Storage de-rating factors methodology review

ESO industry consultation

Context – storage de-rating factor methodology review

- The current duration limited storage de-rating methodology was finalised at the end of 2017 and is summarised in our storage and renewables de-rating factors briefing note. Since 2017, around **4GW of grid-scale battery storage has connected.** Wider access to the BM via internet-based communication protocols and BSC modifications have enabled around **2GW of battery storage to become BMUs**. This provides additional operational experience and data to inform our methodology.
- The Panel of Technical Experts also recommended a review of battery storage de-rating factors in their 2022 report. Based on this recommendation and trends noted above, we initiated a wide-ranging review of our storage de-rating factor methodology.
- This consultation covers our equivalent firm capacity (EFC) approach and technology class weighted average availability (TCWAA) method. **Policy-related issues, including the Duration Limited threshold and extended performance testing are out of scope** and should be directed to Government.
- This presentation summarises the outcome of this review and presents our proposed changes to the methodology. We also have posed a series of consultation questions (see Annex A for summary list), we would welcome any feedback via written consultation responses by **Wednesday 8th May 2024 at 17:00** to our shared inbox:

  emrmodelling@nationalgrideso.com

- We will publish a response to this consultation by July 2024 on the EMR Delivery Body Website.

Recap – why we use a duration limited methodology

- The GB Reliability Standard is 3 hours Loss of Load Expectation (LOLE) per year.
- As more storage capacity and weather-dependent renewable generation is connected to the GB system, the distribution of unserved energy events we expect at 3 hours LOLE is shifting from more frequent, shorter events to potentially less frequent, longer events.
- The table below shows an example from the Resource Adequacy in the 2030s study which we commissioned from Afry in December 2022 (using FES21 Consumer Transformation data). The total number of events decreases from 51 to 33 from 2025 to 2033, while the number events that are 6 hours or longer increases from 3 to 8.
- This means that energy capacity limits of storage become increasingly important, as well as power capacity limits, to valuing the contributions to security of supply.

	Year	Distribution of length of hours with unserved energy (hours)							
		<2	2-3	4-5	6-9	10-14	15-22	23-30	31-40
'Consumer Transformation' (reference)	2025	3	26	19	0	3	0	0	0
	2028	2	24	9	1	5	0	0	0
	2030	3	20	8	4	2	0	0	0
	2033	8	12	5	6	2	0	0	0
	2035	3	8	4	5	6	1	0	0
	2038	7	12	5	5	4	2	0	1
	2040	2	16	8	2	3	2	0	1

Recap – what is equivalent firm capacity (EFC)

- The contribution storage makes to security of supply varies, as the output from storage depends on how long its stored energy can be used to meet demand. Equivalent firm capacity (EFC) is a method that helps to **estimate these varying contributions** of storage that have different durations (i.e. energy capacity limits for a given power capacity).
- Specifically, EFC is the amount (in MW) of **perfectly firm capacity** that would replace a given amount (in MW) of a resource (e.g. storage) for the same risk level (e.g. expected unserved energy).
- Similar (but not the same) risk-based approaches to capacity accreditation are increasingly used by system operators and widely considered as best practice in many international capacity remuneration mechanisms (CRMs), typically using Effective Load Carrying Capability (ELCC) methods. ELCC was initially developed in the 1960s to estimate the contributions of pumped hydro storage to balance out nuclear overnight.
- ELCC approaches typically add an amount of demand and find the equivalent capacity of a resource that can return the system to the original reliability level. We use the term EFC as we are procuring de-rated capacity in the CM, and therefore, want to compare the reliability contribution of storage to a form of (firm) capacity on the supply side, not demand.

Recap – why is a separate technical availability required

- While EFC is useful for measuring the duration limited aspects of storage, it does not provide an assumption on the **expected availability of a storage unit to export (in MW)**.
- Therefore we calculate storage de-rating factors by multiplying a technical availability by the EFC value.
- The technical availability for all storage is currently based on the technology class weighted average availability (TCWAA[1]) of pumped storage. This is because in 2017 when the storage de-rating method was initially introduced, there wasn't sufficient availability data on other operational GB storage. This has now changed with availability data on Li-ion battery storage.

TECHNICAL AVAILABILITY

How much MW can the unit export to the grid?

×

EQUIVALENT FIRM CAPACITY

For how long?

[1]TCWAA is calculated using the average availability (MEL) of each technology class during the winter peak period (0700-1900, Monday-Friday, December-February) at times with demand above the 50th percentile (all plant except CCGT, CHP and autogen) or 90th percentile (CCGT and autogen) over the last 7 years.

Technical availability of battery storage – current data

- Until 1 March 2024, ESO guidance was that maximum export limit (MEL) declarations should be consistent with storage BMUs being able to operate at that MEL for **at least 15 minutes**. From 1 March 2024 onwards, updated ESO guidance is that these MEL declarations should be consistent with operating at that MEL for **at least 30 minutes**.
- These guidance rules have limitations that are being worked through via a Grid Code modification proposal (GC0166). GC0166, if implemented, will introduce new parameters for duration limited assets.
- The current situation means that MEL declarations for battery BMUs may include **both a technical availability and a state of charge** component. Therefore, to calculate a battery-specific technical availability for the CM, **we must adjust for the fact that MEL declarations may be based on 15 minutes (pre March 2024) and 30 minutes (post March 2024)** declarations so as not to double count the duration limit already captured via the EFC and unfairly penalise storage CMUs.
- ESO guidance now also reflects that providers should reduce their MEL according to contracted frequency response capacities in those settlement periods. We therefore must also adjust MELs for any providers that redeclare in this way, so as not to misrepresent availability of these units.

