WHEN TRUST MATTERS

Development and impact quantification of primacy rules

Conflict between STOR and ANM

20 October 2022

Report details

Project name	FUSION	Vivo Building, 30 Stamford Street, London SE1 9LQ, United Kingdom
Client	Scottish Power Energy Networks	

Date of issue	20/10/2022	Project number	10130767
Report number	10130767-2210	Organizational unit	Energy Systems
		Subject group	Power System Planning

Prepared by	Aurora Sáez Armenteros – Senior Consultant	
Prepared by	Elisa Anderson Vázquez - Consultant	
Prepared by	George Martiko - Consultant	
Prepared by	Hans de Heer – Principal Consultant	
Approved by	Rafiek Versmissen – Head of Energy Strategy Advisory	

■ Open	Key words	ESO-DSO coordination, ANM, balancing services
☐ Internal Use only	Service Area	Energy Advisory
☐ Commercial in confidence	Market Segment	Power grids
☐ Confidential		
☐ Secret		

Table of contents

Executive summary

Development and quantification of the impact of primacy rules

DNV, as part of Project FUSION, 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 ESO and DSO services.

This study focuses on the interaction between Short Term Operating Reserve (STOR) providers and Active Network Management (ANM) generators in the same area where opposite instructions are issued by the ESO and DNOs. It explores the use case in which the ESO instructs a STOR generating asset to increase MWs, and subsequently the DNO curtails a different generator through ANM, which counteracts the ESO-instructed STOR service.

The objective of this project is to quantify the economic impact on all parties involved of the primacy rules that would mitigate this conflict, to help ENA members understand which rules deliver the most efficient outcome for the end consumer. This has been achieved by, firstly, assessing a set of rules provided by ENA aiming to have a set as diverse as possible to explore the merits and drawbacks of each approach. These rules were then further defined and scoped to fully understand their implications. Research was carried out and a questionnaire was sent to the ESO and DNOs to assess the interactions between ANM and STOR schemes.

Once this is completed, the mechanics and process flow for each rule is created to then analyse the impact on each of the key stakeholders. Finally, with input from ENA members; UK DNOs and the ESO, as well as information provided by DNV, a cost benefit analysis (CBA) was conducted for each of the rules for four scenarios that explored different levels of distributed STOR assets covered by ANM areas and varying likelihood curtailment in ANM.

The study assesses six primacy rules in total, summarised in the table below and further defined within this study in section 2. This section highlights the complexity of the implementation details and process underpinning the assessed primacy rules. Section 3 describes in detail the assumptions, methodology and implementation of the CBA, to then present the key results in section 4.

The CBA results show that the dynamic versions (labelled “ii”) of the rules perform generally better, even if the implementation cost are, in most cases, comparatively high. Under the current STOR market design and assumptions, Rule 2 ii) is the most economic (i.e. least cost) to end-consumers across all scenarios, because it avoids STOR availability costs and applies dynamic curtailment of ANM generators. Rule 2 ii) gives priority to the ESO to instruct STOR actions at the cost of the DNO holding headroom and eventually curtailing ANM generators to prevent any conflict.

It also shows how, due to the STOR pay-as-clear mechanism and the 24-hour contracted availability period, the STOR auction design has a significant impact on the cost for rules in which the STOR merit order is affected: small movements along the merit order can have a high system-wide cost impact.

Many of the rules can adversely affect the system reliability if not implemented correctly. There is insufficient understanding of the current level of conflict between ANM and STOR activations and it is not clear to what extent implementing a rule would improve the system reliability and performance, or what the associated risks might be. This results in a need for an enhanced understanding of current levels of conflict within the system and what implicit actions are taken. When time progresses, the associated risks may reach a level that falls outside normal operational limits, creating the need to implement a certain rule.

DNV recommends assessing the societal cost and benefits of not implementing any rule for the short term, given that the rules are costly to implement, and it will take time to develop the requisite IT capabilities to implement the rules. We also recommend factoring in any upcoming changes from Ofgem’s Charging Significant Code Review (SCR) and undertaking a sensitivity analysis on the level of DNO forecast accuracy required for the successful application of primacy rules. Finally, DNV recommends to explore the interactions and/or synergy with primacy rules for other types of conflicts between ESO and DNO.

DNO has primacy	ESO has primacy	Joint primacy
RULE 1 **STOR providers excluded (by the ESO)** 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** **The ESO would pay** the DNO (and therefore ANM customers or Flex 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 providers) **to hold headroom on the ANM systems**
RULE 4 **ESO over-procures** to help counteract any non-delivery as a result of ANM pullback.		

Abbreviations

Abbreviation	Definition
ANM	Active Network Management
BaU	Business as Usual
BM	Balancing Mechanims
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
NG ESO	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
USEF	Universal Smart Energy Framework

1. Introduction

1. Introduction

Overview of Project FUSION

Overview of Project FUSION

Project FUSION is funded under Ofgem's 2017 Network Innovation Competition (NIC), to be delivered by SP Energy Networks in partnership with seven project partners: DNV, Origami Energy, PassivSystems, Imperial College London (academic partner), SAC Consulting, The University of St. Andrews, and Fife Council.

Project FUSION represents a key element of SP Energy Network's transition to becoming a Distribution System Operator (DSO), taking a step towards a clean, smart and efficient energy system. As the electricity system changes from a centralised to decentralised model, it enables a smarter and more flexible network to function. Project FUSION is trialling the use of commoditised local demand-side flexibility through a structured and competitive market, based on a universal, standardised market-based framework: the Universal Smart Energy Framework (USEF). USEF provides a standardised framework that defines products, market roles, processes and agreements, as well as specifying data exchange, interfaces and control features. The purpose of USEF is to accelerate the transition to a smart, flexible energy system to maximise benefits for current and future customers.

FUSION will also inform wider policy development around flexibility markets and the DNO-DSO transition through the development and testing of standardised industry specifications, processes, and requirements for transparent information exchange between market participants accessing market-based flexibility services. Ultimately, FUSION will contribute to DSOs and all market actors unlocking potential and value of local network flexibility in a competitive and transparent manner. FUSION aims to contribute to addressing the energy trilemma by making the energy system more secure, more affordable and more sustainable.

Overview of the Universal Smart Energy Framework (USEF)

The USEF framework aims to facilitate effective coordination across all the different actors involved in the electricity market by providing a common standardised roles model and market design while describing communication requirements and interactions between market roles. USEF turns flexible energy use into a tradeable commodity available for all energy market participants, separated from (but in coordination with) the traditional electricity supply chain, to optimise the use of resources.

To facilitate the transition towards a cost-effective and scalable model, the framework provides the essential tools and mechanisms which redefine existing energy market roles, add new roles and specify interactions and communications between them. In addition, the USEF standard ensures that all technologies and projects will be compatible and connectable to the energy system, facilitating project interconnection, hence fostering innovation and accelerating the smart energy transition. By delivering a common standard to build on, USEF connects people, technologies, projects and energy markets in a cost-effective manner. Its market-based mechanism defines the rules required to optimise the whole system, ensuring that energy is produced, delivered and managed at lowest cost for the whole system and effectively for the end-user.

USEF was initially developed by the USEF Foundation. As of 2021, 7 years after its creation, the work of the USEF Foundation is considered complete, and the USEF Foundation has ceased to exist as per 1 July. To safeguard the legacy of the USEF foundation, the USEF framework, including the UFTP protocol (recently rebranded to Shapeshifter) will be maintained by the GOPACS organisation. The Shapeshifter protocol has also been adopted by the Linux Energy Foundation, offering a platform for the maintenance and support of the protocol.

Collaboration with ENA Open Networks Project (ENA ONP) – Workstream 1A

Funded by Project FUSION, this analysis builds on prior work carried out by ENA ONP's workstream 1A (WS1A) that seeks to define clear principles and primacy rules to enhance the network coordination and optimisation. The analysis has been carried out by DNV in collaboration with ENA ONP WS1A representatives.

Managing system constraints without creating conflicts

To achieve the UK's Net Zero objectives, it is essential that the collective operation of the UK's energy networks and coordination among stakeholders is technically and economically efficient.

To resolve network constraints, **Active Network Management (ANM)** systems are becoming more widespread in distribution systems to avoid breaching network limits. ANM systems are managed by the DNOs that use real time network information to calculate safe levels of generation for managed connections in accordance with their commercial agreements and Principles of Access (PoA). Participating in ANM allows generation to be connected to the network quicker and at a lower cost than if grid reinforcements would need to be undertaken. Consumers also benefit from lower connection costs of often, renewable generation.

Furthermore, one of the services that National Grid System Electricity Operator (NG ESO) uses to manage constraints is **Shot-Term Operating Reserve (STOR)**, a service in which the ESO accesses extra power ahead of time to meet the reserve requirement either by providing generation or demand reduction.

This project focuses on solving the conflict that arises when NG ESO activates STOR in an ANM area, in other words, located behind a network constraint managed by an ANM scheme, and these two services directly counteract each other.

This could create a security of supply risk and comes at a cost to consumers, as the System Operators need to activate further services such as STOR or ANM in another area, to obtain the necessary result required.

1. Introduction

Assignment

Assignment

Product 5 (P5) under Workstream 1A is developing and testing the implementation of the 'primacy rules,' that will be used to manage potential conflicts between ESO and DSO services. DNV, as part of Project FUSION, has been commissioned to support the development and quantitative analysis of primacy rules within WS1A P5.

Conflict definition

The analysis focuses on the interaction between Short Term Operating Reserve (STOR) providers and Active Network Management (ANM) generators in the same area where opposite instructions are issued by the ESO and DNOs.

It explores the use case in which the ESO instructs a STOR generating asset to increase MWs, and subsequently the DNO curtails a different generator through ANM, which nullifies the ESO-instructed services.

ANM

- ANM allows the DNO to curtail generation, to ensure safe connection levels based on real-time monitoring. Chapter 3 sets out detailed assumptions in relation to ANM for this analysis.

STOR service

- STOR services allow the ESO to access extra power ahead of time to meet a system requirement at times when the demand in the system is greater than the forecast or there is unforeseen generation unavailability.

ANM Area

- An asset participating in STOR is in an ANM area if it is located behind a network constraint covered by an ANM scheme.

Conflict definition assumptions

- Rules are designed aiming for solutions that achieve comparable overall system reliability (i.e. the system meets frequency and balancing requirements) pre- and post-conflict to be able to draw unbiased conclusions from the CBA from rules with comparable performance; DNV takes this assumption as the quantification on reliability impacts are out of scope in this study;
- Conflicts do not result from individual assets participating in both ANM and STOR, i.e., these are different assets, each operating as they are intended to. The conflict is in the lack of coordination between them; and
- It is assumed all STOR is contracted day-ahead. Long-term STOR contracts for 400MW are not accounted for as they end in 2025.

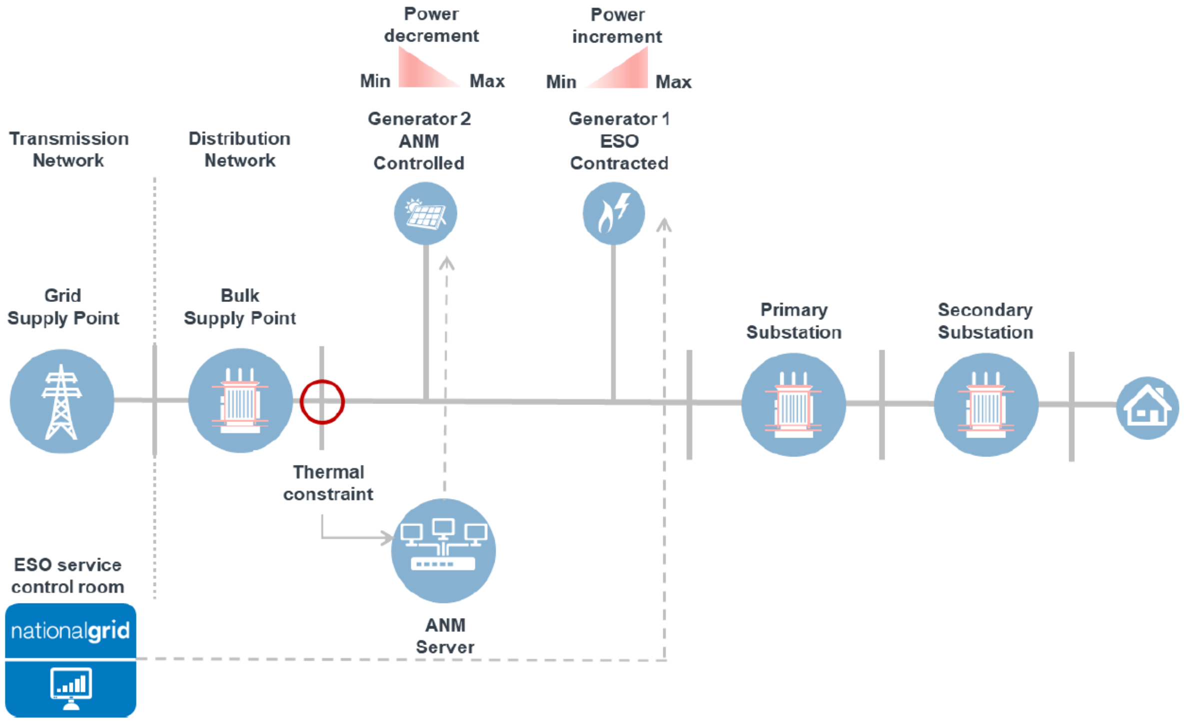


Figure 1.3 – Key stakeholders and interactions.

