ENA Open Networks

Independent cost-benefit analysis on ESO-DSO primacy rules for STOR vs ANM flexibility service conflicts

31 July 2023

Background

As part of the Open Networks Programme and the Primacy work that is being undertaken, the ENA commissioned DNV to carry out analysis around STOR services procured by the ESO and ANM schemes managed by the DNOs and how these potential conflicts when both are actively using flexibility could be best managed. The work was broken down into 6 constituent parts including an assessment of the Counterfactual (Primacy rules are not needed, ESO just continues to procure services via conventional mechanisms).

Part of the complexity that exists with this Use Case is in part the redesign of the STOR Service and the fact that ESO does not currently see assets behind an ANM scheme, making the handling of conflict potentially harder. The latter also applies to DNOs, which do not currently have visibility of STOR assets being dispatched on their networks. Primacy Rules can help mitigate these conflicts and help ESO and DNOs coordinate more efficiently.

The objective of this analysis was to provide solid quantitative evidence of the impact on all parties involved in the primacy rules, that could mitigate this conflict, and help ENA members understand which rules would deliver the most efficient outcome for consumers.

This is the final report from DNV and contains their conclusions. This work is meant as an independent assessment of the options that exist and as such it will form part of the planning for the solution to dealing with flexibility conflict issues.

WHEN TRUST MATTERS

Impact quantification of primacy rules

Conflict between STOR and ANM

3 July 2023

Report details

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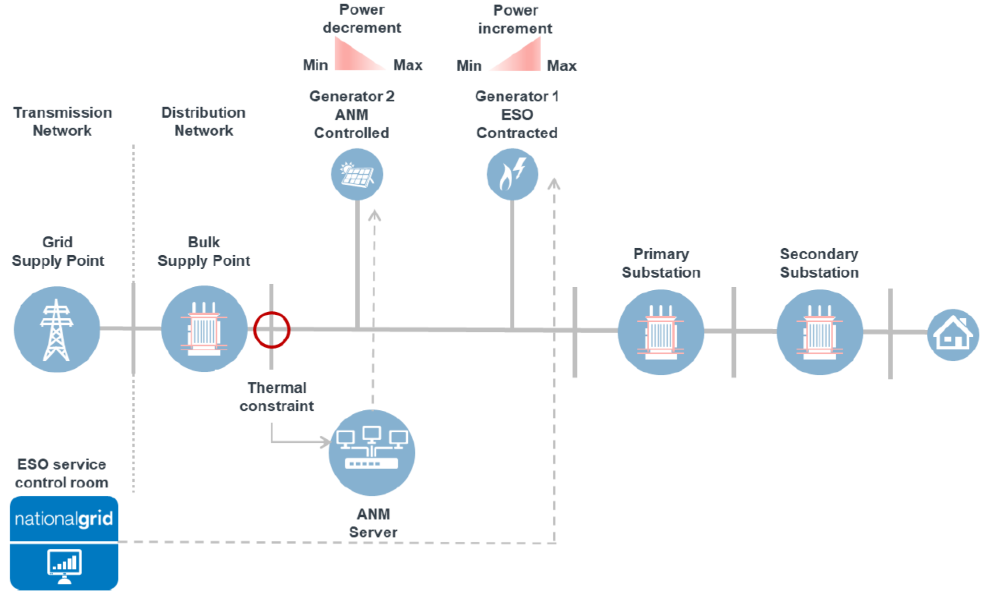
Background

DNV has been commissioned to support ENA Open Network Programme (ONP) Product 5 (P5) under Workstream 1A to develop and assess the potential implementation of the 'primacy rules,' that will be used to manage potential conflicts between NGESO and DSO services.

This study focused on the interaction between Short Term Operating Reserve (STOR) providers and Active Network Management (ANM) generators in the same area where conflicting instructions were issued by NGESO and DNOs: It explored the use case in which NGESO instructed a STOR generating asset to increase power, and subsequently the DNO curtailed a different generator through ANM, which counteracted NGESO-instructed STOR service, as shown below.



Objective

The objective of this project was to provide a solid quantitative analysis of the impact on all parties involved in the primacy rules that would mitigate this conflict, and to help ENA members understand which rules deliver the most efficient outcome for the whole system. The definitions of 'whole system' costs for each rule can be found on slides 37-38.

Scope

The rules suggested by the Product Group and the scope of our study are as follows (all with a static and dynamic variant):

Rule	Description
1	STOR providers excluded (by NGESO) from provision of the service if this coincides with forecast ANM curtailment activity in a given geographical area
2	DNO holds headroom value in ANM Systems to allow STOR to be provided
3	Similar to the principles in rule 1, however, in this case, information would be provided to the market for STOR providers to exclude themselves from participation when ANM activity is forecast in the area
4	NGESO over-procures to help counteract any non-delivery as a result of ANM pullback.
6	NGESO would pay the DNO (and therefore ANM customers or Flex Service Providers) to hold headroom on their ANM systems
7	The STOR provider would pay the DNO (and therefore ANM customers or Flex Service Providers) to hold headroom on the ANM systems

The initial cost-benefit analysis (CBA) performed by DNV in 2022 (Development and impact quantification of primacy rules, DNV) resulted in the dynamic variant of rule 2 being the most cost-efficient rule, however, it also unveiled the complexity choice of the primacy rules and their implementation. There were several elements that could have a significant impact on the results and therefore DNV recommended conducting further analysis. This report explored the following areas:

- The "do nothing" cost and system consequences – what is the counterfactual scenario if no primacy rules are implemented?
- The impact of the STOR product design - how does the length of the availability window and the STOR auction mechanism (pay-as-clear day-ahead 24-hour auctions) impact the primacy rules cost?
- The impact of the quantitative assumptions taken in the initial CBA, such as the CAPEX needed to implement the primacy rules – what are the sensitivities of our assumptions?
- The impact of modelling one ANM area instead of multiple ANM areas in the whole GB – do areas with different energy mix, i.e. curtailment likelihoods, impact the results?
- Are there any other rules of improvements to the current rules that the product group did not consider?

Summary

Evaluating the counterfactual – Why do we need to implement primacy rules?

Counterfactual

In the previous study, we evaluated the primacy rules against a reference case of "no conflict between STOR and ANM" because the scope was to determine what the most cost-effective rule was amongst the suggested rules. However, questions remained on whether the introduction of primacy rules in and of itself would be economic. We recommended additional testing of the business-as-usual scenario (BaU), where the conflict happens and no rule is implemented, to understand the impact it will have not only on costs but also on system reliability.

In this study, we assessed a counterfactual scenario (see Section 5 for detailed analysis). The counterfactual, or 'do nothing' scenario, means that if an ANM conflict happens and DNO curtails certain units, meaning the system will be out of balance and, hence this 'lost' capacity must be secured by NGESO through the Balancing Mechanism (BM) in real-time.

We analysed the extra BM cost that NGESO would incur if the conflict were to occur for the two most extreme scenarios (see Section 2 for a detailed description of all scenarios):

- Scenario 3: the least foreseen conflict due to low STOR and ANM areas overlap and lower ANM curtailment likelihood.
- Scenario 2: near future foreseen conflict due to higher STOR and ANM areas overlap and higher ANM curtailment likelihood.

Results showed that, as expected, the counterfactual whole system costs were lower than the primacy rule implementation cost. This reflected that the rules react on forecast conflict to always maintain the required reserve levels; whereas, in the counterfactual, the system only reacted when the conflict has occurred. However, we also notice that the higher the foreseen conflict, the lower the cost difference between the counterfactual and the rules. In other words, the relation between conflict and the counterfactual cost was not linear.

	Scenario 2 (£m)	Scenario 3 (£m)
Counterfactual	1.4	0.07
Rule 1 ii	36	13
Rule 3 ii	29	5
Rule 4 ii	43	14
Rule 2 ii	39	5
Rule 6 ii	37	14
Rule 7 ii	30	6

Table 1.1. Scenario 3 results

Although the do-nothing scenario is the lower-cost option for now, there are other elements to consider that would impact the whole system:

- **STOR capacity requirements not met:** NGESO has a mandate to have a minimum amount of reserve capacity which is currently procured in the form of STOR. When NGESO cannot fully rely on the response of STOR capacity because this is being counteracted locally, the effective procured capacity will be lower than what is required to comply with the SQSS. With no coordination or rules, it will become increasingly difficult for NGESO to identify the system behaviour and true STOR requirements and procure (STOR) requirements efficiently at a cost to GB.
- **Increase in carbon emissions:** In the do-nothing scenario, the carbon impact will be higher, at a potentially significant cost for GB. Not only ANM generators (mostly renewables) are being curtailed but also additional BM units need to be dispatched to bring the system back to balance.
- **Do nothing will not be future proof:** As more assets connect to the Distribution network it is likely that the level of conflict between Transmission and Distribution will increase. This means that as the network becomes more constrained NGESO will need access to more assets to help with system constraints. This will coincide with the need for DNO's to procure more flexibility services and therefore this may mean that NGESO will be purchasing from the same "pool" as DNOs. This is made more complex due to visibility of assets as well. This effect was not quantified in our analysis but would constitute a potentially significant cost in the future.

As this landscape contains a lot of uncertainty it is difficult to predict precisely how long not using Primacy rules could endure but NGESO expects based on discussions with the networks and their published Flexibility procurement plans, coupled with their own procurement activities to see conflict arising over the next 9-12 months. In using this approach we also took into account the volume of flexibility required, the expected location and general perceived accuracy of the numbers and then took a reasonable view as to when this would emerge or not. We feel that it is likely that conflict may arise in some DNO areas than others and this is more likely in the shorter to medium term. We would not expect it to continue beyond that.

Ultimately, the do-nothing scenario does not correspond with the more coordinated system vision that Ofgem and all the stakeholders have.

Given the qualitative and quantitative analysis, DNV in agreement with the ENA concluded that the implementation of primacy facilitates cost-efficient future system operation for a resilient energy system.

Summary

What primacy rule to implement?

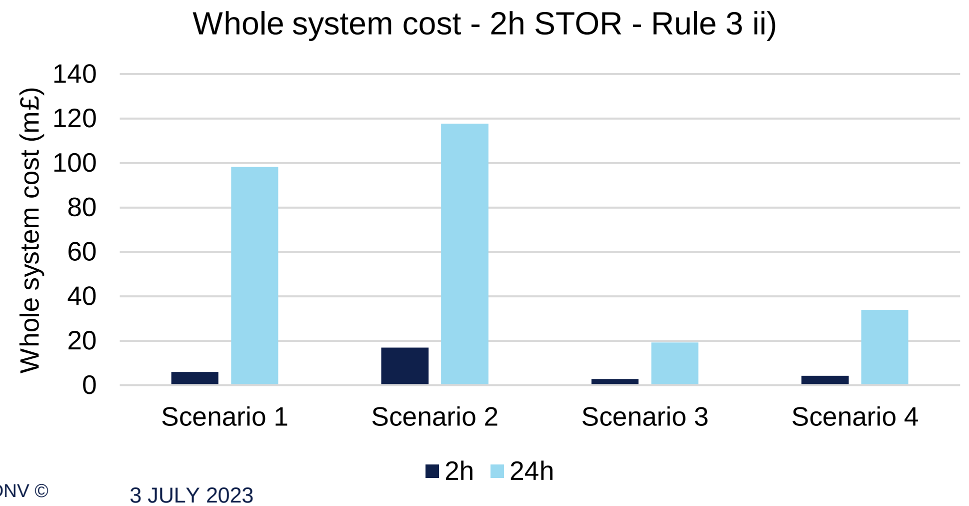
Results – 2hr model

The initial cost benefit analysis (CBA) for a traditional STOR product (24h availability) showed that:

- Under the current STOR market design and assumptions, Rule 2 ii) was the most economic (least cost) to the whole system across all scenarios, because it avoided STOR availability cost and applied dynamic curtailment of ANM generators. Rule 2 ii) gives priority to NGESO to instruct STOR actions at the cost of the DNO holding headroom and eventually curtailing ANM generators to prevent any conflict.
- Because of the STOR pay-as-clear mechanism and the 24-hour contracted availability period, the STOR auction design had a significant impact on the cost for rules in which the STOR merit order was affected. Small movements along the merit order could have a high system-wide cost impact.

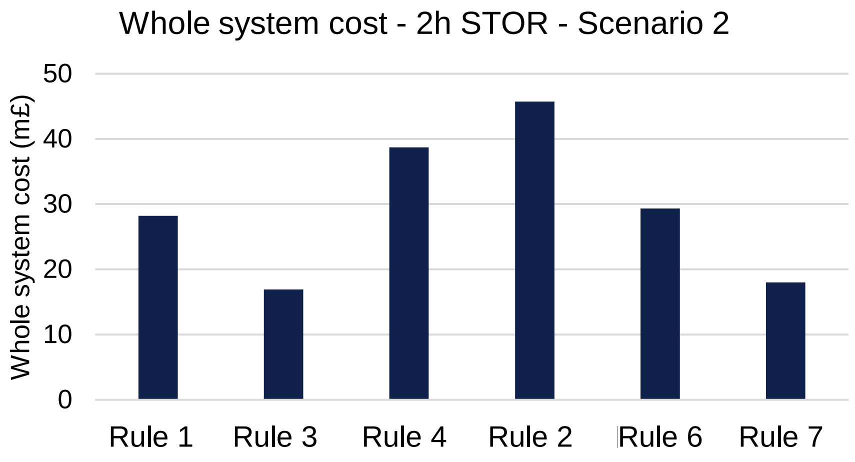
The current STOR product design, therefore, does not allow for a dynamic use of system flexibility and it is foreseen to be replaced by new reserve products to be launched by NGESO. The new reserve products will feature shorter service windows, namely 2-hour periods with slow reserve also featuring one 8-hour service window to simplify management of the service during low demand periods. Therefore, this study explored the impact of the change in the reserve product to 2-hour periods (see Section 3 for the detailed analysis).

The figure below illustrates the significant impact that the length of the STOR availability window has on the results. The figure shows the cost results for 2h and 24h STOR window/auctions for all scenarios (see Section 2 for a detailed description of all scenarios). The most impacted scenarios were the ones with a higher likelihood of curtailment (scenarios 1 and 2).



Modelling the 2-hour STOR window drastically changed the outcome from the previous analysis. The figure below depicts the whole system cost for all the dynamic version (ii) of the rules in the most extreme scenario (scenario 2). Like in the previous CBA, the static version of the rules (i) still performed consistently and significantly worse for most of the rules and therefore is not included in the visualization. The rule that showed the lowest cost in this instance was Rule 3ii, whereas Rule 2ii resulted in the highest cost. Rule 7ii followed rule 3 closely because the rule mechanics are very similar, but the CAPEX and the cost allocation among stakeholders were different.

Rule 3ii gives priority to the DNO on their ANM actions by adapting the STOR procurement. NGESO would inform the STOR providers on the potential conflicting ANM areas, and they would need to remove the STOR units in risk of conflict from their STOR bids.

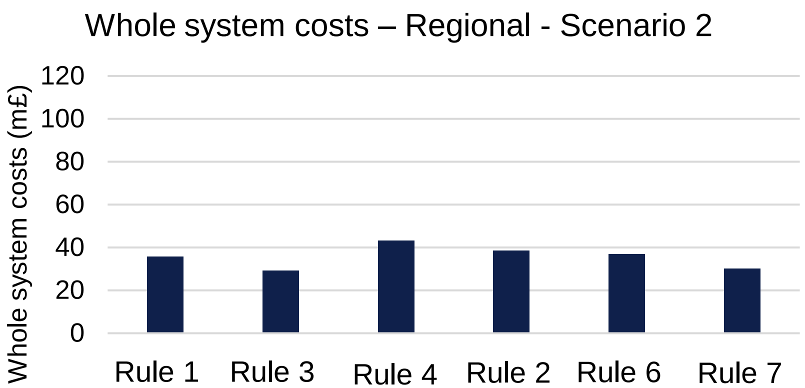


Summary

What primacy rule to implement? (cont.)

Results – 2hr regional model

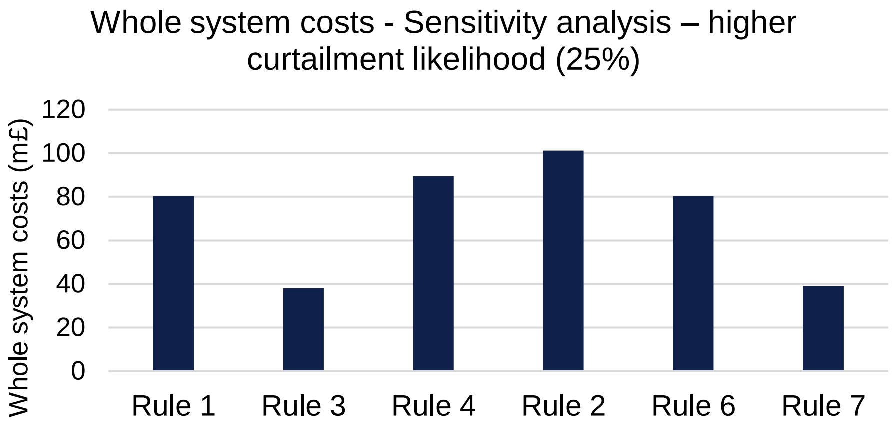
To verify the outcomes of the analysis, the study assessed a more granular ANM modelling by splitting one single ANM area into three distinct ANM areas characterized by different generation mixes (solar dominant, wind dominant and mixed). Section 3 provides a detailed regional analysis. The figure below shows the results for the dynamic version (ii) of all the rules for the most extreme scenario, scenario 2. Rule 3ii was once again the most cost-efficient rule, followed by rule 7ii.



Sensitivity analysis

Finally, the study conducted a sensitivity analysis for the 2hr regional model on a range of parameters (ANM technology mix, CAPEX, % increase in utilisation price), as well as a new scenario with a different curtailment risk matrix, to determine the impact on the whole system cost and whether that would lead to a different outcome. For a detailed analysis see Section 4.

The sensitivity analysis suggested that changes in CAPEX and the STOR utilisation price make, on average, a negligible impact. On the other hand, the likelihood of curtailment made a significant impact on the whole system cost for all rules. See the figure on the right-hand side.



To conclude, having conducted a detailed CBA and a sensitivity analysis, **Rule 3ii was the most cost-efficient primacy rule**. Although Rule 7ii followed it closely, we recommend implementing Rule 3ii because the implementation was simpler and required less capital investment.

Rule 3ii gives priority to the DNO on their ANM actions by adapting the STOR procurement. NGESO would inform the STOR providers of the potential conflicting ANM areas, and they would need to remove the STOR units at risk of conflict from their STOR bids.

Important to note the main purpose of this analysis was to provide a high-level CBA to compare the order of magnitude of the primacy rules. Whilst to implement the optimal solution, further analysis will need to be carried out on the shortlisted option(s).

Summary

Potential rule improvements

New rules

To complete the analysis, we critically reviewed the primacy rules that the ENA product group originally designed, and we suggested potential new rules. See Section 6 for our full analysis.

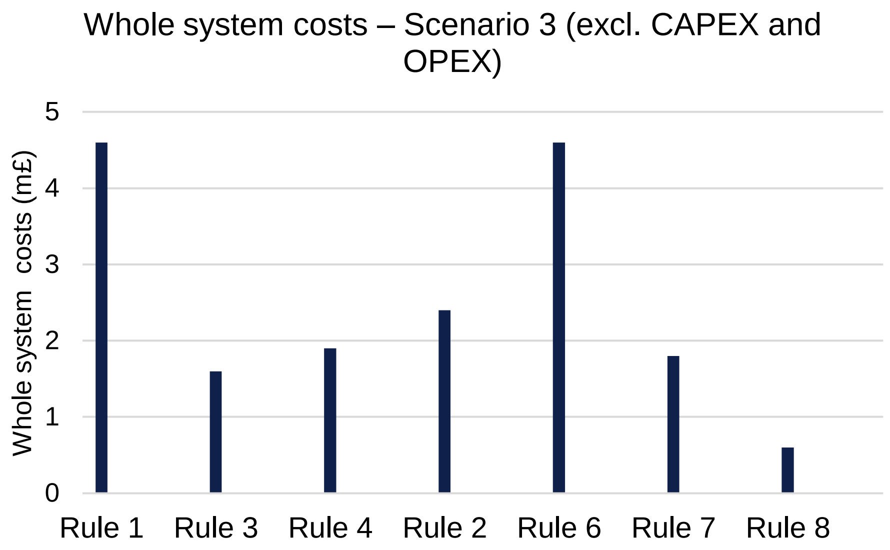
DNV suggested three potential new rules and performed a high-level quantification to assess the cost impact.

Out of the three rules, “Rule 8” resulted in a lower whole system cost, without considering the implementation cost. Rule 8 would effectively facilitate the dynamic choice of different rules based on short-term grid state and cost estimations (see definition below). The facilitation could be done by a central entity, e.g. NGESO (or the future FSO).

In discussion with the ENA, we concluded that the suggested rule would currently be very complex and costly to implement, but that this may change in the future. The complexity is due to the fact that

1. NGESO or the given central entity will need more information to determine the best option in the short term, such as power prices, ANM generators that would be curtailed, etc.
2. A new algorithm would need to be designed to choose the optimal rule,
3. The regulatory implications of this option would need to be explored, and
4. Coordination between NGESO and DNOs will need to be enhanced to facilitate increased data exchanges and allow data processes closer to real time.

Therefore, this concept should be explored at a later stage.



Rule 8: NGESO decides day-ahead whether it is more economical to either 1) exclude all conflicting STOR units from merit order or 2) for the DNOs to hold headroom for the conflicting amount of capacity.

Summary
Recommendations

Recommendations

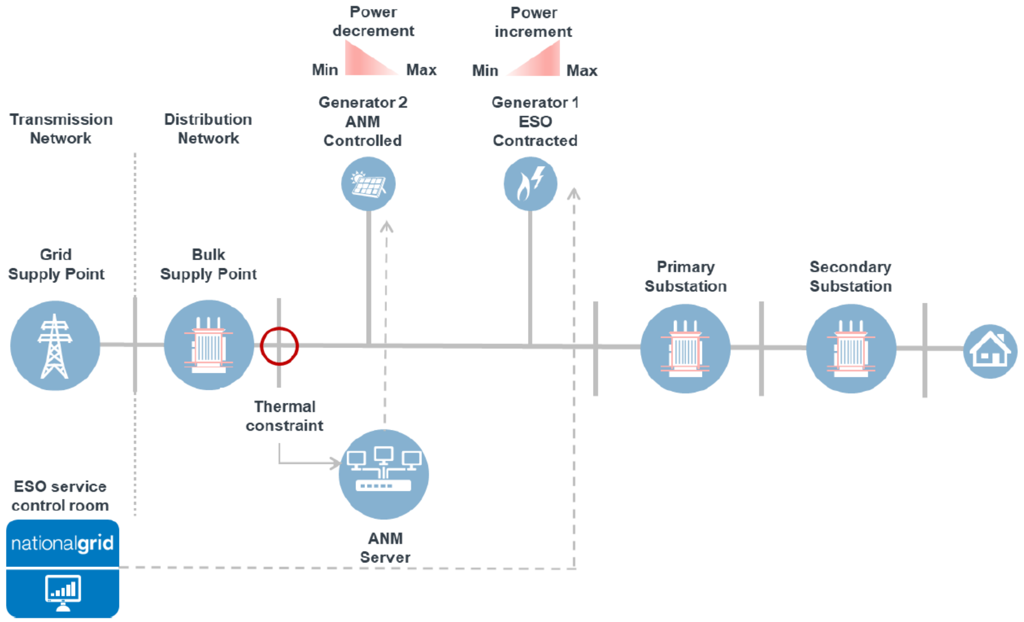
- With the currently estimated frequency of conflict between STOR and ANM generators, it does not make economic sense to implement primacy rules. However, in the medium/long term it will become necessary due to potential STOR reliability problems, the need for a more coordinated system and for a more optimal use of distributed resources.
- The cost-benefit analysis suggested that Rule 3ii was the best-performing rule in terms of whole system costs. The Charging Significant Code Review (SCR) changes that may apply to ANM curtailment would not change this result. Rule 3ii gave priority to the DNO on their ANM actions by adapting the STOR procurement. NGESO would inform the STOR providers of the potential conflicting ANM areas, and they would need to remove the STOR units at risk of conflict from their STOR bids.
- We, therefore, recommended implementing Rule 3ii in the short/medium term in areas where more conflict is foreseen. Consequently, NGESO and DNOs should draw learnings from the local implementation and extend the rule implementation to other ANM areas.
- We also recommended further exploring more dynamic rule choices in the future. According to our analysis, a lower cost can be achieved with further coordination and a dynamic rule selection by a central entity (that can be performed by NGESO – or the FSO in the future). This would inform the choice between DNO and NGESO primacy depending on the cost of each option calculated ex-ante.
- For example, an ongoing innovation Coordinated Operational Methodology for Managing and Accessing Network Distributed Energy Resources (COMMANDER) project is exploring ESO/DSO coordination schemes for accessing and managing DERs, focusing on roles and responsibilities of the key parties involved.
- The next steps for this project is to test some of these rules through the Regional Development Programmes (RDPs), in particular between NGESO and UKPN, as well as NGESO and NGED.

Introduction

Introduction

DNV has been commissioned to support ENA ONP Product 5 (P5) under Workstream 1A to develop and assess the potential implementation of the 'primacy rules,' that will be used to manage potential conflicts between NGESO and DSO services.

This study focused on the interaction between Short Term Operating Reserve (STOR) providers and Active Network Management (ANM) generators in the same area where conflicting instructions were issued by NGESO and DNOs: It explored the use case in which NGESO instructed a STOR-generating asset to increase power, and subsequently, the DNO curtailed a different generator through ANM, which counteracted NGESO-instructed STOR service, as shown below.



The **objective** of this project was to provide a solid quantitative analysis of the impact on all parties involved in the primacy rules that would mitigate this conflict, and to help ENA members understand which rules deliver the most efficient outcome for the whole system. The definitions of 'whole system' costs for each rule can be found on slides 37-38.

The initial cost-benefit analysis (CBA) performed by DNV in 2022 ([Development and impact quantification of primacy rules, DNV]) resulted in the dynamic variant of rule 2 being the most cost-efficient rule, however, it also unveiled the complexity choice of the primacy rules and their implementation. There are several elements that could have a significant impact on the results and therefore DNV recommended conducting further analysis. This report explored the following areas:

- The "do nothing" cost and system consequences – what is the counterfactual scenario if no primacy rules are implemented?
- The impact of the STOR product design - how the length of the availability window and the STOR auction mechanism (pay-as-clear day-ahead 24-hour auctions) impact the primacy rules cost?
- The impact of the quantitative assumptions taken in the initial CBA, such as the CAPEX needed to implement the primacy rules – what are the sensitivities of our assumptions?
- The impact of modelling one ANM area instead of multiple ANM areas in the whole GB – do areas with different energy mix, i.e. curtailment likelihoods, impact the results?
- Are there any other rules of improvements to the current rules that the product group did not consider?

Report structure

The main outcomes and recommendations of this study are summarised in the Executive Summary section above. The rest of the sections serve to describe the detailed quantification and analysis and are structured as follows:

- Section 1 focuses on the rule definition and mechanics;
- Section 2 describes the modelling of the cost benefit analysis and presents the scenarios, assumptions, limitations and impacts per stakeholder;
- Section 3 presents the results of the cost benefit analysis;
- Section 4 depicts the results of the CBA sensitivity analysis;
- Section 5 includes the counterfactual assessment, i.e. the quantification and analysis of the do-nothing scenario; and
- Section 6 describes alternative primacy rules, suggested by DNV to complete any potential gaps or rules that were not included in the initial analysis.

Section 1 - Primacy rules definition

1. Overview of primacy rules

DNO primacy, NGESO primacy and joint primacy rules

This Section includes the detailed ENA proposed primacy rule mechanics and process flows.

The exercise considered all the potential rules that were suggested by the product group. The aim was not to explore only options perceived as efficient or implementable in the shot-term, but to explore the merits and drawbacks across.

The tables below present an overview of the primacy rules to be explored in this study, categorised depending on whether DNO has primacy, NGESO has primacy or the rule can result in either NGESO or DNO having primacy. Each rule has two variants, i) and ii), described below. It is assumed that all rules could feasibly be implemented in practice.

DNO primacy[1]	NGESO primacy[1]	Joint primacy
RULE 1 • **STOR providers excluded (by NGESO)** from provision of the service if this coincides with **forecast ANM curtailment** activity in a given geographical area	**RULE 2** **DNO holds headroom** value in ANM Systems **to allow STOR to be provided**	**RULE 6** **NGESO would pay** the DNO (and therefore ANM customers or Flex Service Providers) **to hold headroom on their ANM systems**
RULE 3 • Similar to the principles in rule 1, however, in this case**, information would be provided to the market for STOR providers to exclude themselves** from participation when ANM activity is forecast in the area		**RULE 7** **The STOR provider would pay** the DNO (and therefore ANM customers or Flex Service Providers) **to hold headroom on the ANM systems**
RULE 4 • **NGESO over-procures** to help counteract any non-delivery as a result of ANM pullback.		

Types of forecast for DNO has primacy rules	Types of headroom for NGESO primacy and joint primacy rules[2]
i) Static forecast – if the DNO curtailment shows any potential for ANM activity, the rule would apply.	i) Static headroom – headroom always held in areas where ANM and STOR providers exist. This allows for simple systems, but means holding more headroom.
ii) Dynamic forecast – A threshold of curtailment would be agreed (as an example), above which the rule would apply.	ii) Dynamic headroom – headroom only held which equates to volume of STOR successful in Day Ahead (DA) auction. Requires more complex integration of systems

**1] The numbering of the rules is legacy from previous work developed by ENA. There are 6 rules in total numbered 1-7, there is no rule 5. 2] Option c) dynamic headroom held by an independent party that handles the payment transfers is considered out of scope.*

1. Primacy rules definition

DNO has primacy rule mechanics

RULE 1 – STOR providers excluded (by NGESO) from provision of the service if this coincides with forecast ANM curtailment activity in a given geographical area

i) Static forecast

Long-term

- STOR assets are prequalified or discontinued. When prequalifying an aggregated unit, NGESO is informed of what assets compose that unit, and in which area they are connected.
- The DNO has a final list of ANM connection agreements that can be enforced.