Technical availability of battery storage – proposed approach

1. **Do you agree with the proposed approach to calculate technical availability for battery storage? Please provide justification for your answer.**
2. **What approaches do you think could help to improve the quality of data used in the technical availability calculation, particularly MEL and available energy data?**

- Two corrections are made to the MEL data[1]: 1) 15-minute/30-minute duration correction 2) correction for MEL declarations based on contracted frequency response volumes. Both these corrections recognise that storage assets operate differently to other assets.
- Based on these corrections for the past three winters we recommend **a technical availability for battery storage of 91.19%.** This compares to the ECR 2023 value for pumped storage of 94.37%.
- The technical availability calculation is a complex process to collect, clean and process data sources. Only a significant minority (~25% of installed MW capacity) of battery storage units have complete, concurrent maximum export limit (MEL) and available energy (MWh) data of sufficient data quality. **We would welcome efforts to improve data quality, particularly for MEL and available energy data**. As the number of batteries connected on the system increases, we will review the viability of running this process annually.
- **Note: CM rules changes would be required to implement this change, which are not in scope of this consultation.**

Analysis winter	# units (MW) with data[2]	TCWAA pre corrections	TCWAA 15-min/30-min correction only	TCWAA both corrections
2020/21	3 (60MW)	94.50%	96.37%	96.37%
2021/22	9 (290MW)	88.46%	90.59%	92.35%
2022/23	15 (450MW)	73.66%	77.07%	84.84%
Average	N/A	85.54%	88.01%	91.19%

[1]Technical availability uses MEL data from December to February, 7am-7pm on days with greater than 50th percentile demand.
[2]Only units that have complete, concurrent maximum export limit (MEL) and available energy (MWh) data for the relevant winter are considered.

EFC approach – context and motivation

- An incremental EFC methodology was selected in 2017 "*in keeping with the economic principle of payment in a market being linked to the marginal contribution of supply to meeting demand at the point at which the market is expected to clear*" *(*ESO storage de-rating factor methodology consultation response, 2017*)*
- In 2017, the projected storage fleet total contribution (as measured by the storage fleet EFC) aligned well with the sum of the expected de-rated capacities using incremental EFC. **There is now a growing inconsistency between the total storage fleet de-rated capacities using incremental EFC and the expected total storage fleet EFC contribution.** This inconsistency has increased since 2017 largely due to an increase in overall size of the storage fleet.
- When reviewing alternative EFC methods, we have evaluated options based on the following high-level criteria:
  - **Incentives for security of supply**: ensures the total de-rated capacity matches the expected storage fleet EFC
  - **Efficient market clearing**: reflects the incremental value of storage at the point where the CM clears
  - **Minimise unintended consequences**: does not incentivise unexpected behaviour
  - **Stakeholder fairness and transparency**: fairly allocates contributions and is not unnecessarily complex
- This review of the storage EFC methodology as the GB resource portfolio evolves is in line with our approaches for other technologies. For example, the renewables derating consultation response in 2019 also selected incremental EFC for renewables, but noted that this may be reviewed once a significantly higher quantity of wind becomes CM-eligible and participates in the CM after leaving the Renewables Obligation scheme.

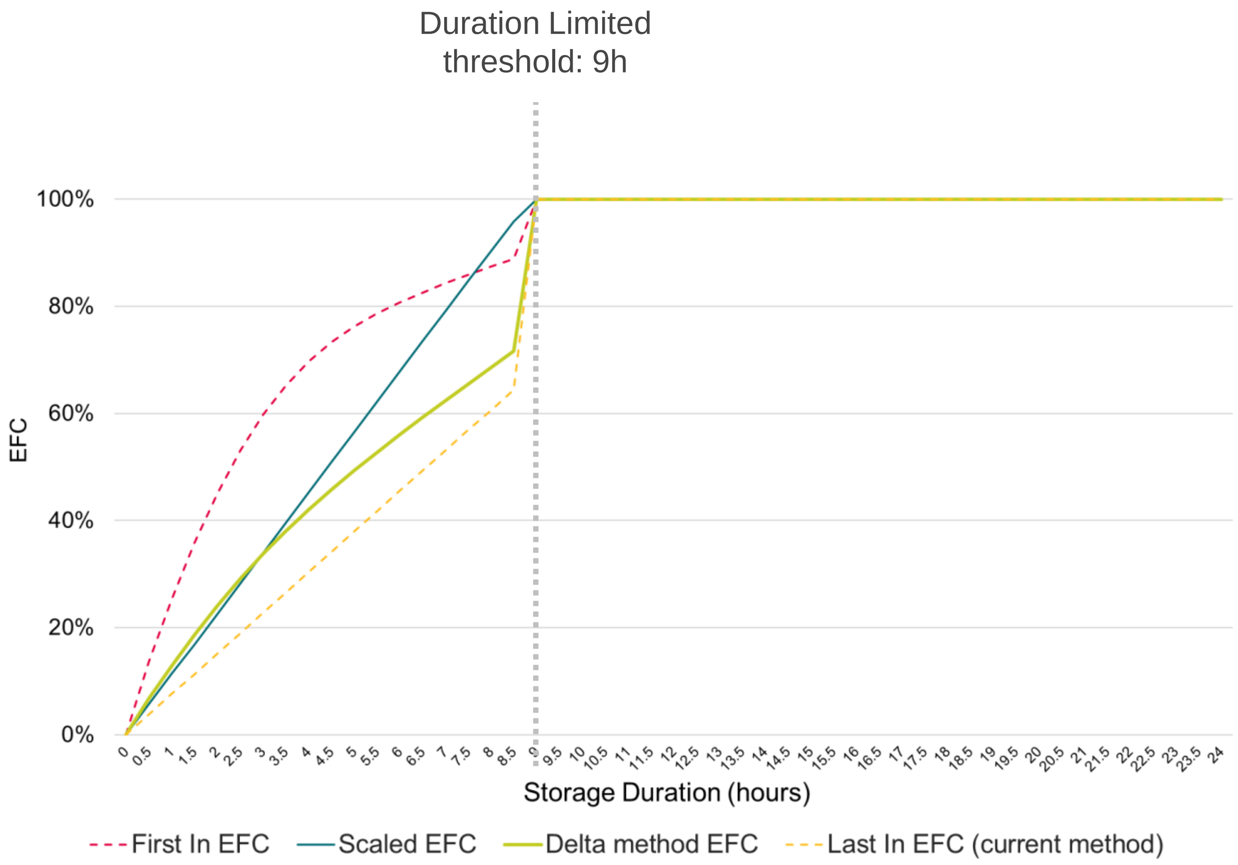
What EFC methods have we reviewed?

- As part of this project, we reviewed international approaches to storage de-rating and capacity accreditation. We also consulted with internal experts and our academic and modelling tool consultants.
- From this review, we shortlisted several EFC methodologies shown in the table below (details in Annex B) and conducted impact analysis in our Unserved Energy Model (UEM) including observation of adequacy metrics and EFC results.