Source: WSP; Cornwall Insight; Complete Strategy (2020). *Optimal Coordination of Active network Management Schemes with balancing services markets.*

1. Introduction

Objective and scope

Objective

Quantify the economic impact of primacy rules on all parties involved, to help ENA members understand which rules deliver the **most efficient outcome for the end consumer.**

Scope

- The reference case for this exercise is the ‘no conflict’ scenario, where ANM is activated, and STOR is also activated, but outside an ANM network constraint without creating a conflict. It limits the calculation to the elements impacted by the rules, allowing for a relative CBA. This is not a counterfactual, but a reference allowing to compare the rules against a common framework.
- The ‘conflict with no rule implementation’ case could have been applied as a counterfactual; however, it was not used in this exercise as it has a complex quantification of the impact of ANM counteraction on the system balance, including the associated costs for restoring system balance and it would result in a lower system efficiency.
- By using the exercise with the reference case, we will identify the optimal rule from a CBA perspective yet will not provide a justification for implementing this rule against the Business as Usual (BaU), ‘conflict with no rule implementation’. This exercise will be done separately, considering the impact on the system’s reliability.
- As the contracting and connecting of ANM and STOR assets is within the reference case, it is considered out of the scope of this exercise.
- It is assumed the contracting of STOR and ANM services is efficient, and that system operators are never in a position where they have to activate a service and it is unavailable, i.e., there is always enough ANM available capacity to curtail.
- The Charging Significant Code Review (SCR) is out of the scope of this assignment, and it has not been considered. It is assumed that any level of curtailment comes with no extra cost to the DSO, which might change depending on the outcome of the SCR.
- The analysis aims at being a high-level CBA to compare the order of magnitude of the primacy rules. To implement the optimal solution, further analysis would need to be carried out on the shortlisted option(s).

Process flow key

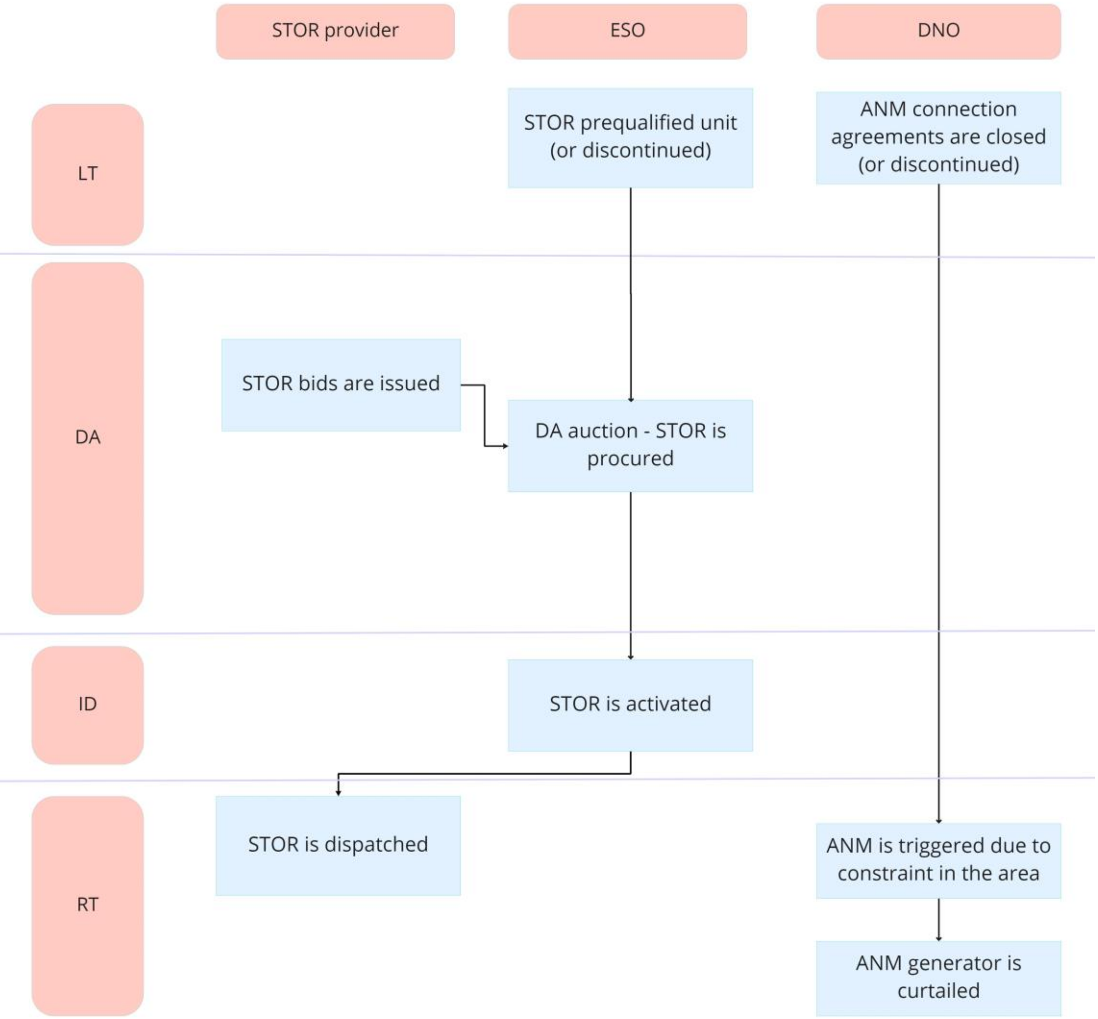


Figure 1.1 - Reference case process flow

1. Introduction

Methodology and report structure

Methodology

The objective presented above is met by implementing the following step-by-step methodology**:**

1. **Further define the proposed rules** - Fully develop and define the primacy rules proposed by ENA.
2. **Analysis of ANM and STOR interaction** – Desk research and questionnaire to ENA to gather information on the ANM and STOR interaction.
3. **Analysis of rule mechanism and impact on stakeholders –** a flow chart is created per rule and option to assess and visualise the rule mechanics. Then, a detailed chart is created with the cost and benefit impact per stakeholder.
4. **Execute cost benefit analysis**
5. **Recommendations for future development**

Report structure

The remainder of this report is structured as follows:

- Section 2 focuses on the rule definition and mechanics;
- Section 3 depicts the cost benefit analysis and presents the assumptions, limitations and impacts per stakeholder, as well as the 4 scenarios for which the CBA has to be implemented per rule;
- Section 4 summarises the results of our analysis; and
- Section 5 summarises the main conclusions and recommendations for future assessment of primacy rules.

Figure 1.2 – Step by step methodology

2. Rule definition

2. Overview of primacy rules

DNO primacy, ESO primacy and joint primacy rules

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, NG ESO has primacy or the rule can result in either the ESO 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]	ESO primacy[1]	Joint primacy
RULE 1 • **STOR providers excluded (by the ESO)** 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** **The ESO would pay** the DNO (and therefore ANM customers or Flex 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 providers) **to hold headroom on the ANM systems**
RULE 4 • **ESO 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 ESO 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.

2. Primacy rules definition

2.1 DNO has primacy rule mechanics

RULE 1 – STOR providers excluded (by the ESO) 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, the ESO 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 the ESO on a long-term basis of what are the ANM areas.
- **The ESO 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, the ESO would have no visibility regarding which assets within the aggregated units would be used. Therefore, for rule 1a) the ESO 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 the ESO.

Intraday

- When needed, STOR is activated by the ESO

Real time

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

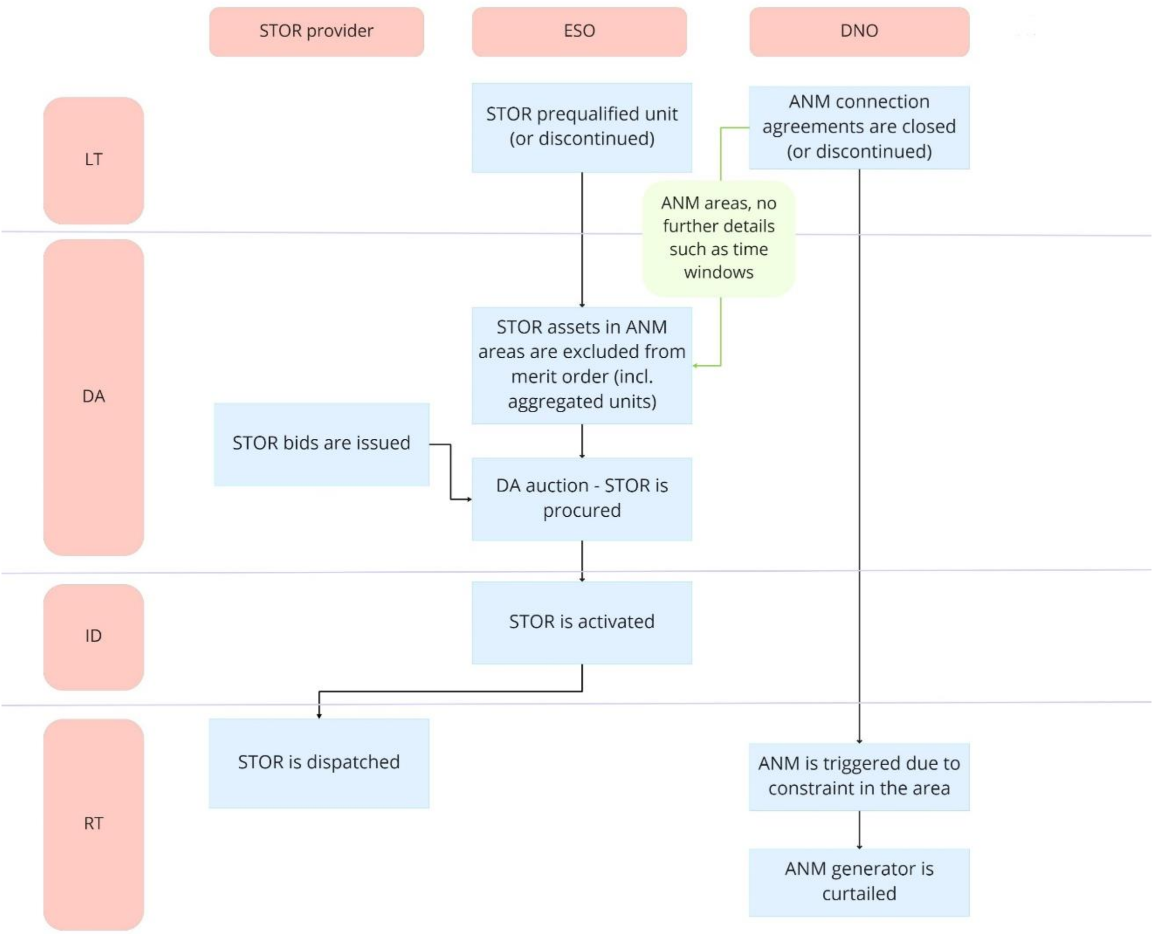


Figure 2.1 – Rule 1 i) process flow

2. Primacy rules definition

2.1 DNO has primacy rule mechanics

RULE 1 – STOR providers excluded (by the ESO) 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, the ESO 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 the ESO of which ANM areas expect ANM activation and when this activation is expected to happen on a half-hourly basis (HH).
- The ESO 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, the ESO would have no visibility regarding which assets within the aggregated units would be used, therefore, for rule 1a) the ESO 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 the ESO.

Intraday

- When needed, STOR is activated by the ESO

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 b) dynamic rules.

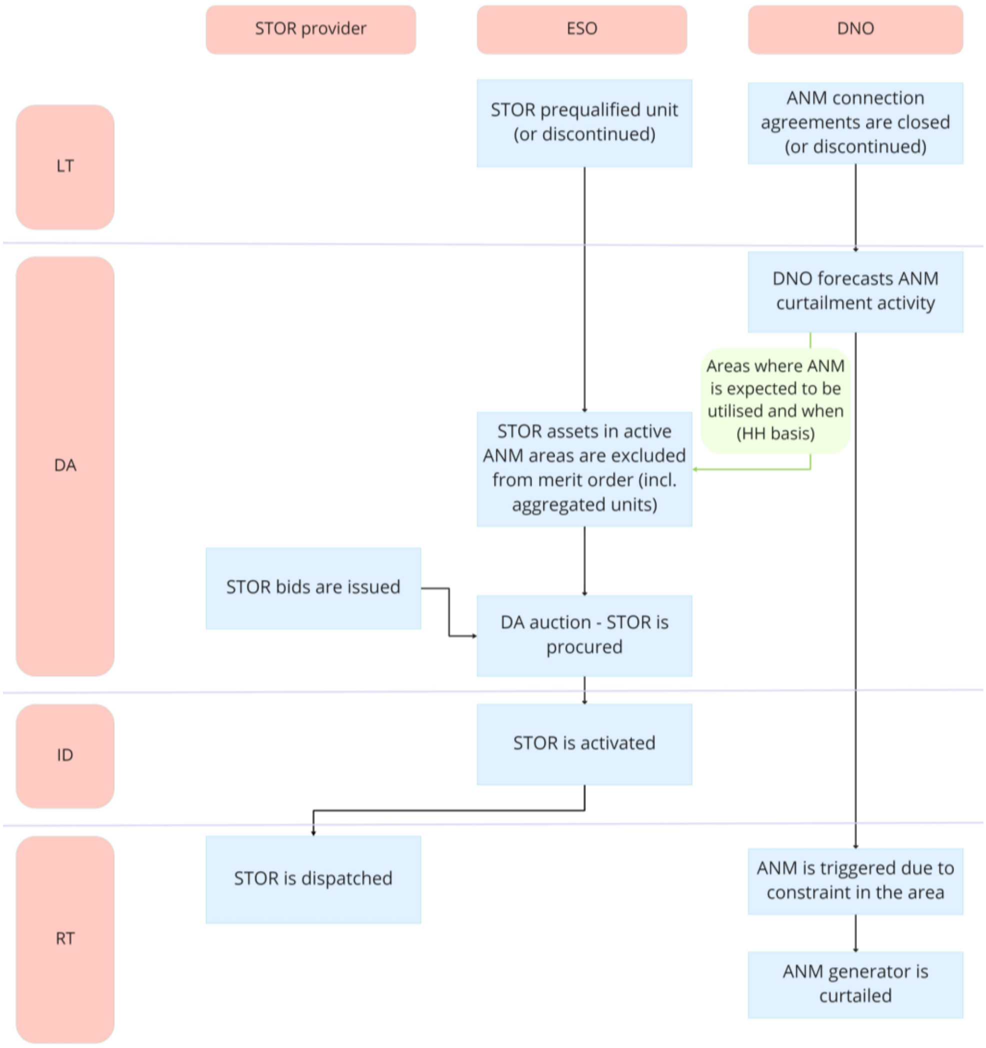


Figure 2.2 – Rule 1 ii) process flow

2. Primacy rules definition

2.1 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, the ESO 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 the ESO.