Day-ahead

- The DNO informs NGESO on a long-term basis of what are the ANM areas.
- **NGESO excludes the STOR providers located in those ANM areas from participating in the STOR DA auction.**
- Aggregated units with assets in ANM areas are removed altogether (no de-rating), so none of the assets composing that unit would be able to participate. This is because when dispatching, NGESO would have no visibility regarding which assets within the aggregated units would be used. Therefore, for rule 1a) NGESO is certain the STOR service will not be counteracted.
    - This differentiates rule 1 and 3, as in rule 3 aggregated units with assets in ANM areas can participate if the STOR provider ensures that assets to be activated are not those in the ANM areas.
- Then, the STOR provider issues the bids from the DA auction, and STOR services are procured by NGESO.

Intraday

- When needed, STOR is activated by NGESO

Real time

- If needed by NGESO, STOR is dispatched by the STOR provider.
- If needed by the DNO, ANM is dispatched causing an ANM generator to be curtailed.

Process flow legend

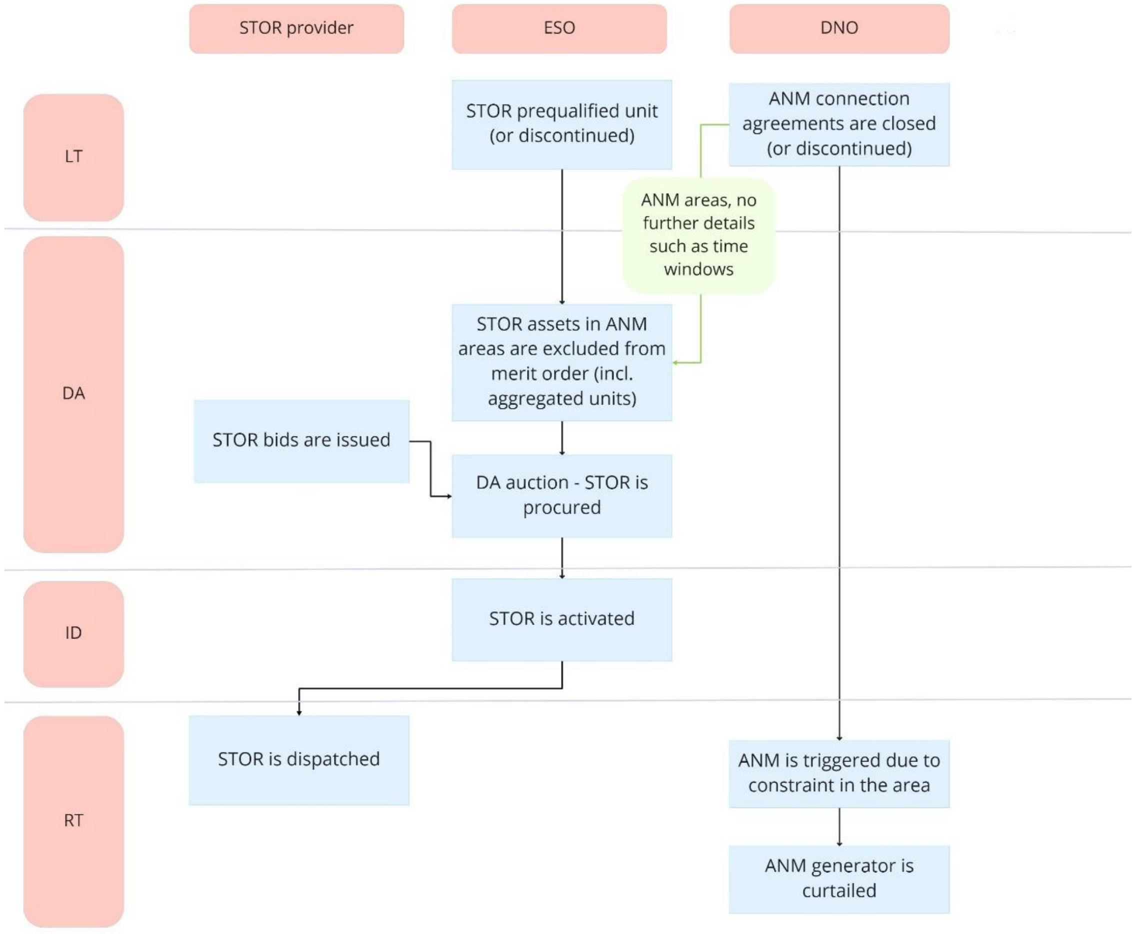


Figure 1.1 – Rule 1 i) process flow

1. Primacy rules definition

DNO has primacy rule mechanics

RULE 1 – STOR providers excluded (by NGESO) from provision of the service if this coincides with forecast ANM curtailment activity in a given geographical area

ii) Dynamic forecast

Long-term

- STOR assets are prequalified or discontinued. When prequalifying an aggregated unit, NGESO is informed of what assets compose that unit, and in which area they are connected.
- ANM connection agreements are closed or discontinued.

Day-ahead

- The DNO forecasts ANM curtailment activity, among other elements this forecast should be based on forecast of STOR dispatch or historical STOR dispatch data. The forecast is assumed to have a certain level of accuracy so that system reliability is maintained, and therefore it should include forward-looking growth.
- The DNO informs NGESO of which ANM areas expect ANM activation and when this activation is expected to happen on a half-hourly basis (HH).
- NGESO excludes the STOR providers located in those ANM areas from participating in the STOR DA auction.
- Aggregated units with assets in ANM areas are removed altogether (no de-rating), so none of the assets composing that unit would be able to participate. This is because when dispatching, NGESO would have no visibility regarding which assets within the aggregated units would be used, therefore, for rule 1a) NGESO is certain the STOR service will not be counteracted.
- Then, the STOR provider issues the bids for the DA auction, and STOR services are procured by NGESO.

Intraday

- When needed, STOR is activated by NGESO

Real time

- STOR is dispatched by the STOR provider.
- If needed by the DNO, ANM is dispatched causing an ANM generator to be curtailed. The possibility of an unforeseen need to activate an ANM generator located in the same ANM area than a STOR provider, for e.g., due to a fault or due to communication discontinuity, means that there is a small chance for STOR and ANM service counteraction. The chances of this type of events (i.e., curtailment due to unforeseen circumstances) have been quantified based on historical data and have been considered marginal for this analysis – hence this rule would maintain same system reliability.
  - This possibility is common to the DNO has primacy ii) dynamic rules.

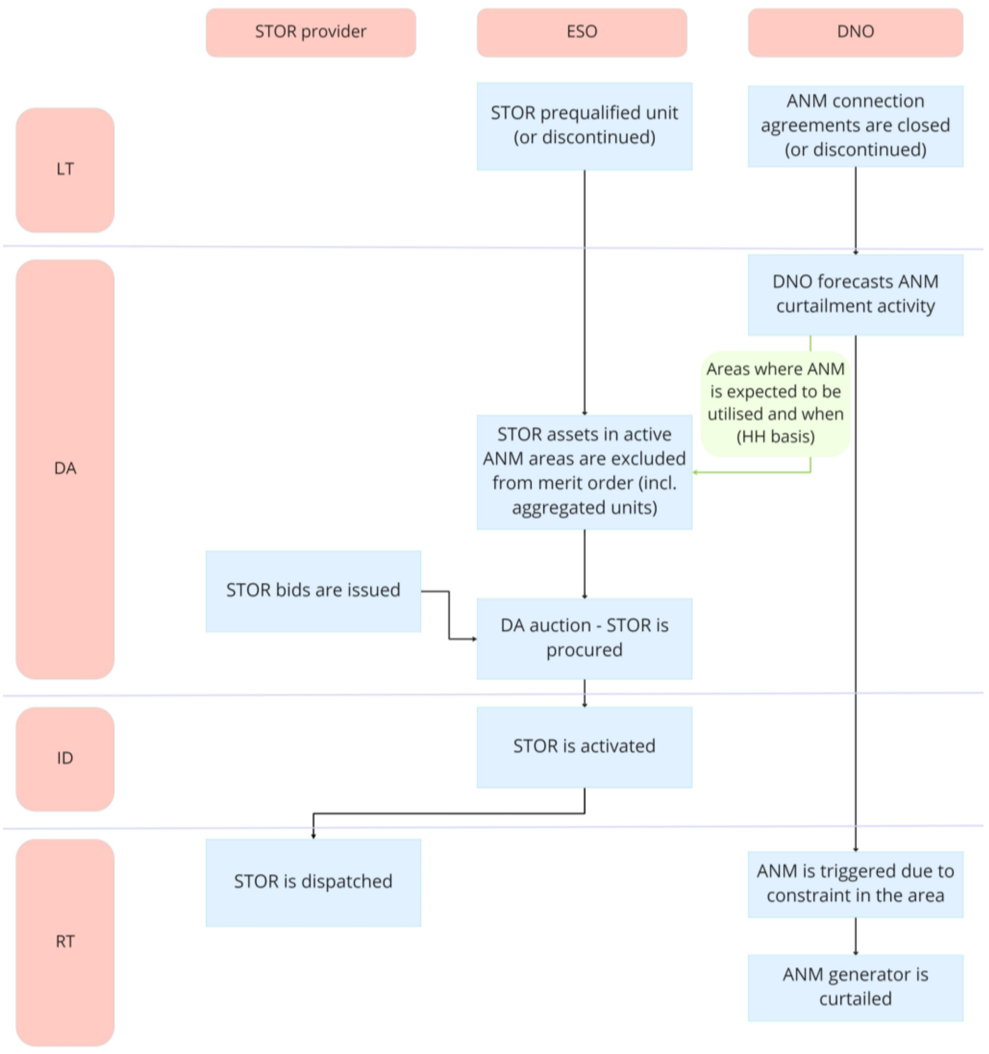


Figure 1.2 – Rule 1 ii) process flow

1. Primacy rules definition

DNO has primacy rule mechanics

RULE 3 – Similar to the principles in rule 1, however, in this case, information would be provided to the market for STOR providers to exclude themselves from participation when ANM activity is forecast in the area

i) Static forecast

Long-term

- STOR assets are prequalified or discontinued. When prequalifying an aggregated unit, NGESO is informed of what assets compose that unit, and in which area they are connected.
- ANM connection agreements are closed or discontinued.

Day-ahead

- The DNO informs the STOR provider on a long-term basis of what are the ANM areas.
- The STOR provider excludes itself from participating in the STOR DA auction if its unit is in an ANM area.
- Aggregated units with assets in ANM areas can participate if the STOR provider ensures that assets to be activated are not those in the ANM areas.
- Then, STOR providers issue the bids for the DA auction, and STOR services are procured by NGESO.

Intraday

- When needed, STOR is activated by NGESO

Real time

- If needed by NGESO, STOR is dispatched by the STOR provider.
- If needed by the DNO, ANM is dispatched causing an ANM generator to be curtailed.

Ex-post

- The DNO informs NGESO about the ANM areas on a long-term basis, for NGESO to the carry out the STOR validation and settlement. Penalisations could be introduced to ensure adherence to the process.

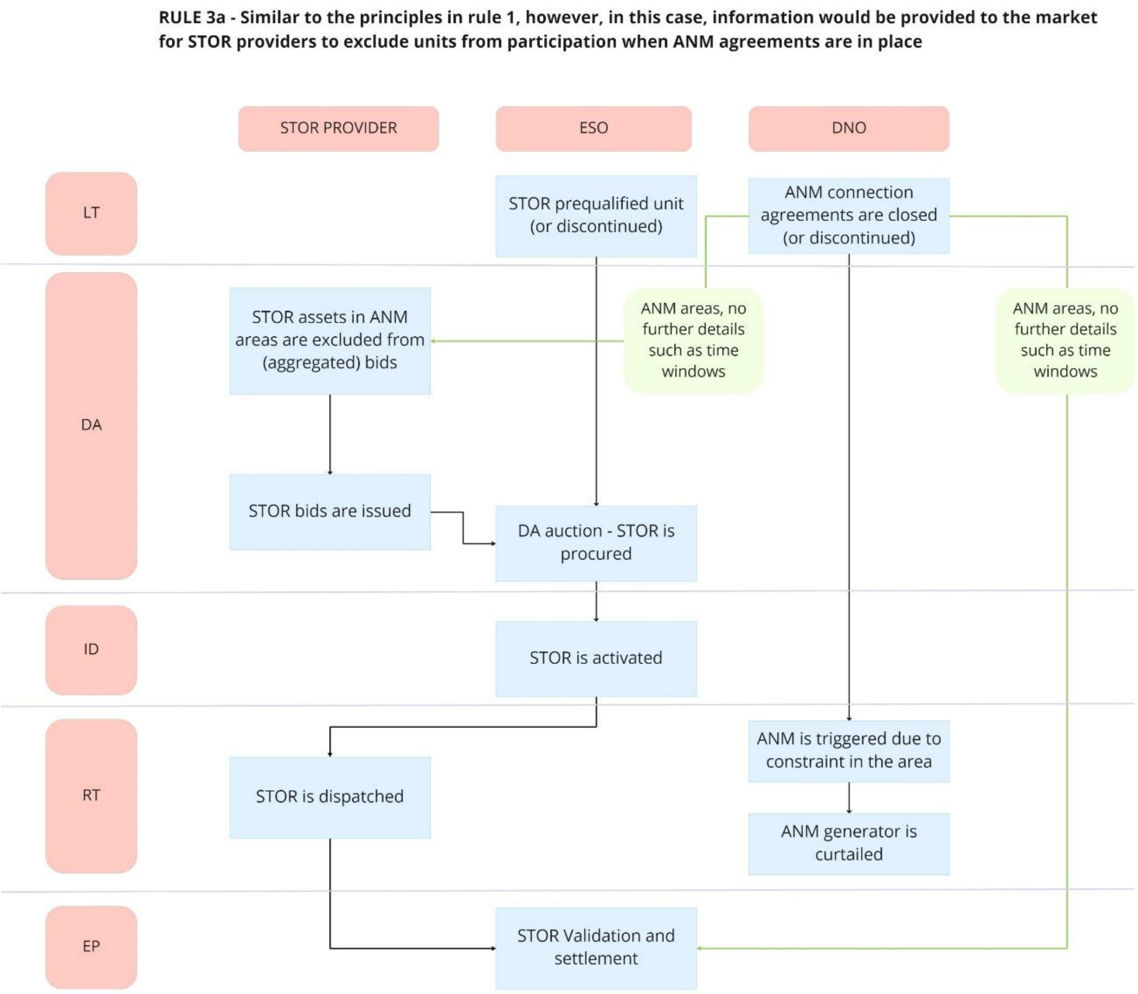


Figure 1.3 – Rule 3 i) process flow

1. Primacy rules definition

DNO has primacy rule mechanics

RULE 3 – Similar to the principles in rule 1, however, in this case, information would be provided to the market for STOR providers to exclude themselves from participation when ANM activity is forecast in the area

ii) Dynamic forecast

Long-term

- STOR assets are prequalified or discontinued. When prequalifying an aggregated unit, NGESO is informed of what assets compose that unit, and in which area they are connected.
- ANM connection agreements are closed or discontinued.

Day-ahead

- The DNO forecasts ANM curtailment activity. It is assumed the forecast is accurate.
- The DNO informs the STOR provider of which ANM areas expect ANM activation and when this activation is expected to happen on a half-hourly basis (HH). The STOR provider excludes itself from participating in the STOR DA auction if its unit is in an ANM area.
- Aggregated units with assets in ANM areas can participate if the STOR provider ensures that assets to be activated are not those in the ANM areas.
- Then, STOR providers issue the bids for the DA auction, and STOR services are procured by NGESO.

Intraday

- When needed, STOR is activated by NGESO

Real time

- If needed by NGESO, STOR is dispatched by the STOR provider.
- If needed by the DNO, ANM is dispatched causing an ANM generator to be curtailed.

Ex-post

- The DNO informs NGESO about the ANM areas on a long-term basis, for NGESO to the carry out the STOR validation and settlement.

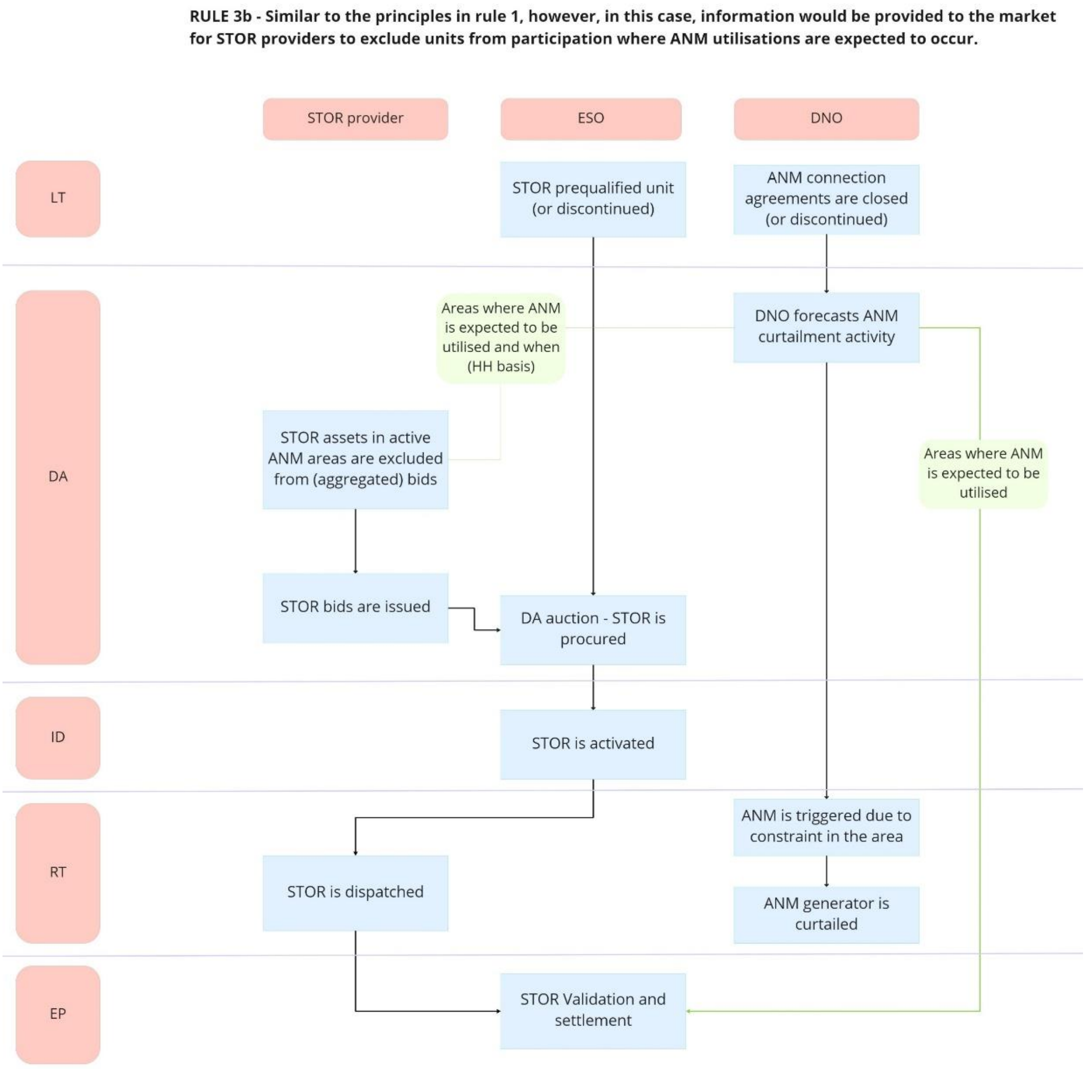


Figure 1.4 – Rule 3 ii) process flow

1. Primacy rules definition

DNO has primacy rule mechanics

RULE 4 – NGESO over-procures to help counteract any non-delivery as a result of ANM pullback.

Rule 4 i) can not be fairly compared with the rest of the rules as its implementation would result in worse system reliability than the other rules. This is because the lack of information exchange in real time might cause that the over-dispatch of STOR is not counteracted by ANM and causes further balancing problems. Therefore, Rule 4 i) is only assessed qualitatively, and is not included in the CBA calculations.

i) Static forecast

Long-term

- STOR assets are prequalified or discontinued. When prequalifying an aggregated unit, NGESO is informed of what assets compose that unit, and in which area they are connected.
- ANM connection agreements are closed or discontinued.
- The DNO informs NGESO of what are the ANM areas.

Day-ahead

- The STOR provider issues the bids for the DA auction
- NGESO calculates the over-procurement needs assessing the bids with the ANM area information.
- In the DA auction, NGESO procures STOR services.

Intraday

- When needed, STOR is activated by NGESO. When NGESO foresees ANM counteraction of one of the activated STOR services, it over-activates to ensure the constraint for which the STOR service was activated is resolved.

Real time

- STOR is dispatched by the STOR provider.
- In some cases when there is a high likelihood of ANM activation, the of STOR service is what triggers ANM activation. This STOR and ANM activations are counteracted, and a second ANM generator needs to be curtailed.

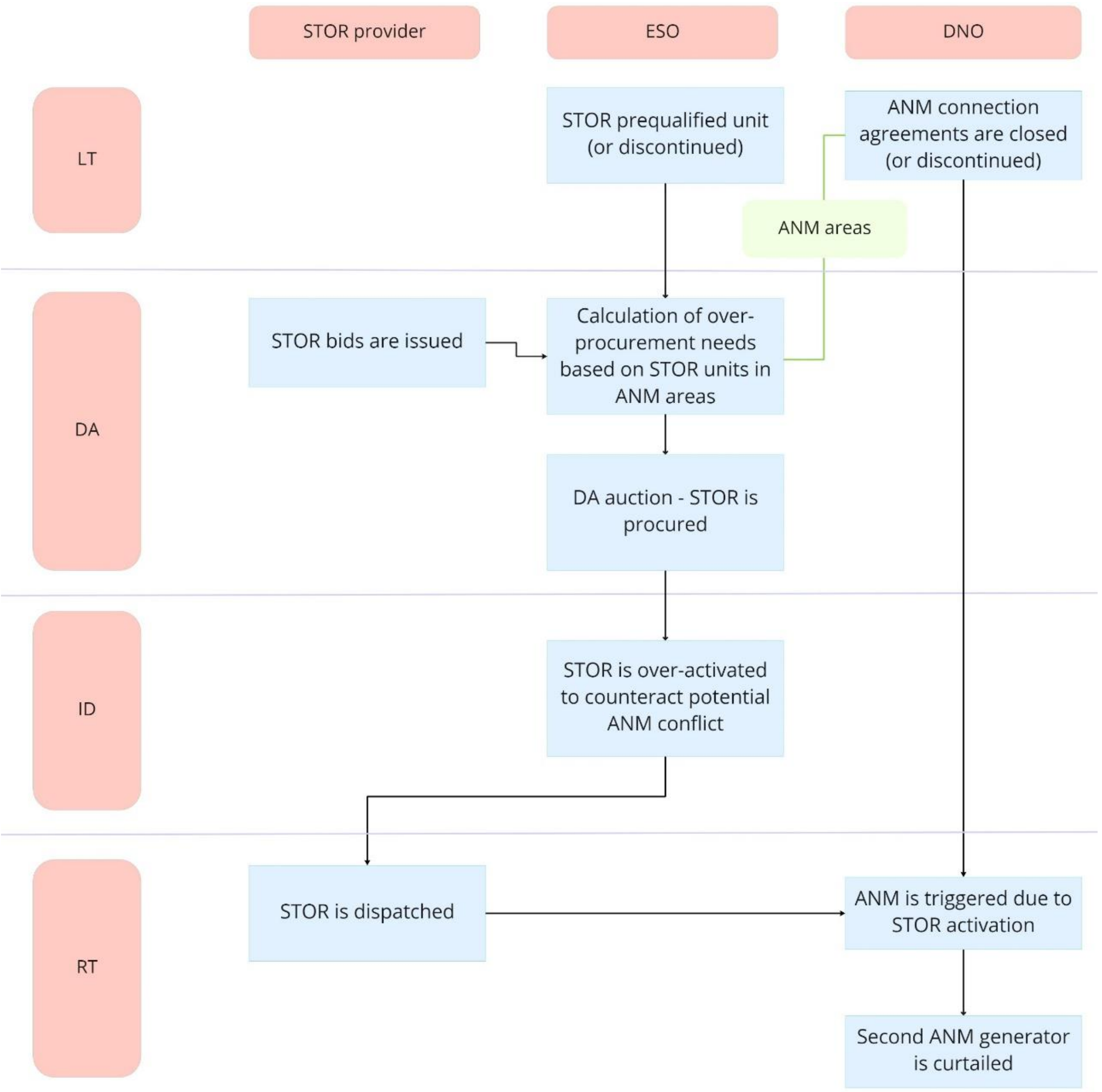


Figure 1.5 – Rule 4 i) process flow

1. Primacy rules definition

DNO has primacy rule mechanics

RULE 4 – NGESO over-procures to help counteract any non-delivery as a result of ANM pullback.

This rule mitigates the effect of the STOR and the ANM service counteraction, rather than explicitly addressing the issue.

There is a risk that the over-dispatching of STOR could create a system imbalance. Nonetheless, as in Rule 4 ii) there is near real-time information exchange with forecasts that are assumed to be perfect for the purpose of the exercise. Therefore, the rule is considered to be sufficiently reliable.

ii) Dynamic forecast

Long-term

- STOR assets are prequalified or discontinued. When prequalifying an aggregated unit, NGESO is informed of what assets compose that unit, and in which area they are connected.
- ANM connection agreements are closed or discontinued.

Day-ahead

- The DNO forecasts ANM curtailment activity, among other elements this forecast should be based on forecast of STOR dispatch or historical STOR dispatch data in the ANM area. The forecast is assumed to have a certain level of accuracy so that system reliability is maintained.
- The DNO informs NGESO of what are the ANM areas, including the likelihood of utilisation of the ANM in those areas.
- The STOR provider issues the bids for the DA auction
- In the DA auction, NGESO over-procures, considering the potential counteraction of the STOR services with the likelihood of ANM utilisation.

Intraday

- When needed, STOR is activated by NGESO. When NGESO foresees ANM counteraction of one of the activated STOR services, it over-activates to ensure the constraint for which the STOR service was activated is resolved.

Real time

- STOR is dispatched by the STOR provider.
- In some cases when there is a high likelihood of ANM activation, the of STOR service is what triggers ANM activation. This STOR and ANM activations are counteracted, and a second ANM generator needs to be curtailed.

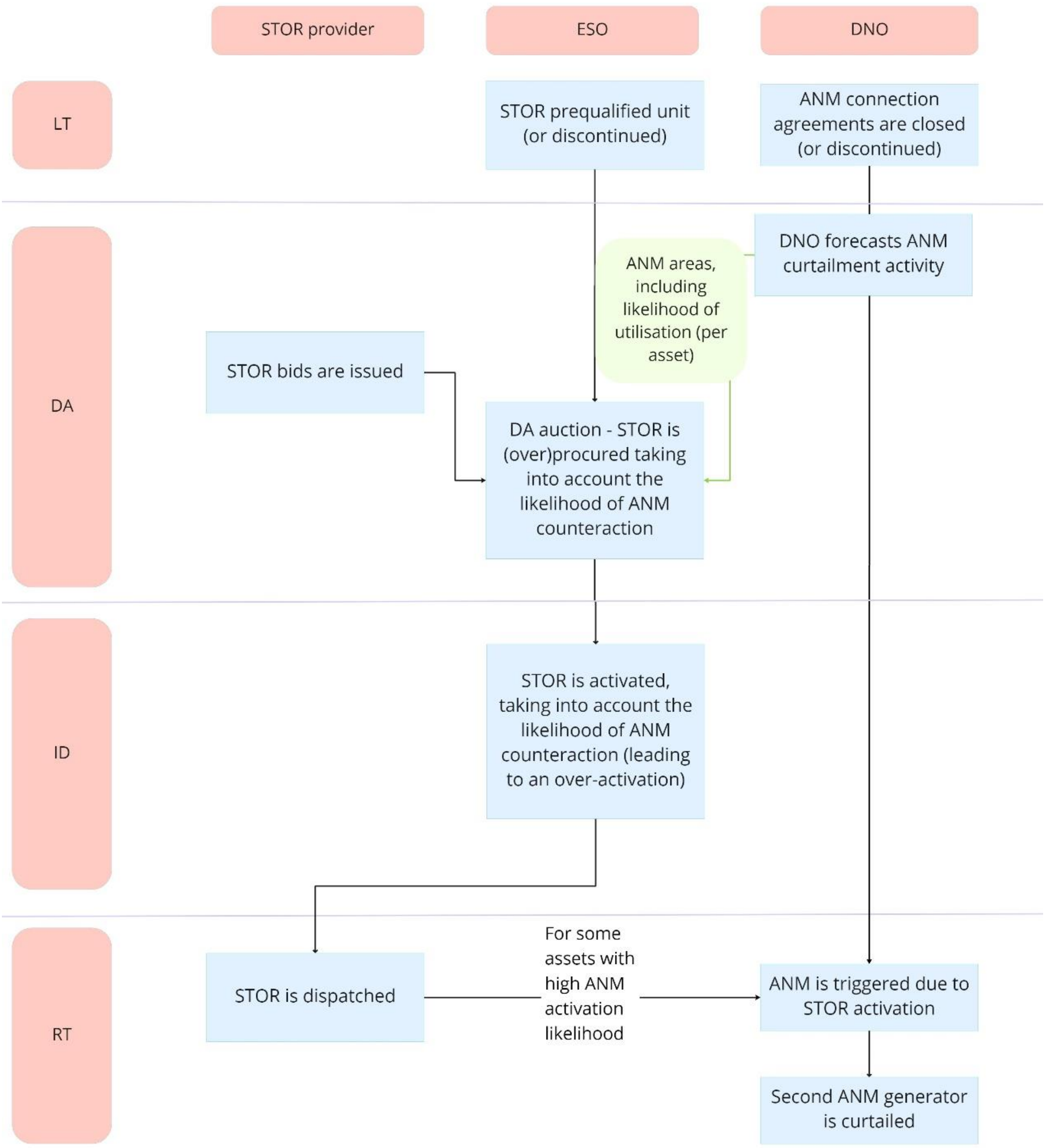


Figure 1.6 – Rule 4 ii) process flow

1. Primacy rules definition

NGESO has primacy rule mechanics

RULE 2 – DNO holds headroom value in ANM Systems to allow STOR to be provided

It is assumed that the technology that would allow the implementation of this rule is in place.

i) Static headroom

Long-term

- STOR assets are prequalified or discontinued. When prequalifying a unit, NGESO is informed of their volume, area connected and if aggregated, what assets compose the unit.
- ANM connection agreements are closed or discontinued.
- NGESO informs the DNO what STOR assets are prequalified and their sites. It is assumed that the prequalified STOR unit list is up to date when used/needed by the DNO and stays constant during a certain time period.
- The DNO configures the ANM system to hold headroom for STOR activations for all the prequalified assets.
  - Headroom is created by the DNO by modifying the triggering thresholds for ANM activations to a lower level of power measurements and removing the associated points from the total (e.g., from 100% to 80% asset rating). Then, as soon as the SCADA measuring point sees the network export exceed the new lower threshold it would curtail generation, leaving STOR activations excluded from this curtailment calculation. This is considered doable, requiring significant development effort with longer lead times, real time monitoring, alignment with policy guidance and communication. It is assumed the technology that would allow the implementation of this rule to be in place.