Method name	Description
Incremental Last-In EFC	(Current method) The amount of firm capacity that provides the same reliability contribution (measured by change in expected unserved energy) as a small unit of capacity added to the GB system at 3 hours LOLE **with the expected storage fleet.**
Incremental First-In EFC	The amount of firm capacity that provides the same reliability contribution as a small unit of capacity added to the GB system at 3 hours LOLE **with no storage.**
Average EFC	The amount of firm capacity required to return the system to the original reliability level if all storage capacity at **a specified duration** were removed.
Storage Fleet EFC	The amount of firm capacity required to return the system to the original reliability level if **all storage capacity** were removed.
Scaled EFC	Distributes the storage fleet EFC proportionally to the Last In incremental EFC MW of each duration as a percentage of the total MW of all Incremental Last In EFCs.
Delta method EFC	Distributes the “shortfall” of the Last In EFCs relative to the storage fleet EFC proportionally to the average of the First-In and Last-In Incremental EFCs

Comparison of different EFC methods

- The graph compares the resulting EFC percentages (before being multiplied by technical availability to calculate de-rating factors) for all EFC methods simulated for the 2027/28 delivery year.
- Storage is defined as Duration Limited in the CM rules *if "at least 5% of Loss of Load Occurrences for the corresponding Delivery Year … last longer than the specified minimum duration for that Generating Technology Class".* This Duration Limited threshold means that all durations above the threshold receive an EFC of 100%.
- The Delta method generally sits between the Last In and the First In EFCs, with a step corresponding to the application of the Duration Limited threshold.
- The Scaled EFC produces results that are effectively a rotation of the Last In EFC curve. There are less potential unintended consequences from this method, as there is no "step" in the EFC results. We find similar results for other modelled years (2025/26 to 2032/33).



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EFC methods - evaluation

3. Do you agree with the rationale for the proposed change of EFC methodology to a Scaled EFC approach? Please provide justification for your answer.

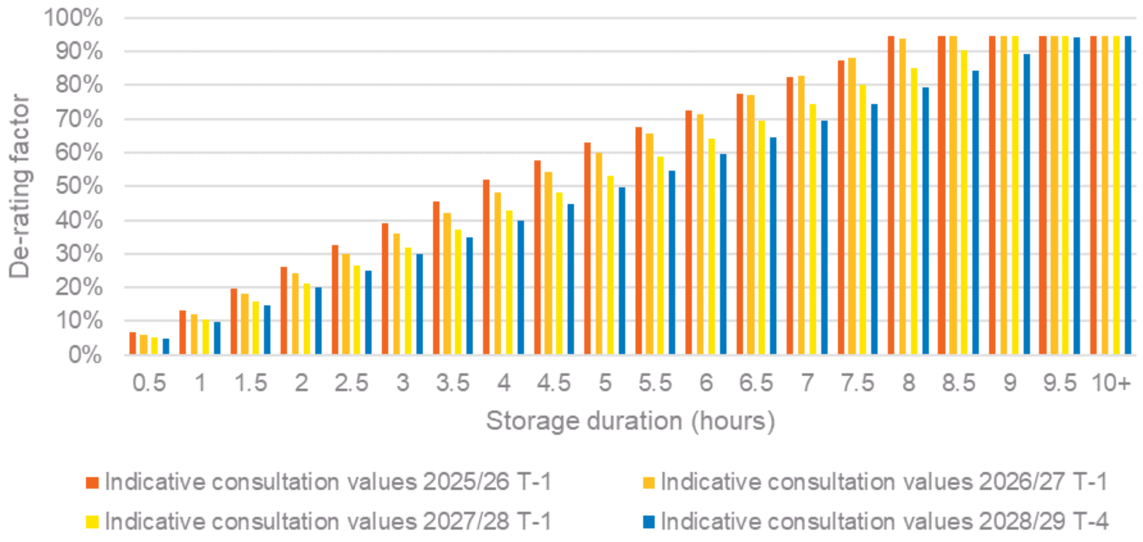
- The following table shows the evaluation process for each EFC method considered against the criteria. Based on this evaluation the **Scaled EFC** was selected.

EFC Method / Criteria	Security of supply incentives	Efficient market clearing	Unintended consequences	Stakeholder fairness / transparency	Progress?
Incremental Last-In EFC (current method)	Does not match expected storage fleet EFC	Aligns to contribution at expected market clearing point	Higher duration declarations with Duration Limited threshold	Allocates contributions according to consistent rule	✘
Average EFC	Does not match expected storage fleet EFC	Does not reflect individual CMU at clearing point	Potential for unexpected variations between durations	Not clear how to calculate for storage durations with no existing capacity	✘
Scaled EFC	Total de-rated capacity matches expected storage fleet EFC	Storage fleet EFC aligned proportionally to Last-In incremental EFC	Less scope for unintended consequences foreseen	Allocates contributions according to consistent rule	✓
Delta method	Total de-rated capacity matches expected storage fleet EFC	Excess storage fleet EFC allocated at mid-point between Last In and First In EFCs	Higher duration declarations with Duration Limited threshold	Allocates contributions according to consistent rule	✘

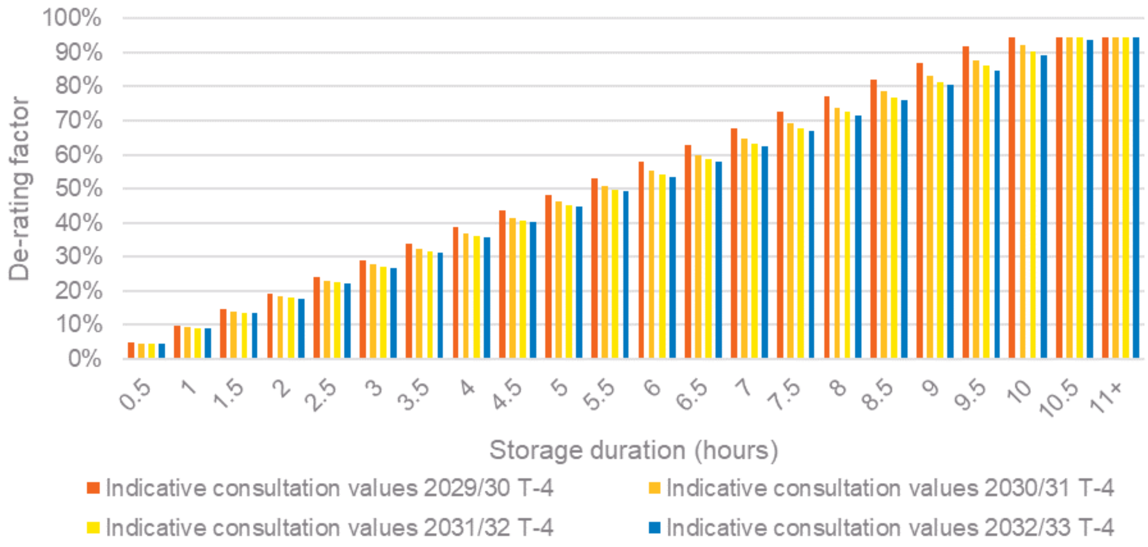
EFC approach – illustrative example of future storage de-rating factor trends