Intraday

- When needed, STOR is activated by the ESO

Real time

- If needed by the ESO, 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 the ESO about the ANM areas on a long-term basis, for the ESO to the carry out the STOR validation and settlement. Penalisations could be introduced to ensure adherence to the process.

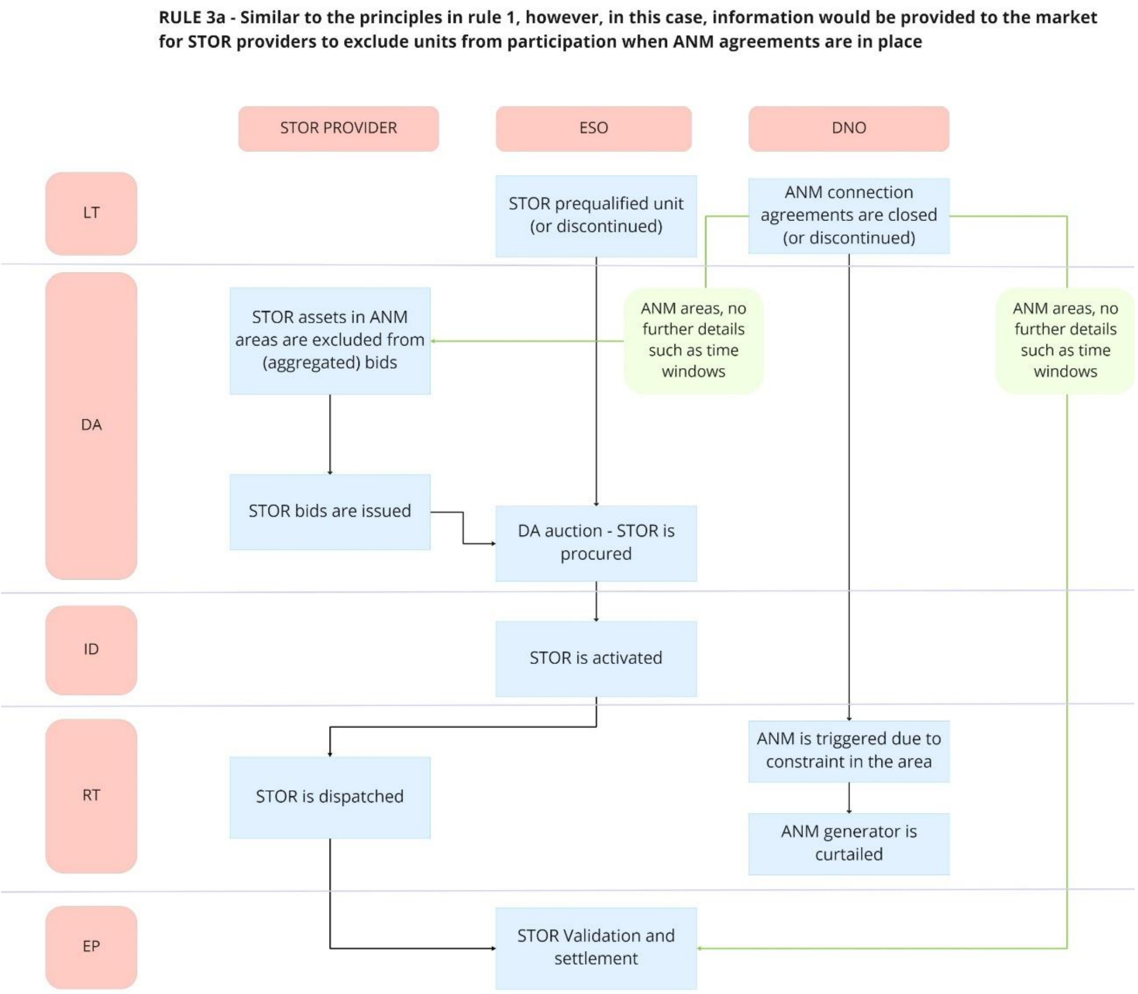


Figure 2.3 – Rule 3 i) process flow

2. Primacy rules definition

2.1 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, the ESO 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 the ESO.

Intraday

- When needed, STOR is activated by the ESO

Real time

- If needed by the ESO, 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 the ESO about the ANM areas on a long-term basis, for the ESO to the carry out the STOR validation and settlement.

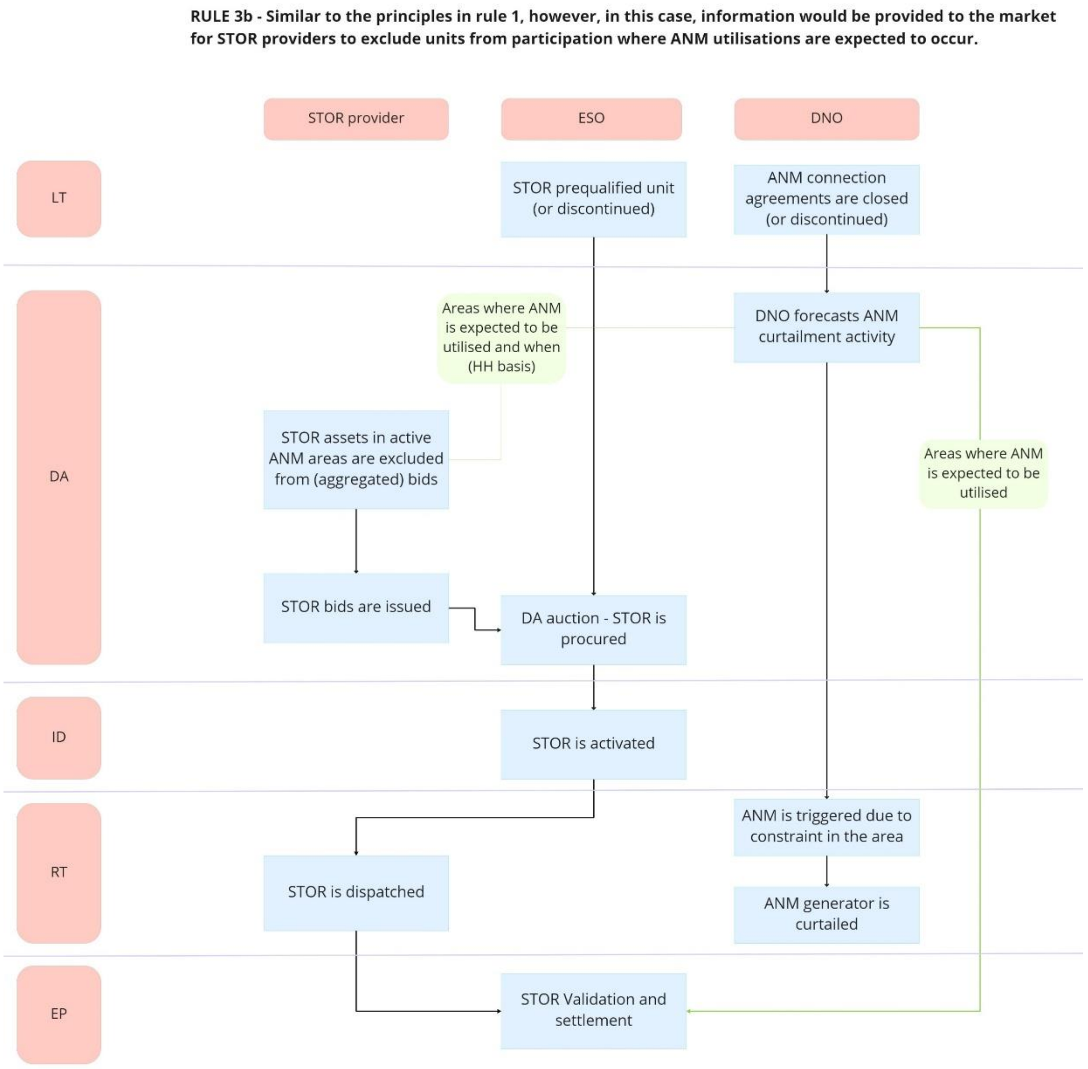


Figure 2.4 – Rule 3 ii) process flow

2. Primacy rules definition

2.1 DNO has primacy rule mechanics

RULE 4 – ESO 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, the ESO 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 the ESO of what are the ANM areas.

Day-ahead

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

Intraday

- When needed, STOR is activated by the ESO. When the ESO 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.

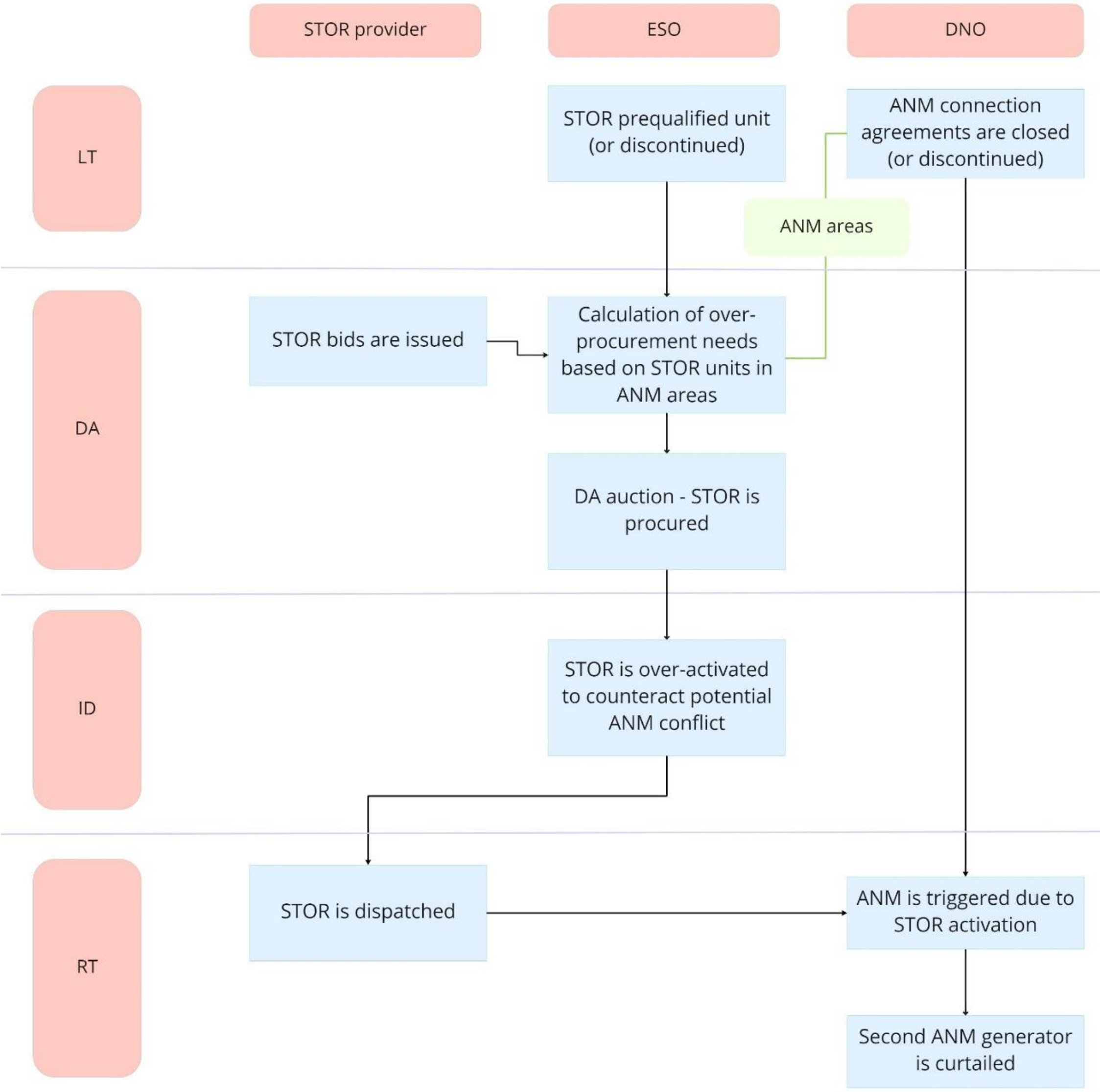


Figure 2.5 – Rule 4 i) process flow

2. Primacy rules definition

2.1 DNO has primacy rule mechanics

RULE 4 – ESO 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, the ESO 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 the ESO 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, the ESO over-procures, considering the potential counteraction of the STOR services with the likelihood of ANM utilisation.

