

Network Options Assessment Methodology

Electricity System Operator

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About this document

This document contains National Grid Electricity System Operator (ESO)'s Network Options Assessment (NOA) methodology established under the Electricity Transmission Licence Standard Condition C27 in respect of the financial year 2022/23. It covers the methodology on which National Grid ESO will base the 2022/23 NOA report to be published in 2023. As the methodology evolves due to experience and stakeholder feedback, the methodology statement will be revised for subsequent NOAs as required by Licence Condition C27.

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List of Abbreviations

ACC	Attributable constraint costs
ACS	Average cold spell
ARW	Asset replacement works
BEIS	Department of Business Energy and Industrial Strategy
CATO	Competitively appointed transmission owner
CBA	Cost benefit analysis
CSNP	Centralised Strategic Network Planning
CUSC	Connection and Use of System Code
CWW	Connection Wider Works
DNO	Distribution network operator
EISD	Earliest in service date
ETNPR	Electricity Transmission Network Planning Review
ETYS	Electricity Ten-Year Statement
FACTS	Flexible AC transmission system
FES	Future Energy Scenarios
HEC	High efficiency co-generation
HND	Holistic Network Design
IWW	Incremental wider works
LOTI	Large Onshore Transmission Investment
LWR	Least worst regret
LWWR	Least worst weighted regret
MSIP	Medium Sized Investment Project
NDP	Network development plan
NETS	National Electricity Transmission System
OCP	Offshore Coordination Project
OTNR	Offshore Transmission Network Review
QB	Quad booster
RES	Renewable energy sources
RIIO	Revenue = incentives + innovation + outputs
SEW	Social economic welfare
SQSS	Security and Quality of Supply Standard
SRF	System Requirements Form
STC	System Operator Transmission Owner Code
STPR	Social Time Preference Rate
SWW	Strategic Wider Works
TO	Transmission Owner
WACC	Weighted average cost of capital



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Introduction

Purpose

- 1.1 The purpose of the Network Options Assessment (NOA) is '*to facilitate the development of an efficient, co-ordinated and economical system of electricity transmission and the development of efficient interconnector capacity.*'¹ This must be consistent with the National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS). At the same time, the NOA process enables the development of the system in a manner that will achieve the Electricity System Operator (ESO)'s ambitions and government net zero targets.
- 1.2 This document provides an overview of the aims of the NOA and details the methodology which describes how the ESO assesses the required levels of network transfer, the options provided by the transmission owners to meet this requirement and recommends options for further development. It is important to note that whilst the ESO recommends progressing options in order to meet system needs, any investment decisions remain with the Transmission Owners (TOs) or other relevant parties as appropriate. This methodology will be used in preparing the 2022/23 NOA report, to be published in 2023.
- 1.3 This methodology describes the end-to-end process from the analysis to the publication of the NOA report and identifies the roles and responsibilities of the ESO and TOs. It includes timescales as set in Electricity Transmission Standard Licence Condition C27. Ofgem, 'The Authority', can change these, which will change the NOA timescales below.
- 1.4 Where this methodology refers to 'TOs', it means onshore TOs.

Interaction of the NOA methodology with other reforms to network planning

Electricity Transmission Network Planning Review (ETNPR)

- 1.5 The Electricity Transmission Network Planning Review (ETNPR) is reviewing the existing Electricity Transmission network planning process and considering the need for improvements that will enable the GB transmission network to efficiently meet the anticipated future needs of the changing energy system to fulfil the decarbonisation targets.
- 1.6 The ETNPR introduces the concept of a Centralised Strategic Network Planning (CSNP) model which would take a GB-wide holistic view to develop an optimised plan for taking forward low regret Strategic Investments in the network (onshore and offshore). The CSNP will be developed and implemented over the next two to three years.
- 1.7 Ofgem are consulting with industry on the model as part of the ETNPR, with workshops on key aspects of the proposal taking place this year.

Holistic Network Design (HND)

- 1.8 Ofgem and BEIS have initiated the Offshore Transmission Network Review (OTNR) project. One element of this work is the Pathway to 2030 workstream whereby NGESO, in collaboration with industry, is leading on the development of a Holistic Network Design (HND). HND has a strong focus on improvements to how we connect offshore generation to the onshore network and the overall coordination of network reinforcement to facilitate 2030 government offshore wind targets. The NOA is a key part of the HND and the NOA 2021-22 refresh report updated the analysis to reflect the onshore recommendations for 2021/22 and the impact of the coordinating in scope offshore wind projects. The HND and a refreshed NOA 2021/22 publication were published in July 2022 providing an update to the NOA report published in January 2022.