- The below graphs show an **illustrative example of future trends** for **Scaled EFC** storage de-rating factors.
- Due to the timing of this consultation, we have used the FES 2023 input assumptions updated with the latest CM auctions data for storage, see next slide for storage installation assumptions. Note that **de-rating factors are subject to change with updated input assumptions**, and in particular the 2025/26 T-1 and 2028/29 T-4 de-rating factors are subject to change in the 2024 Electricity Capacity Report (ECR) following this consultation and updated inputs assumptions.
- The graphs show a general decrease in de-rating factors over time for all durations less than 11h. This reflects the expected addition of storage capacity particularly at 2h duration (see next slide).

2025/26 to 2028/29 indicative trends

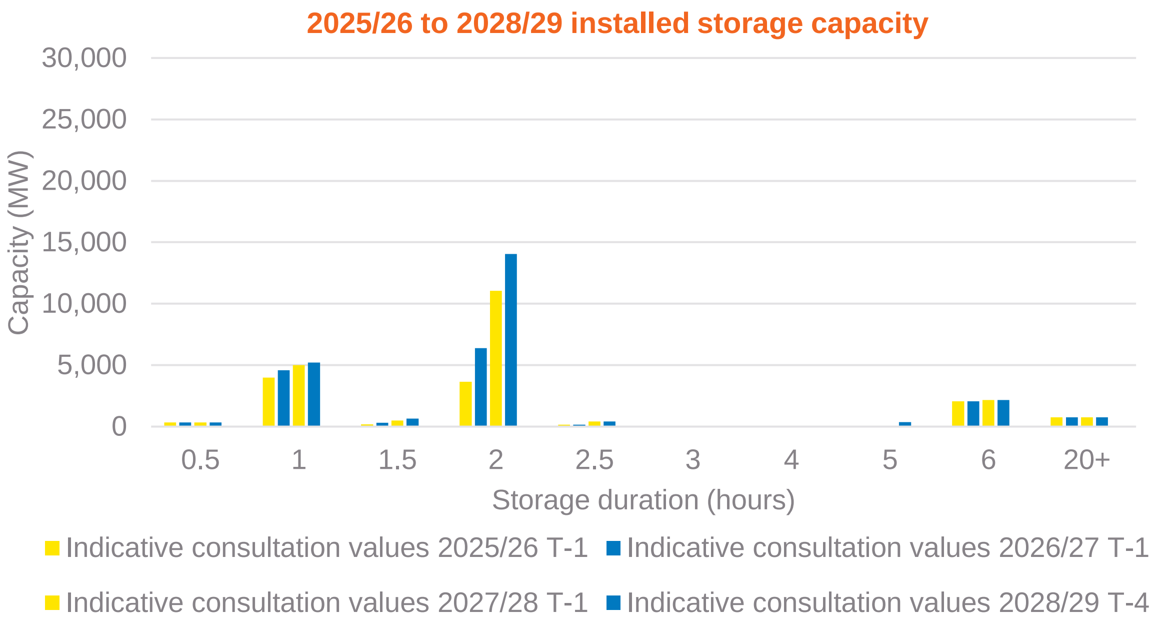


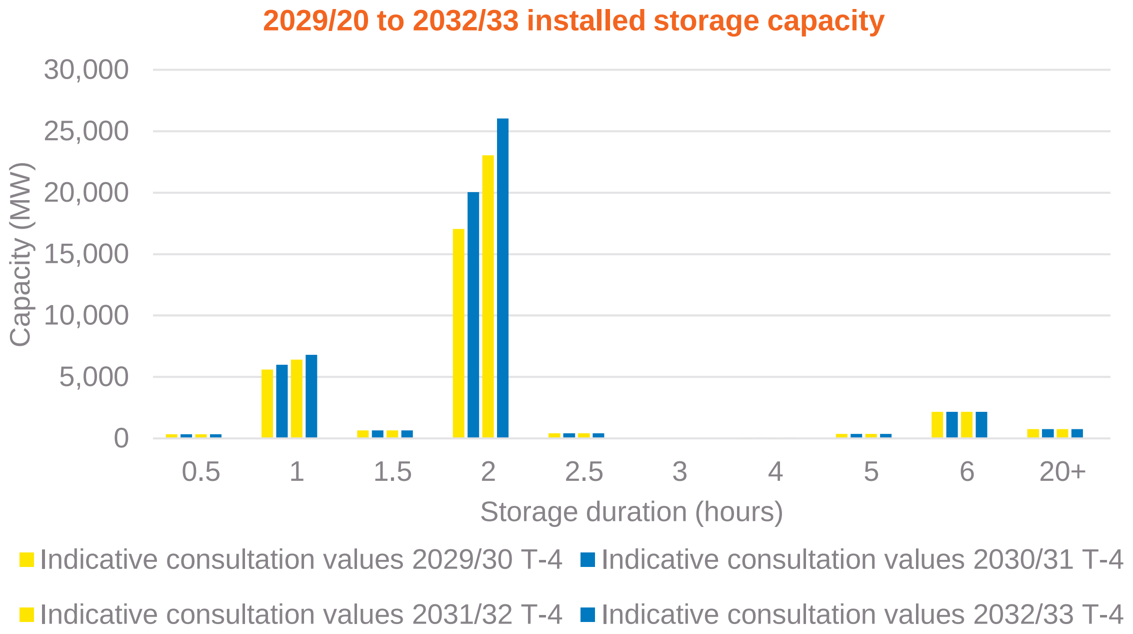
2029/20 to 2032/33 indicative trends



EFC approach – assumptions for trend analysis

- In the trend analysis for the previous slide, we have used our FES 2023 Base Case peak demand and non-storage plant assumptions for modelled years up to 2027/28 and the FES 2023 System Transformation scenario for 2028/29 onwards.
- We have adapted the FES23 Base Case assumptions for installed storage capacities only, to reflect the latest 2024 CM Auctions. However, if these assumptions (and any key other assumptions) were to change then the trends on the previous slide could be significantly different. In particular, if more storage capacity were to come forward then storage de-rating factors would be likely to be lower than the trends shown on the previous slide.