Intraday

- When needed, STOR is activated by the ESO. When the ESO 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.

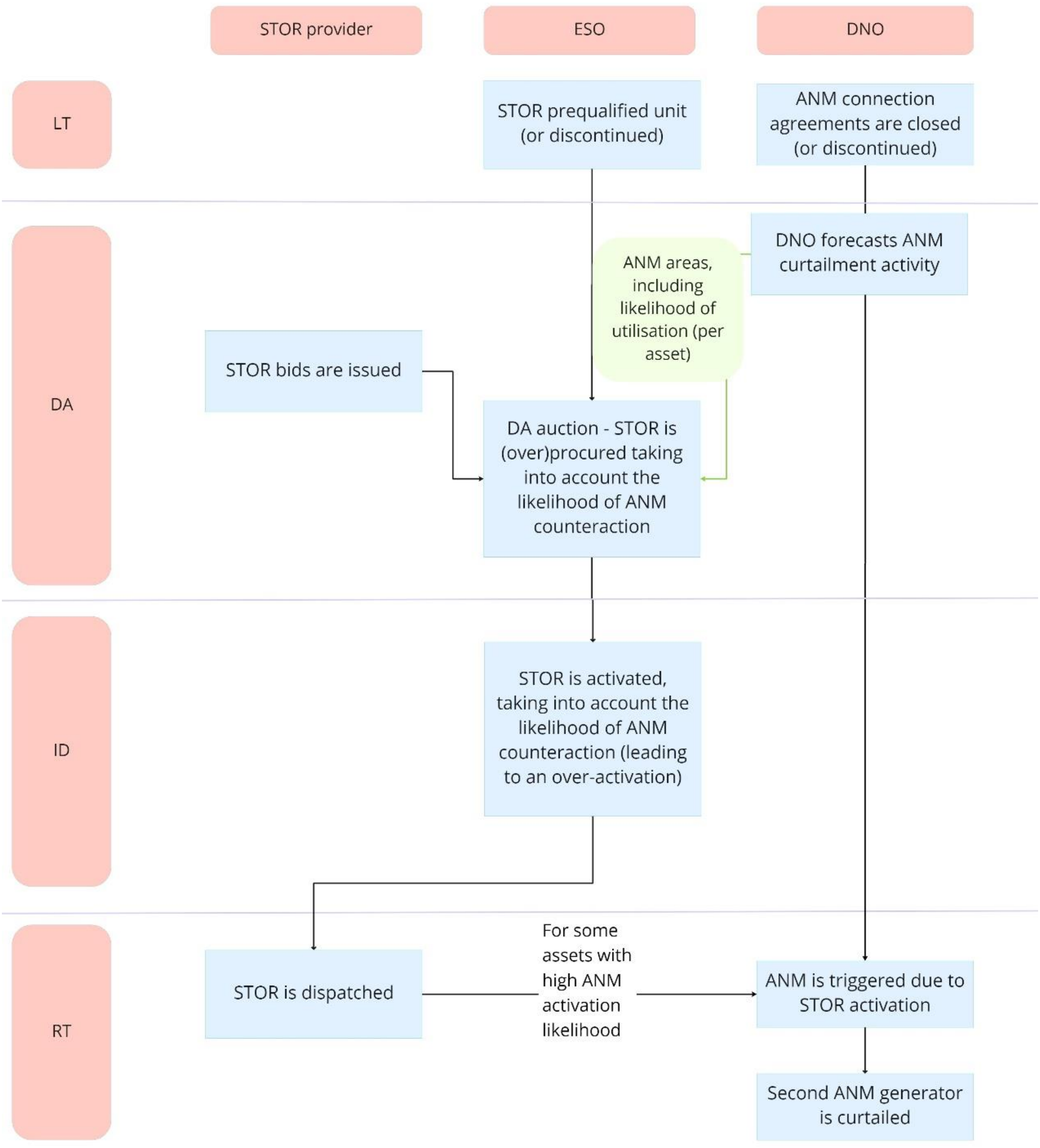


Figure 2.6 – Rule 4 ii) process flow

2. Primacy rules definition

2.2 ESO 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, the ESO is informed of their volume, area connected and if aggregated, what assets compose the unit.
- ANM connection agreements are closed or discontinued.
- The ESO 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 the ESO.

Intraday

- When needed, STOR is activated by the ESO

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.

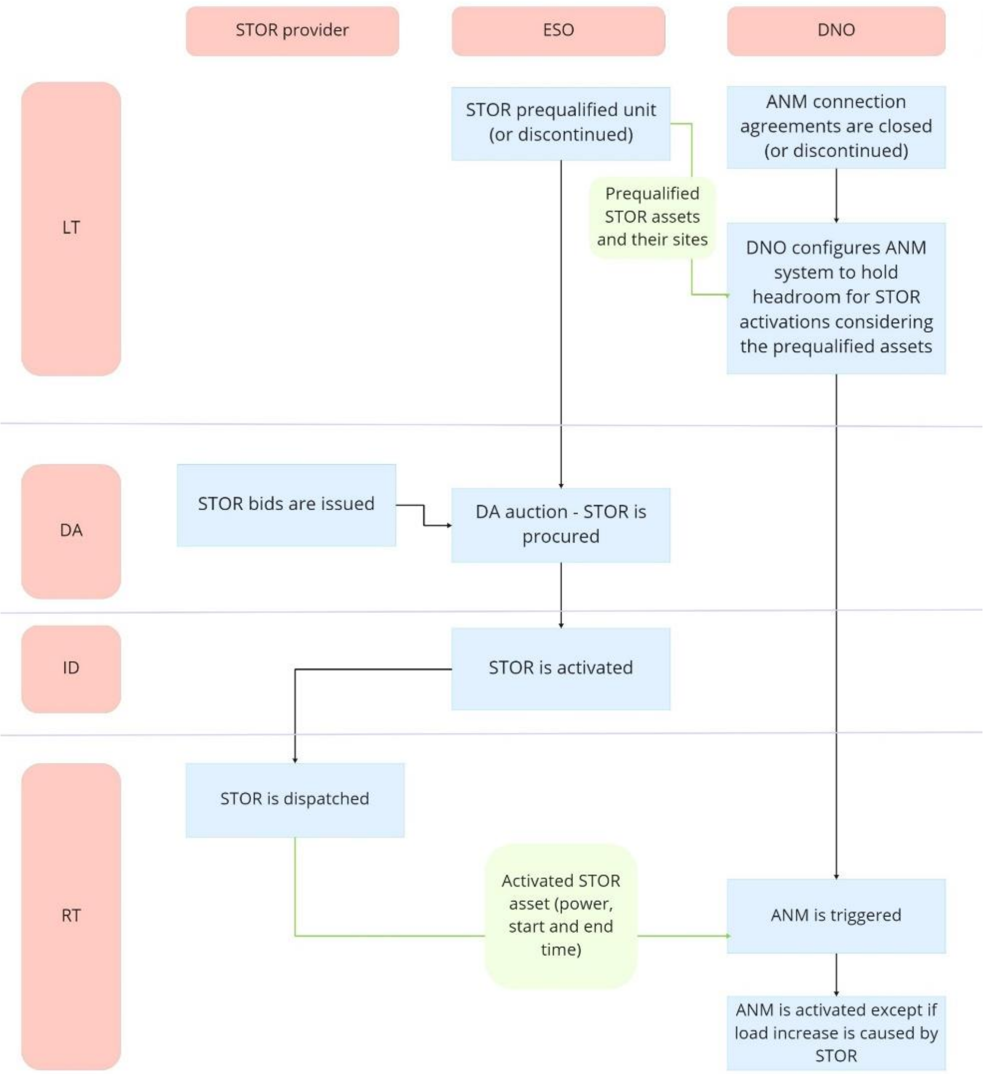


Figure 2.7 – Rule 2 i) process flow

2. Primacy rules definition

2.2 ESO 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, the ESO 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 the ESO.
- 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 the ESO. 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.

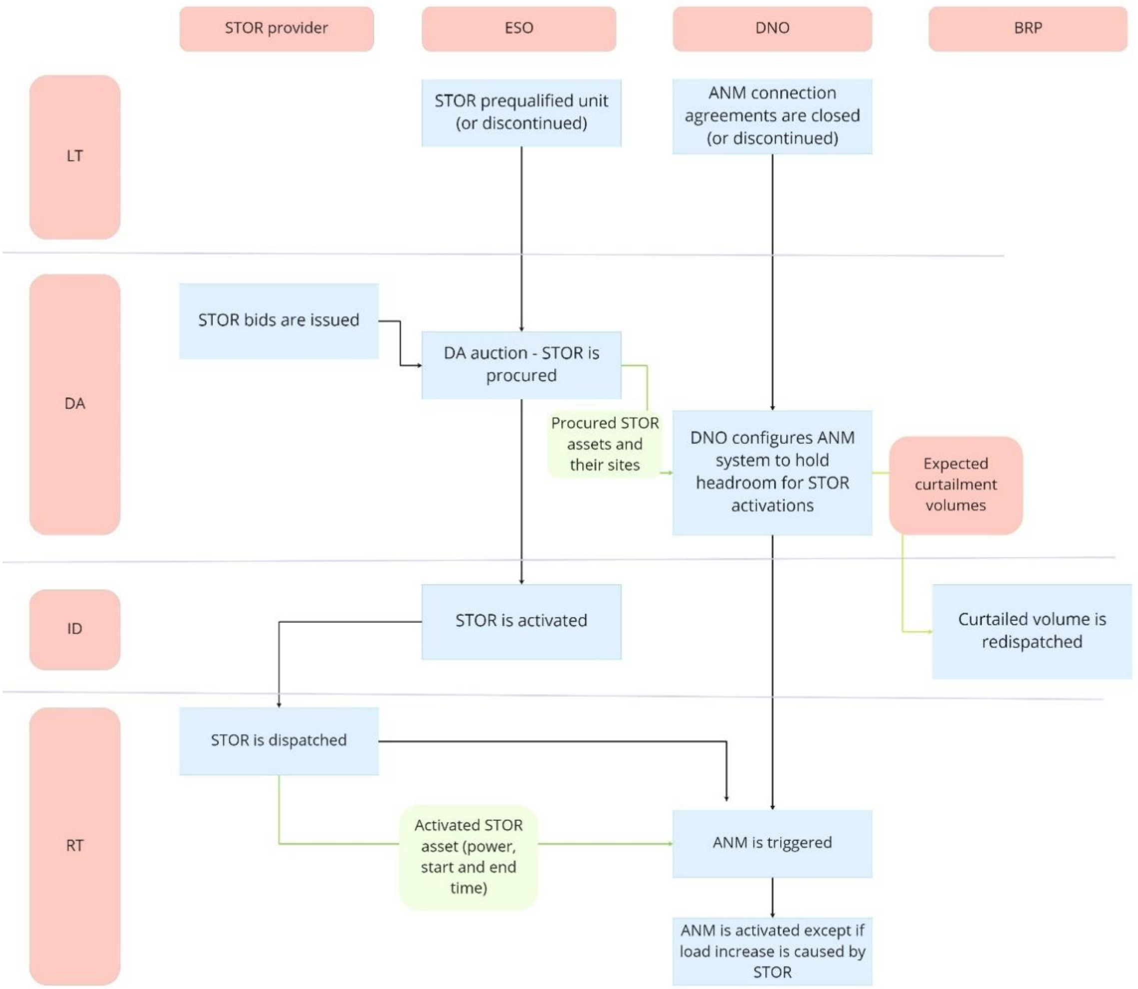


Figure 2.8 – Rule 2 ii) process flow

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

2. Primacy rules definition

2.2 Joint primacy rule mechanics

RULE 6 – The ESO would pay the DNO (and therefore ANM customers or Flex providers) to hold headroom on their ANM systems