¹Electricity Transmission Standard Licence Conditions, Condition C27, <https://epr.ofgem.gov.uk/Content/Documents/Electricity%20transmission%20full%20set%20of%20consolidated%20standard%20licence%20conditions%20-%20Current%20Version.pdf>

- 1.9 The work being undertaken in the HND project will inform the development of the future CSNP.

Impact on the Network Options Assessment and this methodology

- 1.10 There is significant development in the future network planning area, as a country we strive to meet the Government's targets for offshore wind, net zero and other targets.
- 1.11 At present, we do not have definitive changes that would impact on the next NOA cycle. Therefore, at the time of writing, this methodology is presented as an incremental improvement in accordance with the ESO's licence condition. Therefore, there are no changes driven by the ongoing work of ETNPR or HND.
- 1.12 The previous text on Offshore Wider Works (OWW) has been deleted and replaced by a smaller section on HND. We recognise that this section will change in future when the CSNP has been developed.
- 1.13 We will consult with industry in developing the NPR and we will review, update and consult with the industry on our network planning methodologies.

Key changes for 2022/23

1.14 **NOA IC**

For NOA IC 2022/23 we intend to build on the modelling undertaken to support Ofgem's mid-2022 cap and floor window and investigate incorporating elements from previous NOA IC analyses, such as setting a baseline level of interconnection and using an iterative approach to calculate the optimal level of interconnection. We will continue to focus on constraint costs and Social Economic Welfare. We will investigate system operability impacts, as well as carbon costs and the impact on RES curtailment.

1.15 **Recommendation changes**

Following discussion with Ofgem and TOs, we have amended the recommendations in NOA 2022/23. We aim to support the TOs in delivering significant options in the most economic and efficient time. Therefore, we have revised the recommendations this year and this is explained in section 2.99.

1.16 **EISD Advancement**

We have recently implemented an EISD advancement benefit methodology. The aim of this is to support a substantial reduction in network constraint costs and is an outcome of the 5-point plan. A shortlist of options is prepared where significant constraint cost savings could be achieved if the earliest in service date (EISD) is brought forward. The results of the analysis are shared with the relevant TO but not included in the report.

1.17 **Early competition**

The ESO supports Ofgem's view that early competition represents good value for money for consumers and that the ESO can add value through this process. Ofgem believe the ESO should be the Procurement Body. We will continue to work out how early competition will operate. The legislation to enable this is in the Energy Security Bill which was laid before Parliament in July 2022.

Key similarities to 2022/23

- 1.18 The overall NOA process and philosophy are the same as used last year. Our NOA Methodology review that we submitted to Ofgem in March 2017 concluded that single year regret analysis is the best way to evaluate the needs of the national electricity transmission system. You can find the review document at:

<https://www.nationalgrid.com/sites/default/files/documents/NOA%20Methodology%20Review%202017.pdf>

- 1.19 For the NOA 2022/23, we will continue to operate the NOA Committee to provide additional scrutiny throughout the NOA process. The members of the NOA Committee are senior leaders in the ESO who ensure that the NOA recommendations are robust and in the best interest of GB's consumers. Ofgem and representatives of the TOs are invited to attend. The TOs can provide additional information on an option and help to explain the value of an option. You can find the minutes of the past NOA Committee meetings on the NOA webpage at:

<https://www.nationalgrideso.com/research-publications/network-options-assessment-noa/key-documents>

Background

- 1.20 In order to recommend options, the ESO uses the established investment recommendation process. This ultimately leads to the selection of recommended options based upon their capital investment and constraint savings across a range of scenarios as well as forecast earliest in-service date. Constraint costs are a factor of bid/ offer prices and the amount of generation constrained. Both factors vary across the scenarios resulting in no one scenario necessarily seeing higher constraint costs than another.
- 1.21 This methodology describes the NOA Process. Figure 2.1 illustrates the annual NOA process that Section 2 covers. Sections 3, 4, 5 and 7 cover aspects of the NOA process as required by Standard Licence Condition C27. Appendix B contains the System Requirements Form (SRF) template; Appendix C is the cost checking process; and Appendix D is the form of the NOA report. Section 6 covers NOA Pathfinders which are outside of the C27 requirement. This covers the ESO process for High Voltage Management and ESO process for Stability Management. Note that because of different purposes and timescales, we expect the NOA Pathfinder process to remain a separate workstream from the annual NOA process. In accordance with Standard Licence Condition C27, the ESO has sought the input of stakeholders. Appendix E includes a summary of any views that the ESO has not accommodated in producing this NOA methodology.