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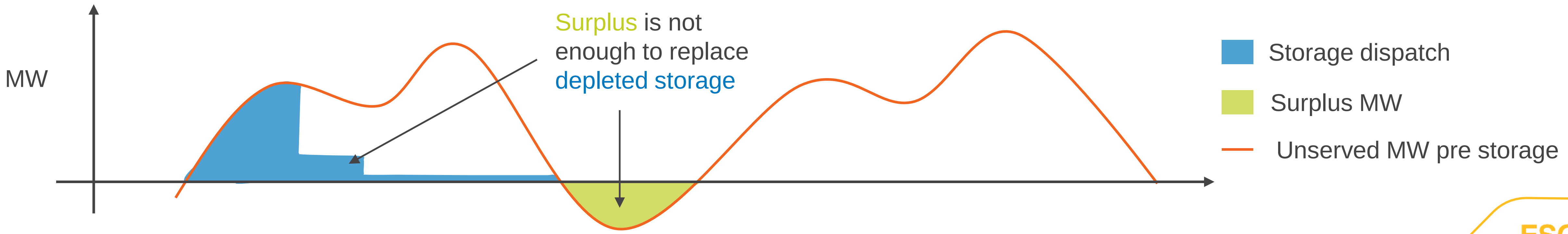
Alternative data-driven methodologies

4. Do you think there are alternative methods instead of EFC, particularly performance-based methodologies, that should be used to de-rate storage that still reflect power capacity and energy capacity limits?

- Alternative non-EFC/ELCC methodologies could use historical performance to define de-rating factors by selecting:
  1. Performance metric (e.g. TCWAA, average state of charge, metered output (MWh), a combination)
  2. Measurement period (e.g. CMN active, high demand, high prices, CM Stress Event)
- Any performance metric **needs to reflect the energy limits of storage as well as power capacity limits**. This means a TCWAA based purely on MEL similar to conventional Generating Technology Classes is not viable.
- There have been no CM Stress Events to date, so we cannot use performance data from these periods. Any proxy performance periods (e.g. CM Notifications, Electricity Margin Notices) are limited by multiple incentives for storage to maintain a certain output (e.g. ESO balancing services, wholesale market dispatch, state of charge management).
- In all previous CMNs to date, the CMN has been cancelled in advance of delivery or the ESO has communicated that it does not believe a stress event will occur (e.g. 18th July 2022).
- From a review of equivalent storage accreditation approaches used by other SOs/TSOs internationally, risk-based approaches such as EFC and ELCC are increasingly being introduced for capacity remuneration mechanisms.
- Therefore, our minded-to-position is to retain an EFC-based methodology with the changes proposed within this consultation. However, we will consider input on any performance-based storage de-rating methods which reflect appropriately reflect storage power capacity and energy capacity limits.

Recap – storage state of charge assumptions

- The assumption on state of charge of the storage fleet prior to the start of modelled unserved energy periods affects the contributions to reducing unserved energy over longer, more severe events. It therefore affects the EFCs calculated.
- In our 2017 storage de-rating factor consultation response, we noted that this de-rating factor methodology aims "*to derive a reliability value for a duration-limited resource behaving* ***in a manner consistent with its CM requirement*****",** due to the CM obligations placed on capacity providers and associated penalties for not meeting these obligations**.** We therefore assumed that **storage was fully charged prior to the start of any modelled unserved energy period** and that storage could perfectly forecast CM stress events for the purposes of storage de-rating factors.
- However, while we continue to assume storage market behaviour in line with current CM obligations and penalties for the purposes of storage de-rating factors, we believe the evolving nature of modelled unserved energy periods may lead to some sequential unserved energy periods where there is **insufficient surplus between these unserved energy periods for the storage fleet to fully recharge**.
- Therefore, we propose to update our modelling assumptions to account for these sequential unserved energy periods.



Storage charging between events – proposed method & assumptions

5. **Do you agree with our proposals for implementing charging between events? Please provide justification.**
6. **Do you agree with our assumptions regarding efficiencies of different technologies? Please provide justification.**

- Some **CM rule changes are required for changes to assumptions of storage charging between events** to be implemented. Specifically, Generating Technology Classes (GTC) are required that separate storage by technology (e.g. Li-ion battery storage, pumped storage and so on), so that de-rating factors can include the effects of round-trip efficiency. These changes could be made alongside those required to enable a technology-specific TCWAA.
- To illustrate the potential impacts of implementing this approach, we have run simulations where storage is required to charge between events. Storage is discharged in highest duration first order and be charged in most efficient first order, given this approach is likely to minimise unserved energy in most cases (see Zachary et al, 2022). However, we will keep this under review, and optimisation-based approaches may be necessary in the future.
- For the purposes of these runs only, we have assumed a round-trip efficiency of 85% for durations lower than 6h (currently dominated by Li-ion batteries) and 80% for durations of 6h and above (currently dominated by pumped storage) based on a recent Regen survey of GB LDES developers (see Figure 10 on p37). **We would welcome further input on what round-trip efficiencies to assume for different storage technologies.**
- Our indicative impact analysis results are shown in Annex C. However, these results may change in the future depending on the evolution of the supply, demand and storage mix in the GB power system.

Next steps

- We welcome your written responses to this consultation by 17:00 Wednesday 8th May. We will publish a response to this consultation by July 2024.
- If any EFC method changes (e.g. Scaled EFC) were implemented these would apply for our recommendations in the 2024 Electricity Capacity Report (ECR) for the 2025/26 T-1 and 2028/29 T-4 auctions.
- The proposals for battery storage specific technical availability and storage charging between events would require Government consultation on changes to the CM rules, and will not be implemented in the 2024 ECR.