i) Static headroom

Long-term

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

Day-ahead

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

Intraday

- When needed, STOR is activated by the ESO

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

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

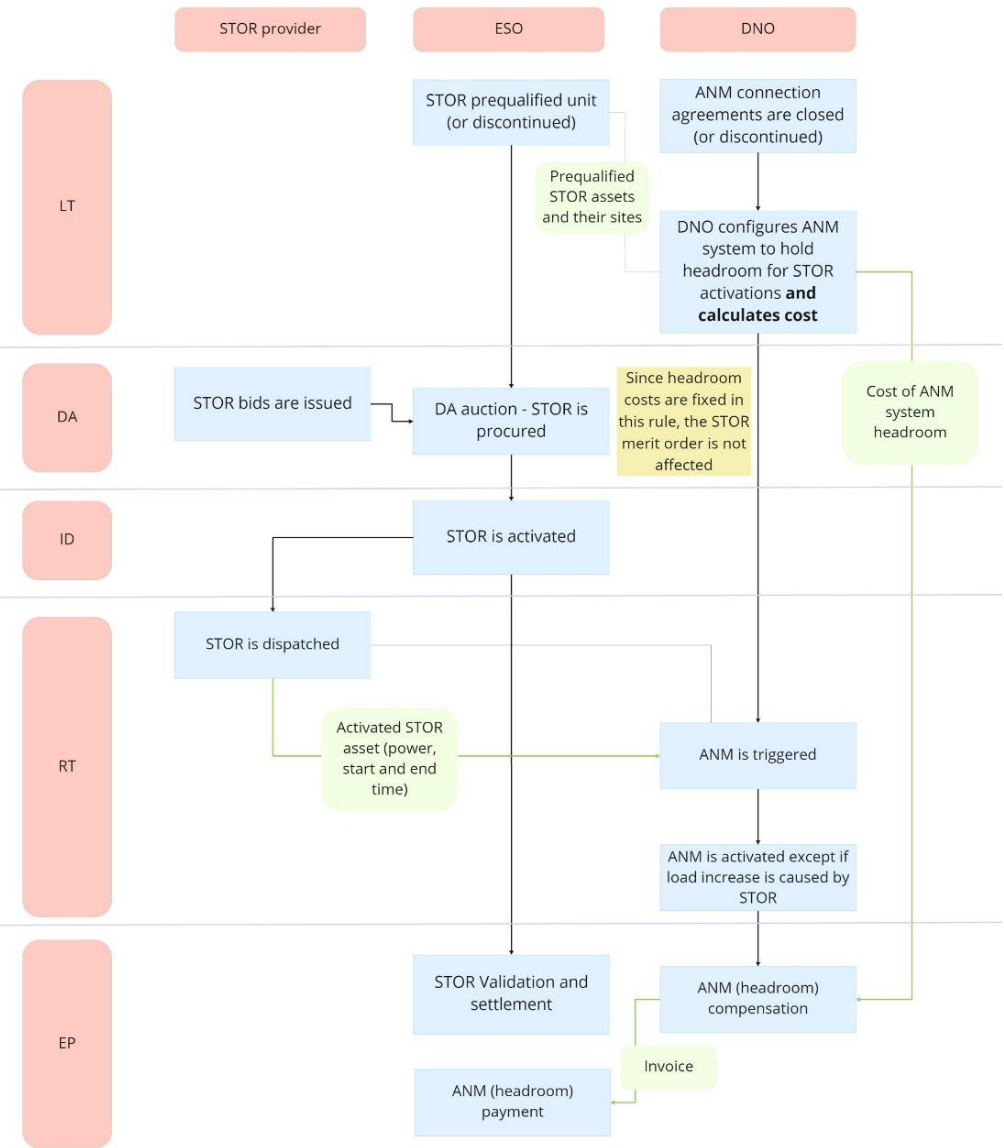


Figure 2.9 – Rule 6 i) process flow

2. Primacy rules definition

2.2 Joint primacy rule mechanics

RULE 6 – The ESO would pay the DNO (and therefore ANM customers or Flex providers) to hold headroom on their ANM systems

ii) Dynamic headroom

Long-term

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

Day-ahead

- The ESO 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 costs and informs the ESO of the next day's ANM headroom costs per MWh for STOR assets in ANM areas.
- STOR providers issue the bids for the DA auction and the ESO adds the ANM costs to the bids in the merit order. Then, STOR services are procured by the ESO.
- 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 BRP of the expected curtailment volumes.

Intraday

- When needed, STOR is activated by the ESO. 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

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

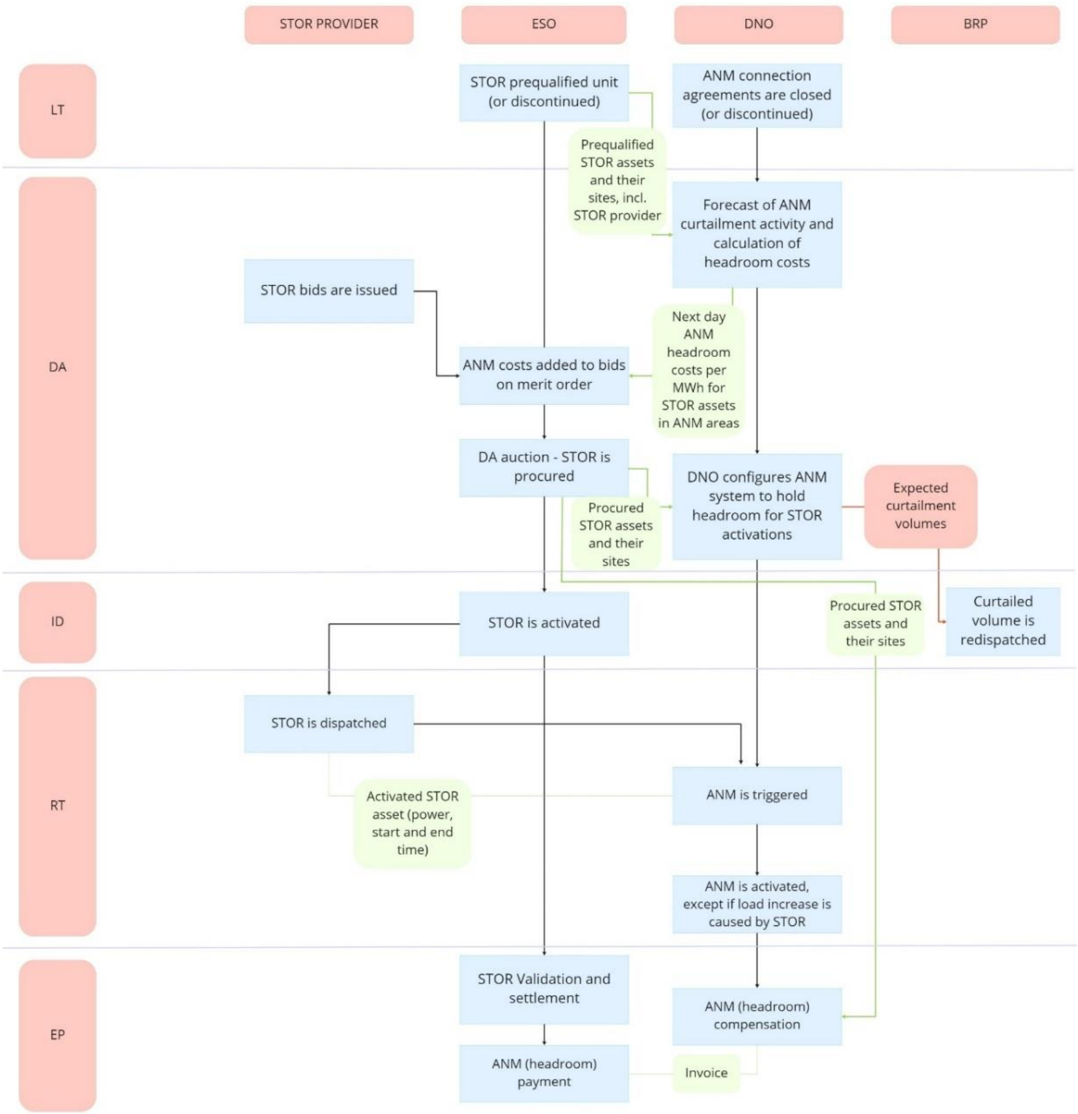


Figure 2.10 – Rule 6 ii) process flow

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

2. Primacy rules definition

2.2 Joint primacy rule mechanics

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

i) Static headroom

Long-term

- STOR assets are prequalified or discontinued. When prequalifying a unit, the ESO is informed of their volume, area connected and if aggregated, what assets compose the unit.
- ANM connection agreements are closed or discontinued.
- The ESO 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 costs per MW and year for STOR assets in ANM areas.
- Then, the STOR provider adds the ANM headroom costs to the STOR assets. Since headroom costs are fixed in this rule, assets may be discontinued from STOR once these fixed costs are known to the STOR provider.

Day-ahead

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

Intraday

- When needed, STOR is activated by the ESO

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

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

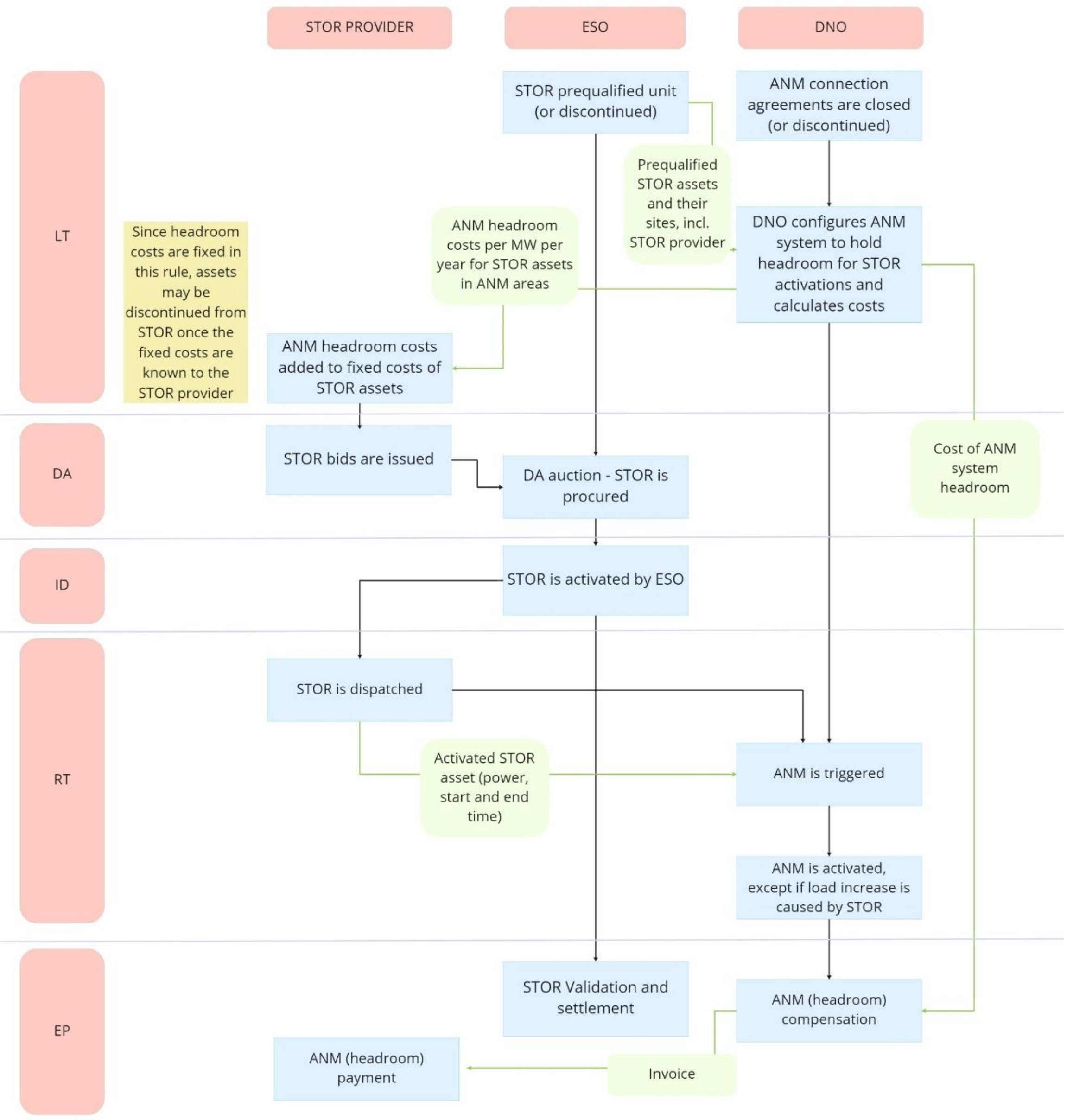


Figure 2.11 – Rule 7 i) process flow

2. Primacy rules definition

2.2 Joint primacy rule mechanics

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

ii) Dynamic headroom

Long-term

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

Day-ahead

- The ESO 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 costs and informs the STOR provider of the next day's ANM headroom costs 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 costs to the bids in the merit order. Then, STOR services are procured by the ESO, 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 the ESO. 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