The Methodology

- 1.22 The Network Options Assessment (NOA) process set out in Electricity Transmission Standard Licence Condition C27 facilitates the development of an efficient, coordinated and economical system of electricity transmission and the development of efficient interconnection capacity. This NOA methodology has been developed in accordance with Standard Licence Condition C27.
- 1.23 This document defines the process by which the NOA is applied to the onshore and offshore electricity transmission system in GB. The process runs from identifying a future reinforcement need, to assessing available options to meet this need, to recommending and documenting the option(s) for further development. It also defines the process of assessing the suitability of recommended options for competition in onshore electricity transmission. This assessment is against criteria defined by Ofgem in their document, '*Guidance on the Criteria for Competition*'². The ESO identifies and evaluates alternative options such as those based around commercial arrangements or reduced-build options in addition to those provided by the TOs. Table 2.2 covers these alternative options in more detail.
- 1.24 The ESO has engaged with the TOs to develop this methodology statement. Following publication of the NOA report, further stakeholder engagement is undertaken to inform the methodology statement for supporting the subsequent NOA process.
- 1.25 As background information changes and new data are sourced, for example in response to changing customer requirements, both the recommended options and their timing will be updated, driving timely progression of investment in the electricity transmission system.

² https://www.ofgem.gov.uk/system/files/docs/2019/02/criteria_guidance.pdf

- 1.26 The ESO engages stakeholders on the annual updates to the key forecast data used in this recommendation process and shares the outputs from this process through the publication of the NOA report.
- 1.27 Transmission Licence Standard Condition C27 Paragraphs 16 and 17 set out the contents of the NOA report following Ofgem's consultation³ and decision on changes to licence condition C27 in 2019/20. These changes require NGENSO to assess certain projects for competition (see chapter 4) and to carry out the early development of options where this work is not done by a TO (chapter 7).
- 1.28 The ESO considers Interested Persons to be parties who propose innovative and new options that may have a demonstrable benefit to the process but perhaps cannot do the analysis or studies. Interested persons may contact NGENSO via noa@nationalgrideso.com. We include the Interested Persons' process in Section 7 Early Development of Options and the ESO Interested Persons' Process.
- 1.29 References to 'weeks' in the NOA methodology are to calendar weeks as defined in ISO 8601. Week 1 is at the start of January and is the same as the system used in the Grid Code OC2.
- 1.30 The ESO continually reviews the operability requirements of the transmission network. Where it finds a new need that competitive services may meet, it develops a Pathfinder project to test the need, the possible approaches, market engagement and interest.

Major National Electricity Transmission System Reinforcements

- 1.31 Standard Licence Condition C27 refers to '*Major National Electricity System Reinforcements*'. For the purpose of this NOA Methodology statement, the definition, which has been agreed after consultation with the onshore TOs and the Authority (Ofgem) is:
- Major National Electricity Transmission System Reinforcements are defined by the ESO to consist of a '*project or projects in development to deliver additional boundary capacity or alternative system benefits as identified in the Electricity Ten Year Statement or equivalent document.*'
- 1.32 The intention is to maximise transparency in the investment decisions affecting the National Electricity Transmission System while omitting schemes that do not provide wider system benefits, such as schemes for a user connection or to improve system reliability.

Eligibility criteria for projects for inclusion / exclusion

- 1.33 The NOA report presents projects as options to reinforce the wider network that are defined by Major National Electricity System Reinforcements (see definition above).
- 1.34 The ESO provides a summary justification for any projects that are excluded from detailed NOA analysis.
- 1.35 Once a Medium Sized Investment Project (MSIP), Large Onshore Transmission Investment (LOTI) or Strategic Wider Work (SWW) Needs Case has been approved by Ofgem, the option is excluded from the NOA analysis although the report refers to it and it is included in the baseline. This is due to it being managed through the separate MSIP, LOTI or SWW process. Ofgem have agreed the approach of excluding options where they have already agreed the LOTI or SWW Needs Case. The NOA report will include analysis of options under construction that are funded through the incremental wider works (IWW) mechanism.

Roles and responsibilities of ESO and TOs

- 1.36 The ESO role and responsibilities are based around its overview of the network requirements. Specific role areas are as follows:

³ <https://www.ofgem.gov.uk/publications-and-updates/decision-modifications-standard-condition-c27-electricity-transmission-licence>

- analysis of UK FES data
- identifying boundary transfer requirements and publishing SRFs
- verification studies of some boundary analysis performed by the TOs to corroborate the TOs' analysis
- devising and developing options including but not limited to operational options, commercial agreements and Offshore Wider Works (OWW) as well as early development of options (see section 7)
- reviewing any options recommended in a previous NOA as "Proceed - Critical" but which have not been progressed by the transmission licensee to which the recommendation was given
- review of reinforcement options and their cost estimates that the TOs propose
- assessment of outages and other factors affecting the availability of system access. These may affect the options' Earliest in Service Dates (EISD)
- running cost-benefit analysis studies
- recommending options for further development
- advise on the performance of boundary reinforcement proposals in the cost-benefit analysis to facilitate further option development by the TOs
- providing an explanation of the NOA Committee recommendations
- recording details if a TO does not follow a NOA recommendation
- assessing eligibility for competition
- producing and publishing the NOA report.