Day-ahead

- STOR providers issue the bids for the DA auction, and STOR services are procured by NGESO.

Intraday

- When needed, STOR is activated by NGESO

Real time

- STOR is dispatched by the STOR provider.
- The STOR provider informs the DNO of the STOR activations, power, start and end time
- ANM can be triggered and activated.
  - However, if the load increase is caused by STOR activations, ANM would not be activated.

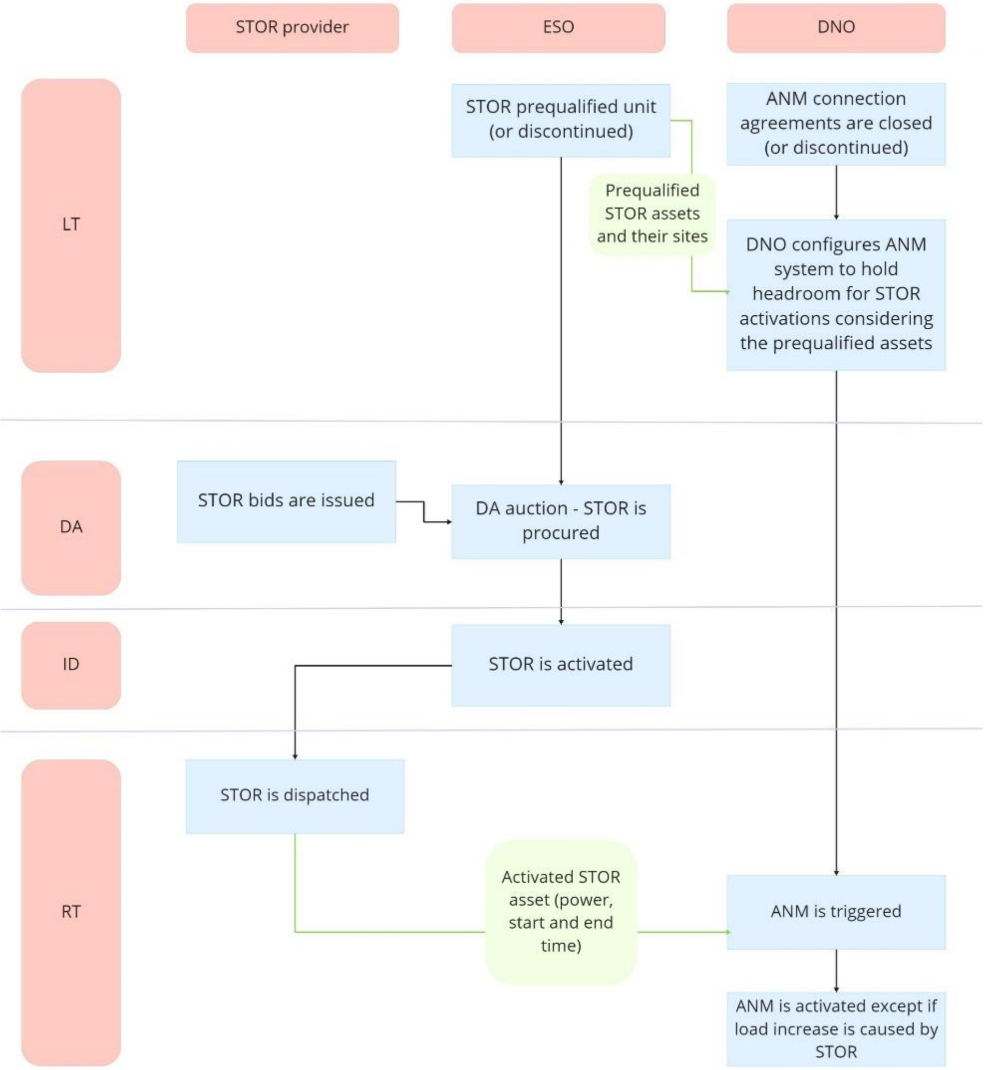


Figure 1.7 – Rule 2 i) process flow

1. Primacy rules definition

NGESO has primacy rule mechanics

RULE 2 – DNO holds headroom value in ANM Systems to allow STOR to be provided

ii) Dynamic headroom

Long-term

- STOR assets are prequalified or discontinued. When prequalifying a unit, NGESO is informed of their volume, area connected and if aggregated, what assets compose the unit.
- ANM connection agreements are closed or discontinued.

Day-ahead

- STOR providers issue the bids for the DA auction, and STOR services are procured by NGESO.
- The DNO configures the ANM system to hold headroom for STOR activations considering the STOR volumes procured. . The DNO informs the Balance Responsible Party (BRP) of the expected curtailment volumes.
  - Headroom is created by the DNO by modifying the triggering thresholds for ANM activations to a lower level of power measurements and removing the associated points from the total (e.g., from 100% to 80% asset rating). Then, as soon as the SCADA measuring point sees the network export exceed the new lower threshold it would curtail generation, leaving STOR activations excluded from this curtailment calculation. This is considered doable, requiring development effort that would take time, real time monitoring, alignment with policy guidance and communication. It is assumed the technology that would allow the implementation of this rule to be in place.

Intraday

- When needed, STOR is activated by NGESO. The BRP[1] redispatches the curtailed volumes.

Real time

- STOR is dispatched by the STOR provider.
- The STOR provider informs the DNO of the STOR activations, power, start and end time
- ANM can be triggered and activated.
  - However, if the load increase is caused by STOR activations, ANM would not be activated.

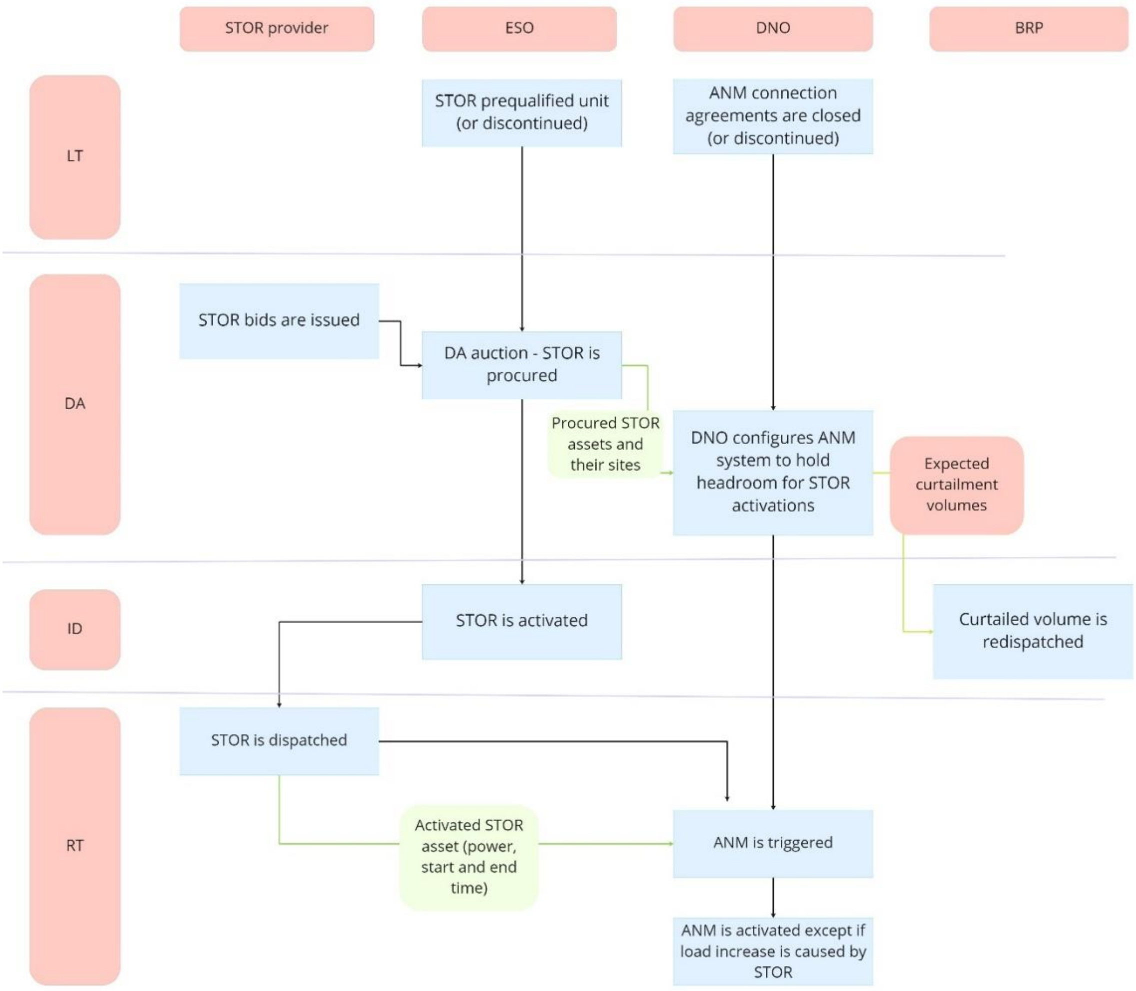


Figure 1.8 – Rule 2 ii) process flow

[1] Redispatch means an adjustment from the active power feed-in from power plants to avoid or resolve occurring congestion.

1. Primacy rules definition

Joint primacy rule mechanics

RULE 6 – NGESO would pay the DNO (and therefore ANM customers or FSP) to hold headroom on their ANM systems

i) Static headroom

Long-term

- STOR assets are prequalified or discontinued. When prequalifying a unit, NGESO is informed of their volume, area connected and if aggregated, what assets compose the unit.
- ANM connection agreements are closed or discontinued.
- NGESO informs the DNO what STOR assets are prequalified and their sites. It is assumed that the prequalified STOR unit list is up to date when used/needed by the DNO and stays constant during a certain time period.
- The DNO configures the ANM system to hold headroom for STOR activations for all the prequalified assets and calculates its cost. Please find an explanation of how headroom is created in rule 2.

Day-ahead

- STOR providers issue the bids for the DA auction, and STOR services are procured by NGESO. Since the headroom cost is fixed , the merit order is unaffected.

Intraday

- When needed, STOR is activated by NGESO

Real time

- STOR is dispatched by the STOR provider.
- The STOR provider informs the DNO of the STOR activations, power, start and end time
- ANM can be triggered and activated. However, if the load increase is caused by STOR activations, ANM would not be activated.

Ex post

- NGESO carried out the validation and settlement.
- The calculation on the volume of headroom needed, informs the ANM headroom compensation that NGESO needs to pay the DNO.
- The DNO then invoices NGESO for this cost, and NGESO proceeds with the payment.

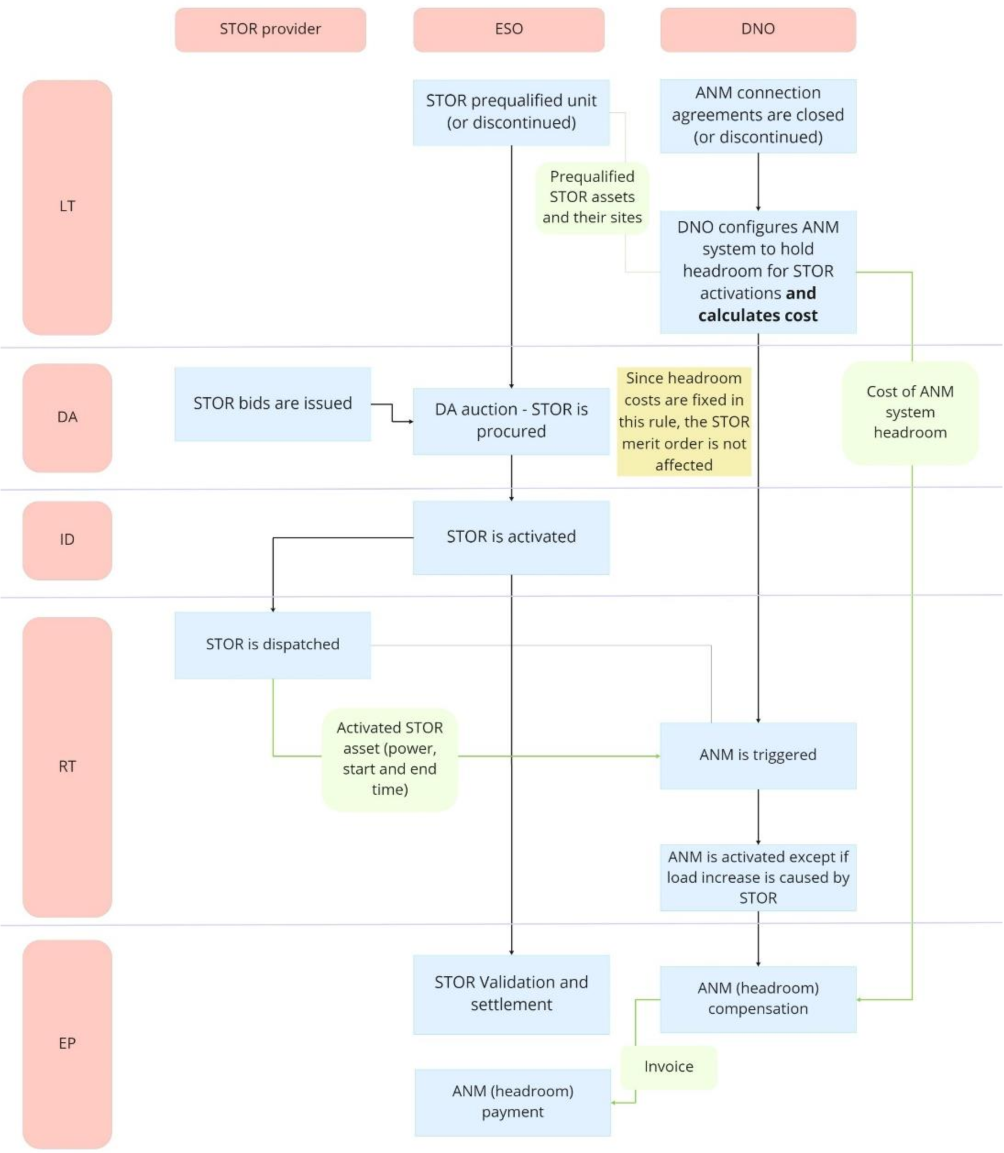


Figure 1.9 – Rule 6 i) process flow

1. Primacy rules definition

Joint primacy rule mechanics

RULE 6 – NGESO would pay the DNO (and therefore ANM customers or Flex Service Providers) to hold headroom on their ANM systems

ii) Dynamic headroom

Long-term

- STOR assets are prequalified or discontinued. When prequalifying a unit, NGESO is informed of their volume, area connected and if aggregated, what assets compose the unit.
- ANM connection agreements are closed or discontinued.

Day-ahead

- NGESO informs the DNO what STOR assets are prequalified and their sites. It is assumed that the prequalified STOR unit list is up to date when used/needed by the DNO and stays constant during a certain time period.
- The DNO forecasts the ANM curtailment activity and calculation of headroom cost and informs NGESO of the next day's ANM headroom cost per MWh for STOR assets in ANM areas.
- STOR providers issue the bids for the DA auction and NGESO adds the ANM cost to the bids in the merit order. Then, STOR services are procured by NGESO.
- The DNO configures the ANM system to hold headroom for STOR activations for all the prequalified assets and calculates its cost. Please find an explanation of how headroom is created in rule 2. The DNO informs the BRP of the expected curtailment volumes.

Intraday

- When needed, STOR is activated by NGESO. The BRP[1] redispatches the curtailed volumes.
- **Real time**
- STOR is dispatched by the STOR provider. The STOR provider informs the DNO of the STOR activations, power, start and end time
- ANM can be triggered and activated. However, if the load increase is caused by STOR activations, ANM would not be activated.

Ex post

- NGESO carried out the validation and settlement.
- The calculation on the volume of headroom needed, informs the ANM headroom compensation that NGESO needs to pay the DNO.
- The DNO then invoices NGESO for this cost, and NGESO proceeds with the payment.

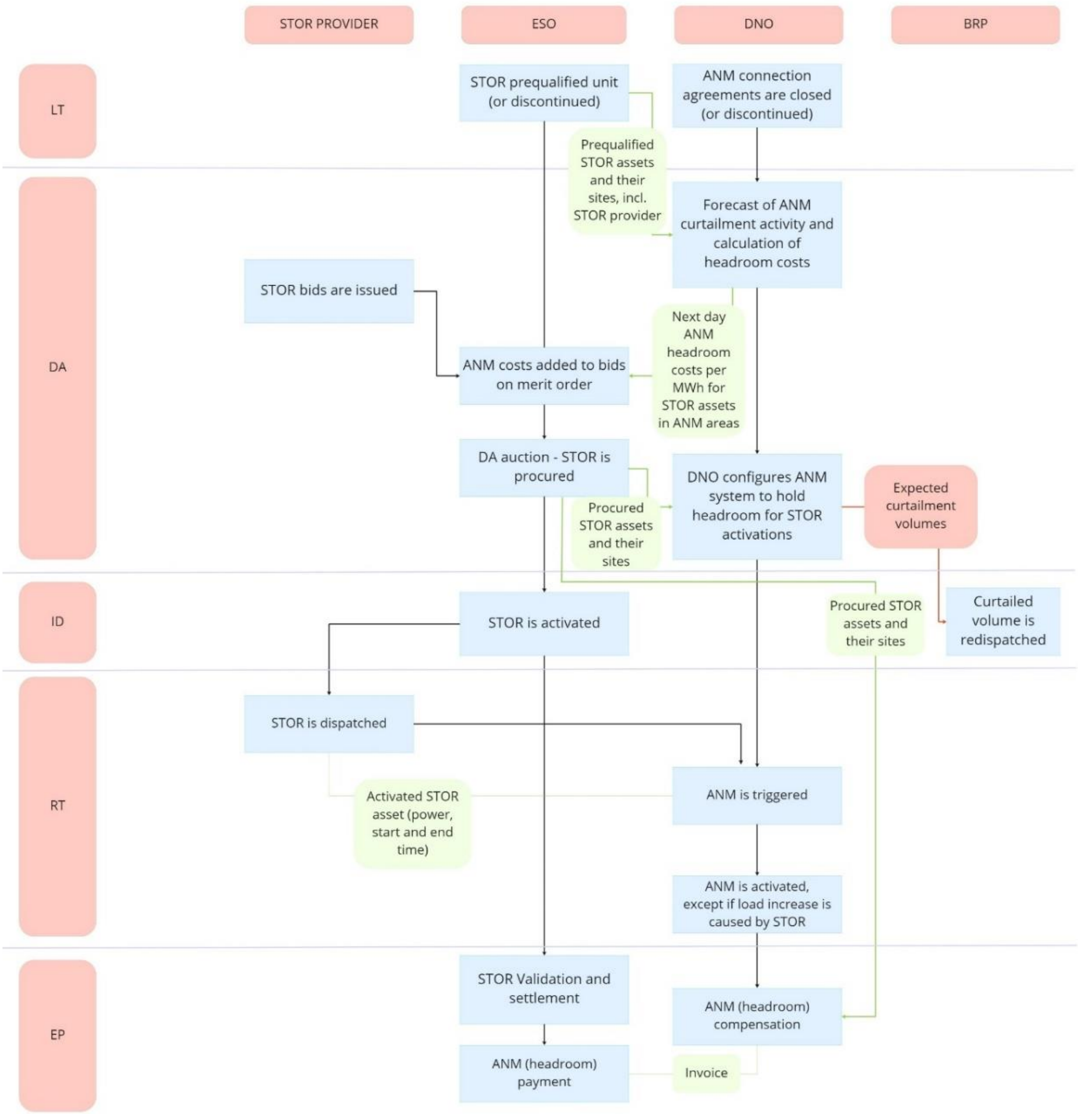


Figure 1.10 – Rule 6 ii) process flow

[1] Redispatch means an adjustment from the active power feed-in from power plants to avoid or resolve occurring congestion.

1. Primacy rules definition

Joint primacy rule mechanics

RULE 7 – The STOR provider would pay the DNO (and therefore ANM customers or Flex Service Providers) to hold headroom on the ANM systems

i) Static headroom

Long-term

- STOR assets are prequalified or discontinued. When prequalifying a unit, NGESO is informed of their volume, area connected and if aggregated, what assets compose the unit.
- ANM connection agreements are closed or discontinued.
- NGESO informs the DNO what STOR assets are prequalified and their sites. It is assumed that the prequalified STOR unit list is up to date when used/needed by the DNO and stays constant during a certain time period.
- The DNO configures the ANM system to hold headroom for STOR activations for all the prequalified assets and calculates its cost. Please find explanation of how headroom is created in rule 2.
- The DNO informs the STOR provider of the ANM headroom cost per MW and year for STOR assets in ANM areas. The DNO calculates the costs based on affected generation (MWh) using DA prices (this could be done with forecasts or using historical DA prices).
- Then, the STOR provider adds the ANM headroom cost to the STOR assets. Since headroom cost are fixed in this rule, assets may be discontinued from STOR once these fixed cost are known to the STOR provider.

Day-ahead

- STOR providers issue the bids for the DA auction, and STOR services are procured by NGESO.

Intraday

- When needed, STOR is activated by NGESO

Real time

- STOR is dispatched by the STOR provider.
- The STOR provider informs the DNO of the STOR activations, power, start and end time.
- ANM can be triggered and activated. However, if the load increase is caused by STOR activations, ANM would not be activated.

Ex post (*Payment structure is indicative, i.e. the payment flow could be designed differently)

- NGESO carried out the validation and settlement.
- The calculation on the volume of headroom needed, informs the ANM headroom compensation that NGESO needs to pay the DNO.
- The DNO then invoices NGESO for this cost, and the STOR provider proceeds with the payment.

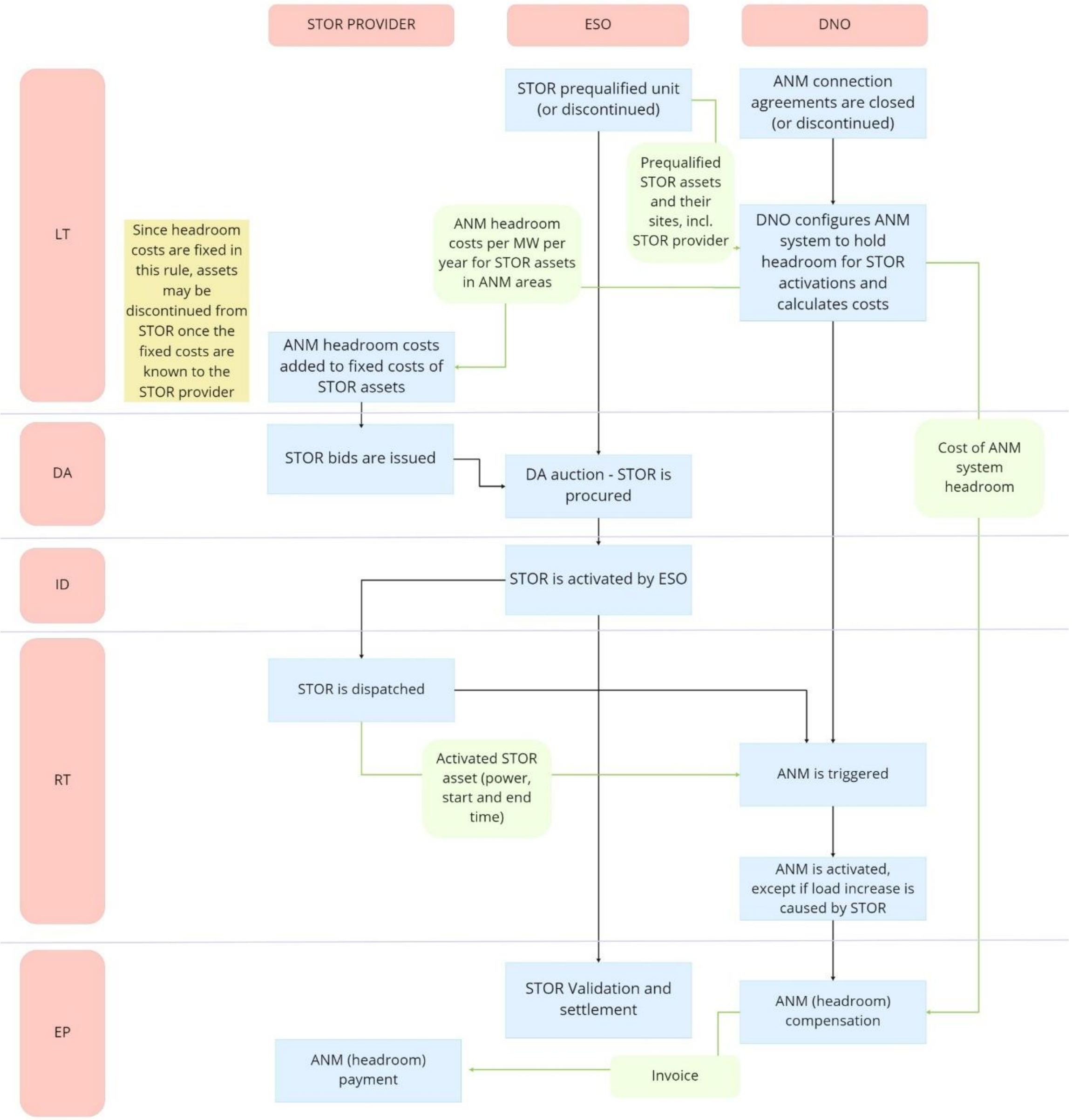


Figure 1.11 – Rule 7 i) process flow

1. Primacy rules definition

Joint primacy rule mechanics

RULE 7 – The STOR provider would pay the DNO (and therefore ANM customers or Flex Service Providers) to hold headroom on the ANM systems

ii) Dynamic headroom

Long-term

- STOR assets are prequalified or discontinued. When prequalifying a unit, NGESO is informed of their volume, area connected and if aggregated, what assets compose the unit.
- ANM connection agreements are closed or discontinued.

Day-ahead

- NGESO informs the DNO what STOR assets are prequalified and their sites. It is assumed that the prequalified STOR unit list is up to date when used/needed by the DNO and stays constant during a certain time period.
- The DNO forecasts the ANM curtailment activity and calculation of headroom cost and informs the STOR provider of the next day's ANM headroom cost per MWh for STOR assets in ANM areas.
- STOR providers issue the bids for the DA auction and the STOR provider adds the ANM headroom cost to the bids in the merit order. Then, STOR services are procured by NGESO, that informs the DNO of the assets procured and their sites.
- The DNO configures the ANM system to hold headroom for STOR activations for all the prequalified assets. Please find explanation of how headroom is created in rule 2. The DNO informs the BRP of the expected curtailment volumes.

Intraday

- When needed, STOR is activated by NGESO. The BRP redispatches the curtailed volumes.

Real time

- STOR is dispatched by the STOR provider. The STOR provider informs the DNO of the STOR activations, power, start and end time
- ANM can be triggered and activated. However, if the load increase is caused by STOR activations, ANM would not be activated.

Ex post

- NGESO carried out the validation and settlement.
- The calculation on the volume of headroom needed, informs the ANM headroom compensation that NGESO needs to pay the DNO.
- The DNO then invoices NGESO for this cost, and the STOR provider proceeds with the payment.