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

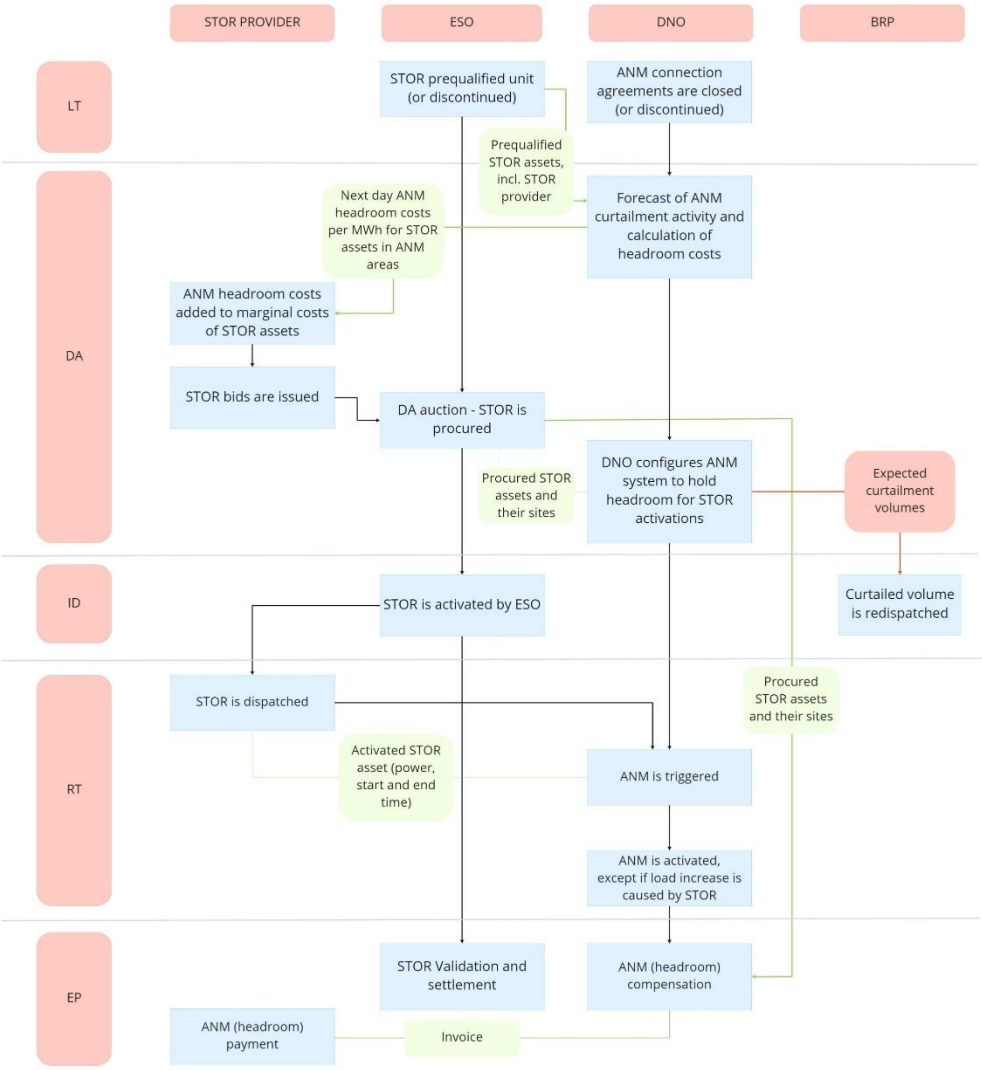


Figure 2.12 – Rule 7 ii) process flow

3. Cost Benefit Analysis

Assumptions and methodology

3. Cost benefit analysis

General assumptions and limitations

Assumptions and input data:

- The CBA uses June 2021 to May 2022 as reference year for the full GB system.
- The CBA granularity is half-hourly, i.e., per settlement period.
- STOR BM dispatch of distributed units are not considered due to data unavailability. However, we consider these to have a negligible impact compared to the non-BM dispatch volumes because, according to the ESO, most of the distributed units were non-BM units in the period of 2021-2022.
- STOR utilisation cost of non-dispatched units is not available; consequently, we assume the next units in the utilisation merit order are 15% more expensive than the last dispatched unit.
- The NBM STOR detailed utilisation data is not available from June 2021 to November 2021. We assume 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 NG ESO [1]
- Regarding emissions, we assume that when STOR units are being substituted by other units in the merit order, the net carbon effect is negligible.
- STOR contracted availability window is assumed 24 hours.
- We assume that STOR provider cost for providing availability is the tendered price times the tendered capacity.
- We assume that STOR providers do not make any profit on utilisation because it is based on marginal prices.
- CAPEX on IT is annualized over 7 years (typical IT system time of use).
- For rules where DNO forecast is shared, it is assumed that the forecast is 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 is also assumed.
- The allocation of direct and indirect costs to the end-user is based on the principle that stakeholders will always externalise costs towards the end-user, but not benefits.
- The CBA is based on the following data:
  - STOR day-ahead auctions results [2]
  - Non-BM STOR dispatch instructions [3]
  - Generation data and embedded renewable generation data – Provided by ESO
  - Day-ahead GB prices [5]
  - Intraday GB prices [5]
  - STOR unit composition list – Provided by DNOs and ESO
  - 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 ESO.
  - Generator marginal costs 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 is meant to give a high-level first indicative order of magnitude relative benefit/cost of the different rules per stakeholder.
- The CBA evaluates rules that would result in the same system reliability. Therefore, all dynamic approaches that could affect system reliability are out of scope. For dynamic variants, we apply a dynamic version of the rule based on forecasts. A further step on dynamic option will be explored qualitatively.
- The CBA assumes that STOR product and market design remains as it is today and does not consider future product changes.
- The ANM curtailment risk is not based on real DNO data due to very low curtailment risks and data unavailability.
- The CBA is limited and assumes one single ANM area for the full GB (see full methodology in the next slide). The results could be interpreted based on the scenario that is more representative given an area for STOR coverage.
- Fully accurate forecasts, and perfect procurement and dispatch is assumed.

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

3. Cost benefit analysis

Scenarios

We conducted the CBA for 4 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.

Parameters:

- **Percentage of STOR covered by ANM:** Scenarios 1 and 3 account 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 NG ESO, that shared the list of STOR assets, and the UK DNOs, that signalled which of these STOR assets where located in areas where a potential conflict could arise. Then, scenarios 2 and 4 simulate that 50% of the STOR assets are located in ANM areas, this level of overlap is 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 assume since a higher percentage would not insure sufficient available STOR units at all times. Note that this parameter is calculated over the total of distributed connected STOR units, i.e. transmission connected capacity is 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 amount of settlement periods where the curtailment likelihood is 80% (i.e. red status). We calculate this figure based on the ANM methodology described on the next slide. The level of curtailment is considered to be directly dependent on the proportion of system demand met by embedded renewables.

The table on the right depicts the 4 scenarios that will be explored for each primacy rule.

The selected scenarios are meant to explore:

- 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 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 – Overview of the scenarios

DNV

3. Cost benefit analysis

Rule modelling

This section describes how each primacy rule is modelled. Because many elements are modelled similarly, we will explain each element only once and then refer 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 costs 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 costs (MCP x required capacity x 24 hours) are calculated with the newly calculated MCP and the daily required capacity. 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 costs

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 costs is then calculated.

Application of rule CAPEX implementation and OPEX

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

Rule 1 ii)

This rule follows the same steps as rule 1ii). The difference is that in this rule there is additional information exchange, which allows the ESO 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;

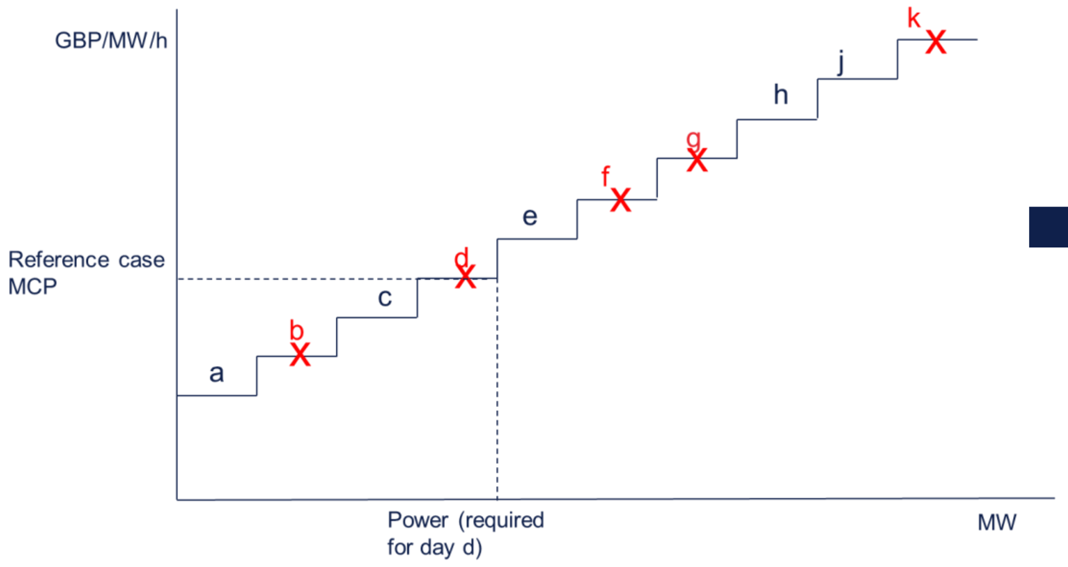
- Is tendered capacity of aggregated STOR unit X < capacity of aggregated STOR unit X outside ANM area?
  - Yes -> Don't remove STOR unit from merit order
  - No -> Remove only the capacity within ANM area from the merit order tendered capacity of unit X. If the resulted capacity is under 3 MW, exclude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

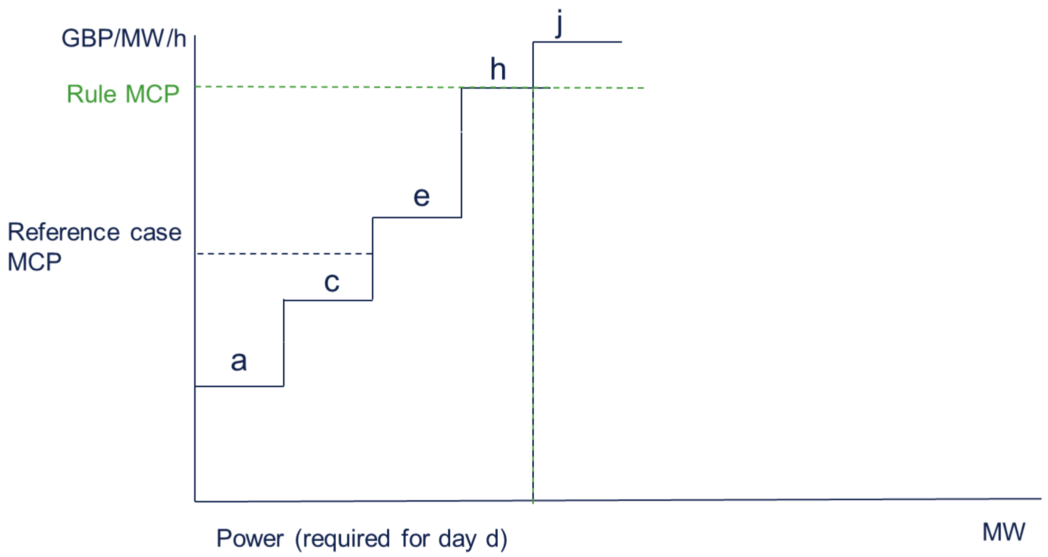
Rule 3 ii)

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.

3. 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.

3. Cost benefit analysis

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

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

3. Cost benefit analysis
Rule modelling

Rule 4 i)

This rule is not modelled (see slide 18)

Rule 4 ii)

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

Calculation of availability costs

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 costs 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 costs

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 costs 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.

3. 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, the ESO bears the costs 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 * 24)).
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 costs and utilisation costs are calculated following rule 1ii) logic.
5. Whether there are any accepted units within ANM areas is assessed.
6. The costs for holding headroom (curtail) for the recalculated capacity according to rule 2 i) is obtained for the calculated capacity in this rule.
7. The costs for holding headroom are allocated to the ESO (recalculate ESO costs)
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 costs 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: Costs for holding headroom are allocated to the STOR provider (recalculate STOR provider profit).

3. Cost benefit analysis

Impact on stakeholders for DNO has primacy

RULES		STOR provider	ANM generator	ESO	DNO	End consumer
Rule 1	i) Binary	- Δ STOR provider margin		- Δ STOR procurement & utilisation cost - CAPEX* - OPEX*	- CAPEX - OPEX	Indirect impact = ESO + DNO net impact)
	ii) Risk- based	- Δ STOR provider margin		- Δ STOR procurement & utilisation cost - CAPEX - OPEX	- CAPEX - OPEX	Indirect impact = ESO + DNO net impact)
Rule 3	i) Binary	- Δ STOR provider margin		- Δ STOR procurement & utilisation cost - CAPEX - OPEX	- CAPEX - OPEX	Indirect impact = ESO + DNO net impact)
	ii) Risk- based	- Δ STOR provider margin		- Δ STOR procurement & utilisation cost - CAPEX - OPEX	- CAPEX - OPEX	Indirect impact = ESO + DNO net impact
Rule 4	i) Binary	- Δ STOR provider margin		- Δ STOR procurement & utilisation cost - CAPEX - OPEX	- CAPEX - OPEX	Indirect impact = ESO + 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 = ESO + DNO net impact

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

Table 3.2 – Overview of the cost and benefits that the stakeholders experience for each of the rules in which the DNO has primacy

DNV

3. Cost benefit analysis

Impact on stakeholders for ESO has primacy

RULES		STOR provider	ANM generator (and their BRP)	ESO	DNO	End consumer
Rule 2	i) Static headroom		- CAPEX - OPEX - Cost for holding headroom	- CAPEX - OPEX	- CAPEX - OPEX	- Direct impact = Δ carbon emissions - Indirect impact = ESO + 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 = ESO + 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 = ESO + 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 = ESO + 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 = ESO + 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 = ESO + DNO net impact+ ANM generator impact

Table 3.3 – Overview of the cost and benefits that the stakeholders experience for each of the rules in which the ESO has primacy

4. Results

4. CBA results

Scenario 3 – Results interpretation

In this section, we explain the results of the CBA. This section is structured as follows:

- Figure 4.1 on the right summarises the CBA results for Scenario 3, the colours indicating the range and level of increase in costs, green being the least cost/most benefit and red being the most costly.
- We describe the results for Scenario 3 in full, since this scenario most closely reflect the current situation in terms of curtailment levels and STOR coverage (reflecting the current STOR units located in most of the DNOs areas) (Page 37-40).
- To avoid repetition, and since the mechanics of the CBA are essentially the same across scenarios, we highlight the relevant and differentiating aspects of scenarios 1, 2 and 4 in a comparative analysis (Page 41).
- As explained previously, this CBA is conducting against a reference case, that cannot be considered a counterfactual:
  - The reference case for this exercise is the 'no conflict' scenario, where ANM is activated, and STOR is also activated, but outside an ANM network constraint without creating a conflict. It limits the calculation to the elements impacted by the rules, allowing for a relative CBA. This is not a counterfactual, but a reference allowing to compare the rules against a common framework.
  - The 'conflict with no rule implementation' case could have been applied as a counterfactual; however, it was not used in this exercise as it has a complex quantification of the impact of ANM counteraction on the system balance, including the associated costs for restoring system balance and it would result in a lower system reliability.
  - By using the exercise with the reference case, we will identify the optimal rule from a CBA perspective yet will not provide a justification for implementing this rule against the Business as Usual (BaU), 'conflict with no rule implementation'. This exercise will be done separately, considering the impact on the system's reliability.