1.37 The TOs' roles and responsibilities include:

- technical analysis of boundary capabilities of the base network and uplifts from reinforcement options
- proposing and developing reinforcement and reduced-build options
- providing their technical information to the ESO
- cost information for options
- outage and system access requirements for options
- environmental information for options
- consents and deliverability information for options
- EISD of options
- verification studies of some boundary analysis performed by the ESO to corroborate the ESO's analysis of alternative options
- stakeholder engagement (following review of draft outputs of the NOA outcome)
- community engagement
- review of the draft NOA report and appendices related to TO options.

Stakeholder consultation

- 1.38 The ESO has consulted with the TOs and Ofgem whilst preparing this NOA methodology.
- 1.39 The key consultation areas are the NOA methodology, form of the NOA report and the NOA report outputs and contents.
- 1.40 This section shows the timescales for the ESO's consultation of stakeholders during the period of writing the NOA report.

Methodology review

- 1.41 The ESO seeks stakeholder views annually for consideration and where appropriate implementation before the NOA process starts its annual cycle.
- 1.42 The ESO consults on the NOA methodology annually as part of meeting our licence condition. The methodology contains processes that operate at different times, notably the NOA pathfinders that are separate from the annual NOA process. We retain the option to separate out parts of the methodology in future years with pathfinders being the most likely, while accommodating stakeholder feedback. The minimum duration of any NOA methodology consultation would be six weeks. The ESO considers feedback for a revised NOA methodology and submits the methodology to Ofgem by 1 August of that year.
- 1.43 The ESO seeks approval from The Authority (Ofgem) on the NOA methodology and form of the NOA report as part of the annual stakeholder engagement process.

Report output

- 1.44 The ESO makes selected parts of the pre-release NOA report available to key stakeholders, particularly the relevant TOs, on a bilateral discussion basis to ensure confidentiality obligations. This is as the NOA report is being written based on assessment data, particularly economic data, becoming available. These discussions will occur as results become available and the report is being drafted.
- 1.45 Further key stakeholder engagement occurs with release of drafts of the NOA report, three weeks ahead of publication. These drafts are always shared with the TOs and may be shared with Ofgem and BEIS. This provides a final opportunity for stakeholders to comment on the NOA report and raise any significant concerns. When a stakeholder expresses concern with the conclusions of the report, a comment is incorporated in the relevant section(s).

Provision of information

Engagement with interested parties to share relevant information and how that information will be used to review and revise the NOA methodology

- 1.46 The NOA methodology and NOA report adequately protects any confidential information provided by stakeholders or service providers, for example, balancing services contracts. For this reason, this methodology seeks to be as open and transparent as possible to withstand scrutiny and provide confidence in its outcomes, while maintaining confidentiality where necessary.
- 1.47 In accordance with Licence Condition C27 Part C, the ESO provides information to electricity transmission licensees, interconnector developers and to the Authority (Ofgem) if requested to do so. The ESO will assist TOs with cost-benefit analysis for LOTI or MSIP. Where appropriate the ESO can use the NOA results as part of a LOTI, MSIP or SWW initial Needs Case with the agreement of the relevant TO(s).

Future developments

- 1.48 The ESO expects to make the following changes to the NOA methodology:
 - Build on the Pathfinder projects to test distribution solutions as NOA options which include identifying non-MW requirements and the necessary cost-benefit analysis methodology.
 - The thermal probabilistic tool has been developed during 2021-22. The methodology and findings have been discussed with our TO colleagues. Further discussion with the TOs will take place in 2022-23.
 - Probabilistic tools that would facilitate:
 - i. Simulation analysis of full year network operation with variation in generation and demand profiles to identify both common and infrequent problems.