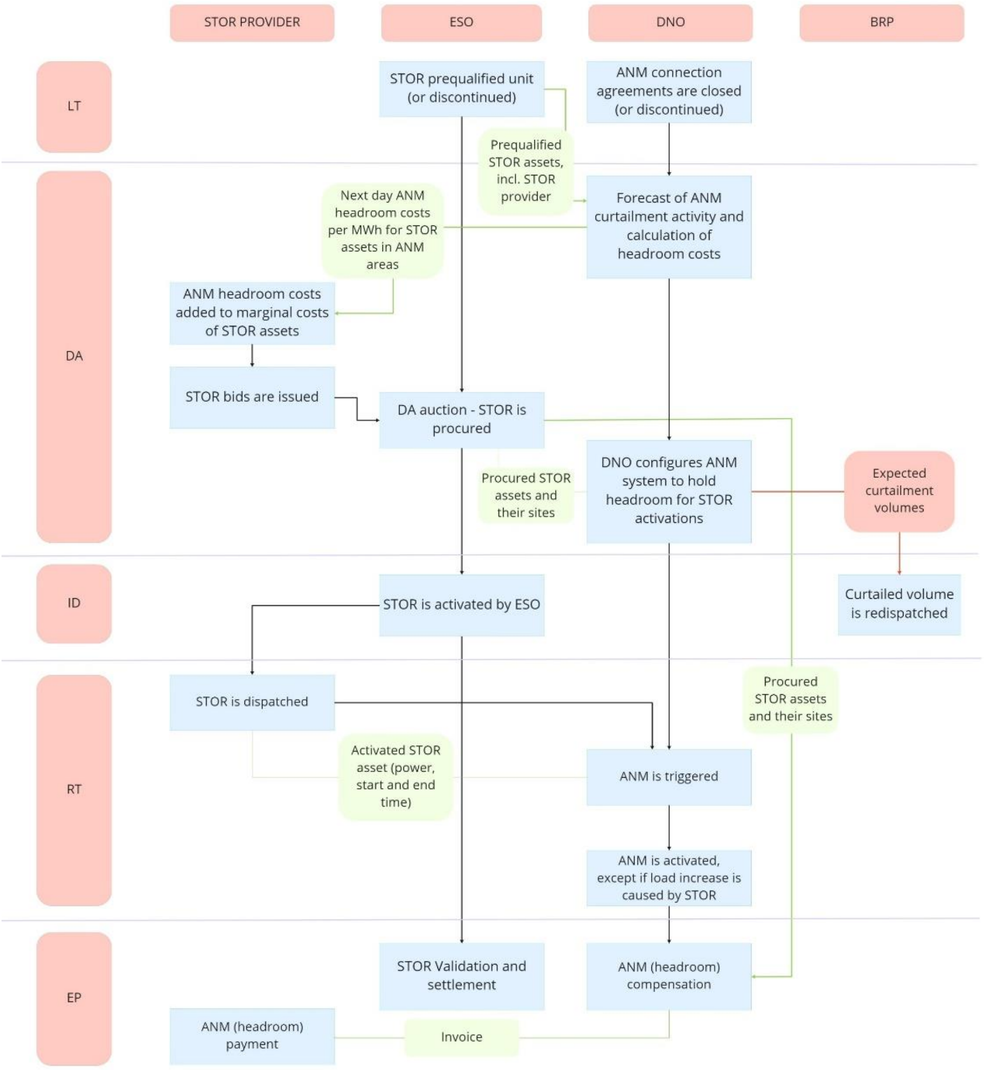


Figure 1.12 – Rule 7 ii) process flow

Section 2 – Modelling of cost benefit analysis

2. Cost benefit analysis

Objective and scope

This Section addresses the CBA modelling logic and Section 3 discusses the results.

Context

In the previous study, we conducted the CBA for the current STOR product design, 24-hour single procurement window, day-ahead auctions with a pay-as-clear payment mechanism, and considered GB as a single ANM area. These factors, as well as the absence of the counterfactual in the analysis, led to inconclusive results. Therefore in this study, we modelled the 1) 2-hour STOR auction (future product design), 2) regional modelling of ANM (3 areas), and 3) the counterfactual, or ‘do nothing’ option.

Objective

Quantify and compare the economic impact of primacy rules on all parties involved for four different scenarios and two cases:

- 2-hour STOR auctions and single ANM area
- 2-hour STOR auctions and three ANM areas (regional)

to help ENA members understand which rules deliver the **most efficient outcome for the whole system.**

Scope

- The reference case for this exercise was the ‘no conflict’ scenario, where ANM was activated, and STOR was also activated, but outside an ANM network constraint without creating a conflict. It limited the calculation to the elements impacted by the rules, allowing for a relative CBA. This was not a counterfactual, but a reference allowing us to compare the rules against a common framework.
- By using the exercise with the reference case, we identified the optimal rule from a CBA perspective without providing a justification for implementing this rule against the Business as Usual (BaU), ‘conflict with no rule implementation’.
- The ‘conflict with no rule implementation’ case was quantified in Section 5.
- As the contracting and connecting of ANM and STOR assets were within the reference case, it was considered out of the scope of this exercise.
- It was assumed the contracting of STOR and ANM services was efficient, and that system operators were never in a position where they have to activate a service and it was unavailable, i.e., there was always enough ANM available capacity to curtail.
- The Charging Significant Code Review (SCR) was not directly quantified, however, we could assume the dispatch cost in rules 2, 6 and 7 as an approximation.
- The main purpose of this analysis was to compare the order of magnitude of the primacy rules through a high level CBA. To implement the optimal solution, further analysis will need to be carried out on the shortlisted option(s).

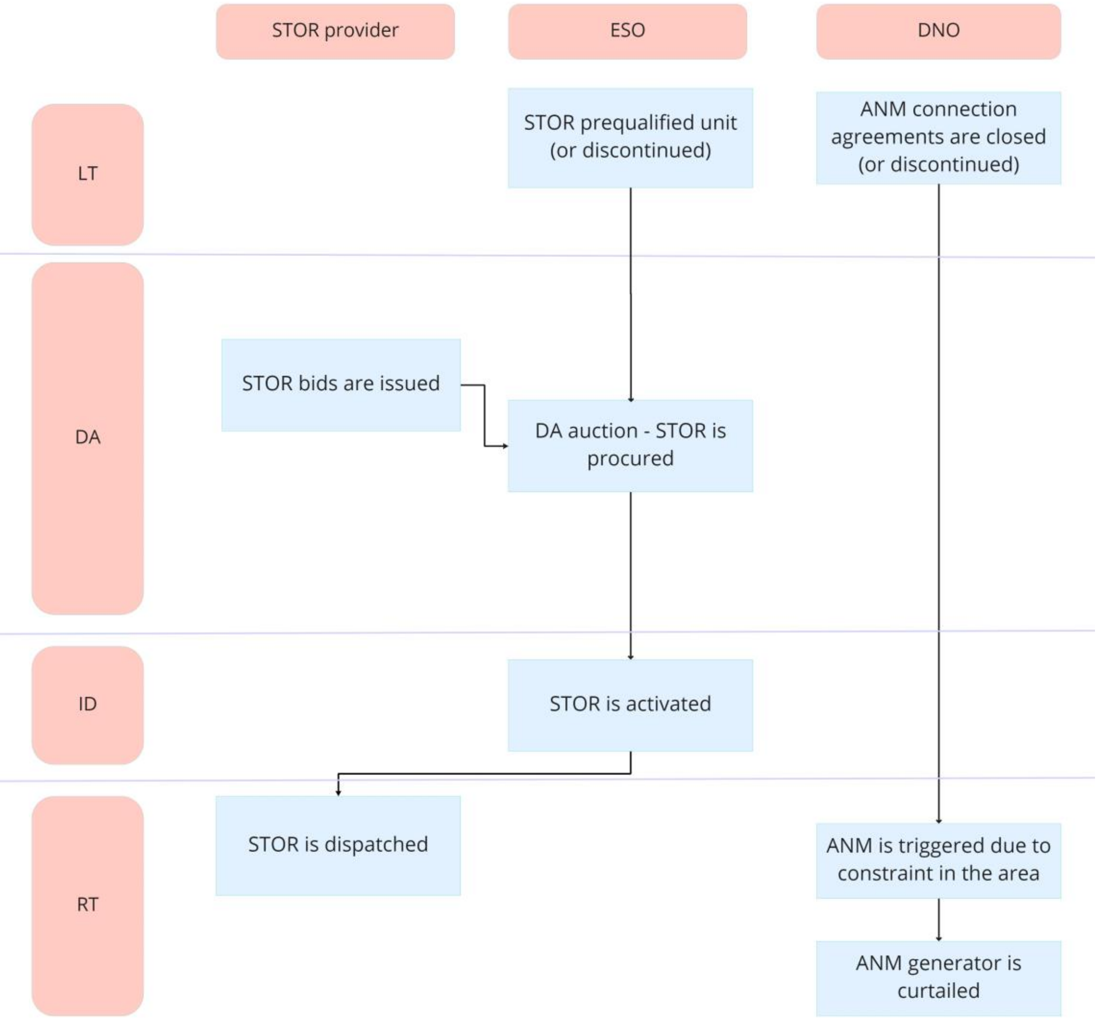


Figure 2.1 - Reference case process flow

2. Cost benefit analysis

General assumptions and limitations

Assumptions and input data:

- The CBA used June 2021 to May 2022 as a reference year for the full GB system.
- The CBA granularity was half-hourly, i.e., per settlement period.
- STOR BM dispatch of distributed units was not considered due to data unavailability. However, we considered this to have a negligible impact compared to the non-BM dispatch volumes because, according to NGESO, most of the distributed units were non-BM units in the period of 2021-2022.
- STOR utilisation cost of non-dispatched units was not available; consequently, we assumed the next units in the utilisation merit order were 15% more expensive than the last dispatched unit. This assumption was challenged in the sensitivity analysis (see Section 6).
- The non-BM STOR detailed utilisation data was not available from June 2021 to November 2021. We assumed the same STOR utilisation data for this period as for the inversed STOR data from November 2021 – May 2022.
- The STOR auction merit order was based on the methodology described by NGESO [1]
- Regarding emissions, we assumed that when STOR units were being substituted by other units in the merit order, the net carbon effect was negligible.
- STOR contracted availability window is assumed to be 2 hours.
- We assumed that STOR provider cost for providing availability was the tendered price times the tendered capacity.
- We assumed that STOR providers did not make any profit on utilisation because it is based on marginal prices.
- CAPEX on IT was annualized over 7 years (typical IT system time of use).
- For rules where DNO forecast was shared, it was assumed that the forecast was perfect. An imperfect forecast could lead to further system imbalances, especially for rules 4 ii), 2 i) & ii), 6 i) & ii) and 7 i) & ii). A perfect functioning of the STOR service was also assumed.
- The allocation of direct and indirect costs to the whole system was based on the principle that stakeholders would always externalise costs towards the whole system, but not benefits.
- The CBA was based on the following data:
  - STOR day-ahead auctions results [2]
  - Non-BM STOR dispatch instructions [3]
  - ANM curtailment risk matrix developed by WPD and NGESO [4]
  - Generation data and embedded renewable generation data – Provided by NGESO
  - Day-ahead GB prices [5]
  - Intraday GB prices [5]
  - STOR unit composition list – Provided by DNOs and NGESO
  - ANM technology breakdown (%) developed in [4]
  - Generation network tariffs – WPD East Midlands DUoS charges are assumed [7]
  - STOR unit located under ANM areas list – Provided by DNOs.
  - CAPEX and OPEX expenditure to implement rules based on best-estimate at the time the CBA was conducted – Provided by DNOs and NGESO.
  - Generator marginal cost for operation – DNV expert knowledge.
  - CO_2 Emission coefficient for gas [6]

Limitations:

- Due to the time limitations of the assignment, assumptions and unavailability of data, this CBA was meant to give a high-level first indicative order of magnitude relative benefit/cost of the different rules per stakeholder.
- The CBA evaluated rules that would result in the same system reliability. Therefore, all dynamic approaches that could affect system reliability were out of scope. For dynamic variants, we applied a dynamic version of the rule based on forecasts. A further step on the dynamic option will be explored qualitatively.
- The CBA assumed that the historical prices of STOR were applicable to a different market design with a shorter (2 hour) auction window.
- The ANM curtailment risk was not based on real DNO data due to very low curtailment risks and data unavailability.
- The CBA was limited and assumed one single ANM area or three ANM areas (regional modelling) area for the full GB.
- Fully accurate forecasts, and perfect procurement and dispatch were assumed.

[1], [2], [3] NGESO data portal, [4] WPD Cornwall study, [5] Nordpool market data, [6] RTE, [7] WPD DUoS charges for East Midlands

2. Cost benefit analysis

Single ANM area and regional ANM modelling - Scenarios

Single ANM area

The initial CBA showed that one of the main cost drivers was the 24-hour availability window of STOR. Furthermore, NGESO is planning to replace STOR with a new reserve product with an availability window of around 2 hours. Therefore, the aim of Task 2 was to test how a shorter availability window would affect the CBA results.

Regional ANM area

The first CBA assumed a single ANM zone (whole GB) and did not consider local conditions on likelihood of ANM curtailment. This could have a significant impact on the results since the overlap between STOR assets and ANM areas will affect the likelihood of conflict. The aim of this exercise was to understand the impact of including a zonal distinction in the CBA model. This entailed significant changes to the model set-up as it included three types of ANM zones: wind-dominated, solar-dominated, and mixed (baseline set). The distribution of STOR units in overlapping ANM regions is presented in table 2.2.

Scenarios

Similar to the first study, we conducted the CBA for four different scenarios which resulted from the combination of two different parameters: % of STOR units covered by ANM areas and % of settlement periods that are likely to be curtailed under ANM. The main two parameters are listed below:

- Percentage of STOR covered by ANM: For both single and regional ANM areas modelling, Scenarios 1 and 3 accounted for the current levels of STOR assets located behind a network constraint managed by an ANM. The value of 16% was calculated with the contribution of NGESO, who shared the list of STOR assets, and the UK DNOs, who signalled which of these STOR assets were located in areas where a potential conflict could arise. Then, scenarios 2 and 4 simulated that 50% of the STOR assets were located in ANM areas, this level of overlap was close to what was reported by some areas, and foreseen to be the level for other DNO areas in the future. Additionally, a limited percentage of overlap had to be assumed since a higher percentage would not ensure sufficient available STOR units at all times. Note that this parameter was calculated over the total of distributed connected STOR units, i.e. transmission connected capacity was excluded from the ratio calculation. The overlapping units were selected in a random fashion as every other unit in the STOR merit order.
- % of settlement periods that are likely to be curtailed: The number of settlement periods where the curtailment likelihood is 80% (i.e. red status). We calculated this figure as described in the ANM methodology in the previous report. For single ANM area modelling, the level of curtailment was directly dependent on the proportion of system demand met by embedded renewables, which was the same process as in 24-hour modelling but adjusted for 2-hour windows. For regional ANM modelling, we used the same logic but calculated the percentage of settlement periods on each curtailment matrix provided for each zone separately.

The table below depicts the four scenarios that were explored for each primacy rule. The selected scenarios were meant to explore the following: 1) What would be the primacy rule impact on a situation that approximates the present? - Scenario 3, 2) What would be the primacy rule impact on a future with more renewables and more ANM connections? - Scenario 2, 3) What would be the primacy rule impact on an area(s) with more ANM connections and the same renewable generation as the current one? - Scenario 4, and 4) What would be the primacy rule impact on an area(s) with more renewable generation and the same coverage of STOR as the current one? - Scenario 1

	% of distributed STOR covered by ANM	ANM, Likelihood of curtailment
Scenario 1	Current coverage – 16% coverage	Curtailment 11% of settlement periods
Scenario 2	50% coverage	Curtailment 11% of settlement periods
Scenario 3	Current coverage – 16% coverage	Curtailment 5% of settlement periods
Scenario 4	50% coverage	Curtailment 5% of settlement periods

Table 2.1 – Overview of the scenarios

The table below shows the capacity distribution of STOR units between regions for 16% coverage (given by ENA) and 50% coverage (DNV randomly chose every other unit from the remaining units).

	16% coverage	50% coverage
Wind	12 MW	308 MW
Solar	165 MW	352 MW
Mixed	156 MW	424 MW

Table 2.2 – Overlapping STOR capacity with ANM areas across ANM regions

2. Cost benefit analysis

Rule modelling

This section describes how each primacy rule was modelled. Because many elements were modelled similarly, we explained each element only once and then referred to the explanation when necessary.

Rule 1 i)

Calculation of reference case

1. Based on 2021-2022 data, STOR availability payments, STOR provider profits and STOR utilisation cost were calculated.

Calculation of STOR availability cost and STOR provider profits

1. All STOR units within ANM areas are removed from the STOR auction merit order for every day throughout the reference year. Based on the new merit order, the units that fulfil the required capacity are selected.
2. The market clearing price (MCP) is calculated based on the price of the last accepted STOR unit per day.
3. The STOR availability cost (MCP x required capacity x 2 hours) are calculated with the newly calculated MCP and the required capacity for each procurement window. Then, the difference between rule cost and reference cost is obtained.
4. Finally, the delta between rule STOR provider profit and reference case can be determined by deducting the STOR provider profit calculated for rule 1 i) to the STOR provider profit calculated for the reference case.

Calculation of STOR utilisation cost

1. STOR units within ANM areas are removed from the tendered NBM dispatch instruction data
2. The removed STOR units are substituted within ANM areas by the utilisation of more expensive units. It is assumed that the unit by which is substituted is 15% more expensive than the last dispatched unit. The sensitivity of this parameter has not been analysed further because it is later shown in the results that this has minimal impact.
3. The delta between rule utilisation cost and reference cost is then calculated.

Application of rule CAPEX implementation and OPEX

1. The CAPEX information provided by DNOs and NGESO is annualized to a period of 7 years.

Rule 1 ii)

This rule follows the same steps as rule 1i). The difference is that in this rule there is additional information exchange, which allows NGESO to exclude the STOR unit within ANM area from the merit order ONLY for the days that curtailment is expected.

How this translates into the modelling approach is by removing STOR units from the merit order only for days where there is one or more red settlement periods. The rest of the days the STOR auctions work as usual.

We follow the same approach as rule 1 i) for days with one or more red settlement periods.

Rule 3 i)

This rule largely follows the approach of rule 1 i).

The difference with rule 3 i) is that for STOR units within ANM areas that are aggregated (i.e., are composed of several assets in different geographical locations), only the capacity within ANM areas is removed from the merit order. For that, we do the following check;

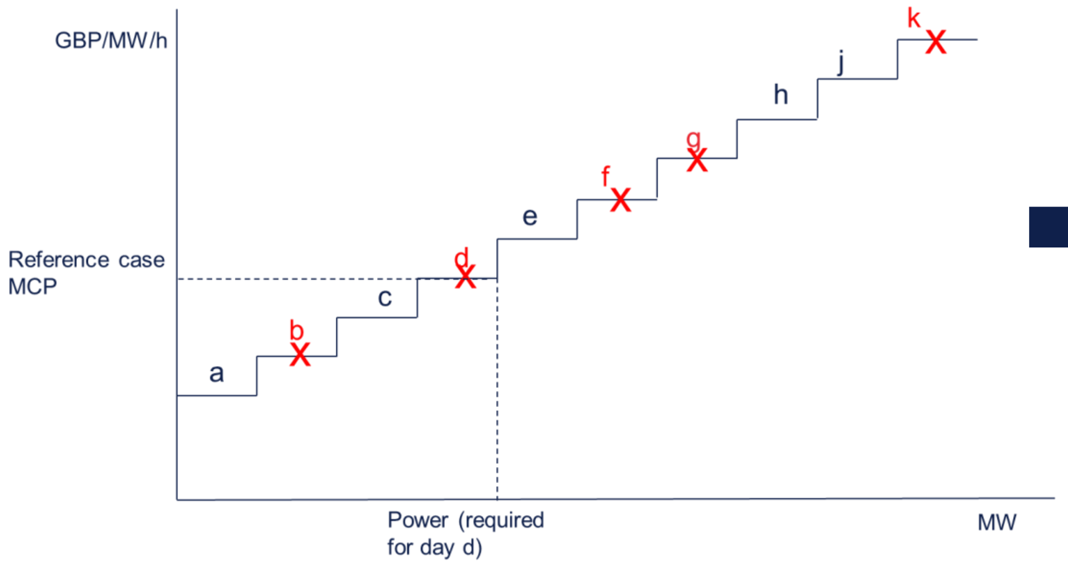
- Is tendered capacity of aggregated STOR unit X < capacity of aggregated STOR unit X outside ANM area?
  - Yes -> Don’t remove STOR unit from merit order
  - No -> Remove only the capacity within ANM area from the merit order tendered capacity of unit X. If the resulted capacity is under 3 MW, exclude the unit completely.

Rule 3 ii)

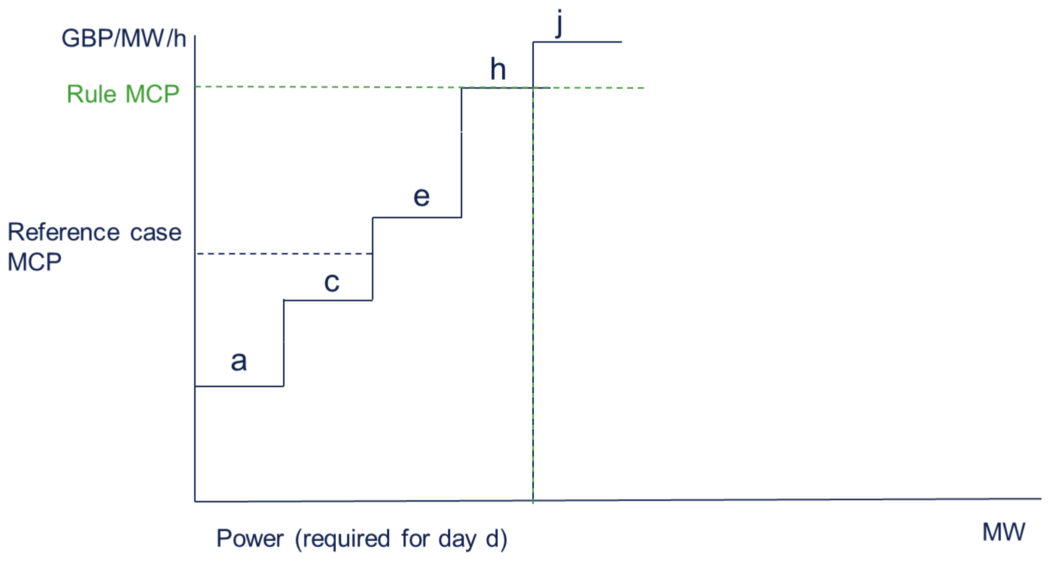
This rule combines the principles of rule 1 ii) on only excluding units for days with 1 or more red SPs, and rule 3 i) on aggregated units.

2. Cost benefit analysis

Rule modelling – Example of STOR auction merit order impact (Rule 1 & 3)



Red STOR units are within ANM areas, and they are removed from the merit order.



New merit order resulted from the removal of STOR units within ANM areas and STOR bid selection rules.

2. Cost benefit analysis

Rule modelling – Example of STOR auction merit order impact applied to area

According to rule criteria, MOD-10 and MOD-4 are not available in the new merit order ranking. Therefore, 14 MW should be replaced by other units to fulfil the required capacity. Though cheaper units are available, according to "Minimum acceptable MW" (column AA) criteria, these units cannot be used. Overall, according to the merit order ranking rules, the missing 14 MW must be covered by FASN-1, which results in a total price that is 83 times higher for this day.

There are days with much more extreme price differences, but this one was selected as there is only one merit order ranking rule that applies in this example (minimum acceptable MW), apart from the cheapest available option, ant thus is easier to visualize. There are multiple merit order subrules that can apply simultaneously.

Original

Daily Rank	Unit ID	Tendered MW	Minimum Acceptable MW	Tendered Availability Price	Status	MCP	Contracted capacity (MW)	Required daily capacity (MW)	Cummulative capacity (MW)	Payment (£)
1	KILLPG-1	290	290	0.01	Accepted	6	290	1281	290	£41,760
2	PETEM1	230	229	0.01	Accepted	6	230	1281	520	£33,120
3	KIWI-6	45	45	0.01	Accepted	6	45	1281	565	£6,480
4	KIWI-5	43	43	0.01	Accepted	6	43	1281	608	£6,192
5	DRAXX-10	32	32	0.01	Accepted	6	32	1281	640	£4,608
6	DRAXX-12	32	32	0.01	Accepted	6	32	1281	672	£4,608
7	DRAXX-9G	32	32	0.01	Accepted	6	32	1281	704	£4,608
8	WBUGT-4	20	20	0.01	Accepted	6	20	1281	724	£2,880
9	WBUGT-1	20	20	0.01	Accepted	6	20	1281	744	£2,880
10	KIWI-3	3	3	0.01	Accepted	6	3	1281	747	£432
11	MOD-10	10	10	0.02	Accepted	6	10	1281	757	£1,440
12	ENOC-1	45	45	0.03	Accepted	6	45	1281	802	£6,480
13	MOD-4	4	4	0.03	Accepted	6	4	1281	806	£576
14	KILLPG-2	290	290	1.25	Accepted	6	290	1281	1096	£41,760
15	TAYL3G	60	60	1.9	Accepted	6	60	1281	1156	£8,640
16	TAYL2G	60	60	1.9	Accepted	6	60	1281	1216	£8,640
17	GRAI4G	25	25	3.3	Accepted	6	25	1281	1241	£3,600
18	GRAI1G	25	25	3.3	Accepted	6	25	1281	1266	£3,600
19	RATSGT-2	15	15	6	Accepted	6	15	1281	1281	£2,160
20	CHICK-1	45	35	39	Rejected	-	-	1281	-	£0
21	KEADGT-3	23	17	40	Rejected	-	-	1281	-	£0
22	BURGH-1	45	35	100	Rejected	-	-	1281	-	£0
23	ERRO-2	25	20	300	Rejected	-	-	1281	-	£0
24	NANT-1	15	15	300	Rejected	-	-	1281	-	£0
25	CLAC-1	40	20	400	Rejected	-	-	1281	-	£0
26	FASN-1	22	7	500	Rejected	-	-	1281	-	£0
27	GLNDO-1	100	11	999	Rejected	-	-	1281	-	£0
									Total	£184,464

Modified

Unit ID	Tendered MW	Minimum Acceptable MW	Tendered Availability Price	Status	MCP	Contracted capacity (MW)	Required daily capacity (MW)	Cummulative capacity (MW)	Payment (£)
KILLPG-1	290	290	0.01	Accepted	500	290	1281	290	£3,480,000
PETEM1	230	229	0.01	Accepted	500	230	1281	520	£2,760,000
KIWI-6	45	45	0.01	Accepted	500	45	1281	565	£540,000
KIWI-5	43	43	0.01	Accepted	500	43	1281	608	£516,000
DRAXX-10	32	32	0.01	Accepted	500	32	1281	640	£384,000
DRAXX-12	32	32	0.01	Accepted	500	32	1281	672	£384,000
DRAXX-9G	32	32	0.01	Accepted	500	32	1281	704	£384,000
WBUGT-4	20	20	0.01	Accepted	500	20	1281	724	£240,000
WBUGT-1	20	20	0.01	Accepted	500	20	1281	744	£240,000
KIWI-3	3	3	0.01	Accepted	500	3	1281	747	£36,000
ENOC-1	45	45	0.03	Accepted	500	45	1281	792	£540,000
KILLPG-2	290	290	1.25	Accepted	500	290	1281	1082	£3,480,000
TAYL3G	60	60	1.9	Accepted	500	60	1281	1142	£720,000
TAYL2G	60	60	1.9	Accepted	500	60	1281	1202	£720,000
GRAI4G	25	25	3.3	Accepted	500	25	1281	1227	£300,000
GRAI1G	25	25	3.3	Accepted	500	25	1281	1252	£300,000
RATSGT-2	15	15	6	Accepted	500	15	1281	1267	£180,000
CHICK-1	45	35	39	Rejected	-	-	1281	-	£0
KEADGT-3	23	17	40	Rejected	-	-	1281	-	£0
BURGH-1	45	35	100	Rejected	-	-	1281	-	£0
ERRO-2	25	20	300	Rejected	-	-	1281	-	£0
NANT-1	15	15	300	Rejected	-	-	1281	-	£0
CLAC-1	40	20	400	Rejected	-	-	1281	-	£0
FASN-1	22	7	500	Accepted	500	14	1281	1281	£168,000
GLNDO-1	100	11	999	Rejected	-	-	1281	-	£0
MOD-10	10	10	0.02	Not available					
MOD-4	4	4	0.03	Not available					
								Total	£15,372,000

- Accepted units in the original and modified merit order
- Not available due to ANM overlap
- Accepted units to fulfil the missing STOR capacity

2. Cost benefit analysis

Rule modelling

Rule 4 i)

This rule is not modelled (see slide 20)

Rule 4 ii)

Calculation of reference case -> Same as in rule 1 i)

Calculation of availability cost

1. STOR required procurement capacity is calculated per day. Because of the rule functioning, the MCP will be the same as rule 3 ii), however for rule 4 ii) all providers get paid, without avoiding the excluded ones. For each day, we apply rule 3 ii) MCP to the original STOR merit order to check the required capacity.
2. STOR availability cost are calculated with rule 3 ii) MCP. Then, the delta between rule cost and reference cost is computed.
3. Finally, the delta between rule STOR provider profit and reference case is obtained.

Calculation of STOR utilisation cost

1. Per day, the energy dispatched through STOR units within ANM area is checked.
2. The extra over-dispatch energy required is calculated. A price 15% more expensive than the last dispatched unit is assumed.

Curtailment cost are calculated based on the dispatched STOR capacity within ANM areas per settlement period:

- Loss of revenue/curtailed SP= Spot price * curtailed capacity * ½
- Discount on generation tariffs/ curtailed SP = Generation tariff (per time band) * curtailed capacity * ½
- Saving on marginal cost for generating / curtailed SP = curtailed capacity * (% of gas in ANM) * marginal cost of operating gas turbine * ½ [renewable generation is assumed to have 0 marginal cost]

Application of CAPEX and OPEX as per rule 1 i).

For the calculation of carbon emissions, the emission factor of gas is applied to the extra dispatched STOR.

Rule 2 i)

For this rule, we assume that the equivalent volume of STOR in ANM areas is curtailed under ANM.

