectation, EEU = Expected Energy Unserved

Indicative De-Rating Factors for T-1, T-3, T-4 CM Years

	De-Rating Factors (%)		
Base Cases	**Onshore Wind**	**Offshore Wind**	**Solar PV**
T-1 2020/21	8.98%	14.65%	1.17%
T-3 2022/23	8.40%	12.89%	1.76%
T-4 2023/24	8.20%	12.11%	1.56%

Next Steps

Future Modelling Developments for Consideration

- There will inevitably be some additional follow up technical modelling work to improve the approach taken in this project to date, for example this work could seek to:
  - Better understand wind speed modelling with MERRA data (hub height extrapolation methods may vary from linear to logarithmic approaches which could have a minor impact with very tall hub heights)
  - Consider the impacts of historical demand time series updates with the benefit of Electralink embedded generation data, thus improving wind, solar and demand ‘correlation’ modelling at peak demands
  - Use Electralink data to consider refinement of an embedded wind generation onshore power curve
  - Consider future power curves for newer offshore wind farms with very high hub height and turbine power sizes, which we do not yet have any historical data for
  - Include the 2017/18 winter weather data to capture any “Beast from the East” effects – note that NASA changed the format of their data files recently which meant we could not use the most recent winter data for this analysis, though we expect it to have a relatively low impact due to the fact that it was not a stress event
  - Further understand the combined EFC effects and relationships with sum of average and incremental EFCs
  - Consider any wider CM design issues for EFC-based de-rated resources that arise via the policy and rules consultations later
  - Etc
- These possible future modelling improvements would be subject to PTE/BEIS/Ofgem endorsement and prioritisation via the annual EMR Modelling development process
- We will also take account of any suggested improvements from industry via this consultation

Timeline of Next Steps

- Your feedback on the methodology and reliability modelling issues raised here today is welcome - please send any comments via email by 5.00pm on January 31st to:

  emrmodelling@nationalgrid.com

- Note that any policy related feedback or concerns should be sent to BEIS directly – the EMR Delivery Body is consulting on the renewables de-rating factor methodology only
- We will publish a response to this consultation by the end of February on our EMR Delivery Body Portal, feeding in to the final methodology agreed with BEIS and Ofgem
- That consultation response will summarise the feedback from industry, the final methodology proposal and any further details of the numerical assessments
- BEIS/Ofgem policy/rules consultations will proceed at a later date, after which the new proposed methodology for renewable de-rating factors could be written in to the CM rules
- The numerical de-rating factors indicated here should be taken as indicative
  - Renewables participation in the CM requires additional policy and rules consultation efforts and given the time requirements for both, then the resultant de-rating factors that would apply may be on the basis of later EMR modelling studies with the most up to date data and assumptions at the time
- Today's slides containing the consultation questions will be posted on the EMR Delivery Body Portal tomorrow

Annex

Annex 1 – Wind, Solar PV and Demand Data Sources

- The NASA MERRA data files can be downloaded here for free (upon registration)

https://gmao.gsfc.nasa.gov/reanalysis/MERRA/

- The Sheffield Solar PV project is described here

https://www.solar.sheffield.ac.uk/pvlive/

- The University of Reading NIA project on wind and solar modelling can be seen as summarised here

http://www.smarternetworks.org/project/NIA_NGET0183

http://www.met.reading.ac.uk/~energymet/home/index.php

- Finally, GB system historical demand and generation data can be downloaded from the National Grid ESO data portal here

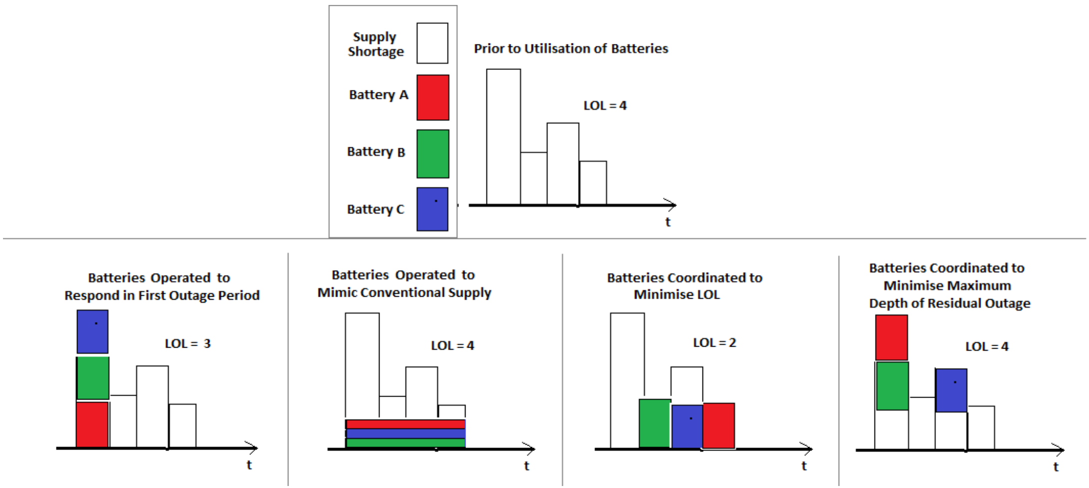
https://www.nationalgrideso.com/balancing-data/data-explorer

Annex 2 – Storage Coordination Algorithms Recap

Consider a simple stylised example of a CM stress event on a given day in the case below

There are multiple possible ways (four coordination approaches characterised below) one could utilise a fleet of duration limited storage resources during an actual system outage – the number of loss of load (LOL) periods is affected, though overall unserved energy level (EU) remains similar – hence the additional robustness offered by EEU as a risk metric when there is duration-limited storage on the system.

These issues were covered in our recent consultation on de-rating factors for duration limited storage in the CM, and are built in to our GB risk modelling tools as standard now.



For further info, see our duration-limited storage derating factor methodology consultation and final reports here:

https://www.emrdeliverybody.com/Capacity%20Markets%20Document%20Library/Duration-Limited%20Storage%20Workshop%20-%2010%20August%202017.pdf

https://www.emrdeliverybody.com/Lists/Latest%20News/Attachments/150/Duration%20Limited%20Storage%20De-Rating%20Factor%20Assessment%20-%20Final.pdf

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