- ii. Representation of typical operational optimisation actions such as control of power flow controllable devices (e.g., Quad Boosters (QBs) and other similar Flexible AC Transmission System (FACTS) devices)
 - iii. Automation of study set-up and contingency analysis
 - iv. Automated data manipulation and results handling and filtering
 - v. Continuous assessment of individual circuit parameters instead of boundary representation.
 - vi. Benchmarking year-round circuit-based constraints representation in the economic assessment.
- 1.49 Our current work led to a thermal probabilistic case study. Through this we investigated the viability of using probabilistic tools for thermal studies during 2020 and 2021. We have successfully used the probabilistic circuit-based methodology for the ESO 5-point plan for constraint costs in 2021. This year we are going to validate the approach further and conclude our findings. Based on this we will propose the road map and methodology for the integration of a year-round probabilistic assessment within the NOA process in agreement with stakeholders. Having gained experience with thermal studies, which includes performance levels and validation, we envisage voltage, and any other elements would follow in the subsequent two years.
- 1.50 As part of our business plan obligations, A11, we have undertaken a tender exercise to review the economic assessment tool used in the NOA process. We have used BID3, supplied by AFRY up to NOA 2021-22 and NOA refresh. As a result of this competitive process we selected Plexos, produced by Energy Exemplar as our new economic assessment tool. This tool will give us additional features including nodal modelling and more detailed constraint analysis. We are building up our model in Plexos and will undertake benchmarking activities against BID3 to ensure that the output is consistent. It is likely that the economic modelling for the next NOA report will use Plexos.
- 1.51 We recognise the need to evaluate more Connection Wider Works (CWW) and Asset Replacement Works (ARW) in the NOA process in fulfilment of our Business Plan obligations, objective A9. We have been planning how to achieve this while we develop plans for the system wide review of network planning in the ETNPR. Our plan for ETNPR has been expanded to include CWW and ARW. Since this has a broader approach, it is expected that the outcomes will be stronger and more future proof than considering any topic in isolation.



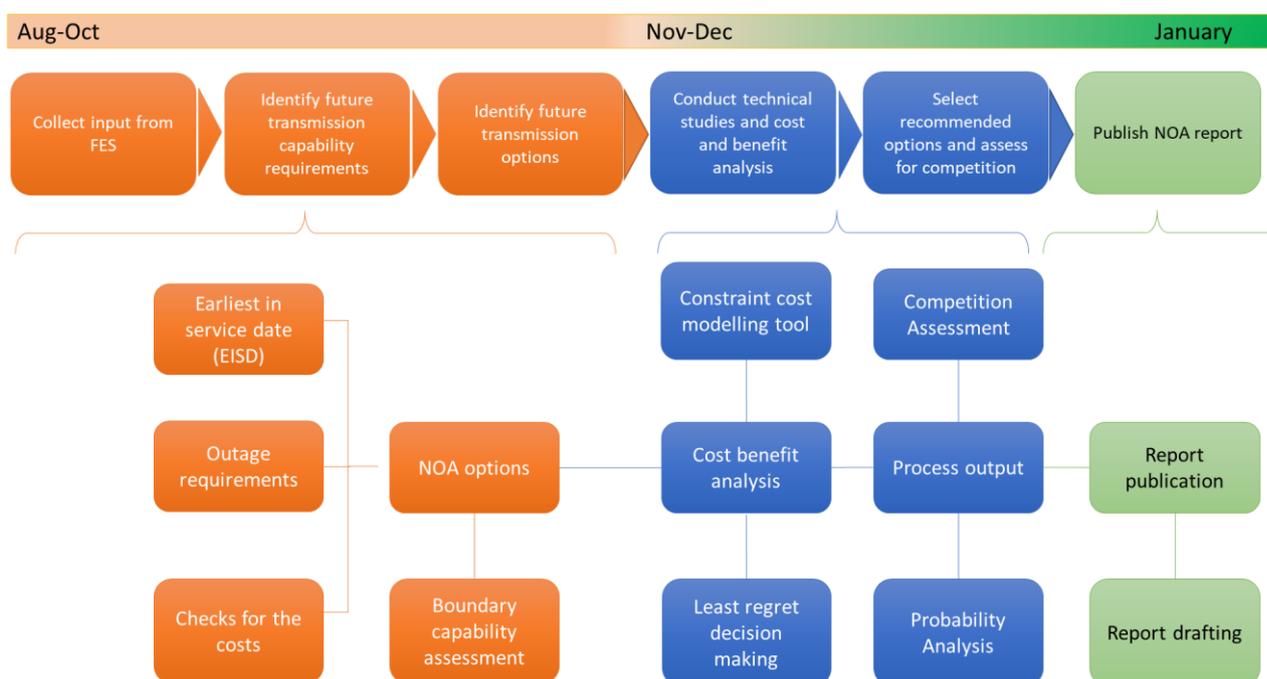
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The NOA process

Overview of the NOA process

- 2.1. The NOA methodology describes how we assess the required levels of power flow, evaluate the proposed options and recommend network reinforcements for further development. These options are proposed by the TOs, Interested Persons and the ESO. The methodology describes the end to end process from the analysis to the publication of the NOA report and identifies the roles and responsibilities of the Electricity System Operator (ESO) and onshore Transmission Owners (TOs). The process of integration with the offshore network is being developed separately in the Holistic Network Design (HND).
- 2.2. The National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS) version 2.5, April 2021, is used in the NOA process⁴. Figure 2.1 gives an overview of the NOA process. This methodology describes how the ESO, working with the TOs and other relevant parties, carries out these activities.