1. Firstly, the STOR prequalified capacity within ANM areas for the full year is calculated
2. Then, curtailed capacity for red settlement periods for static headroom defined by point 1 is obtained
3. To calculate the net cost for holding headroom for curtailed settlement periods:
   - Loss of revenue/curtailed SP= Spot price * curtailed capacity * ½
   - Discount on generation tariffs/ curtailed SP = Generation tariff (per time band) * curtailed capacity * ½
   - Saving on marginal cost for generating / curtailed SP = curtailed capacity * (% of gas in ANM) * marginal cost of operating gas turbine * ½ [renewable generation is assumed to have 0 marginal cost]
   - Cost of redispatch = Intraday price * curtailed capacity * ½
4. Then, the rule CAPEX implementation and OPEX is included
5. Calculation of carbon emissions:
   - Scenario 1 & 2 = In these scenarios, as the ratio of renewable generation is higher, it is assumed that the curtailed capacity that is redispatched is substituted by more renewable generation, i.e. no extra emissions
   - Scenario 3 & 4 = In these scenarios, as the ratio of renewable generation is lower, it is assumed that the curtailed capacity that is redispatched is substituted by gas generation. We calculate the emissions by applying the gas emission factor to the redispatched energy.

2. Cost benefit analysis

Rule modelling

Rule 2 ii)

This rule follows the same logic as 2 i), but applying dynamic headroom.

The dynamic headroom is calculated for every day and it is determined by the STOR units within ANM areas that were selected in the day-ahead auction. Therefore, the headroom (i.e. curtailment) is different every day.

Rule 6 i)

This rule follows the same logic as rule 2 i). The difference is the cost for holding headroom allocation. In this rule, NGESO bears the cost for holding headroom, instead of the ANM generator + BRP.

Rule 6 ii)

1. The cost for holding headroom to STOR units within ANM areas participating in day-ahead auction is allocated (= tendered price + weighted cost for holding headroom / (tendered capacity * 2)).
2. Then, the merit order is adapted based on the recalculated tendered price.
3. Accepted bids are recalculated based on the new merit order. The new MCP is obtained.
4. THE STOR availability cost and utilisation cost are calculated following rule 1ii) logic.
5. Whether there are any accepted units within ANM areas is assessed.
6. The cost for holding headroom (curtail) for the recalculated capacity according to rule 2 i) is obtained for the calculated capacity in this rule.
7. The cost for holding headroom are allocated to NGESO (recalculate NGESO cost)
8. The CAPEX and OPEX has to be applied as per rule 1 i).
9. Emissions are calculated as per rule 2 i)

Rule 7 i)

This rule follows the same logic as rule 2 i). The difference is the cost for holding headroom allocation. In this rule the STOR provider bears the cost for holding headroom, instead of the ANM generator + BRP.

Rule 7 ii)

This rule follows the same logic as rule 6 ii), expect for;

- Step 4: For this rule, the calculation of STOR availability and utilisation is done based on rule 3 ii)
- Step 7: cost for holding headroom are allocated to the STOR provider (recalculate STOR provider profit).

2. Cost benefit analysis

Impact on stakeholders for DNO has primacy

RULES		STOR provider	ANM generator	NGESO	DNO	Whole system
Rule 1	i) Binary	- Δ STOR provider margin		- Δ STOR procurement & utilisation cost - CAPEX* - OPEX*	- CAPEX - OPEX	Indirect impact = NGESO + DNO net impact)
	ii) Risk- based	- Δ STOR provider margin		- Δ STOR procurement & utilisation cost - CAPEX - OPEX	- CAPEX - OPEX	Indirect impact = NGESO + DNO net impact)
Rule 3	i) Binary	- Δ STOR provider margin		- Δ STOR procurement & utilisation cost - CAPEX - OPEX	- CAPEX - OPEX	Indirect impact = NGESO + DNO net impact)
	ii) Risk- based	- Δ STOR provider margin		- Δ STOR procurement & utilisation cost - CAPEX - OPEX	- CAPEX - OPEX	Indirect impact = NGESO + DNO net impact
Rule 4	i) Binary	- Δ STOR provider margin		- Δ STOR procurement & utilisation cost - CAPEX - OPEX	- CAPEX - OPEX	Indirect impact = NGESO + DNO net impact
	ii) Risk- based	- Δ STOR provider margin	- Δ curtailment	- Δ STOR procurement & utilisation cost - CAPEX - OPEX	- CAPEX - OPEX	- Direct impact = Δ carbon emissions - Indirect impact = NGESO + DNO net impact

*CAPEX and OPEX for NGESO and DNO refer to the extra investment needed to implement the rule and the operation and maintenance cost of its implementation respectively.

Table 2.3 – Overview of the cost and benefits that the stakeholders experience for each of the rules in which the DNO has primacy

2. Cost benefit analysis

Impact on stakeholders for NGESO has primacy

RULES		STOR provider	ANM generator (and their BRP)	NGESO	DNO	Whole system
Rule 2	i) Static headroom		- CAPEX - OPEX - Cost for holding headroom	- CAPEX - OPEX	- CAPEX - OPEX	- Direct impact = Δ carbon emissions - Indirect impact = NGESO + DNO net impact + ANM generator impact
	ii) Dynamic headroom		- CAPEX - OPEX - Cost for holding headroom	- CAPEX - OPEX	- CAPEX - OPEX	- Direct impact = Δ carbon emissions - Indirect impact = NGESO + DNO net impact+ ANM generator impact
Rule 6	i) Static headroom		- CAPEX - OPEX	- CAPEX - OPEX - Cost for holding headroom	- CAPEX - OPEX	- Direct impact = Δ carbon emissions - Indirect impact = NGESO + DNO net impact + ANM generator impact
	ii) Dynamic headroom	- Δ STOR provider margin	- CAPEX - OPEX	- CAPEX - OPEX - Cost for holding headroom - Δ STOR procurement & utilisation cost	- CAPEX - OPEX	- Direct impact = Δ carbon emissions - Indirect impact = NGESO + DNO net impact + ANM generator impact
Rule 7	i) Static headroom	- Cost for holding headroom	- CAPEX - OPEX	- CAPEX - OPEX	- CAPEX - OPEX	- Direct impact = Δ carbon emissions - Indirect impact = NGESO + DNO net impact+ ANM generator impact + STOR provider impact
	ii) Dynamic headroom	- Cost for holding headroom - Δ STOR provider margin	- CAPEX - OPEX	- CAPEX - OPEX - Δ STOR procurement & utilisation cost	- CAPEX - OPEX	- Direct impact = Δ carbon emissions - Indirect impact = NGESO + DNO net impact+ ANM generator impact

Table 2.4 – Overview of the cost and benefits that the stakeholders experience for each of the rules in which NGESO has primacy

Section 3 - CBA results and interpretation

3. CBA results

Introduction

- We conducted the CBA for four different scenarios as described in the previous section. The scenarios were defined by the two parameters, namely the % of STOR units covered by ANM areas, and the % of settlement periods that were likely to be curtailed under ANM.
- This section will present results from two models: 1) the 2hr procurement window, and 2) the 2hr procurement window regional, which explored different ANM areas for solar, wind and mixed generators.
- Although the results from each rule vary by scenario, their interpretation is largely the same across all of them, hence we will only provide a detailed analysis of Scenario 3, as this scenario most closely reflects the current energy system.
- The table on the right depicts the four scenarios that were explored for each primacy rule.
- The selected scenarios were meant to explore the following:
  - What would be the primacy rule impact on a situation that approximates the present? (Scenario 3)
  - What would be the primacy rule impact on a future with more renewables and more ANM connections? (Scenario 2)
  - What would be the primacy rule impact on an area(s) with more ANM connections and the same renewable generation as the current one (Scenario 4)
  - What would be the primacy rule impact on an area(s) with more renewable generation and the same coverage of STOR as the current one (Scenario 1)

	% of distributed STOR covered by ANM	ANM, Likelihood of curtailment
Scenario 1	Current coverage – 16% coverage	Curtailment 11% of settlement periods
Scenario 2	50% coverage	Curtailment 11% of settlement periods
Scenario 3	Current coverage – 16% coverage	Curtailment 5% of settlement periods
Scenario 4	50% coverage	Curtailment 5% of settlement periods

Table 3.1 – Scenario overview

3. CBA results – 2hr STOR

Scenario 3 – Results interpretation

- NGESO is currently developing new reserve services, slow reserve and quick reserve, which will eventually replace STOR. The new services are due to launch by the end of 2023 and will have shorter procurement windows, namely 8hr and 2hr.
- The ENA Product group requested to update the modelling to study the impact of shorter procurement windows on the ANM conflict. For the purpose of the exercise, we applied the same rules 1-7 on the 2hr STOR service.
- In the static rule i) all STOR units in the ANM areas were removed for that day regardless of the length of the procurement window, therefore the results from 24hr model and 2hr model were exactly the same. A detailed analysis of these results can be found in the previous report[1]
- This section will focus on the results from the dynamic rules ii). Table 3.2 summarises the outcomes of the cost-benefit analysis for all rules in Scenario 3 for 24hr and 2hr models.
- In general, the results from the 2hr model were significantly lower than in the previous study, as a shorter contract window meant fewer STOR providers had to be excluded from the merit order, hence increasing the market clearing price (MCP) only marginally. Moreover, the higher MCP was only applied to the accepted units in a given 2hr slot rather than the entire service day, as in the previous model. For example, if there was only one settlement period with a risk of curtailment in the whole day, then the merit order, and subsequently the MCP, would only change for the 2hr period where the red settlement window happened, leaving the rest of the auction results unchanged.
- Based on the whole system cost, the most cost-effective rule was now rule 3 ii) where DNO has primacy and the STOR providers exclude themselves from participating in the auction when an ANM conflict is expected. These results were approximately 8 times lower than in the 24hr model.
- Shorter procurement window didn't affect the cost to DNO in comparison to the original 24hr results, as DNOs only bear the rule implementation cost and there was no extra cost to implement the rule in comparison to the 24hr model.
- The detailed results from each rule in Scenario 3 are discussed on slides 42-49.

Scenario 3

	RULES (£m)		STOR provider	ANM generator + BRP	NGESO	DNO	Whole system
DNO has primacy	Rule 1	24hr	35.99		-37.49	-0.72	-38.21
		2hr	4.13		-5.18	-0.72	-5.9
	Rule 3	24hr	13.87		-18.54	-0.72	-19.26
		2hr	1.22		-2.04	-0.72	-2.76
	Rule 4	24hr	37.54	-0.24	-38.89	-0.72	-39.85
		2hr	4.45	-0.04	-5.42	-0.72	-6.18
NGESO has primacy	Rule 2	24hr		-2.35	-1.11	-1.08	-4.55
		2hr		-2.35	-1.11	-1.08	-4.55
Joint primacy	Rule 6	24hr	35.99		-38.06	-1.29	-39.35
		2hr	4.13		-5.75	-1.29	-7.04
	Rule 7	24hr	13.87		-19.08	-1.29	-20.37
		2hr	1.22		-2.59	-1.29	-3.88

Table 3.2 – Cost and benefit overview for the dynamic rules ii) when scenario 3 parameters are applied

1] 20102022 ENA primacy rules_FINAL report

3. CBA results – 2hr STOR

Scenario 3 – Results interpretation – 2hr Single Area

Rule 1 i) and 1 ii) – Key observations

Figures 3.1 and 3.2 include all the cost/benefits expressed in £m, using the reference case as a baseline.

- The main cost element of this rule is the additional cost for NGESO. This cost consists of CAPEX, OPEX, STOR availability payments and STOR utilisation payments. The single biggest cost element is the STOR availability payments, representing 90% of NGESO's additional cost.
- In rule 1 i), the STOR availability cost resulted in over 6 times the reference case STOR availability payments. Rule 1 ii) resulted in only 8% increase compared to the reference case. The availability cost difference was due to:
  a) The market design of day-ahead STOR auctions. As STOR auctions apply a pay-as-clear mechanism, the last chosen STOR unit tendered price set the market clearing price. The market clearing price (MCP) of the procurement block was used to calculate the payments to all procured capacity for 2 hours. The MCP difference between the reference case and the modified merit order could be several orders of magnitude.
  b) Reduction of the merit order. Rule 1 i) and ii) design specified that all STOR units within ANM areas should be removed from the merit order, permanently or dynamically respectively. This led to a decrease of options in the merit order, resulting in more expensive units to cover the required STOR capacity.
  c) The large difference between availability cost for rule 1 i) and 1 ii) was because in rule i), the STOR units within ANM areas were removed permanently from the STOR merit order. This had a significant impact because it affected the merit order every day of the year.

  Whereas in rule ii), the STOR units within ANM areas were removed only for the procurement window where curtailment was forecasted in one or more settlement periods. Taking into account that there were smaller chances of ANM conflict happening in a 2hr window, the additional cost was significantly lower. For example, only 9% of all units were removed due to a potential ANM conflict.
- The net impact on the whole system reflected an indirect impact from the net cost of NGESO and DNO. As described above, most of this cost reflected margins for STOR providers.
- The dynamic version of the rule was more expensive to implement for both NGESO and DNO than the static one. NGESO was slightly more impacted than the DNOs by the additional implementation cost.
- Rule 1 i) was the most costly/inefficient rule to implement.
- The dynamic approach related to system reliability was out of the scope of this study. However, it is worth exploring further the impact of the exclusion of the units based on a dynamic evaluation of the likelihood of the conflict and the impact based on the predicted time. This may further reduce the STOR availability payments under rule 1 ii).
- In general, the more advanced the forecasting systems and risk prediction are, the lower the cost.

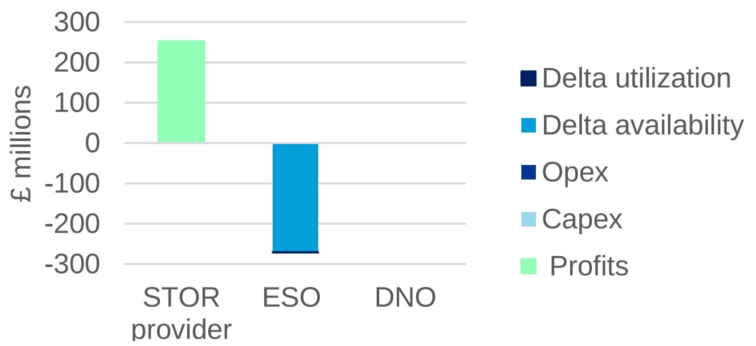


Figure 3.1 – Cost per stakeholder in Scenario 3 - Rule 1 i)

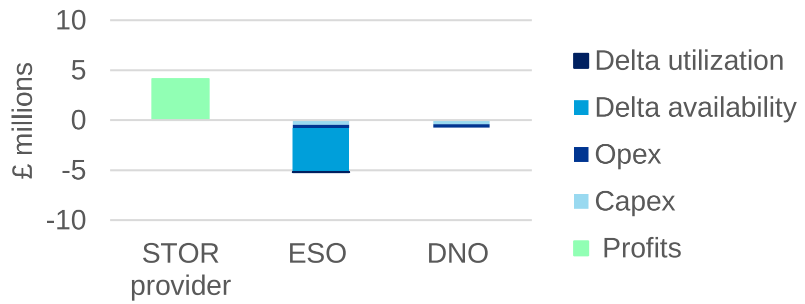


Figure 3.2 – Cost per stakeholder in Scenario 3 - Rule 1 ii)

DNV

3. CBA results – 2hr STOR

Scenario 3 – Results interpretation – 2hr Single Area

Rule 3 i) and 3 ii) – Key observations

- Key observations of rules 1 i) & ii) were equally applicable to rules 3 i) & ii).
- The results in rule 3 ii) showed a further drop in NGESO cost, decreasing by roughly 50% in comparison to rule 1ii). This difference was due to the STOR aggregated units within ANM areas. In rule 1, the full STOR unit was excluded from the merit order regardless of its composition, whereas in rule 3, only the capacity within the ANM area was excluded. Although only 23% of all units within ANM areas were aggregated units, this still generated a significant cost reduction. This could be due to the fact that aggregated units tend to be cheaper.
- Rule 3 ii) showed the lowest overall cost in the 2hr model.

Rule 4 ii) – key observations

- Even though the MCP was the same as in 3 ii), the overall cost was higher than in the previous two rules due to two main reasons:
  a) Need for more STOR capacity to be procured; and
  b) All providers get availability payments, even the ones that are excluded due to an ANM conflict.
- The whole system costs in rule 4 ii) were almost twice as high as in 3 ii) but only 5% higher than the overall cost in rule 1 ii). However, the utilisation payments that NGESO would incur were almost double than in both rules 1 ii) and 3 ii) but still remained negligible relative to NGESO availability cost.
- This was the only "DNO has primacy" rule that has an impact on carbon emissions. The overall impact was also almost negligible, and even lower than in the 24hr model, with only 26 tCO_2 eq. reduction
- Out of the all dynamic rules where DNO has primacy, this was the most expensive one.

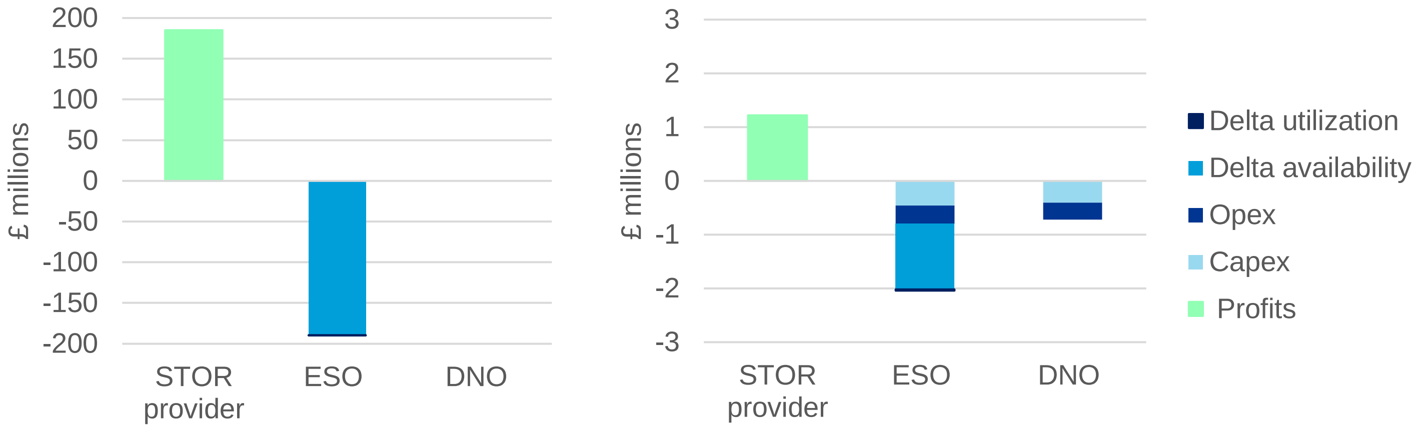


Figure 3.3 – Cost per stakeholder in Scenario 3 - Rule 3 i) (left) and 3 ii) (right)

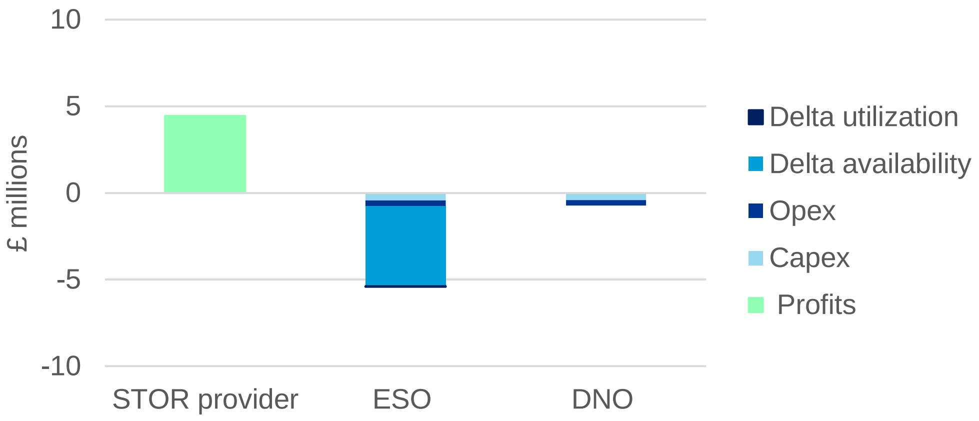


Figure 3.4 – Cost per stakeholder in Scenario 3 - Rule 4 ii)

3. CBA results – 2hr STOR

Scenario 3 – Results interpretation – 2hr Single Area

Rule 2 i) and 2 ii) – Key observations

- Rule 2 was one of the rules where NGESO has primacy.
- The implementation cost for these rules was overall twice as high as the implementation cost for rules where the DNO has primacy.
- In addition to the rule implementation cost, the main cost component was the cost for holding headroom incurred by the ANM generator and their BRP.
- The cost was broken down into loss of revenue, savings on marginal cost, savings on generation network tariffs, and redispatch cost.
  - The bulk of the cost (over 90%) related to loss of revenue and redispatch cost
  - The network tariff chosen for the model presented negative values, therefore, this element was a cost instead of a saving. (~ 3% of cost of holding headroom)
  - The marginal cost savings were only incurred by gas generators. The savings on generation cost were also marginal compared to the total cost. The order of magnitude was 6% relative to the total cost of holding headroom
- The difference in cost of rule 2 ii) and the previous rules was because when curtailing ANM generators, there was no availability or utilisation cost; the ANM generator and their BRP only incurred cost when there was curtailment. In this scenario, curtailment only happened in 5% of all SPs in a year.
- The main difference in rules 2 i) and 2 ii) cost was the amount of capacity curtailed. In the former, we curtailed a fixed amount which corresponded to the prequalified STOR units in the ANM area, whereas in the latter the curtailed capacity was dynamic, and it was determined based on day-ahead auctions results.
- Due to increased curtailment, the carbon impact of rule 2 i) was almost 7 times higher than for rule 2 ii).
- The results for rules 2 i) and ii) in a 2hr model were exactly the same as in the 24hr model. Since all the action in this rule was on the DNO, who would only hold extra headroom for the exact duration of the conflict, therefore the length of the procurement window did not affect the results.

Rule 2 – Emissions [t CO_2 eq]	**i)**	44,215
	ii)	6,526

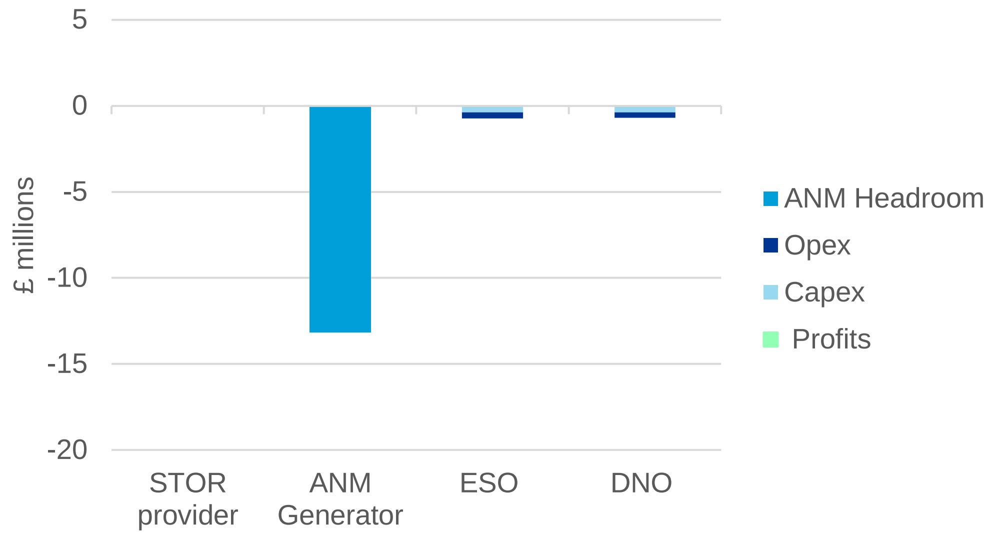


Figure 3.5 – Cost per stakeholder in Scenario 3 - Rule 2 i)

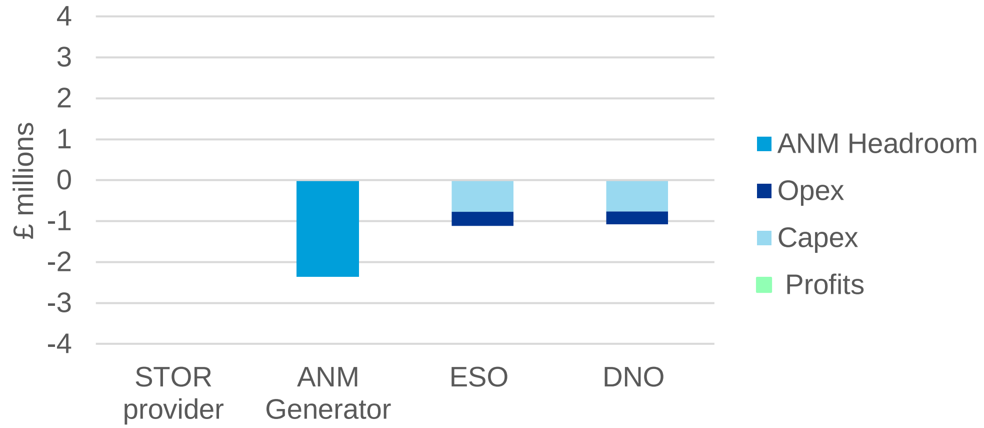


Figure 3.6 – Cost per stakeholder in Scenario 3 - Rule 2 ii)

3. CBA results – 2hr STOR

Scenario 3 – Results interpretation – 2hr Single Area

Rule 6 i) and ii) – Key observations

- The same observations on 2 i) were applicable to 6 i). The only difference was that the cost for holding headroom was allocated to NGESO instead of the ANM generator + BRP.
- Rule 6 ii) was very different from 2 i). In this variant, the STOR merit order was modified so the cost for holding headroom could be factored in for STOR units within ANM areas.
- When modifying the STOR merit order, for nearly 100% of the cases, the STOR units in the ANM area did not make it into the accepted units. This meant that effectively there was no cost for holding headroom but there were added costs on STOR procurement and utilisation for NGESO. This rule resulted in the same STOR provider profits as in rule 1 ii). However, NGESO costs were only 10% higher in 6 ii) than in rule 1ii). This was due to the higher CAPEX and OPEX of the rule.
- As in rule 6 ii), the modification of the merit order created more cost overall than holding headroom due to the STOR market clearing mechanism. When compared to rule 2 ii), the STOR cost of rule 6 ii) was approximately twice as high as the cost for holding headroom in rule 2 ii), due to the STOR merit order effect. However, the cost was significantly lower than in the 24hr model.

Rule 7 i) and ii) – Key observations

- The same observations on 2 i) were applicable to 7 i). The only difference is that the cost for holding headroom was allocated to the STOR provider instead of the ANM generator + BRP.
- Rule 7 ii) had the same logic as 6 ii) with the exception that the STOR service provider was the stakeholder modifying the tendered prices. Hence, the aggregated units could be taken into consideration.
- Like in rule 6, when modifying the STOR bid prices and (hence) the STOR merit order, for nearly 100% of the cases, the STOR units in the ANM area did not make it into the accepted units. This meant that effectively there was no cost for holding headroom but there were added costs on STOR procurement and utilisation for NGESO. This rule resulted in the same STOR provider profits as in rule 3 ii). However, NGESO costs were slightly higher than in 3 ii).
- As in rule 6 ii), the modification of the merit order created more cost overall than holding headroom due to the STOR market clearing mechanism. However, rule 7 ii) was the second cheapest overall rule in the 2hr model.