RULES (million GBP)		STOR provider	ANM generator + BRP	ESO	DNO	End consumer
Rule 1	i)	252.30		-270.17	-0.34	-270.51
	ii)	35.99		-37.49	-0.72	-38.21
Rule 3	i)	185.26		-189.72	-0.34	-190.06
	ii)	13.87		-18.54	-0.72	-19.26
Rule 4	i)					
	ii)	37.54	-0.24	-38.89	-0.72	-39.85
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)	35.99		-38.06	-1.29	-39.35
Rule 7	i)	-13.18	0.00	-0.98	-0.93	-15.08
	ii)	13.87		-19.08	-1.29	-20.37

Table 4.1 – Cost allocation for each stakeholders for all rules when scenario 3 is implemented

4. CBA results

Scenario 3 – Results interpretation

Rule 1 i) and 1 ii) – Key observations

The figures 4.1 and 4.2 include all the cost/benefits expressed in £m, using the reference case as a reference.

- The main cost element of this rule is the additional cost for the ESO. This cost consists of CAPEX, OPEX, STOR availability payments and STOR utilisation payments. The single biggest cost element is the STOR availability payments, representing 99% of the ESO additional costs.
- In rule 1 i), the STOR availability cost results in over 6 times the reference case STOR availability payments. Rule 1 ii) results in less than 100% increase compared to the reference case. The steep availability cost difference is 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 for 24 hours. 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. For example, shifting the MCP of 0.1£/MW/h to 54£/MW/h.
  - c) The large difference between availability costs for rule 1 i) and 1 ii) is because
  - d) In rule a, the STOR units within ANM areas are removed permanently from the STOR merit order. This has a significant impact because it affects the merit order every day of the year.
  - e) In rule ii), the STOR units within ANM areas are removed only for the days where curtailment is forecast in 1 or more settlement periods. Most of the ESO STOR availability payment would translate into margins for the STOR provider. Only 6% of ESO availability payments would be destined to cover STOR provider availability **cost**, the rest is considered as margin for the STOR provider.
- The net impact on the end consumer reflects an indirect impact from the net costs of ESO and DNO. As described above, most of this cost reflects margins for STOR providers.
- The ii) version of the rule is more expensive to implement for both ESO and DNO. The DNO is relatively more impacted than the ESO by the additional implementation costs.
- Rule 1 i) proves to the one of the most costly/inefficient rules to implement.
- The high availability costs are largely due to the current STOR auction type. This does not necessarily mean that a different auction type would prove to be more efficient. This question is out of scope of this study and could be further explored in future analysis.
- There is a large impact on rule 1 ii) because the STOR is procured daily, and even if curtailment is forecast only for one SP, that influences a full day merit order. To give an order of magnitude: for scenario 3, the % of red SPs is 5%, whereas 29.3% of the days in a year have 1 or more red SPs. The daily removal of units creates an impact of around 5 times larger than removal of the units for red SPs.
- The dynamic approach related to system reliability was out of 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 costs.

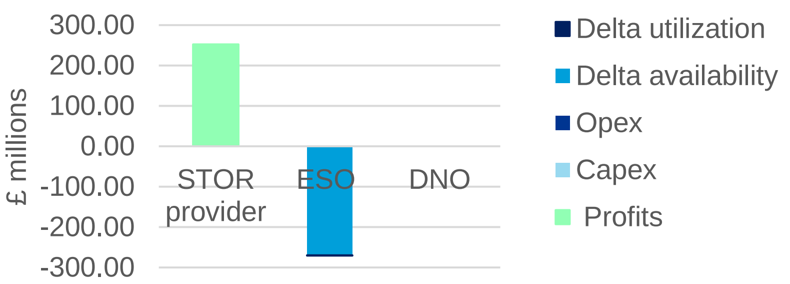


Figure 4.1 – Cost per stakeholder in Scenario 3 - Rule 1 i)

Figure 4.2 – Cost per stakeholder in Scenario 3 - Rule 1 ii)

4. CBA results

Scenario 3 – Results interpretation

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 ESO cost under rules 1 and 3 is roughly 50%. This difference is due to the STOR aggregated units within ANM areas. Whereas in rule 1, the full STOR unit is excluded from the merit order regardless of its composition, in rule 3, only the capacity within the ANM area is excluded.
- The STOR aggregated units represent around 18% of the total units within ANM areas. However, the impact is quite large because these units are generally tendered at a cheaper price, which influences the STOR merit order significantly.
- Rule 3 ii) proves to be the least costly/most efficient rule under the "DNO has primacy" rule categories.

Rule 4 ii) – key observations

- The main cost element of this rule is again the STOR availability payments. Under this rule, this high cost is 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 shows higher costs than rule 1 ii) and 3 ii).
- Utilisation payments are also higher than for rule 1 ii) and 3 ii) due to the need for "overdispatch". However, these costs are still negligible relative to ESO availability costs.
- This is the only "DNO has primacy" rule that has an impact on carbon emissions. The overall impact is relatively low compared to other rules – 161 tCO_2 eq.

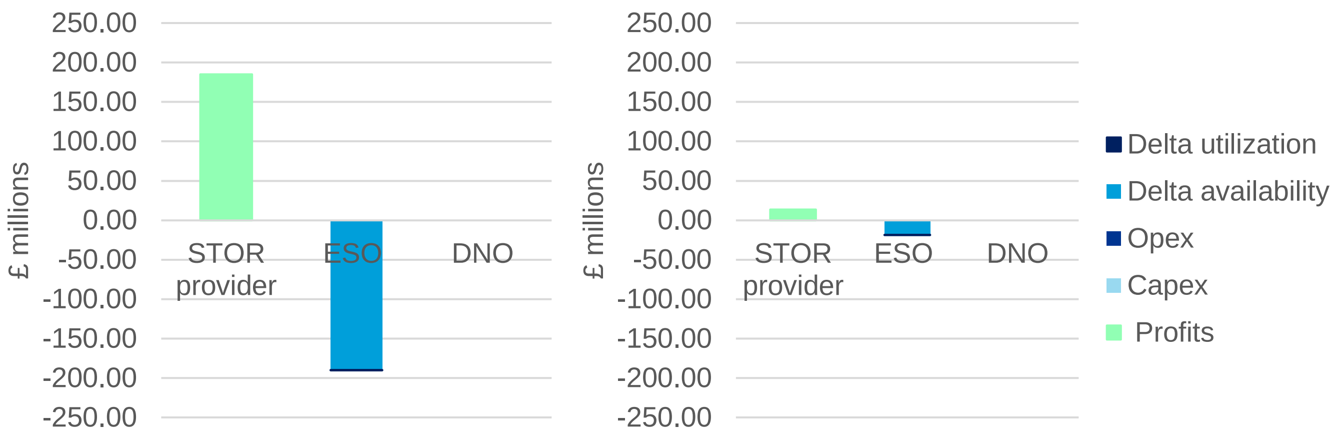


Figure 4.3 – Cost per stakeholder in Scenario 3 - Rule 3 i) (left) and 3 ii) (right)

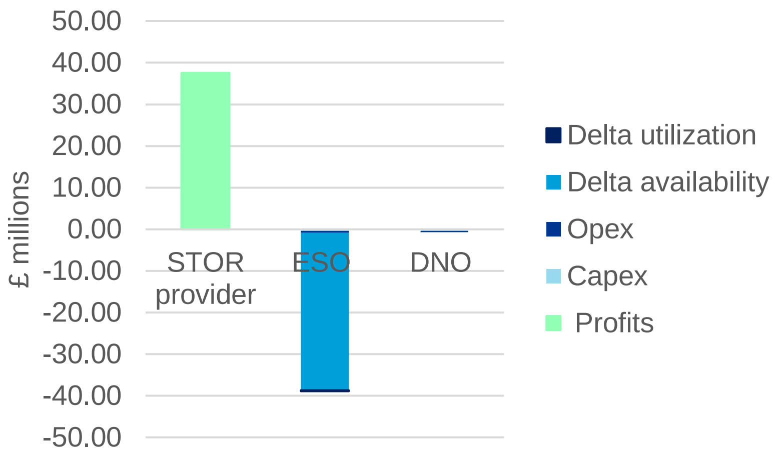


Figure 4.4 – Cost per stakeholder in Scenario 3 - Rule 4 ii)

4. CBA results

Scenario 3 – Results interpretation

Rule 2 i) and 2 ii) – Key observations

- Rule 2 ii) shows the lowest overall cost among all rules.
- The implementation cost for these rules is overall higher than the implementation cost for rules where the DNO has primacy.
- In addition to the rule implementation costs, the main cost component is the cost for holding headroom incurred by the ANM generator and their BRP.
- The cost is broken down into loss of revenue, savings on marginal cost, savings on generation network tariffs, and redispatch costs.
    - The bulk of the costs (over 90%) relates to loss of revenue and redispatch costs
    - The network tariff chosen for the model presented negative values, therefore, this element is a cost instead of a saving. (~ 3% of cost of holding headroom)
    - The marginal costs savings are only incurred by gas generators. The savings on generation costs are also marginal compared to the total costs. The order of magnitude is 6% relative to the total costs for holding headroom
- The difference in cost of rule 2 ii) and the previous rules is because when curtailing ANM generators, there are no availability or reservation costs; the ANM generator and their BRP only incur on costs when there is curtailment. In this scenario, there is curtailment in only 5% of the SPs of a year.
- The main difference in rules 2 i) and 2 ii) costs is the amount of capacity curtailed. In the former, we curtail a fixed amount which corresponds to the prequalified STOR units in the ANM area, whereas in the latter the curtailed capacity is dynamic, and it is determined based on day-ahead auctions results.
- Due to increased curtailment, the carbon impact of rule 2 i) is almost 7 times higher than for rule 2 ii).

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

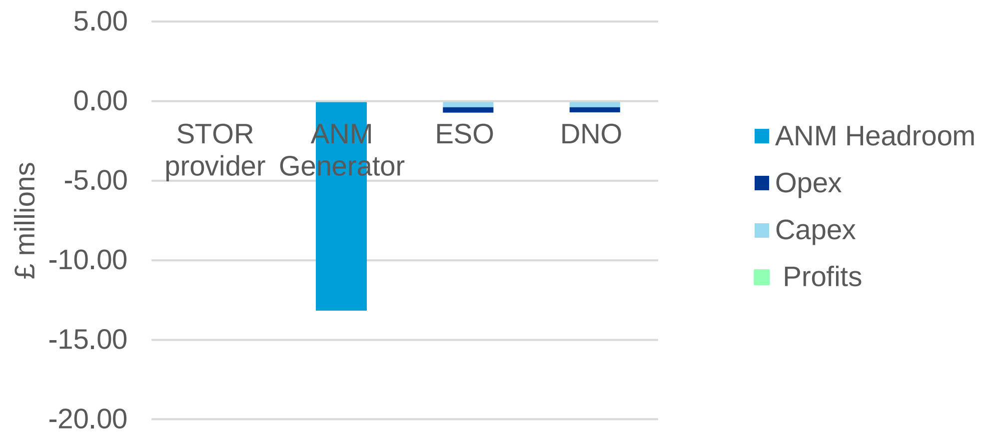


Figure 4.5 – Cost per stakeholder in Scenario 3 - Rule 2 i)

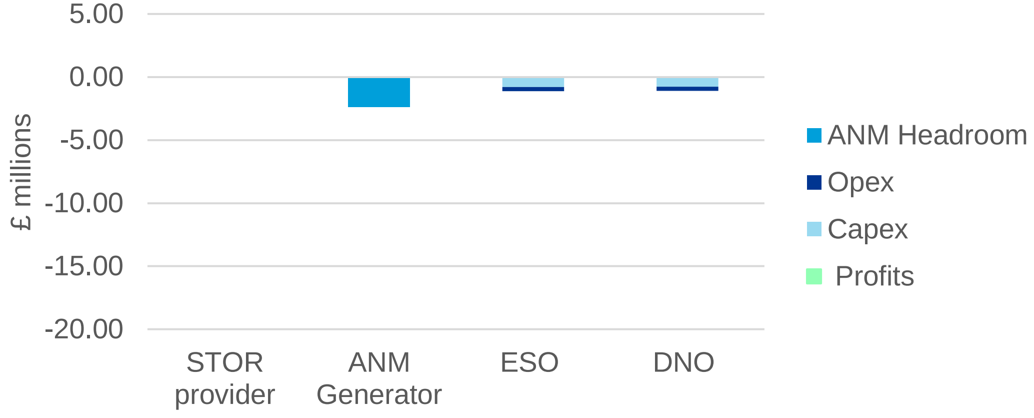


Figure 4.6 – Cost per stakeholder in Scenario 3 - Rule 2 ii)

4. CBA results

Scenario 3 – Results interpretation

Rule 6 i) and ii) – Key observations

- The same observations on 2 i) are applicable to 6 i). The only difference is that the cost for holding headroom are allocated to the ESO instead of the ANM generator + BRP.
- Rule 6 ii) is very different from 2 i). In this variant, the STOR merit order is modified so the cost for holding headroom can be factored it for STOR units within ANM areas. This results in adding up to 30-50 GBP/MW/h to the tendered price
- When modifying the STOR merit order, for nearly 100% of the cases, the STOR units do not make it into the accepted units. This means that effectively there is no cost for holding headroom but there are added costs on STOR procurement and utilisation for the ESO. This rule results in the same ESO STOR costs and STOR provider profits than rule 1 ii). The same observations that are applicable for rule 1 ii) can be applied to 6 ii).
- As in rule 6 ii), the modification of the merit order creates more costs overall than holding headroom due to the STOR market clearing mechanism. When compared to rule 2 ii), the STOR costs of rule 6 ii) are 16 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 i) and ii) – Key observations

- The same observations on 2 i) are applicable to 7 i). The only difference is that the cost for holding headroom are allocated to the STOR provider instead of the ANM generator + BRP.
- Rule 7 ii) has the same logic as 6 ii) with the exception that the STOR service provider is the stakeholder modifying the tendered prices. Hence, the aggregated units can be taken into consideration.
- When modifying the STOR merit order, for nearly 100% of the cases, the STOR units do not make it into the accepted units. This means that effectively there is no cost for holding headroom but there are added costs on STOR procurement and utilisation for the ESO. This rule results in the same ESO STOR costs and STOR provider profits than rule 3 ii). The same observations that are applicable for rule 3 ii) can be applied to 7 ii).
- As in rule 6 ii), the modification of the merit order creates more costs overall than holding headroom due to the STOR market clearing mechanism. When compared to rule 2 ii), the STOR costs of rule 6 ii) are 7 times higher than the cost for holding headroom in rule 2 ii), due to the STOR merit order effect.