Figure 2. 1 Overview of the NOA process



Note: The investment recommendations from our economic analysis are presented to the NOA Committee as an additional, transparent level of scrutiny to our recommendations.

Updated Future Energy Scenarios (FES)

- 2.3. The relevant set of scenarios as required by Electricity Transmission Standard Licence Condition C11, is used as the basis for each annual round of analysis. These provide self-consistent generation and demand scenarios which extend to 2050. The FES document is consulted upon widely and published each year as part of the FES process.
- 2.4. The NOA process utilises the Future Energy Scenarios to form the background for the analysis. The FES model is subject to change based on stakeholder feedback received

⁴ <https://www.nationalgrideso.com/industry-information/codes/security-and-quality-supply-standards/code-documents>

through the FES consultation process. To keep up to date, please register for updates to the FES process⁵.

- 2.5. FES 2022 retains the scenario framework introduced for FES 2020 which reflects the UK net zero emissions target for 2050. As a result, it is based on the following scenarios taking into account the rapid changes in the energy market. The last three achieve net zero by 2050 or earlier:
- Falling Short⁶
 - System Transformation
 - Consumer Transformation
 - Leading the Way

Sensitivities

- 2.6. Sensitivities are used to enrich the analysis for particular boundaries to ensure that relevant boundary issues are captured, such as the sensitivity of boundary capability to the connection of a large generator or interconnector power flow condition. The ESO and TOs use a Joint Planning Committee subgroup as appropriate to coordinate sensitivities. This allows regional variations in generation activity and anticipated demand levels that still meet the scenario objectives to be appropriately considered.
- 2.7. For example, the contracted generation background on a national basis far exceeds the boundary requirements under the four main scenarios, but on a local basis, the possibility of the contracted generation occurring is credible and there is a need to ensure that we are able to meet customer requirements. A “one in, one out” rule is applied: any generation added in a region of concern is counter-balanced by the removal of a generation project of similar fuel type elsewhere to ensure that the scenario is kept whole in terms of the proportion of each generation type. This effectively creates sensitivities that still meet the underlying assumptions of the main scenarios but accounts for local sensitivities to the location of generation.
- 2.8. The inclusion of a local contracted scenario generally forms a high local generation case and allows the maximum regret associated with inefficient congestion costs to be assessed. In order to ensure that the maximum regret associated with inefficient financing costs and increased risk of asset stranding is assessed; a low generation scenario where no new local generation connects is also considered. This is particularly important where the breadth of scenarios considered do not include a low generation case.
- 2.9. Interconnectors to Europe give rise to significant swings of power on the network due to their size and because they can act as both a generator (when importing energy into GB) and demand (when exporting energy out of GB). For example, when interconnectors in the South East are exporting to mainland Europe, this changes the loading on the transmission circuits in and around London and hence creates different boundary capabilities.
- 2.10. The ESO models interconnector power flows from economic simulation using a market model of forecast energy prices for GB and European markets. The interconnector market model covers full-year European market operation. The results of the market model are then used to inform which sensitivities are required for boundary capability modelling. Sensitivities may be eliminated for unlikely interconnector flow scenarios.
- 2.11. The ESO and TOs extend sensitivity studies to test credible conditions that may cause constraints. FES data tends to produce boundary flows in one direction, such as north to

⁵ See, <https://www.nationalgrideso.com/future-energy/future-energy-scenarios/be-involved-stay-connected-fes> to contribute to the FES discussion. For general FES information please see: <https://www.nationalgrideso.com/future-energy/future-energy-scenarios>

⁶ This scenario used to be called ‘Steady Progression’ and is the scenario that does not meet the 2050 Net Zero target. It was changed to reflect feedback from stakeholders that it was not clear from the name that Steady Progression missed the target. Only the name is changing for FES 2022.

south. In some circumstances, flows may be reversed. The ESO develops relevant sensitivities in consultation with stakeholders to produce boundary capabilities for these sensitivity cases.

Interconnectors

- 2.12. For the NOA for Interconnectors (NOA IC), the ESO undertakes analysis to assess and provide a view on the optimum level of interconnection with other European markets. The markets considered will include Belgium, Denmark, France, Germany, Ireland (the combined market of Northern Ireland and the Republic of Ireland), The Netherlands and Norway. The NOA IC process will use the output from the 2022/23 NOA as the baseline network reinforcement assumptions. The proposed NOA IC approach for 2022/23 is presented in the NOA IC methodology in Section 3 of this document.

Holistic Network Design (HND)

- 2.13. At the time of writing this Methodology for NOA 2022-23, the methodology for HND is being developed. The impact of HND will be assessed in the analysis for NOA 2022-23; the method for this is currently being worked through.