Rule 6 – Emissions [t CO_2 eq]		
	i)	44,215
	ii)	-

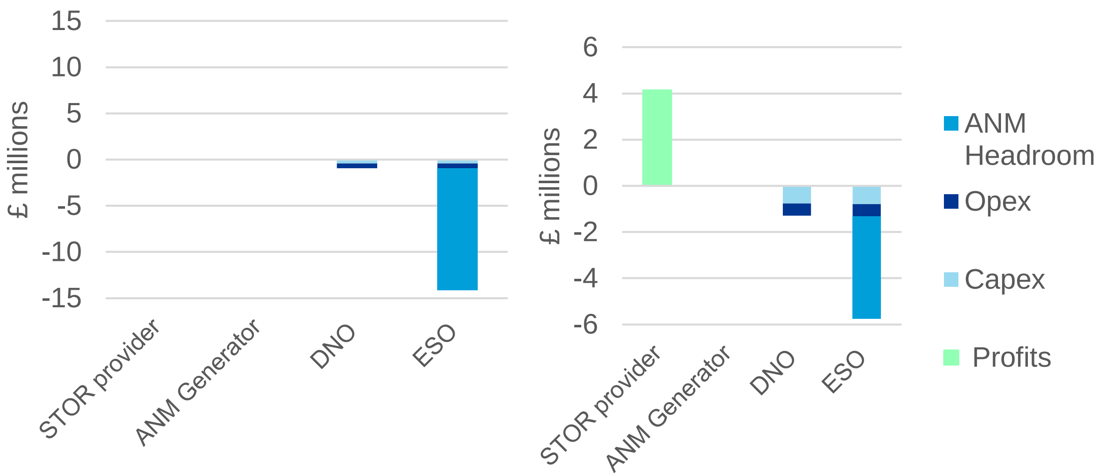


Figure 3.7 – Cost per stakeholder in Scenario 3 - Rule 6 i) (left) and 6 ii) (right)

Rule 7 – Emissions [t CO_2 eq]		
	i)	44,215
	ii)	-

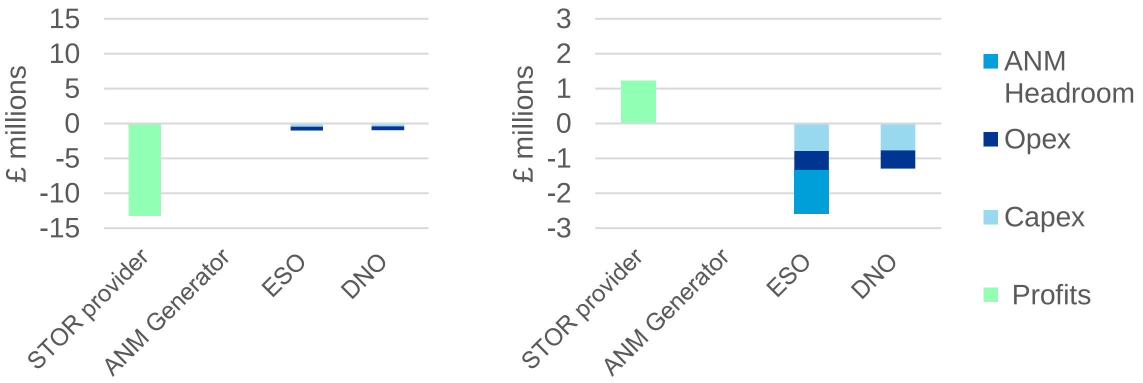


Figure 3.8 – Cost per stakeholder in Scenario 3 - Rule 7 i) (left) and 7 ii) (right)

3. CBA results – 2hr STOR

Comparative analysis – whole system impact

- Table 3.3 captures rule ranking across all four scenarios based on the impact on the whole system.
- When comparing the whole system outcomes for all scenarios, the least costly rule across all four scenarios was rule 3 ii), due to a different treatment of aggregated units where only the capacity in the ANM area was excluded rather than the entire unit.
- Rule 7 ii) was the second-best option across all scenarios, it was approximately 30% more expensive than the 3 ii) in terms of the whole system cost. This is because the STOR cost was the same as in rule 3ii), but the CAPEX and OPEX costs were higher for rule 7 ii).
- Rules 1 i) and 3 i) were the worst-performing rules across all scenarios. This is due to the high impact on the STOR merit order every day. This rule was highly affected by a higher STOR coverage (higher MCP) and a higher % of curtailed periods (more STOR auction days are affected).
- Rule 4 ii) was one of the lowest ranked rules and always ranked lower than rules 1 ii) and 3 ii), because of a greater need for STOR capacity at a higher MCP.
- Ruled 6 i) and 7 i) ranked similarly low.
- Generally, the "ii)" version of the rules outperformed the "i)" version.
- Finally, in terms of carbon emissions, rule 4 ii) had the most negligible carbon footprint across all scenarios. Whereas rules 2 i), 6 i) and 7 i) were the worst performing rules in scenarios 3 & 4 (i.e., low renewable generation scenarios).

Ranking based on whole system impact (cost)				
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
1	3 ii)	3 ii)	3 ii)	3 ii)
2	7 ii)	7 ii)	7 ii)	7 ii)
3	2 ii)	1 ii)	2 ii)	1 ii)
4	1 ii)	6 ii)	1 ii)	6 ii)
5	6 ii)	4 ii)	4 ii)	4 ii)
6	4 ii)	2 ii)	6 ii)	2 ii)
7	2 i)	2 i)	2 i)	2 i)
8	6 i) & 7 i)	6 i) & 7 i)	6 i) & 7 i)	6 i) & 7 i)
9	3 i)	3 i)	3 i)	3 i)
10	1 i)	1 i)	1 i)	1 i)

Ranking based on whole system impact (carbon emissions) – Only the rules with additional carbon emissions are included.				
	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
1	4 ii)	4 ii)	4 ii)	4ii)
2			2 ii)	2 ii)
3			2 i), 6 i), 7 i)	2 i), 6 i), 7 i)

Table 3.3 – Ranking of the rules based on whole system impact (above), considering carbon emissions (below)

3. CBA results - 2hr STOR

Detailed CBA output (data) – 2hr Single Area

Scenario 1

RULES (£m)		STOR provider	ANM generator + BRP	NGESO	DNO	Whole system
Rule 1	i)	252.30		-270.17	-0.34	-270.51
	ii)	22.49		-24.81	-0.72	-25.54
Rule 3	i)	185.26		-189.72	-0.34	-190.06
	ii)	4.33		-5.22	-0.72	-5.94
Rule 4	i)					
	ii)	24.47	-0.11	-26.35	-0.72	-27.18
Rule 2	i)		-27.61	-0.73	-0.70	-29.03
	ii)		-5.39	-1.11	-1.08	-7.59
Rule 6	i)			-28.58	-0.93	-29.52
	ii)	22.49		-25.38	-1.29	-26.68
Rule 7	i)	-27.61		-0.98	-0.93	-29.52
	ii)	4.33		-5.76	-1.29	-7.05

Table 3.4 – Cost and benefit overview for the rules when scenario 1 parameters are applied

Scenario 2

RULES (£m)		STOR provider	ANM generator + BRP	NGESO	DNO	Whole system
Rule 1	i)	315.84		-355.63	-0.34	-355.97
	ii)	23.76		-27.50	-0.72	-28.22
Rule 3	i)	307.24		-345.91	-0.34	-346.24
	ii)	13.67		-16.17	-0.72	-16.89
Rule 4	i)					
	ii)	30.87	-0.23	-35.49	-0.72	-36.44
Rule 2	i)		-156.61	-0.73	-0.70	-158.04
	ii)		-43.54	-1.11	-1.08	-45.73
Rule 6	i)			-157.59	-0.93	-158.52
	ii)	23.76		-28.07	-1.29	-29.36
Rule 7	i)	-156.61		-0.98	-0.93	-158.52
	ii)	13.67		-16.71	-1.29	-18.01

Table 3.5 – Cost and benefit overview for the rules when scenario 2 parameters are applied

3. CBA results - 2hr STOR

Detailed CBA output (data) – 2hr Single Area

Scenario 3

RULES (£m)		STOR provider	ANM generator + BRP	NGESO	DNO	Whole system
Rule 1	i)	252.30		-270.17	-0.34	-270.51
	ii)	4.13		-5.18	-0.72	-5.90
Rule 3	i)	185.26		-189.72	-0.34	-190.06
	ii)	1.22		-2.04	-0.72	-2.76
Rule 4	i)					
	ii)	4.45	-0.04	-5.42	-0.72	-6.18
Rule 2	i)		-13.18	-0.73	-0.70	-14.60
	ii)		-2.35	-1.11	-1.08	-4.55
Rule 6	i)			-14.15	-0.93	-15.08
	ii)	4.13		-5.75	-1.29	-7.04
Rule 7	i)	-13.18		-0.98	-0.93	-15.08
	ii)	1.22		-2.59	-1.29	-3.88

Table 3.6 – Cost and benefit overview for the rules when scenario 3 parameters are applied

Scenario 4

RULES (£m)		STOR provider	ANM generator + BRP	NGESO	DNO	Whole system
Rule 1	i)	315.84		-355.63	-0.34	-355.97
	ii)	4.49		-5.82	-0.72	-6.54
Rule 3	i)	307.24		-345.91	-0.34	-346.24
	ii)	2.48		-3.58	-0.72	-4.30
Rule 4	i)					
	ii)	5.77	-0.24	-7.26	-0.72	-8.23
Rule 2	i)		-75.59	-0.73	-0.70	-77.02
	ii)		-19.02	-1.11	-1.08	-21.22
Rule 6	i)			-76.57	-0.93	-77.50
	ii)	4.49		-6.39	-1.29	-7.68
Rule 7	i)	-75.59		-0.98	-0.93	-77.50
	ii)	2.48		-4.12	-1.29	-5.41

Table 3.7 – Cost and benefit overview for the rules when scenario 4 parameters are applied

3. CBA results - 2hr STOR

Detailed CBA output (data) – 2hr

CO_2 emissions [tCO_2 eq]		Scenario 1	Scenario 2	Scenario 3	Scenario 4
Rule 1	i) Static headroom	-	-	-	-
	ii) Dynamic headroom	-	-	-	-
Rule 3	i) Static headroom	-	-	-	-
	ii) Dynamic headroom	-	-	-	-
Rule 4	i) Static headroom	-	-	-	-
	ii) Dynamic headroom	46	109	26	154
Rule 2	i) Static headroom	-	-	44,215	186,231
	ii) Dynamic headroom	-	-	6,526	40,123
Rule 6	i) Static headroom	-	-	44,215	186,231
	ii) Dynamic headroom	-	-	-	-
Rule 7	i) Static headroom	-	-	44,215	186,231
	ii) Dynamic headroom	-	-	-	-

Table 3.8 – Carbon emission comparison for the rules and scenarios

3. CBA results – 2hr STOR regional

Scenario 3 – Results interpretation

- To verify the outcomes of the analysis, the study assessed a more granular ANM modelling by splitting one single ANM area into three distinct ANM areas characterized by different generation mixes (solar dominant, wind dominant and mixed). For the purpose of the exercise, we applied the same rules 1-7 on the 2hr STOR service with three different ANM areas.
- We received updated curtailment matrices from the ENA, where STOR assets were split into three zones based on the ANM zone generation profile, namely wind, solar and mixed.
- Similar to the 2hr model, the static variants of the rules did not change with the introduction of regional ANM zones, as all STOR units in all ANM areas were removed for that day. Therefore, the results remained the same as in the 24-hr model.
- This section will focus on the results from the dynamic rules ii). Table 3.9 summarises the outcomes of the cost-benefit analysis for all rules in Scenario 3 for 2hr and 2hr regional models.
- In general, the costs were between two to three times higher than in the previous model without ANM splitting. This is because the previous analysis did not consider local conditions that could affect the likelihood of a conflict, whereas the regional model, performed a more granular assessment taking into account areas with higher proportions of renewable generation. For example, if one area had a high proportion of wind generation, it was likely to see not only higher chances of having an ANM conflict but also higher volumes of curtailment, meaning more STOR units in the merit order would need to be 'compensated for', resulting in a higher MCP.
- The results from the regional analysis further confirmed that rule 3 ii) was the most cost-efficient despite being around 40% more expensive than in the 2hr model. In rule 3ii DNO had primacy and the STOR providers excluded themselves from participating in the auction when an ANM conflict was expected.
- Rules 1, 4 and 6 tend to have the largest cost increase in comparison to the previous results. As we have seen from the previous analysis, the rules where the STOR merit order changes tend to have a larger cost increase than in the reference case. This effect was further amplified in the regional model, as there were more instances during the day where the merit order was affected in comparison to the single ANM area. For example, a bright clear morning was likely to generate a lot of solar energy and might have resulted in more curtailment causing changes to the first six STOR availability windows. If there was a strong wind in the afternoon, then we might have seen changes in the last six STOR availability windows as well, as some wind units were removed from the original merit order.
- As in the previous model with shorter procurement windows and a single ANM area, having different ANM zones didn't affect the cost to DNO in comparison to the original 24hr results, as DNOs only bear the rule implementation cost. And there was no extra cost to implement the rule in comparison to the 24hr model or the single ANM area 2hr model.
- The detailed results from each rule in Scenario 3 are discussed on slides 51-58.

Scenario 3

Primacy	RULES (£m)		STOR provider	ANM generator + BRP	NGESO	DNO	Whole system
DNO has primacy	Rule 1	2hr reg	11.16		-12.74	-0.72	-13.46
		2hr	4.13		-5.18	-0.72	-5.9
	Rule 3	2hr reg	2.98		-3.88	-0.72	-4.60
		2hr	1.22		-2.04	-0.72	-2.76
	Rule 4	2hr reg	12.04	-0.09	-13.43	-0.72	-14.23
		2hr	4.45	-0.04	-5.42	-0.72	-6.18
NGESO has primacy	Rule 2	2hr reg		-2.56	-1.11	-1.08	-4.75
		2hr		-2.35	-1.11	-1.08	-4.55
Joint primacy	Rule 6	2hr reg	11.16		-13.31	-1.29	-14.60
		2hr	4.13		-5.75	-1.29	-7.04
	Rule 7	2hr reg	2.98		-4.42	-1.29	-5.71
		2hr	1.22		-2.59	-1.29	-3.88

Table 3.9 – Cost and benefit overview for the dynamic rules ii) when Scenario 3 parameters are applied

DNV

3. CBA results - 2hr STOR regional

Scenario 3 – Results interpretation – 2hr Regional

Rule 1 i) and 1 ii) – Key observations

In general, the logic behind the results in the regional model broadly follows that of the 2hr model.

Figures 3.9 and 3.10 include all the cost/benefits expressed in £m, using the reference case as a reference.

- The main cost element of this rule was the additional cost for NGESO. This cost consists of CAPEX, OPEX, STOR availability payments and STOR utilisation payments. The single biggest cost element was the STOR availability payments, representing 99% of NGESO additional cost.
- In rule 1 i), the STOR availability cost resulted in over 6 times the reference case STOR availability payments. Rule 1 ii) results were 23% higher than the reference case. The steep availability cost difference was due to:
  - a) The market design of day-ahead STOR auctions. As STOR auctions apply a pay-as-clear mechanism, the last chosen STOR unit tendered price sets the market clearing price. The market clearing price (MCP) of the day is used to calculate the payments to all procured capacity in a given service window. The MCP difference between the reference case and the modified merit order can be several orders of magnitude.
  - b) Reduction of the merit order. Rule 1 i) and ii) design specifies that all STOR units within ANM areas should be removed from the merit order, permanently or dynamically respectively. This leads to a decrease of options in the merit order, resulting in significantly more expensive units to cover the required STOR capacity. The large difference between availability cost for rule 1 i) and 1 ii) is because
    - In the static version i, the STOR units within ANM areas were removed permanently from the STOR merit order. This had a significant impact because it affected the merit order every auction every day of the year.
    - In the dynamic rule ii), the STOR units within ANM areas were removed only for the periods where curtailment was forecasted in one or more settlement periods. Most of NGESO STOR availability payment would translate into margins for the STOR provider.
- The net impact on the whole system cost reflected an indirect impact from the net cost of NGESO and DNO. As described above, most of this cost reflected margins for STOR providers.
- Although the dynamic version of rule 1 in the regional model was significantly less expensive than the static version, it was still more expensive than the rule without the split of ANM areas. The specific conditions of each area were likely to have a bigger impact on the results. For example, a high wind day would affect all 12 STOR service windows, leading to more units being left from the merit order and new more expensive units being accepted.

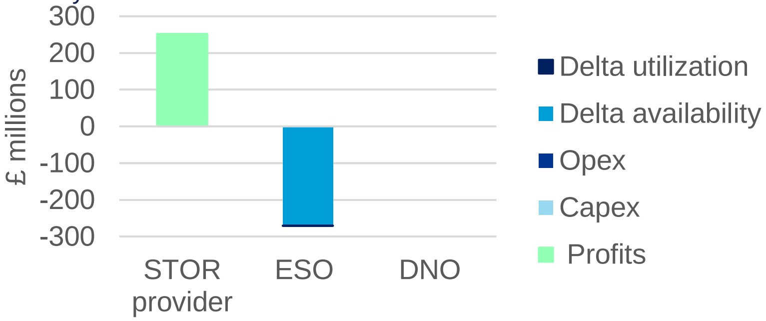


Figure 3.9 – Cost per stakeholder in Scenario 3 - Rule 1 i)

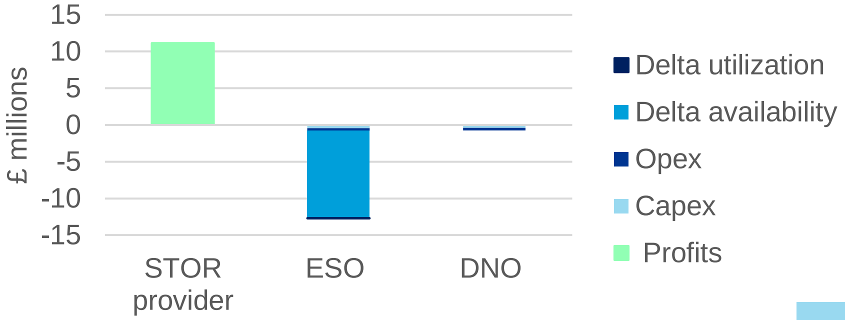


Figure 3.10 – Cost per stakeholder in Scenario 3 - Rule 1 ii)

3. CBA results - 2hr STOR regional

Scenario 3 – Results interpretation - 2hr Regional

Rule 3 i) and 3 ii) – Key observations

- Key observations of rule 1 i) & ii) are equally applicable for rules 3 i) & ii).
- The difference between NGESO cost under rules 1 and 3 was almost 70%. This difference was due to the STOR aggregated units within ANM areas. Whereas in rule 1, the full STOR unit was excluded from the merit order regardless of its composition, in rule 3, only the capacity within the ANM area was excluded.
- There were only four aggregated units within ANM areas, three in the Wind dominated ANM and one in the Solar dominated. However, there was still an impact on the cost, as these units were generally tendered at a cheaper price, which influenced the STOR merit order significantly.
- Rule 3 ii) continued to be the least costly/most efficient rule in the 2hr regional model.

Rule 4 ii) – key observations

- The main cost element of this rule was again the STOR availability payments. Under this rule, this high cost was due to two main reasons:
  a) Need for more STOR capacity to be procured; and
  b) Higher MCP due to greater STOR capacity procured.
- For these reasons, this rule always showed higher cost than rule 1 ii) and 3 ii).
- Utilisation payments were approximately 30% higher than in rules 1 ii) and 3 ii) due to the need for "overdispatch". However, these costs were still negligible relative to NGESO availability cost.
- This was the only "DNO has primacy" rule that had an impact on carbon emissions. The overall impact was relatively low compared to other rules – 58 tCO_2 eq, almost double the emissions in the 2hr single area model.

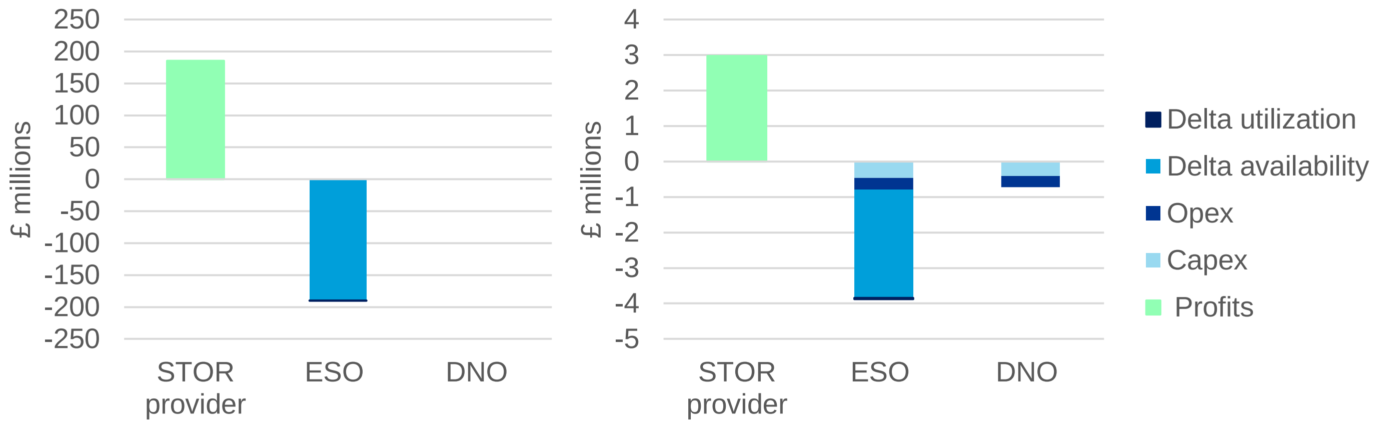


Figure 3.11 – Cost per stakeholder in Scenario 3 - Rule 3 i) (left) and 3 ii) (right)

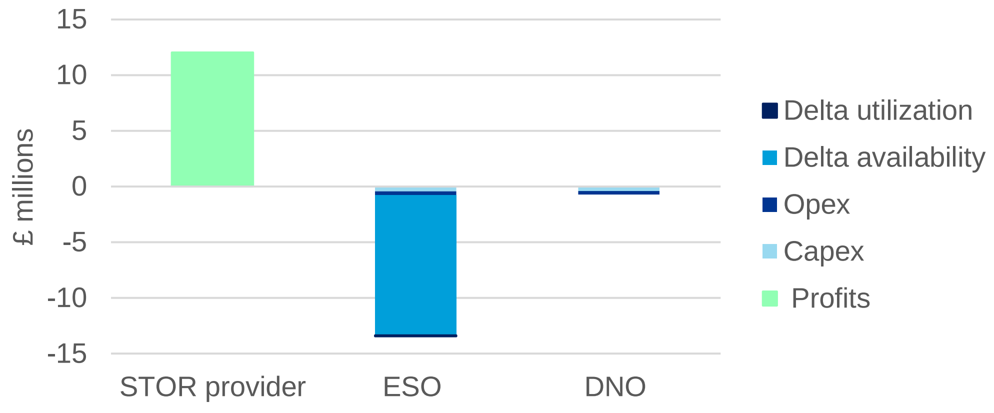


Figure 3.12 – Cost per stakeholder in Scenario 3 - Rule 4 ii)

3. CBA results - 2hr STOR regional

Scenario 3 – Results interpretation – 2hr Regional

Rule 2 i) and 2 ii) – Key observations

- Although, these results were almost identical to the 2hr model, with slightly higher ANM generator cost and higher emissions, still rule 2ii produced the second most cost-efficient results.
- The implementation cost for these rules was overall higher than the implementation cost for rules where the DNO had primacy.
- In addition to the rule implementation cost, the main cost component was the cost for holding headroom incurred by the ANM generator and their BRP.
- Due to increased curtailment, the carbon impact of rule 2 i) was almost 6 times higher than for rule 2 ii).

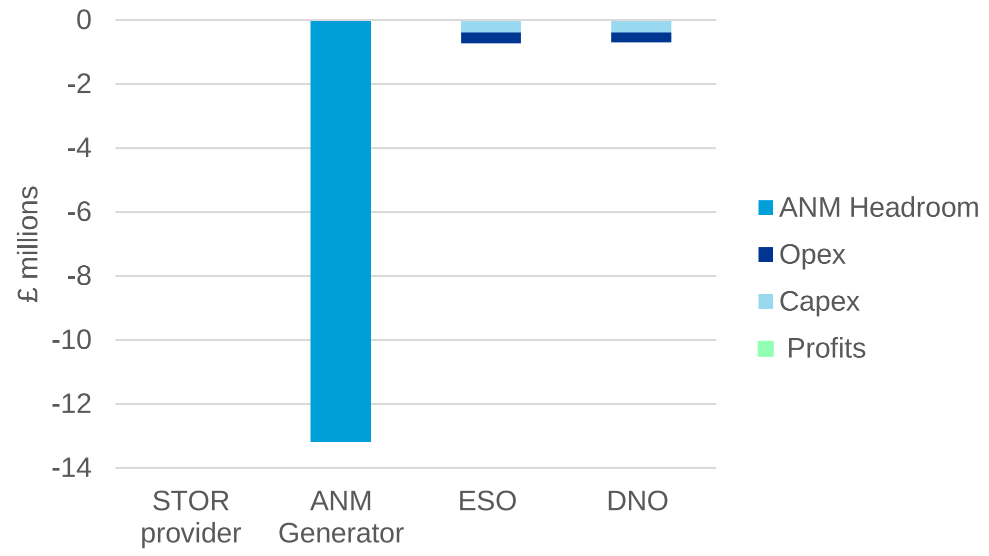


Figure 3.13 – Cost per stakeholder in Scenario 3 - Rule 2 i)

Rule 2 – Emissions [t CO_2 eq]	**i)**	44,215
	ii)	7,093

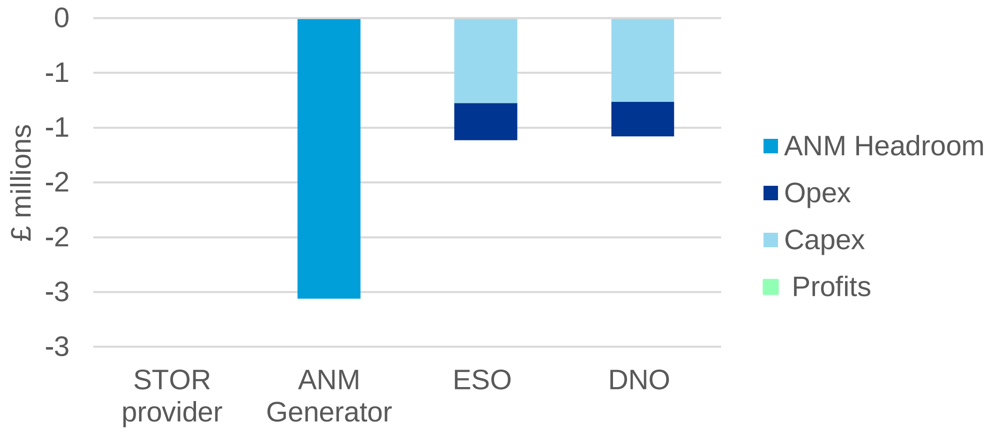


Figure 3.14 – Cost per stakeholder in Scenario 3 - Rule 2 ii)

3. CBA results - 2hr STOR regional

Scenario 3 – Results interpretation - 2hr Regional

Rule 6 i) and ii) – Key observations

- The same observations on 2 i) are applicable to 6 i). The only difference was that the cost for holding headroom was allocated to NGESO instead of the ANM generator + BRP.
- Rule 6 ii) was very different from 2 i). In this variant, the STOR merit order was modified so the cost for holding headroom could be factored in for STOR units within ANM areas.
- This difference was more prominent in the regional model, as the level of curtailment was higher than in the previous models, resulting in more capacity needed to be filled with more expensive available units, which also increased the utilisation cost for NGESO.
- Such modification of the merit order created a higher cost overall than holding headroom due to the STOR market clearing mechanism. When compared to rule 2 ii), the STOR cost of rule 6 ii) was 13 times higher than the cost for holding headroom in rule 2 ii), due to the STOR merit order effect.

Rule 7 i) and ii) – Key observations

- The same observations on 2 i) are applicable to 7 i). The only difference was that the cost for holding headroom was allocated to the STOR provider instead of the ANM generator + BRP.
- Rule 7 ii) had the same logic as 6 ii) with the exception that the STOR service provider was the stakeholder modifying the tendered prices. Hence, the aggregated units could be taken into consideration. This resulted in a smaller increase in the overall cost than in the previous rule.
- As in rule 6 ii), the modification of the merit order created more cost overall than holding headroom due to the STOR market clearing mechanism. When compared to rule 2 ii), the STOR cost of rule 7 ii) was approximately 4 times higher than the cost for holding headroom in rule 2 ii), due to the STOR merit order effect.

Rule 6 – Emissions [t CO_2 eq]		
	i)	44,215
	ii)	-

Rule 7 – Emissions [t CO_2 eq]		
	i)	44,215
	ii)	-

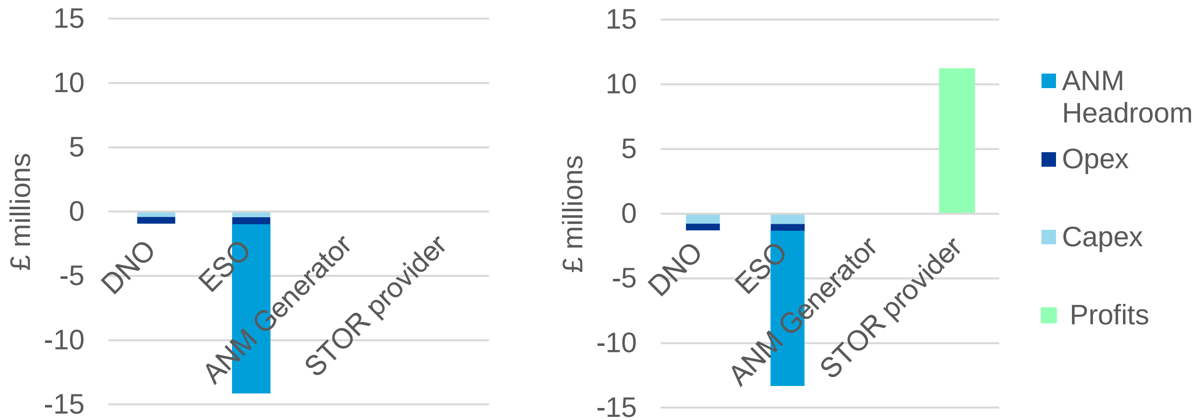


Figure 3.15 – Cost per stakeholder in Scenario 3 - Rule 6 i) (left) and 6 ii) (right)

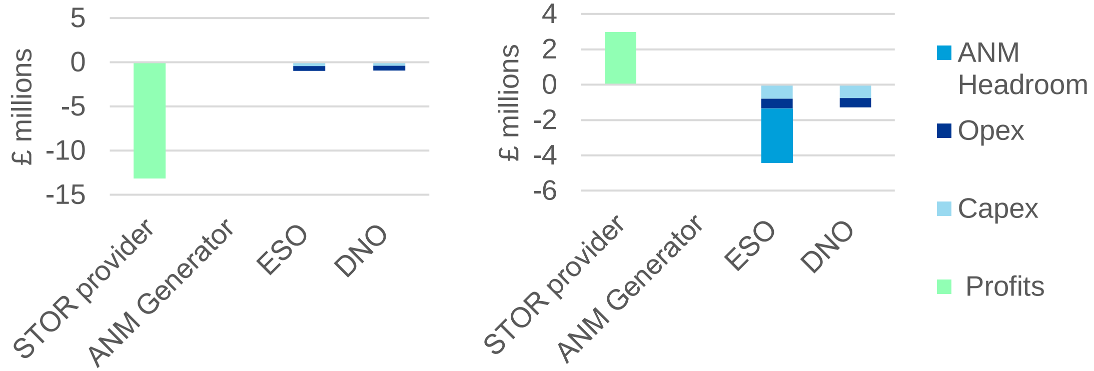


Figure 3.16 – Cost per stakeholder in Scenario 3 - Rule 7 i) (left) and 7 ii) (right)

3. CBA results - 2hr STOR regional

Comparative analysis – whole system impact

- In three out of four scenarios, rule 3 ii) was the most cost-efficient rule. Lower cost was driven by the treatment of the aggregated STOR units, where only the capacity of the conflicting unit was foregone rather than the capacity of the entire aggregated unit.
- In general, the results from Scenario 1 were quite different to the other three scenarios, including the other low-coverage Scenario 3. For example, the most optimal rule in this scenario was rule 2 ii), the same as in the 24hr model. However, it is important to note that this scenario is highly unlikely to realise in the future, as we are going to see higher levels of renewables on the system to reach multiple government targets, such as 50GW of wind by 2030. Furthermore, the sensitivity analysis in the new scenario demonstrated that the rule 2ii cost was significantly higher than rule 3 ii). More details on the sensitivity analysis can be found on slides 60-62.
- Rules 1 i) and 3 i) were the worst-performing rules for all scenarios. This is due to the high impact on the STOR merit order for every service window.
- The dynamic variant of each rule tends to perform better on average. However, there were a few instances, where the static version outperformed, namely rules 6 i) & 7i) in scenario 1. The reason for this is that version "i)" of these two rules is very different to the "ii)" version, since the "ii)" version involves changing the STOR merit order, which has a larger impact in the scenario with low STOR in ANM coverage but high curtailment capacity. In general, rules 6 i) and 7 i) tend to follow the pattern of rule 2 i) and always scored below it.
- Finally, in terms of carbon emissions, there were no changes in emission ranking across scenarios. Rules 2 i), 6 i) and 7 i) were the worst performing rules on emissions in scenarios 3 & 4 (i.e., low renewable generation scenarios). These results were the same as in the 2hr model.