Capacity Market – Phase 2 Consultation (DESNZ)

- In October 2023, Government published a consultation on proposals to reform the CM to improve security of supply, align the scheme with the government's net zero goals, and improve the functioning of the scheme.
- The proposals in this consultation constitute Phase 2 of the changes that we set out earlier this year in the government response to our January 2023 consultation.
- To incentivise further **investment in low carbon technologies**, the government outlined **proposals to de-risk investment in storage** by addressing the barriers faced by batteries in meeting the CM's performance and duration testing requirements.
- Questions 6 to 9 of the October 2023 "Phase 2 Consultation" sought views on proposals to address barriers faced by storage CMUs in managing battery degradation by introducing:

  - an **amendment of Rule 4.4.4 of the CM Rules**, to enable **Permitted Augmentation** of battery storage sites and

  - enabling the level of **EPT requirement to be appropriately adjusted** when secondary trading occurs.
- As stated in the consultation, government considers the **EPT framework a necessary measure** for ensuring confidence that Storage CMUs can deliver against their Capacity Agreements, both in terms of duration and capacity.
- The government has historically made changes to the CM through **secondary legislation for the following delivery year**, however, as with every year, this is subject to when **parliamentary time allows.**
- **For any questions relating to the phase 2 consultation, please email:** remamailbox@energysecurity.gov.uk

Annex A – list of consultation questions

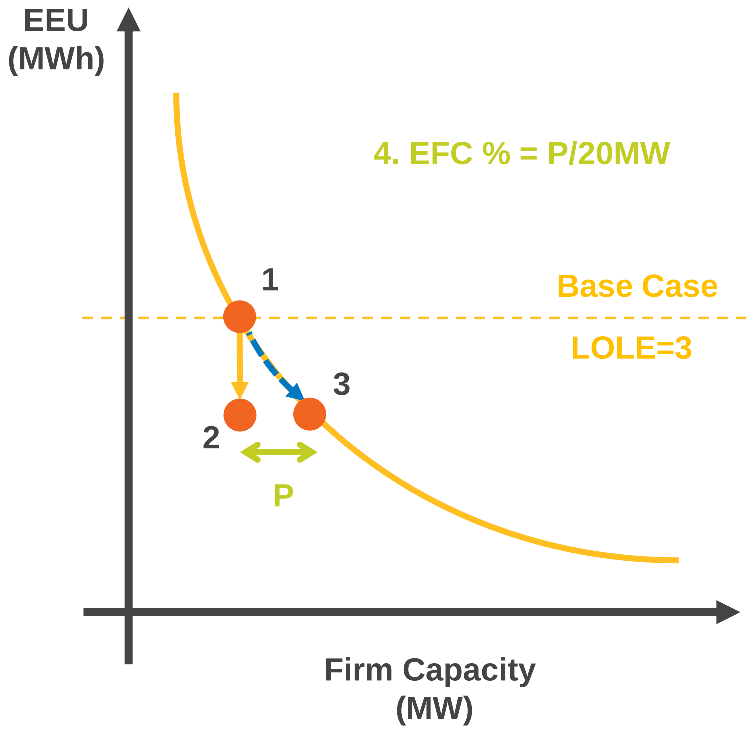
List of consultation questions

We welcome any feedback on **technical aspects** of the storage de-rating factor methodology including the following questions.

1. **Do you agree with the proposed approach to calculate technical availability for battery storage? Please provide justification for your answer.**
2. **What approaches do you think could help to improve the quality of data used in the technical availability calculation, particularly MEL and available energy data?**
3. **Do you agree with the rationale for the proposed change of EFC methodology to a Scaled EFC approach? Please provide justification for your answer.**
4. **Do you think there are alternative methods instead of EFC, particularly performance-based methodologies, that should be used to de-rate storage that still reflect power capacity and energy capacity limits?**
5. **Do you agree with our proposals for implementing charging between events? Please provide justification.**
6. **Do you agree with our assumptions regarding efficiencies of different technologies? Please provide justification.**

Annex B – EFC methodology details

Recap - Incremental EFC (current method)



For the incremental EFC method, a small unit of capacity added to the existing fleet. A Loss of Load Expectation (LOLE) of 3 hours is used as the calculation starting point in line with the GB reliability standard. Expected Energy Unserved (EEU) - essentially the mean average energy demand (MWh) not met over the long-term - is used for the following EFC calculation as it is less sensitive to storage's operational strategy and has a direct link to the cost of unreliability.

This is implemented for each duration of storage (e.g. 2h storage) as the following steps shown on the graph:

1. Find EEU for the Base Case
2. Add a specified amount (20MW) of resource and recalculate EEU
3. Find the amount of firm capacity (P) that gives the **same EEU as step 2**.
4. EFC % = P/20MW

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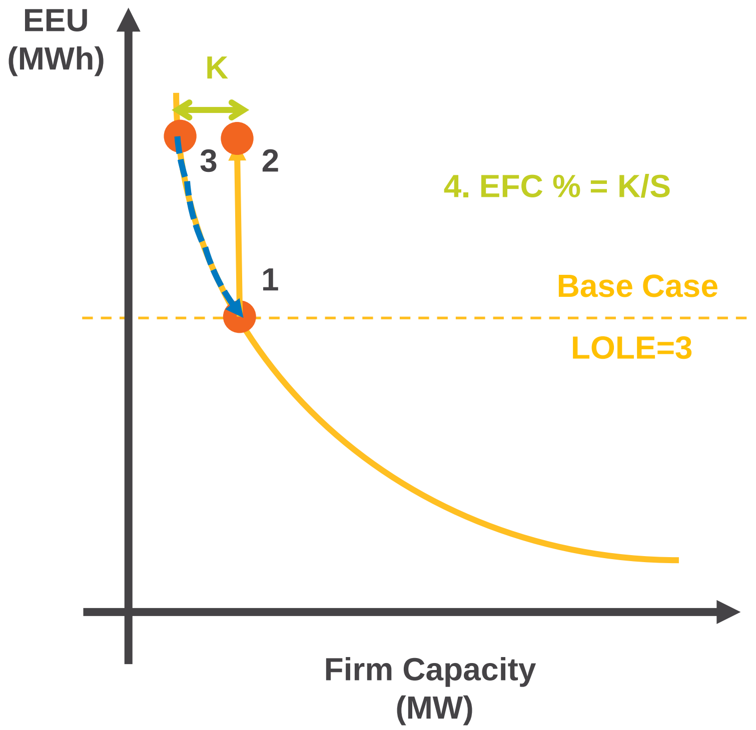
Average EFC