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

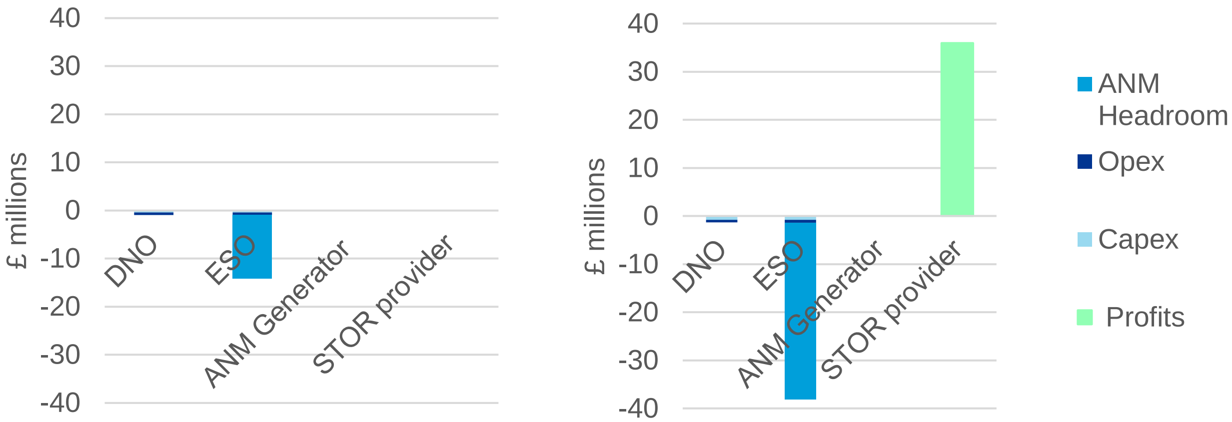


Figure 4.7 – Cost per stakeholder in Scenario 3 - Rule 6 i) (left) and 6 ii) (right)

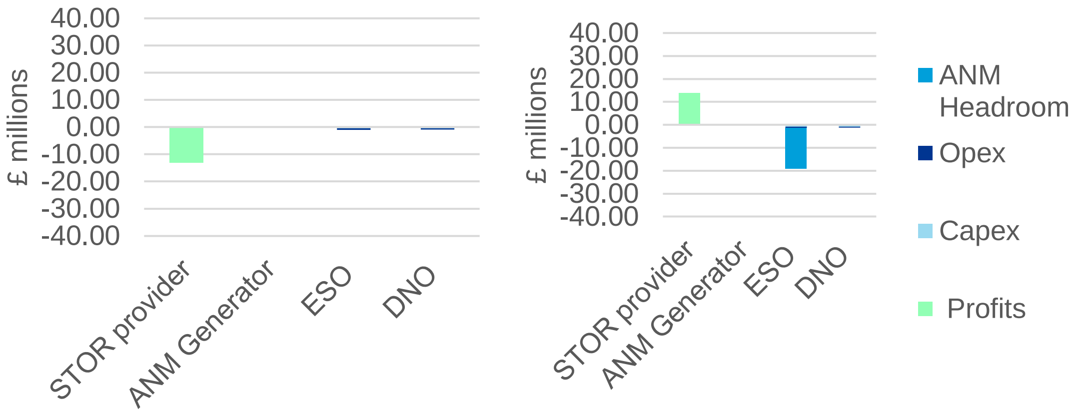


Figure 4.8 – Cost per stakeholder in Scenario 3 - Rule 7 i) (left) and 7 ii) (right)

4. CBA results

Comparative analysis – End consumer impact

- When comparing the end-consumer outcomes for all scenarios, the least costly rule across all four scenarios is rule 2 ii), which avoids availability or reservation costs and applies dynamic curtailment of ANM generators.
- Rule 3 i) & ii) always perform better than rules 1 i) & ii) respectively. This is due to treatment of, and lower costs for, STOR aggregated units (see page 38).
- Rules 1 i) and 3 ii) are the worst performing rules for 3 out of the 4 scenarios. This is due to the high impact on the STOR merit order for every day. Rule 1 i) is the lowest ranked rule for 3 out of 4 of the scenarios. Only for scenario 2, rule 4 ii) ranks lower. This can be explained because this rule is highly affected by a higher STOR coverage (higher MCP) and higher % of curtailed periods (more STOR auction days are affected).
- Rule 4 ii) is one of the lowest ranked rules and always ranks lower than rules 1 ii) and 3 ii), because of a greater need for STOR capacity at a higher MCP.
- Rule 7 ii) is always ranked just below 3 ii), this is because the STOR costs are the same, but the CAPEX and OPEX costs are higher for rule 7 ii). The same applies to rules 6 ii) and 1 ii).
- Generally, the “ii)” version of the rules outperforms the “i)” version. There are 2 exceptions to this, which are rules 6 i) & 7i) in scenario 1 and 3. The reason for this is that the version “i)” of these two rules is very different to the “ii)” version, since the “ii)” version involves changing the STOR merit order. For scenarios with low STOR in ANM coverage, the “i)” version of the rule performs better than the “ii)” version. A high coverage of STOR in ANM areas has a larger impact in rules 6 i) & 7 i) because the curtailment level (i.e., headroom) is the same capacity as the capacity of STOR assets in ANM areas (50% in scenarios 2 & 4). The same observation can be made for rule 2 i).
- Generally, rule 3 ii) performs better than most of the other rules for scenarios with 50% STOR coverage. This is because under this rule, aggregated units are not fully excluded from the merit order – the STOR provider would exclude the capacity that is within the ANM area and tender the rest of the unit. Although this is also the case for scenarios 1 & 3, the impact of aggregated units is not as relevant because the STOR merit order is more liquid at lower coverage.
- Relatively, rules where one of the main cost elements is cost for holding headroom, perform better for low coverage scenarios, whereas rules that modify STOR merit order, perform better for higher coverage scenario.
- Finally, in terms of carbon emissions, there are no changes on emission ranking across scenarios. Rules 2 i), 6 i) and 7 i) are the worst performing rules on emissions on scenarios 3 & 4 (i.e., low renewable generation scenarios).

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

Ranking based on end-consumer 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 4.2 – Ranking of the rules based on end consumer impact (above), considering carbon emissions (below)

4. CBA results

Detailed CBA output (data)

Scenario 1

RULES (£m)		STOR provider	ANM generator + BRP	ESO	DNO	End consumer
Rule 1	i)	252.30		-270.17	-0.34	-270.51
	ii)	99.95		-115.42	-0.72	-116.14
Rule 3	i)	185.26		-189.72	-0.34	-190.06
	ii)	92.72		-97.51	-0.72	-98.23
Rule 4	i)					
	ii)	106.81	-0.49	-122.46	-0.72	-123.67
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)	99.95		-115.99	-1.29	-117.28
Rule 7	i)	-27.61		-0.98	-0.93	-29.52
	ii)	92.72		-98.05	-1.29	-99.34

Table 4.3 – Cost and benefit overview for the rules when scenario 1 parameters are applied

Scenario 2

RULES (£m)		STOR provider	ANM generator + BRP	ESO	DNO	End consumer
Rule 1	i)	315.84		-355.63	-0.34	-355.97
	ii)	108.56		-125.57	-0.72	-126.29
Rule 3	i)	307.24		-345.91	-0.34	-346.24
	ii)	108.44		-117.04	-0.72	-117.76
Rule 4	i)					
	ii)	371.61	-2.50	-410.36	-0.72	-413.58
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)	108.56		-126.14	-1.29	-127.43
Rule 7	i)	-156.61		-0.98	-0.93	-158.52
	ii)	108.44		-117.58	-1.29	-118.87

Table 4.4 – Cost and benefit overview for the rules when scenario 2 parameters are applied

4. CBA results

Detailed CBA output (data)

Scenario 3

RULES (£m)		STOR provider	ANM generator + BRP	ESO	DNO	End consumer
Rule 1	i)	252.30		-270.17	-0.34	-270.51
	ii)	35.99		-37.49	-0.72	-38.21
Rule 3	i)	185.26		-189.72	-0.34	-190.06
	ii)	13.87		-18.54	-0.72	-19.26
Rule 4	i)					
	ii)	37.54	-0.24	-38.89	-0.72	-39.85
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)	35.99		-38.06	-1.29	-39.35
Rule 7	i)	-13.18		-0.98	-0.93	-15.08
	ii)	13.87		-19.08	-1.29	-20.37

Table 4.5 – Cost and benefit overview for the rules when scenario 6 parameters are applied

Scenario 4

RULES (£m)		STOR provider	ANM generator + BRP	ESO	DNO	End consumer
Rule 1	i)	315.84		-355.63	-0.34	-355.97
	ii)	36.35		-39.16	-0.72	-39.88
Rule 3	i)	307.24		-345.91	-0.34	-346.24
	ii)	27.10		-33.19	-0.72	-33.91
Rule 4	i)					
	ii)	44.89	-1.40	-51.92	-0.72	-54.04
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)	36.35		-39.73	-1.29	-41.02
Rule 7	i)	-75.59		-0.98	-0.93	-77.50
	ii)	27.10		-33.73	-1.29	-35.03

Table 4.6 – Cost and benefit overview for the rules when scenario 4 parameters are applied

4. CBA results

Detailed CBA output (data)

RULES - DNO HAS PRIMACY [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	204	1,162	161	889
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 4.7 – Carbon emission comparison for the rules and scenarios

5. Conclusions and recommendations for future analysis

4. Conclusions and recommendations

Conclusions

- This analysis highlights the complexity of implementation details and processes underpinning the different primacy rules that were evaluated.
- The CBA results show that, under the current STOR market design and assumptions, Rule 2 ii) is the most economic (least cost) to end-users across all scenarios, because it avoids STOR availability costs and applies dynamic curtailment of ANM generators. Rule 2 ii) gives priority to the ESO 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 has a significant impact on the cost for rules in which the STOR merit order is affected. Small movements along the merit order can have a high system-wide cost impact.
- The CBA results indicate that the most advanced versions of the rules ii) perform generally better, even if the implementation cost are comparatively high.
- One of the main take-aways is that many of the rules can affect the system reliability if not implemented correctly. The ENA needs to consider aspects such as redispatch responsibility, impact on reliability and system balance, and the accuracy of DSO curtailment forecasts.
- There is insufficient understanding on the current level of conflict between ANM and STOR activations and it is not clear to what extent implementing a rule would improve the system reliability and performance, or what the associated risks might be. This results in a need for an enhanced understanding of what is currently happening within the system, what the level of conflict is and what implicit actions are taken. When time progresses, the associated risks to may reach a level that is not acceptable for BaU, creating the need to implement a certain rule.
- It should be noted that all results and conclusions of the CBA are based on the rule process flows and assumptions developed throughout this project in collaboration with the ENA.

Recommendations

DNV recommends to assess the system and societal cost and benefits of not implementing any rule for the short term, given that the rules are costly to implement, and it will take time to develop the IT capabilities to implement the rules.

- DNV recommends factoring in any changes from Ofgem’s Charging Significant Code Review (SCR) when they are available and analyse how they affect the rules where ESO has primacy.
- This study only analysis one type of conflict, whereas there are several other conflicts between ESO and DNO. As such, the results of this analysis should not be taken in isolation. DNV recommends to explore the synergy with primacy rules for other types of conflicts between ESO and DNO.
- One of the limitations of this study is that future changes to the STOR product were not considered, DNV recommends further exploring STOR market arrangements and how they would affect the rule evaluation outcome.
- DNV recommends the ENA conduct a sensitivity analysis on the level of DNO forecast accuracy required for the application of primacy rules, to determine the point at which greater accuracy is no longer worth the cost.

WHEN TRUST MATTERS

Development and impact quantification of primacy rules

Conflict between STOR and ANM

20 October 2022

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.

DNV