Ranking based on whole system impact (cost)

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
1	2 ii)	3 ii)	3 ii)	3 ii)
2	3 ii)	7 ii)	2 ii)	7 ii)
3	7 ii)	1 ii)	7 ii)	1 ii)
4	2 i)	6 ii)	1 ii)	6 ii)
5	6 i) & 7 i)	2 ii)	4 ii)	2 ii)
6	1 ii)	4 ii)	2 i)	4 ii)
7	6 ii)	2 i)	6 ii)	2 i)
8	4 ii)	6 i) & 7 i)	6 i) & 7 i)	6 i) & 7 i)
9	3 i)	3 i)	3 i)	3 i)
10	1 i)	1 i)	1 i)	1 i)

Ranking based on whole system impact (carbon emissions) – Only the rules with additional carbon emissions are included.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
1	4 ii)	4 ii)	4 ii)	4ii)
2			2 ii)	2 ii)
3			2 i), 6 i), 7 i)	2 i), 6 i), 7 i)

Table 3.10 – Ranking of the rules based on whole system impact (above), considering carbon emissions (below)

DNV

3. CBA results - 2hr STOR regional

Detailed CBA output (data) – 2hr Regional

Scenario 1

RULES (£m)		STOR provider	ANM generator + BRP	NGESO	DNO	Whole system
Rule 1	i)	252.30		-270.17	-0.34	-270.51
	ii)	30.63		-33.61	-0.72	-34.33
Rule 3	i)	185.26		-189.72	-0.34	-190.06
	ii)	14.69		-15.89	-0.72	-16.61
Rule 4	i)					
	ii)	33.11	-0.15	-35.56	-0.72	-36.43
Rule 2	i)		-27.61	-0.73	-0.70	-29.03
	ii)		-6.65	-1.11	-1.08	-8.85
Rule 6	i)			-28.58	-0.93	-29.52
	ii)	30.63		-34.18	-1.29	-35.47
Rule 7	i)	-27.61		-0.98	-0.93	-29.52
	ii)	14.69		-16.43	-1.29	-17.72

Table 3.11 – Cost and benefit overview for the rules when scenario 6 parameters are applied

Scenario 2

RULES (£m)		STOR provider	ANM generator + BRP	NGESO	DNO	Whole system
Rule 1	i)	315.84		-355.63	-0.34	-355.97
	ii)	30.15		-35.12	-0.72	-35.84
Rule 3	i)	307.24		-345.91	-0.34	-346.24
	ii)	24.23		-28.46	-0.72	-29.18
Rule 4	i)					
	ii)	34.07	-0.26	-40.55	-0.72	-41.53
Rule 2	i)		-156.61	-0.73	-0.70	-158.04
	ii)		-36.43	-1.11	-1.08	-38.62
Rule 6	i)			-157.59	-0.93	-158.52
	ii)	30.15		-35.69	-1.29	-36.98
Rule 7	i)	-156.61		-0.98	-0.93	-158.52
	ii)	24.23		-29.00	-1.29	-30.29

Table 3.12 – Cost and benefit overview for the rules when scenario 4 parameters are applied

3. CBA results - 2hr STOR regional

Detailed CBA output (data) – 2hr Regional

Scenario 3

RULES (£m)		STOR provider	ANM generator + BRP	NGESO	DNO	Whole system
Rule 1	i)	252.30		-270.17	-0.34	-270.51
	ii)	11.16		-12.74	-0.72	-13.46
Rule 3	i)	185.26		-189.72	-0.34	-190.06
	ii)	2.98		-3.88	-0.72	-4.60
Rule 4	i)					
	ii)	12.04	-0.09	-13.43	-0.72	-14.23
Rule 2	i)		-13.18	-0.73	-0.70	-14.60
	ii)		-2.56	-1.11	-1.08	-4.75
Rule 6	i)			-14.15	-0.93	-15.08
	ii)	11.16		-13.31	-1.29	-14.60
Rule 7	i)	-13.18		-0.98	-0.93	-15.08
	ii)	2.98		-4.42	-1.29	-5.71

Table 3.13 – Cost and benefit overview for the rules when scenario 6 parameters are applied

Scenario 4

RULES (£m)		STOR provider	ANM generator + BRP	NGESO	DNO	Whole system
Rule 1	i)	315.84		-355.63	-0.34	-355.97
	ii)	11.63		-14.08	-0.72	-14.80
Rule 3	i)	307.24		-345.91	-0.34	-346.24
	ii)	6.83		-8.70	-0.72	-9.42
Rule 4	i)					
	ii)	12.74	-0.45	-15.84	-0.72	-17.01
Rule 2	i)		-75.59	-0.73	-0.70	-77.02
	ii)		-14.47	-1.11	-1.08	-16.67
Rule 6	i)			-76.57	-0.93	-77.50
	ii)	11.63		-14.65	-1.29	-15.94
Rule 7	i)	-75.59		-0.98	-0.93	-77.50
	ii)	6.83		-9.24	-1.29	-10.53

Table 3.14 – Cost and benefit overview for the rules when scenario 4 parameters are applied

3. CBA results - 2hr STOR regional

Detailed CBA output (data) - 2hr Regional

CO_2 emissions [tCO_2 eq]		Scenario 1	Scenario 2	Scenario 3	Scenario 4
Rule 1	i) Static headroom	-	-	-	-
	ii) Dynamic headroom	-	-	-	-
Rule 3	i) Static headroom	-	-	-	-
	ii) Dynamic headroom	-	-	-	-
Rule 4	i) Static headroom	-	-	-	-
	ii) Dynamic headroom	61	121	58	287
Rule 2	i) Static headroom	-	-	44,215	186,231
	ii) Dynamic headroom	-	-	7,093	30,520
Rule 6	i) Static headroom	-	-	44,215	186,231
	ii) Dynamic headroom	-	-	-	-
Rule 7	i) Static headroom	-	-	44,215	186,231
	ii) Dynamic headroom	-	-	-	-

Table 3.15 – Carbon emission comparison for the rules and scenarios

Section 4 – Sensitivity analysis

4. Sensitivities

Sensitivities & CAPEX

Introduction

In this section, we explain the outcomes of the sensitivity analysis.

- The CBA model relied on a number of assumptions (e.g. CAPEX), which we considered to have a potentially low impact on the modelling outcomes but were quantified before this study.
- DNV ran a sensitivity analysis on a range of parameters (ANM technology mix, CAPEX, utilisation price % increase), as well as a new scenario with a different curtailment risk matrix, to determine the impact on total cost and whether that would lead to a new ranking of rules.
- Our approach was to: 1) determine values for sensitivity parameters together with ENA; 2) do a sensitivity analysis for each of the parameters for all rules and scenarios, leaving the rest constant; and 3) interpret and report on results.
- The sensitivity analysis confirmed that rule 3ii remains the rule with the lowest implementation cost.

CAPEX – Key observations

Below, we explain the findings of the CAPEX sensitivities.

- The methodology for this sensitivity was relatively simple, as we deducted CAPEX cost from whole system cost and tested five CAPEX possibilities (-50%, 0%, 25%, 50%, and 100% increase in the CAPEX used for the original calculations). Then the new CAPEX were added to the remainder of the cost, and we measured the new whole system cost for all rules and scenarios for the 2-hour STOR window with ANM regional differentiation modelling.
- Table 4.1 includes all the cost/benefits expressed in £m, using the 0% case as a reference, whereas 100% and -50% represent the highest and lowest cases, respectively.
- Additionally, we selected scenario 3 to illustrate the results, as this showed the highest CAPEX sensitivity since this was the least expensive scenario. In other words, as CAPEX is steady across different scenarios, the impact of CAPEX on total cost can be examined in greater detail.
- From the table, we can see that although CAPEX had impact on certain rules, Rule 3 ii) remained the cheapest option. Total cost were higher in all other scenarios, and therefore this results in the same outcome.

CAPEX

Sensitivity		0%		-50%		100%	
Rules		£m	Diff.	£m	Diff.	£m	Diff.
1	i)	270.51	0%	270.48	0%	270.57	0%
	ii)	13.46	0%	13.04	-3%	14.30	6%
3	i)	190.06	0%	190.01	0%	190.15	0%
	ii)	4.60	0%	4.17	-9%	5.47	19%
4	i)						
	ii)	14.23	0%	13.80	-3%	15.08	6%
2	i)	14.60	0%	14.21	-3%	15.37	5%
	ii)	4.75	0%	3.98	-16%	6.29	32%
6	i)	15.08	0%	14.67	-3%	15.92	6%
	ii)	14.60	0%	13.82	-5%	16.16	11%
7	i)	15.08	0%	14.67	-3%	15.92	6%
	ii)	5.71	0%	4.94	-14%	7.27	27%

Table 4.1 – Cost and benefit overview for the rules when CAPEX sensitivity is applied in scenario 3 (2hr regional).

4. Sensitivities

Utilisation & ANM Technology Mix

Utilisation – Key observations

- For STOR utilisation cost, we applied the same approach as in CAPEX and tested five possibilities (-10%, 0%, 25%, 50%, and 100% increase in relative utilisation cost) for DNO primacy rules in all 2-hour STOR window scenarios (risk-based option) with ANM regional differentiation modelling. This parameter was used to simulate the price to activate STOR units that would be part of the merit order for rules 1, 3, 4, 6ii) and 7 ii). The parameter was defined as the relative increase in price from the last unit that was utilised in the reference case and it was defined as 15% in the original modelling.
- It is important to note that utilisation was not associated with absolute cost but with the difference between total utilisation cost and reference utilisation cost (the same process as STOR payments).
- Figure 4.1 includes all the cost/benefits expressed in £m (utilisation cost for rules 6 & 7 are equal to rules 1 & 7 respectively), using the 0% case as a reference, whereas 100% and -10% represent the highest and lowest cases.
- Similar to CAPEX sensitivity, we used scenario 3 to show our findings.
- From the figure, we can see that utilisation cost did not have a significant impact on the whole system cost as the differences across all rules were less than 1%. The outcome was the same across all scenarios, since in comparison to CAPEX, utilisation was not a constant (it was affected by curtailment likelihood as happens with STOR payments). Overall, Rule 3 remained the cheapest option.

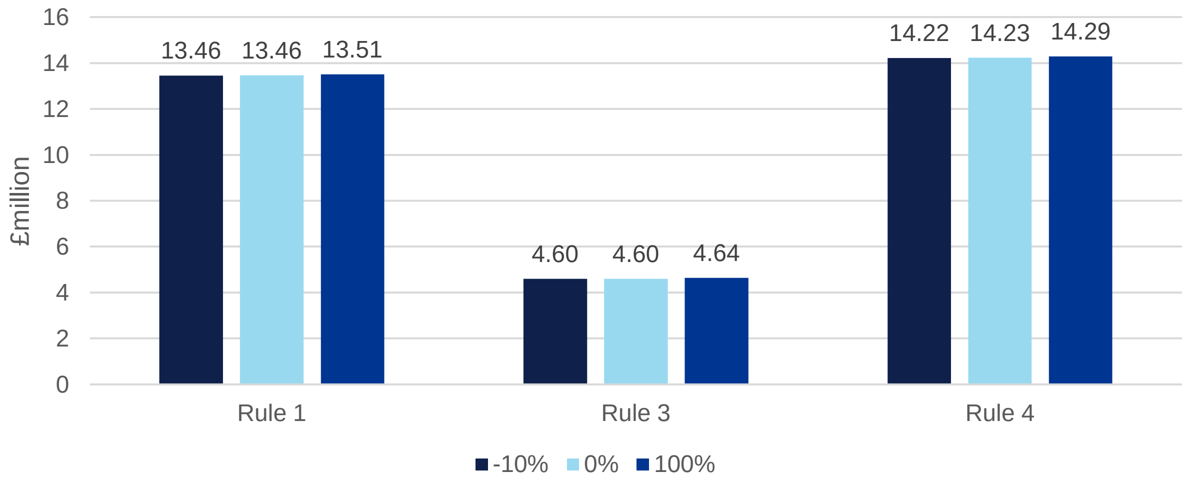


Figure 4.1 – Cost and benefit overview for the rules when utilisation sensitivity is applied in Scenario 3 (2hr Regional – Risk based)

ANM technology mix – Key observations

- For ANM technology mix cost, we applied the same approach as in the previous two parameters and tested an alternative possibility.
- We calculated again Rule 2 and assumed marginal cost equal to £13.01/MWh for the reference ANM mix, and £8.33/MWh for the new ANM mix.
- Marginal cost for generating were calculated based on the marginal cost of operating gas turbines and the percentage of gas in ANM. The new cost reflected a lower share of gas and a higher share of renewables in the ANM mix.
- Similar to our previous findings, there was no significant impact on the whole system cost for Rule 2 – and by extension the NGESO primacy rule - that would change the rule rankings in any scenario.

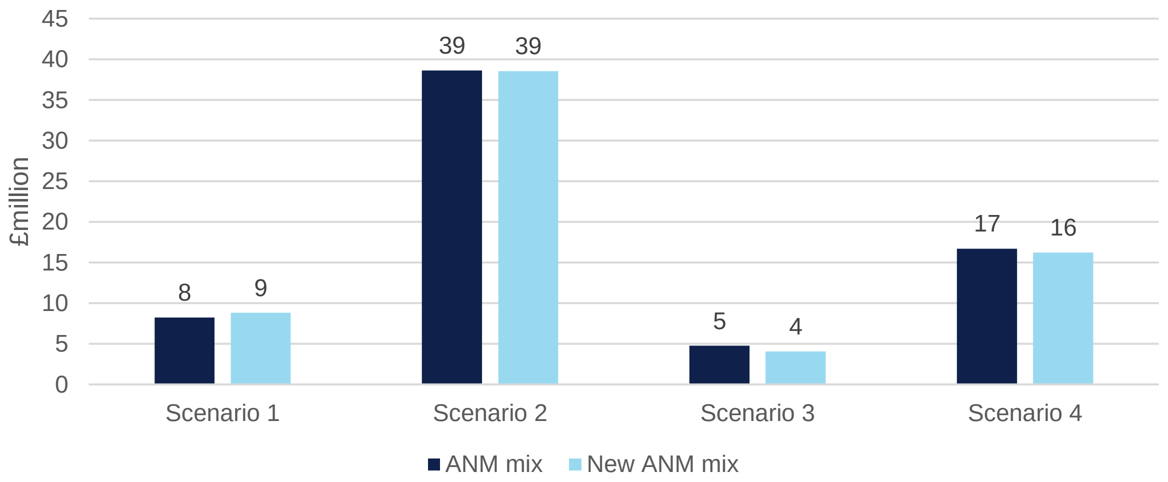


Figure 4.2 – Cost and benefit overview for Rule 2 when ANM Technology Mix sensitivity is applied in all scenarios (2hr Regional – Dynamic headroom)

4. Sensitivities

New Scenario – High curtailment likelihood

New Scenario – Key observations

- For this sensitivity, it was required to run a new scenario with a higher curtailment likelihood (25%) to evaluate a more extreme case with a higher risk of conflicts. We updated the curtailment data and then replicated the process we used to calculate the cost for the 2hr regional scenarios (risk-based option). Figure 4.3 includes all the cost/benefits expressed in £m, using scenarios 3 & 2 (the least and most expensive scenarios based on our previous findings) to compare against the new scenario.
- Overall, although there was a significant impact on total cost there was no change in the rule rankings.
- The results of the sensitivity analysis, further confirmed that rule 3ii is the most appropriate rule to implement.
- Another observation is that as the level of curtailment increases, the relative cost difference between rules 3ii and 7ii becomes smaller. More detailed testing of both rules, and understanding how the market participants would behave, is required to draw further conclusions.

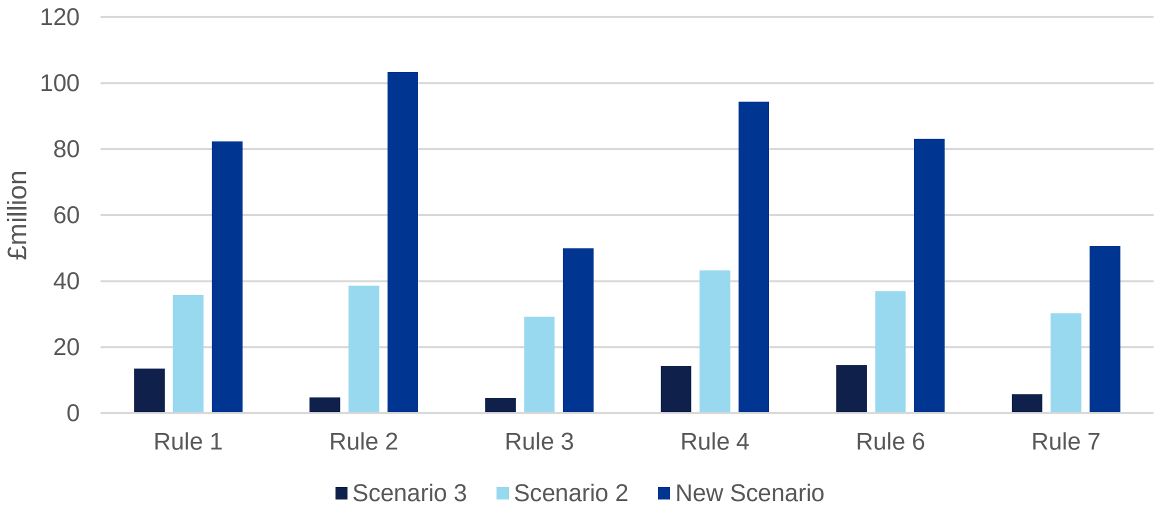


Figure 4.3 – Cost and benefit overview for the new scenario - 25% curtailment likelihood, 50% overlap (2hr Regional – Risk based)

Section 5 – Counterfactual analysis

5. Counterfactual analysis

Introduction

Context

- After completing the first CBA on STOR-ANM primacy rules, the ENA requested to conduct an additional analysis of the counterfactual. This work builds on the existing analysis and CBA model to quantify impacts, further building an evidence base that the ENA can put forward as recommendations regarding primacy rules.
- The counterfactual, or ‘do nothing’, means that if an ANM conflict happens and DNO curtails certain units, this ‘lost’ capacity must be secured by NGESO through the Balancing Mechanism (BM) in real-time.
- Modelling the counterfactual contributed to the completeness of our analysis of the primacy rules.

Scope

- The counterfactual model analysed the conflicting settlement periods where STOR was utilised and replace the conflicting STOR volume with BM units
    - We studied the BM data provided by ENA/NGESO to confirm the relevant cost of these actions
    - Whilst only 16% of all STOR contracted units are connected at the distribution level, we expect this to increase relative to the wider deployment of ANM schemes throughout RIIO-ED2, and will therefore revisit previous scenarios for (conflicts associated with) increasing amounts of STOR connected in ANM zones
- We understand that NGESO control room has a wide range of balancing products to use on a daily basis and usually applies a combination of these to balance the system. However, for the purpose of this analysis, we only considered the STOR actions in isolation, whilst acknowledging the full complexity of balancing actions and interaction of various products.
- NGESO shared the logic behind the control room actions to procure extra reserve capacity in the BM, which consisted of two steps:
    1. In the first 60 seconds, choose the fastest unit to bring the frequency back to the safe operational boundary
    2. Then, look for units that offer longer duration to cover the rest of the curtailed STOR unit volume at a lower cost
- NGESO noted that these actions were mainly driven by human decisions, therefore it was very hard to predict the exact outcomes.

- As our main goal was to understand the order of magnitude of cost caused by the conflict if no party has a priority (no rule implemented), we used monthly average prices of previously rejected offers to calculate the total cost
    - Note, a more detailed analysis of actions per settlement period had not been performed. The aim was to validate our modelling and perform a more detailed analysis, if requested

Methodology

- Gather and interpret historic BM data from ENA/NGESO
- Develop the counterfactual and model the two extreme cases (Scenario 2 – highest cost and Scenario 3 – lowest cost) in Excel (Table 5.1)
- Report the results
- Add these results into a dedicated chapter of the main report

	% of distributed STOR covered by ANM	ANM, Likelihood of curtailment
Scenario 1	Current coverage – 16% coverage	Curtailment 11% of settlement periods
Scenario 2	50% coverage	Curtailment 11% of settlement periods
Scenario 3	Current coverage – 16% coverage	Curtailment 5% of settlement periods
Scenario 4	50% coverage	Curtailment 5% of settlement periods

Table 5.1 - Scenarios used for the counterfactual analysis

5. Counterfactual analysis

Approach

Calculation of the counterfactual cost

1. Create two groups from the list of all BOAs for the period of June 2021-May 2022. These groups are:
   - **Group 1**= online units that are assumed able to provide response fast
   - **Group 2** = units with outputs generating below SEL
2. Calculate monthly average offer price for Group 1 and Group 2
3. Calculate volume of ANM conflict for each Scenario
4. Calculate total cost

Creating two groups

- **Data:** To perform this analysis we used data provided by NGESO from the following sources:
  - Potential alternatives
  - BMU Cap
  - Ramps BMU
- **Approach:** From the sheet with Potential alternatives (Figure 5.1), we looked at the Alternative BMUs and reason group to separate them into two groups: 1) online units that are assumed able to provide fast response; and 2) units with outputs generating below SEL (yellow)

	ACCEPTED BMU	BOA REF	BID/OFFER	BOA PRICE (GBP/MWh)	ALTERNATIVE BMU	REASON GROUP
3	AG-HEL00G	16377	BID	23	CONTB-1	Frequency
3	AG-HEL00G	16377	BID	23	BHOLB-1	Frequency, Zonal Management
3	AG-HEL00G	16377	BID	23	AG-FLX00L	Frequency
3	AG-HEL00G	16377	BID	23	ARNKB-1	Frequency
3	AG-HEL00G	16377	BID	23	NFSE02	Frequency, Zonal Management
3	DINO-2	147763	OFFER	245	ARNKB-1	Frequency, Incomplete, Zonal Management, BOA Unit Below SEL
3	DINO-2	147763	OFFER	245	COWB-1	Frequency, Incomplete, Zonal Management, BOA Unit Below SEL
3	DINO-2	147763	OFFER	245	AG-GSTK05	Frequency, Incomplete, Zonal Management, BOA Unit Below SEL
3	DINO-2	147763	OFFER	245	PINFB-2	Frequency, Incomplete, Zonal Management, BOA Unit Below SEL

Figure 5.1 - Potential alternative

5. Counterfactual analysis

Approach

Calculation of monthly average offer price

- For each group, we took the offer price and calculated a monthly average price

Month	Group 1 (£/MWh)	Group 2 (£/MWh)
Jan	246	274
Feb	214	246
Mar	288	325
Apr	242	275
May	178	195
Jun	108	112
Jul	116	125
Aug	140	136
Sep	200	218
Oct	209	231
Nov	212	236
Dec	271	306

Table 5.2 - Monthly average prices of Group 1 and Group 2

Calculation of volume of ANM conflict for each Scenario

- Data from June – October 2021 was missing from the ANM curtailment matrix. We created the new data based on the values from the available months
- We used the same approach to calculate the level of ANM conflict in each scenario, as in previous tasks:
    - Using the curtailment matrix provided by ANM, we identified settlement periods where renewable generation is above 15% (red settlement period)
    - For Scenario 3, ENA provided a list of 24 STOR units currently in the ANM areas
    - For Scenario 2, we assumed 50% of STOR providers connected at distribution level are in the ANM area. We took the original 24 units and added new units, taking every other unit left. In total, we got 64 units in ANM area
    - For each scenario, we checked the following two conditions:
        1) A contracted unit is in the red settlement period
        2) A contracted unit is on the list of ANM units
    - If both conditions are met, we assumed there is an ANM conflict
    - We recorded the contracted volume of such unit. The sum of this volumes is the total volume of ANM conflict in each month
- For Scenario 3, based on the calculations above, we only found conflict in the month of August. This could be because the data submitted with curtailment matrix for Scenario 3 was less than the anticipated 5% curtailment
- In Scenario 2, which assumes 50 % of STOR providers connected at distribution level are at the risk of ANM conflict. This tends to concentrate in the following four months: January, March, August and October

Month	Scenario 2 (MWh)	Scenario 3 (MWh)
Jan	446	0
Feb	0	0
Mar	89	0
Apr	0	0
May	0	0
Jun	0	0
Jul	0	0
Aug	483	15
Sep	0	0
Oct	446	0
Nov	0	0
Dec	0	0

Table 5.3 - Monthly volume of ANM conflict

5. Counterfactual analysis

Approach

Calculation of total cost

- Total cost is the sum of the average monthly offer prices for units in Group 1 and Group 2, and the cost of curtailment, multiplied by the level of conflict in a given month

  $$Total\ cost_i = \sum_i^{12}(\ level\ of\ ANM\ conflicti\ (MW)\ x\ (average\ price\_1_i + average\ price\_2_i + cost\ of\ headroom))$$

- For the purpose of this exercise, we assumed curtailment cost, i.e. lost revenue, each month (£320/MWh). This curtailment cost is based on the cost for holding headroom calculated during the CBA exercise. The definition of cost for holding headroom is given in section 2.

Month	Group 1 (£/MWh)	Group 2 (£/MWh)	Curtailment (£/MWh)	Volume of conflict (MWh)	Total
Jan	246	274	320	446	840
Feb	214	246	320	0	780
Mar	288	325	320	89	933
Apr	242	275	320	0	837
May	178	195	320	0	694
Jun	108	112	320	0	540
Jul	116	125	320	0	561
Aug	140	136	320	483	596
Sep	200	218	320	0	737
Oct	209	231	320	446	760
Nov	212	236	320	0	768
Dec	271	306	320	0	897

Table 5.4 – Example of the total cost for Scenario 2

5. Counterfactual analysis
Results

- The tables summarise the results for Rules 1-4 from the **2hr regional model** and the counterfactual case.
- The counterfactual case estimates were significantly lower than the results from any of the rules, implying that the 'do nothing' option could be the most economic approach given our assumptions. However, it can also be observed that the higher the conflict, the lower the cost difference
- Although the do-nothing scenario seemed to be the cheaper option now, there were other elements to consider that would impact the wider system:
    - As the level of renewable generation connected at the distribution level grows, the risk of conflict also increases, hence a new rule might be necessary in the future. 'Do nothing' will not be future-proof.
    - This task assumes a low risk of STOR curtailment hence it considers that NGESO will have enough options to replace the STOR unit being curtailed. However, this is a big assumption that might not always hold true and there is a possibility that the STOR capacity requirements might not be met
    - Finally, there might be an increase in carbon emissions if no rules are implemented and additional non low carbon generators have to come online.

	Scenario 2 (£m)	Scenario 3 (£m)
Counterfactual	1.4	0.07
Rule 1 ii	36	13
Rule 3 ii	29	5
Rule 4 ii	43	14
Rule 2 ii	39	5
Rule 6 ii	37	14
Rule 7 ii	30	6

Table 5.5 - Results from the 2hr regional model against the counterfactual

Section 6 - Alternative rules

6. Alternative rules

Introduction

Context and scope

The previous DNV primacy rules study focused on the rules that were designed by the ENA product group team but did not challenge the completeness of the rule alternatives. Therefore, in this new study, DNV was tasked with re-assessing and challenging the rule definitions to provide recommendations on potential improvements to existing rules, and if possible, propose different rule(s).

Methodology

DNV analysed whether there were any potential rules that were not originally captured by the product group. To do so, we:

- Assessed the primacy rules principles that ENA designed so we could provide recommendations in line with these principles
- Discussed with ENA the reasons for discarding the original rule 5
- Designed new rules based on the previous studies' results and discussions with the product group
- Quantified, on a high level, the potential cost impact of the alternative rules

Suggested rules

We suggested three new alternative rules – Rule 8, Rule 9 and Rule 10. Rules 8 and 10 also incorporate different options (i and ii) whereby regional differentiation is applied.

The short definition of the rules is on the right-hand side of the slide. Next slides describe the alternative rule mechanics in detail.

Rule 8: NGESO decides day-ahead whether it is more economical to either 1) exclude all conflicting STOR units from merit order or 2) for the DNOs to hold headroom for the conflicting amount of capacity.

i) NGESO does not consider differences and applies the same measure for all ANM areas	ii) NGESO considers regional differences and applies different measures per ANM area

Rule 9: NGESO overprocures STOR capacity based on the foreseen curtailment risk. NGESO coordinates real time with DNO to dispatch the STOR units with no conflict.