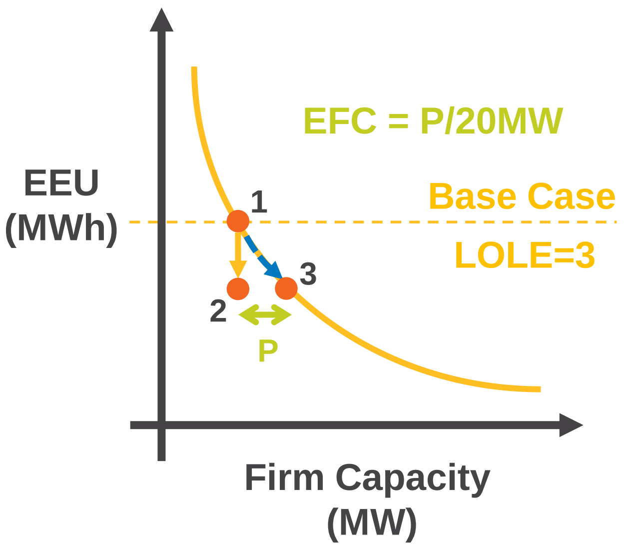
For the **average EFC** method, all capacity at the duration is removed from a system starting with a LOLE of 3h. Firm capacity is then added back to the system until it reaches the same reliability level, measured in EEU.

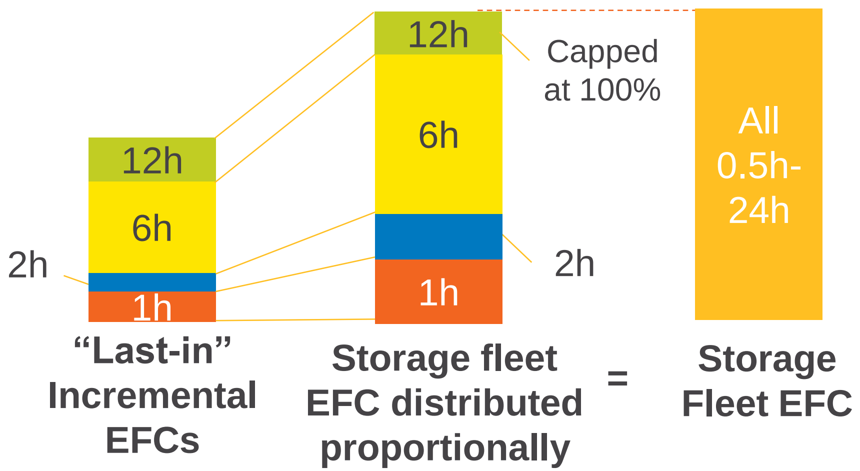
This is implemented for each duration of storage (e.g. 2h storage) as the following steps shown on the graph:

1. Find EEU for the Base Case at 3h LOLE
2. Remove all capacity at that duration (S)
3. Find the amount of firm capacity (K) that needs to be added to return to the **same EEU as step 1**.
4. EFC % = K/S

The **Storage Fleet EFC** is a special case of average EFC where storage capacity at all durations is removed at step 1.

Scaled EFC





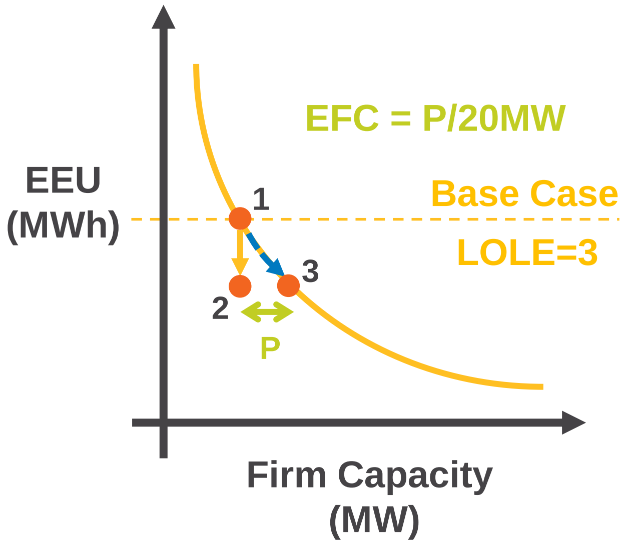
Incremental EFCs

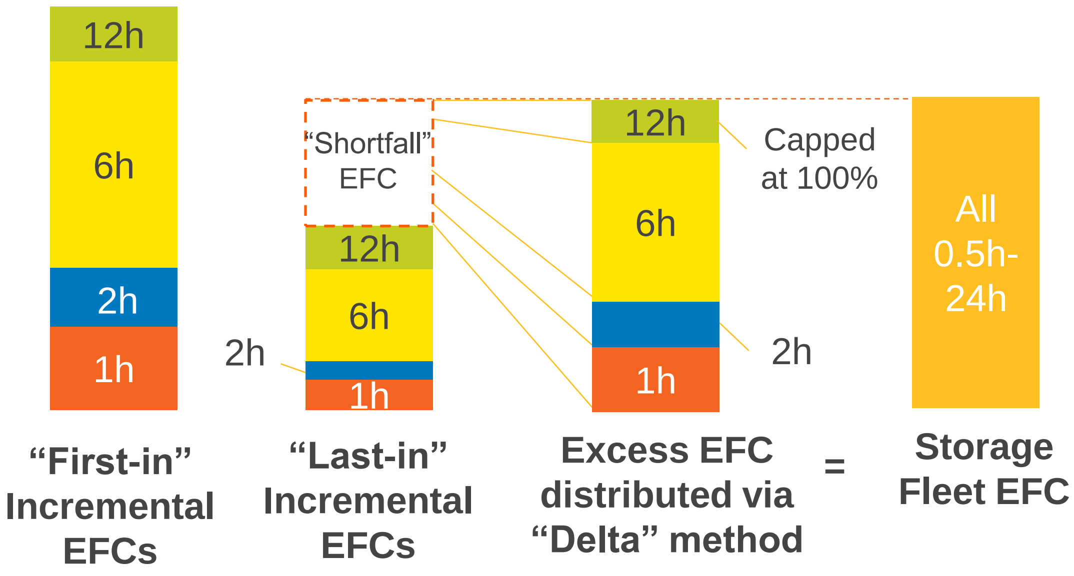
- % EFC calculated for individual storage **increment (e.g. 20MW)** at each duration with the full expected storage fleet ("Last-In")
- See slide 14 of the current methodology briefing note for details