Identify NOA options

- 2.14. At this stage, all the high-level transmission options which may provide additional capability across a system boundary requiring reinforcement (using “economic and security criteria”) are identified, including a review of any options considered in previous years. The NOA options are based around choices for example:
- an onshore route of conventional AC overhead line (OHL) or cable
 - an onshore route of (High Voltage Direct Current) HVDC
 - integration between offshore generation stations.
- 2.15. Variations in each of these choices may be presented where there are significant differences in options, for instance between different OHL routes where they could provide very different timescales and costs, due to planning and consents.

Table 2. 1 Description of the parts of the SRF template and when the TOs return them

SRF Part	Description	When SRF part is returned by TOs
A	Boundary requirement and capability	Mid-August (draft) Mid-September (final)
B	TO proposed options	Mid-August (draft) Mid-September (final)
C	Outage requirements	Mid-August (draft) Mid-September (final)
D	Studied option combinations and their impacts on the network	Mid-September
E	Options' costs	Mid-September
F	Publication information	Late October

- 2.16. In response to the data on boundary capabilities and requirements, TOs identify and develop multiple credible options that deliver the required boundary capabilities. The ESO produces and circulates the SRF Part A to the TOs and publishes them on the ESO website for Interested Persons (table 2.1). In response to Part A, TOs provide high level details of credible reinforcement options that are expected to satisfy the requirements. These options

could be subsea links as well as onshore. Appendix D of this document provides detailed information about the SRF template. The SRF is split into six parts with a guideline on when the TO is required to complete and return each part.

- 2.17. The ESO has the opportunity to suggest concepts to the TOs for options to achieve the boundary requirements.
- 2.18. The options that the TOs provide are listed and described in the NOA report along with ESO alternatives such as commercial options. Each option's description includes the boundary that the option relieves, categorising the option into 'build', 'reduced-build' or 'operational' and a technical outline. The option description includes any associated aspects such as the nature of the area affected, related network changes etc. The ESO undertakes NOA Pathfinder projects to trial analysis of additional system needs and this includes options from both TOs and non-TO sources. Where relevant the ESO will include any applicable options in the economic analysis.
- 2.19. As part of the process to identify future transmission options, the ESO will develop alternative options in collaboration with the relevant TO (and the relevant affected parties if applicable). The ESO will provide information about network benefit of proposed alternative options and identify regions that might benefit from alternative options. Table 2.2 provides examples of alternative options. The TOs will have the opportunity to shadow the analysis performed by the ESO in their relevant networks. The ESO and TOs will agree a detailed assessment methodology appropriate to each option. To facilitate the development of these options, the TOs are expected to provide network information such as limiting trips and components, existing communication and control assets, and information on feasibility of alternative running arrangements.
- 2.20. It is recognised that as options develop, their level of detail and design confidence tends to increase. In the early stages, alternative options developed by the ESO will be high level based on the best available information and will not assume availability of market data. The assumptions for each option will be agreed with the relevant TO while developing the option. The assumptions regarding EISD, required infrastructure, cost and effectiveness will vary depending on the studied region. Similarly, 'build' and 'reduced-build' options at a very early development stage might lack detail due to uncertainty in detailed project design such as land and consents requirements.
- 2.21. If the alternative option proves beneficial in the NOA cost-benefit analysis, the ESO will investigate the market to further develop the options. The ESO will use its existing NOA Pathfinder projects, or establish new NOA Pathfinders if necessary, to perform more detailed analysis to deliver these options. The ESO will share details of the technical and economic assessment approach with TOs/ DNOs/ Third parties as we develop the NOA Pathfinders. The TOs, DNOs, third parties will collaborate with the ESO to undertake technical analysis of relevant solutions/options to confirm their effectiveness as well as to determine any works required on the TO/DNO network to facilitate these solutions. The TOs, DNOs will also provide the ESO with details of associated costs and programme details for TO/DNO works.
- 2.22. All TOs return the draft SRF Parts A and B in mid-August and the final version in mid-September. The timing is to support the ESO's verification studies and cost checking process. All TOs provide draft Part C in mid-August and final Parts C to E in mid-September. These form the key inputs to the cost-benefit analysis process. Part F is the means for the TOs to advise the ESO of the descriptions of the options to be published in the NOA report. The exact date is agreed between the ESO and the TOs for the year's programme for the ETYS and NOA.
- 2.23. Where an option affects an adjacent TO, the TOs and ESO coordinate their views on the reinforcement options and produce an agreed set of options by the second week of August (Week 32). The ESO uses the agreed set of options in its economic analysis and might use the options in its verification studies. Where an option affects more than one TO and the TOs do not agree, the ESO decides which options it assesses.
- 2.24. Once the TOs have returned the SRF Part A to E the ESO reviews the data and understands the costs by discussing them with the TOs. Through engagement, the ESO presents the data that it plans to use in the economic studies.