Rule 10: NGESO decides day-ahead whether it is more economical to either 1) overprocure STOR or 2) for the DNOs to hold headroom for the conflicting amount of capacity.

i) NGESO does not consider differences and applies the same measure for all ANM areas	ii) NGESO considers regional differences and applies different measures per ANM area

6. Proposed new rules

Rule 8 i) mechanics

Rule 8 - NGESO coordinates conflict avoidance I

NGESO decides day-ahead whether it is more economical to either 1) exclude all conflicting STOR units from merit order or 2) for the DNOs to hold headroom for the conflicting amount of capacity.

Option i) NGESO does not consider differences and applies the same measure for all ANM areas

Long-term

- STOR assets are prequalified or discontinued. When prequalifying an aggregated unit, NGESO is informed of what assets compose that unit, and in which area they are connected.
- ANM connection agreements are closed or discontinued.

Day-ahead

- The DNO forecasts ANM curtailment activity. The forecast is assumed to have a certain level of accuracy so that system reliability is maintained.
- The DNO informs NGESO of what are the ANM areas, including the likelihood of utilisation of the ANM in those areas.
- The STOR provider issues the bids for the DA auction
- NGESO evaluates the forecasts and determines what the cost associated to different options would be:
    - Exclude conflicting STOR units from merit order
    - For DNOs to hold headroom for the amount of conflicting STOR capacity that would be awarded
- NGESO choses the most cost-effective option (**same decision for all units/ ANM areas**)

Intraday

- Depending on NGESO choice DNO might need to hold headroom after being informed by NGESO.

Real time

- NGESO sends signal for utilisation of STOR

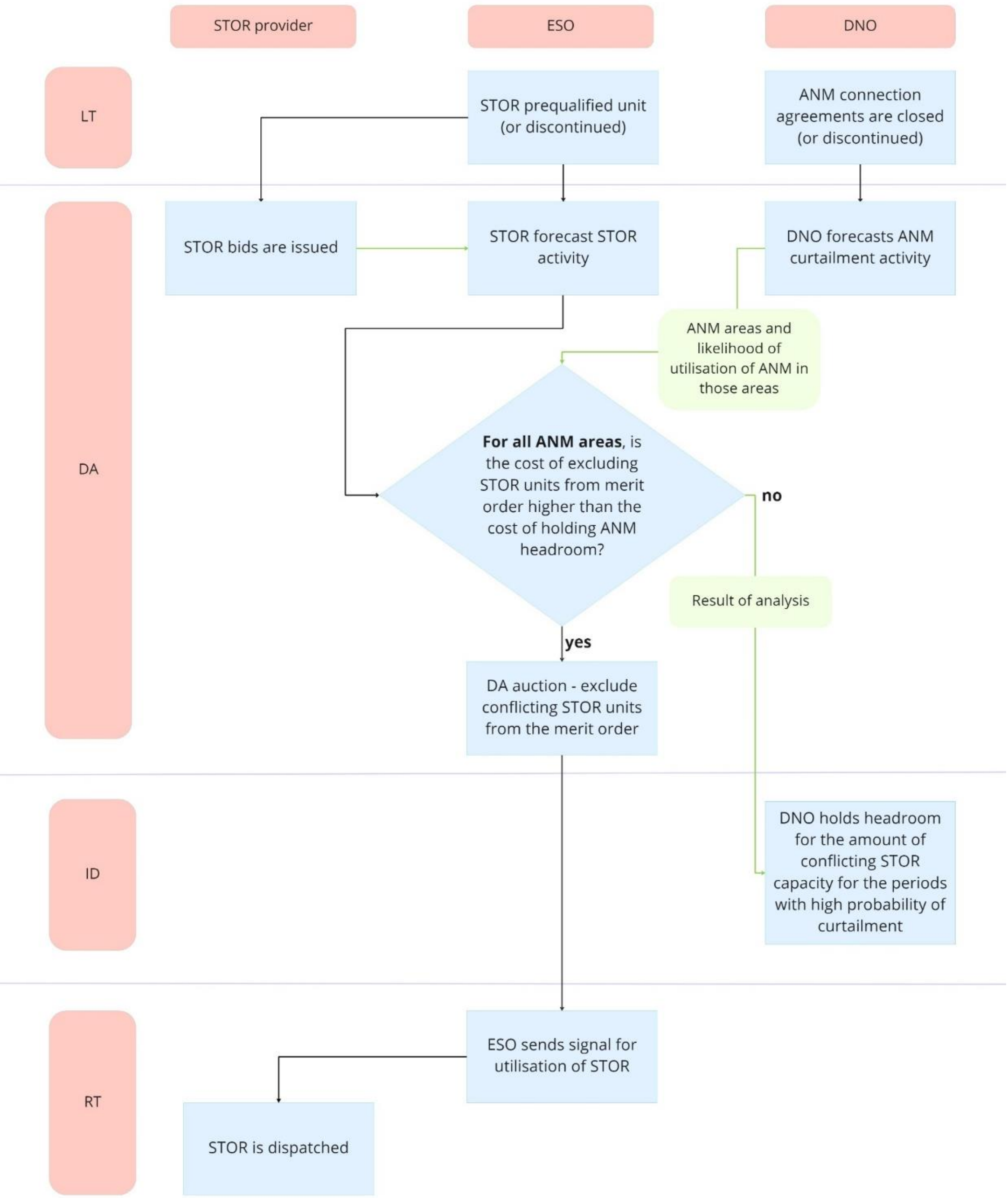


Figure 6.1 – Rule 8 i) process flow

6. Primacy rules definition

Rule 8 ii) mechanics

Rule 8 - NGESO coordinates conflict avoidance I

NGESO decides day-ahead whether it is more economical to either 1) exclude all conflicting STOR units from merit order or 2) for the DNOs to hold headroom for the conflicting amount of capacity.

Option ii) NGESO considers regional differences and applies different measures per ANM area

Long-term

- STOR assets are prequalified or discontinued. When prequalifying an aggregated unit, NGESO is informed of what assets compose that unit, and in which area they are connected.
- ANM connection agreements are closed or discontinued.

Day-ahead

- The DNO forecasts ANM curtailment activity. The forecast is assumed to have a certain level of accuracy so that system reliability is maintained.
- The DNO informs NGESO of what are the ANM areas, including the likelihood of utilisation of the ANM in those areas.
- The STOR provider issues the bids for the DA auction
- NGESO evaluates the forecasts and determines what the cost associated to different options would be:
    - Exclude conflicting STOR units from merit order
    - For DNOs to hold headroom for the amount of conflicting STOR capacity that would be awarded
- NGESO choses the most cost-effective **option <u>for each ANM area</u>**

Intraday

- Depending on NGESO choice DNO might need to hold headroom after being informed by NGESO.

Real time

- NGESO sends signal for utilisation of STOR

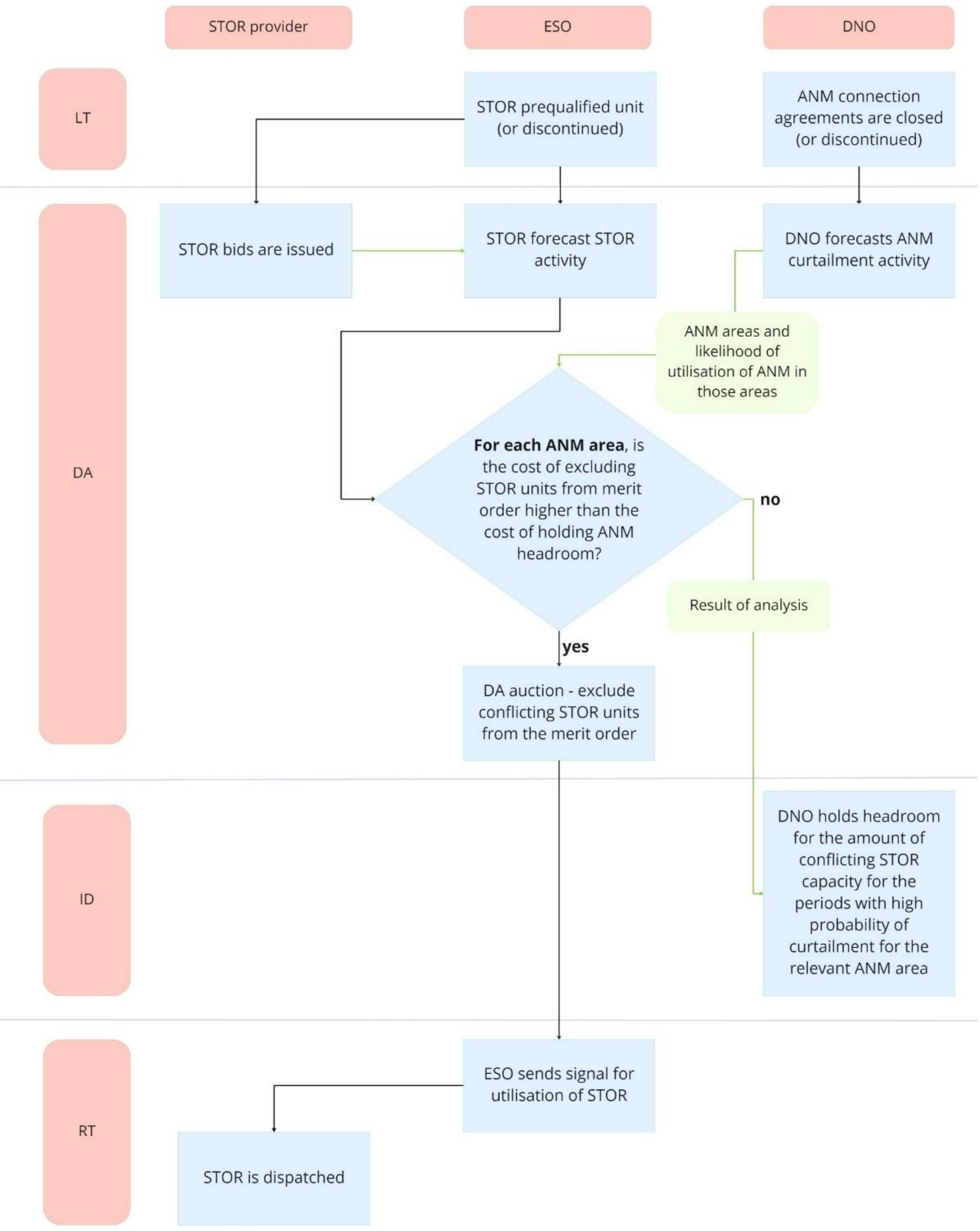


Figure 6.2 – Rule 8 ii) process flow

6. Primacy rules definition

Rule 9 mechanics

Rule 9 – STOR over procurement (not over dispatching)

NGESO over procures STOR capacity based on the foreseen curtailment risk. NGESO coordinates real time with DNO to dispatch the STOR units with no conflict.

Long-term

- STOR assets are prequalified or discontinued. When prequalifying an aggregated unit, NGESO is informed of what assets compose that unit, and in which area they are connected.
- ANM connection agreements are closed or discontinued.

Day-ahead

- The DNO forecasts ANM curtailment activity. The forecast is assumed to have a certain level of accuracy so that system reliability is maintained.
- The DNO informs NGESO of what are the ANM areas, including the likelihood of utilisation of the ANM in those areas.
- The STOR provider issues the bids for the DA auction
- NGESO evaluates the forecasts and determines the amount of over-procurement on a risk-based approach taking into consideration the risk evaluation from DNO
- In the DA auction, NGESO over-procures as per the described approach above

Intraday

- DNO sends an updated forecast of ANM curtailment
- NGESO evaluates, if the STOR utilisation would take place in an ANM area with high curtailment likelihood, they will utilize the next unit in the merit order

Real time

- NGESO sends signal for utilisation of STOR (not over dispatch)

Ex-post

DNO compensates holding headroom to ANM generator

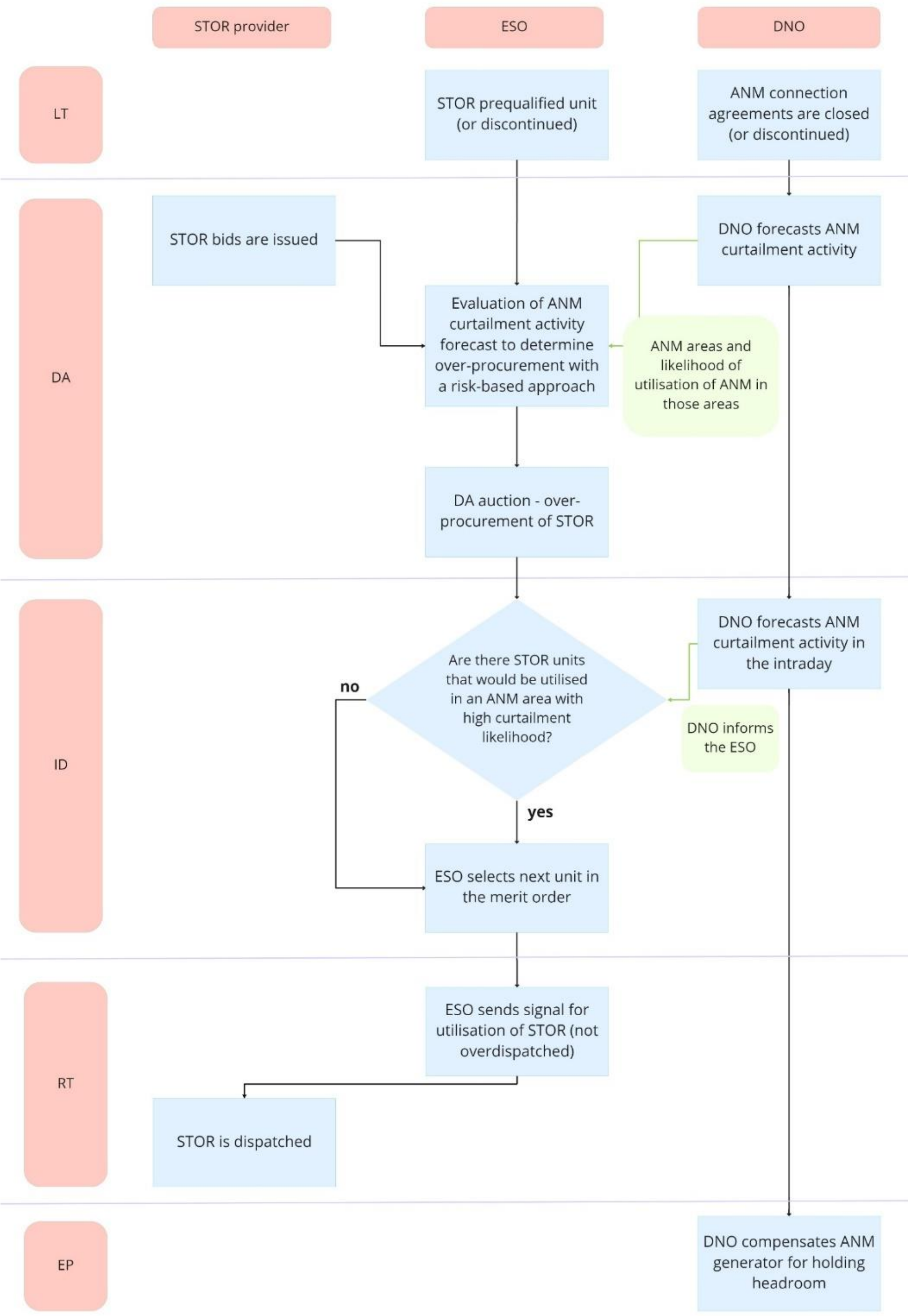


Figure 6.3 – Rule 9 process flow

6. Primacy rules definition

Rule 10 i) mechanics

Rule 10 – NGESO coordinates conflict avoidance II

NGESO decides day-ahead whether it is more economical to either 1) over procure STOR or 2) for the DNOs to hold headroom for the conflicting amount of capacity.

Option i) NGESO does not consider differences and applies the same measure for all ANM areas

Long-term

- STOR assets are prequalified or discontinued. When prequalifying an aggregated unit, NGESO is informed of what assets compose that unit, and in which area they are connected.
- ANM connection agreements are closed or discontinued.

Day-ahead

- The DNO forecasts ANM curtailment activity. The forecast is assumed to have a certain level of accuracy so that system reliability is maintained.
- The DNO informs NGESO of what are the ANM areas, including the likelihood of utilisation of the ANM in those areas.
- The STOR provider issues the bids for the DA auction
- **NGESO evaluates the forecasts and their own STOR forecast and determines whether over procuring or holding headroom is more economically attractive (same decision for all units/ ANM areas)**
  - If holding headroom – DNO holds headroom for the units that are selected in the DA auction
  - If over procuring – NGESO follows the same logic as option i)
- In the DA auction, NGESO over-procures (or not) as per the described approach above. If holding headroom is a better option, NGESO should communicate the auction result to DNO so they can hold headroom.

Intraday

- DNO sends an updated forecast of ANM curtailment
- NGESO evaluates, if the STOR utilisation would take place in an ANM area with high curtailment likelihood, they will utilize the next unit in the merit order

Real time

- NGESO sends signal for utilisation of STOR (not over dispatch)

Ex-post

NGESO pays for the cost of holding headroom

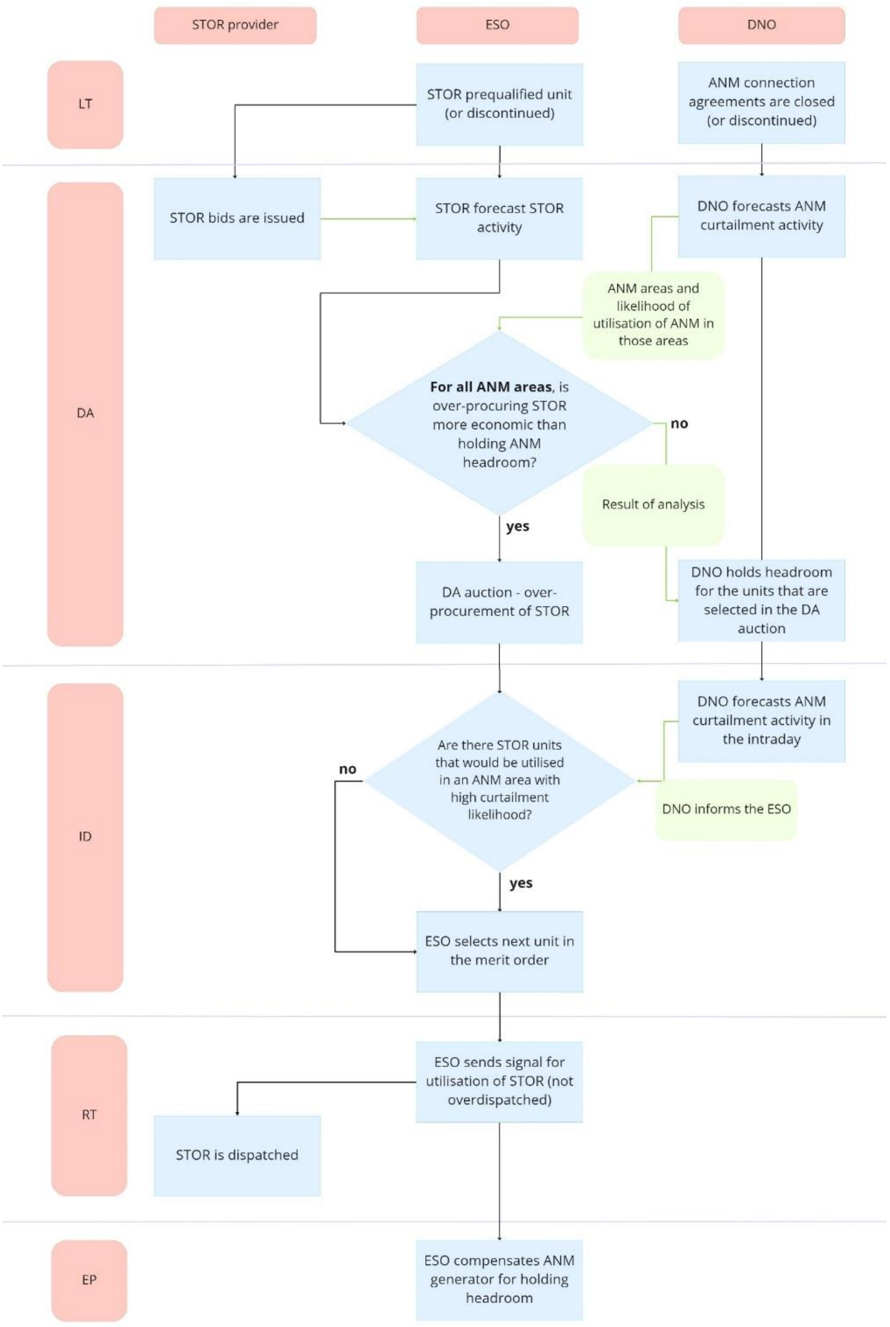


Figure 6.4 – Rule 10 i) process flow

6. Primacy rules definition

Rule 10 ii) mechanics

Rule 10 – NGESO coordinates conflict avoidance II

NGESO decides day-ahead whether it is more economical to either 1) over procure STOR or 2) for the DNOs to hold headroom for the conflicting amount of capacity.

Option ii) NGESO considers regional differences and applies different measures per ANM area

Long-term

- STOR assets are prequalified or discontinued. When prequalifying an aggregated unit, NGESO is informed of what assets compose that unit, and in which area they are connected.
- ANM connection agreements are closed or discontinued.

Day-ahead

- The DNO forecasts ANM curtailment activity. The forecast is assumed to have a certain level of accuracy so that system reliability is maintained.
- The DNO informs NGESO of what are the ANM areas, including the likelihood of utilisation of the ANM in those areas.
- The STOR provider issues the bids for the DA auction
- **NGESO evaluates the forecasts and their own STOR forecast and determines whether over procuring or holding headroom is more economically attractive for each ANM area**
  - If holding headroom – DNO holds headroom for the areas with units that are selected in the DA auction
  - If over procuring – NGESO follows the same logic as option i)
- In the DA auction, NGESO over-procures (or not) as per the described approach above. If holding headroom is a better option, NGESO should communicate the auction result to DNO so they can hold headroom.

Intraday

- DNO sends an updated forecast of ANM curtailment
- NGESO evaluates, if the STOR utilisation would take place in an ANM area with high curtailment likelihood, they will utilize the next unit in the merit order

Real time

- NGESO sends signal for utilisation of STOR (not over dispatch)

Ex-post

NGESO pays for the cost of holding headroom

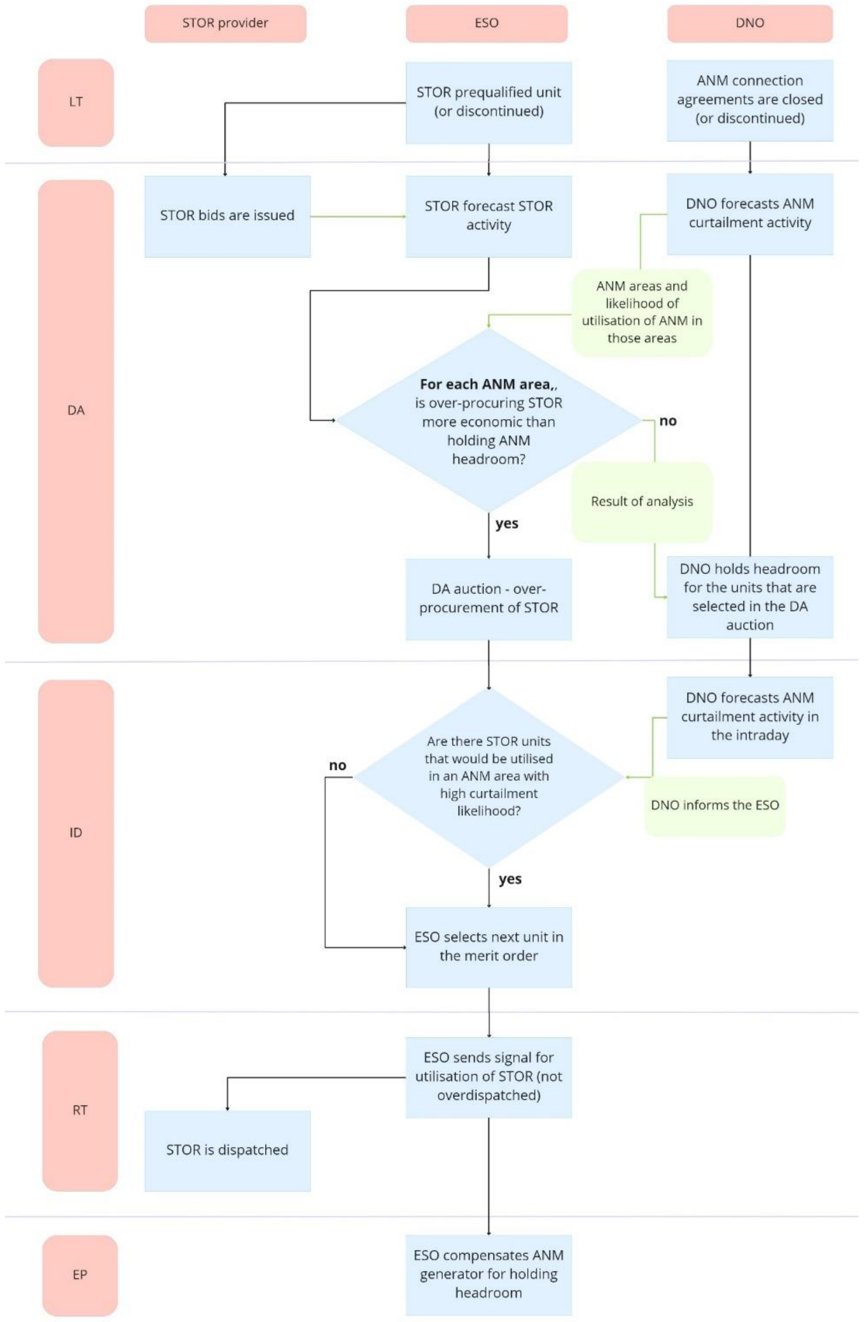


Figure 6.5 – Rule 10 ii) process flow

6. Primacy rules definition

Alternative rules quantification (excl. CAPEX and OPEX)

We performed a high-level quantification exercise to illustrate the cost difference between the original rules and the alternative rules 8, 9 and 10. The quantification used the 2h model results for scenario 3. The reason this scenario was chosen was that if there was a cost difference at the lowest frequency of conflict, the logical conclusion was that there would also be a benefit for more frequent levels of conflict.

The results suggested that both rules 8 and 10 would achieve lower whole system costs (excl. CAPEX and OPEX) than the rest of the rules. Particularly rule 8 performed very well, with costs down to nearly three times in comparison to Rule 3ii. The reason for this is that this rule optimised NGESO and DNO primacy dynamically based on the total cost associated to the different actions.

Although rule 8 performed better according to this quantification exercise, the resulting costs did not include CAPEX and OPEX, which according to ENA would be significantly higher than for the implementation of the other rules. The higher cost would be due to the increased complexity of rule 8. Implementation of rule 8 requires improved coordination between a given central entity, such as NGESO, and DNOs. This could only be achieved with increased and streamlined bidirectional data flows between the parties, which in turn, requires adjustments to all the relevant processes and systems. Furthermore, a new and more complex algorithm has to be developed to optimise the choice at the system and local levels.

Therefore, we concluded that these rules were interesting to explore in the future when NGESO and DNOs would have achieved further coordination and would have gained experience with the implementation of primacy rule 3ii.

Rules		Scenario 3 - Whole system cost excl. CAPEX and OPEX [£m]
Rule 1	ii) Dynamic headroom	4.6
Rule 3	ii) Dynamic headroom	1.6
Rule 4	ii) Dynamic headroom	1.9
Rule 2	ii) Dynamic headroom	2.4
Rule 6	ii) Dynamic headroom	4.6
Rule 7	ii) Dynamic headroom	1.8
Rule 8	i) No regional differentiation	0.6
Rule 9	-	1.6
Rule 10	i) No regional differentiation	1.1

Table 6.1 – Whole system cost excl. CAPEX and OPEX for original rules and alternative rules

Section 7 - Abbreviations

7. Abbreviations

Abbreviation	Definition
ANM	Active Network Management
BaU	Business as Usual
BM	Balancing Mechanim
BRP	Balance Responsible Party
CBA	Cost Benefit Analysis
DA	Day ahead
DNO	Distribution Network Operator
ENA	Electricity Networks Asociation
GHG	Green House Gases
HH	Half-hourly
ID	Intra Day
LT	Long Term
MCP	Market Clearing Price
NBM	non Balancing Mechanims
NGESO	National Grid Electricity System Operator
PoA	Principles of Access
RT	Real Time
SCR	Charging Significant Code Review
STOR	Short-Term Operating Reserve
TSO	Transmission System Operator

Table 7.1 – List of abbreviations

About DNV

DNV is the independent expert in risk management and assurance, operating in more than 100 countries. Through its broad experience and deep expertise DNV advances safety and sustainable performance, sets industry benchmarks, and inspires and invents solutions. Whether assessing a new ship design, optimizing the performance of a wind farm, analyzing sensor data from a gas pipeline or certifying a food company's supply chain, DNV enables its customers and their stakeholders to make critical decisions with confidence. Driven by its purpose, to safeguard life, property, and the environment, DNV helps tackle the challenges and global transformations facing its customers and the world today and is a trusted voice for many of the world's most successful and forward-thinking companies.

Next Steps

As part of the refocussing of the Primacy work, the outcomes and recommendations for this report will form part of the implementation planning of the next increment. The next increment is likely to encompass more Use Cases than previously planned, more information of this will be published over the summer of 2023. The Primacy Technical Working Group and the ENA thanks DNV for their hard work and dedication in producing this report.

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