Scaled EFC

1. % EFC calculated as for incremental EFC for each individual duration
2. Storage fleet EFC calculated based on adding all storage to system at 3 hours LOLE, assuming 100% technical availability of the storage fleet
3. Durations with no existing installed capacity are assigned a nominal value (0.01MW).
4. Storage fleet EFC **distributed proportionally to the incremental EFC MW of each duration relative to the total MW of all incremental EFCs.**
5. Each duration's EFC percentage is capped at 100%.
6. Any shortfall EFC MW due to capping at 100% is distributed to other durations iteratively per step 4, looping until all storage fleet EFC has been allocated.
7. De-rating factor = Scaled EFC x technical availability

“Delta” method[1] EFC





Incremental EFCs

- Same as last slide, except incremental EFCs are calculated for both “**First-In**” (when no storage has been installed) and “**Last-In**” (when all expected storage has been installed, equivalent to the EFC method used currently and for the distributed fleet EFC)

Delta method EFC

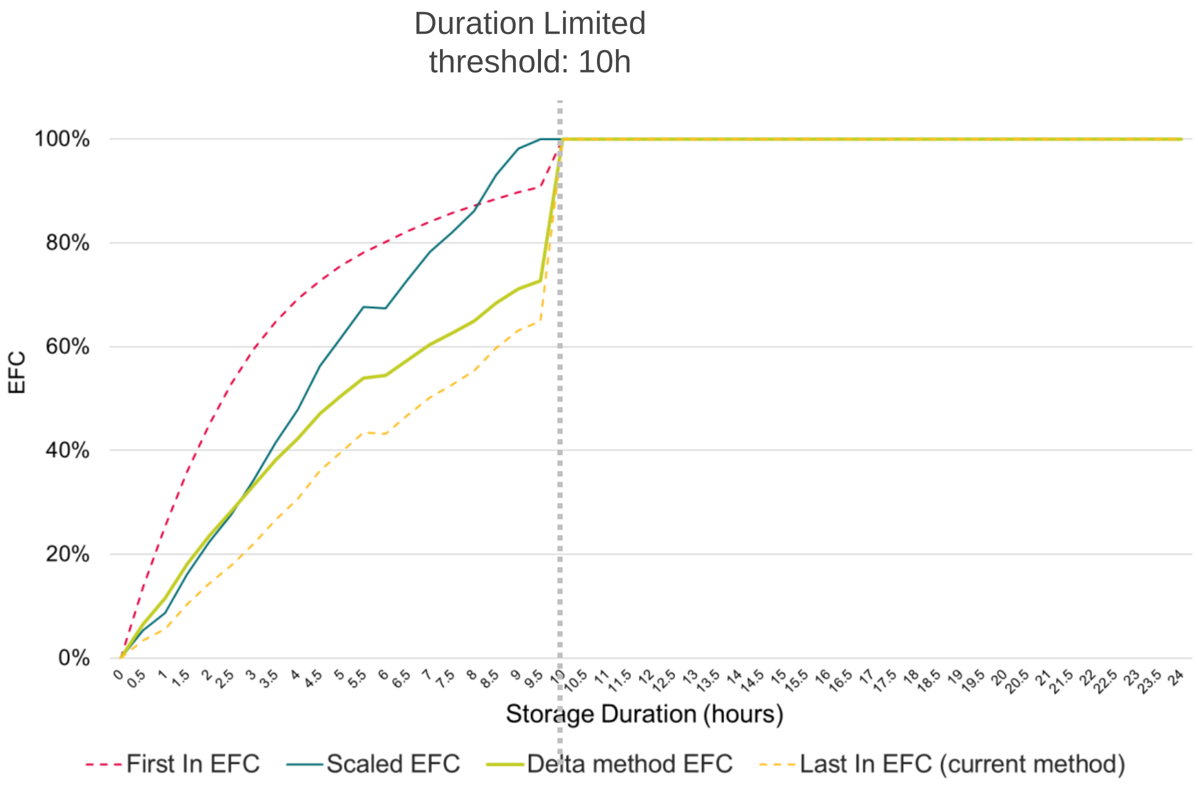
1. “First-In” incremental % EFC calculated for each individual duration
2. “Last-In” incremental % EFC calculated for each individual duration
3. Storage fleet EFC calculated based on adding all storage to system at 3 hours LOLE, assuming 100% technical availability of the storage fleet
4. Durations with no existing installed capacity are assigned a nominal value (0.01MW).
5. Any shortfall relative to the Storage fleet EFC is **distributed proportionally to the individual differences between the Last-In and total First-In EFCs**
6. Each duration’s EFC percentage is capped at 100%.
7. Any excess EFC MW due to capping at 100% is distributed to other durations iteratively per step 4, looping until all storage fleet EFC has been allocated.
8. De-rating factor = delta EFC x technical availability

[1]*Based on the Delta method initially proposed by E3 on p14 here*

Annex C – Storage charging between events testing results

Scaled EFC testing with charging between unserved energy events

- The graph compares the resulting EFC percentages (before being multiplied by technical availability to calculate de-rating factors) for all EFC methods simulated for the **2027/28** delivery year including charging between events with 85% round-trip efficiency for durations below 6h and 80% for durations above 6h.
- Compared to the graph without charging between events, there is a distinctive additional kink in all EFC curves (note the charging between events has not been implemented for First In EFC in this case). We believe that this shows that efficiencies should be implemented on a technology basis rather than duration basis, to avoid unintended consequences and/or unfair EFC allocation. We therefore believe **regulatory change is required to allow storage EFCs to be allocated by technology** (e.g. by creation of new GTCs).
- Generally the curves are less smooth, reflecting the additional complexity introduced by considering surpluses (and charging) as well as deficits.



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Scaled EFC testing with charging between unserved energy events – provisional testing results

- The below graphs show **indicative testing results** for Scaled EFC de-rating factors (including a technical availability of 94.37%) including charging between unserved energy events as set out earlier. Note that **this method is not being considered for the 2024 ECR** as regulatory change is required to implement it appropriately. Testing results are included for information only.
- Differences between de-rating factors with and without charging vary significantly between durations, due to the complexities involved when discharging storage in highest duration first order, while charging in highest efficiency first order.

2025/26 to 2028/29 testing results