- 2.25. The ESO and TOs agree the combinations of options that the ESO will use in the cost-benefit analysis.
- 2.26. A non-exhaustive list of potential transmission solutions is presented in Table 2. 2. A wide range of options is encouraged including, where relevant, any innovative solutions and options suggested by other interested persons.

Table 2. 2 Potential transmission solutions

Category	NOA option	Nature of constraint			
		Thermal	Voltage	Stability	Fault Levels
Operational Options	Availability contract (<i>contract to make generation available, capped, more flexible and so on to suit constraint management</i>)	✓	✓	✓	
	Reactive demand reduction (<i>this could ease voltage constraints</i>)		✓		
	Enhanced generator reactive range through reactive markets (<i>generators contracted to provide reactive capability beyond the range obliged under the codes</i>)		✓	✓	
	Automatic MW redistribution (<i>Contracted for certain boundary transfers and faults</i>). For example, contracted services from Demand side, generation deload/ intertrip, energy storage charge/ import and discharge/ export	✓	✓	✓	
	Generation advanced control systems (<i>such as faster exciters which improves transient stability</i>)		✓	✓	
Alternative Options	Co-ordinated Quadrature Booster (QB) Schemes (<i>automatic schemes to optimise existing QBs</i>)	✓	✓		
	Automatic switching schemes for alternative running arrangements (<i>automatic schemes that open or close selected circuit breakers to reconfigure substations on a planned basis for recognised faults</i>)	✓	✓	✓	✓
	Dynamic ratings (<i>circuits monitored automatically for their thermal and hence rating capability</i>)	✓			
Reduced-build Options	Addition to existing assets of fast switching equipment for reactive compensation (<i>a scheme that switches in/out compensation in response to voltage levels which are likely to change post-fault</i>)		✓	✓	
	Protection changes (<i>faster protection can help stability limits while thermal capabilities might be raised by replacing protection apparatus such as current transformers (CTs)</i>)	✓		✓	
	HVDC de-load Scheme (<i>reduces the transfer of an HVDC Intralink either automatically following trips or as per control room instruction</i>)	✓	✓	✓	
	'Hot-wiring' overhead lines (<i>re-tensioning OHLs so that they sag less, insulator adjustment and ground works to allow greater loading which in effect increases their ratings</i>)	✓			

Category	NOA option	Nature of constraint			
		Thermal	Voltage	Stability	Fault Levels
Build Options	Overhead line re-conductoring or cable replacement (replacing the conductors on existing routes with ones with a higher rating)	✓			
	Reactive compensation in shunt or series arrangements (MSC, SVC, reactors). <i>Shunt compensation improves voltage performance and relieves that type of constraint. Series compensation lowers series impedance which improves stability and reduces voltage drop.</i>		✓	✓	
	Switchgear replacement (to improve thermal capability or fault level rating which in turn provides more flexibility in system operation and configuration. This would be used to optimise flows and hence boundary transfer capability).	✓			✓
	OHL reconfiguration (turn-in works at substations)	✓	✓	✓	
	Upgrading of circuits (for higher voltage levels)	✓	✓	✓	
	Power flow control devices (a type of Flexible AC Transmission System device that can be used to alter power flows over a circuit)	✓	✓	✓	
	New build (HVAC/HVDC) – new plant on existing or new routes.	✓	✓	✓	✓

- 2.27. It is intended that the range of options identified has some breadth and includes both small-scale reinforcements with short lead-times and larger-scale alternative reinforcements which are likely to have longer lead-times. The ESO applies a sense check in conjunction with the TOs and builds an understanding of the options and their practicalities. In this way, the ESO narrows down the options whilst allowing assessment of the most beneficial solution for consumers. Other than the application of economic tools and techniques, to refine a shortlist of options or identify a potential recommended option, the ESO relies on the TO for deliverability, planning and environmental factors. The ESO leads on operability and offshore integration matters ahead of the cost-benefit analysis.
- 2.28. In checking for the suitability of an option, the ESO reviews options for their operability and their effect on the wider system. As a result, the ESO checks for system access, ease of operation and the ability to adhere to operational policy and national standards.
- 2.29. TOs must submit the equipment outages required to deliver each NOA option in SRF Part C. The information required per option is: the circuit or apparatus that needs to be on an outage and the required duration of the outages (in weeks) in each calendar year if the option is to be delivered on its EISD; and the number of distinct calendar years that the outage works take place in. The schemes will be assessed initially based on the outage schedule provided by the TOs. However, there will be a further optimisation of outage dates and EISD to ensure economic value.
- 2.30. When developing the outage requirements TOs must consider the results of the previous year's NOA report. The outage requirements of all the options need to be considered in a coordinated way such that the optimal years and the recommendations for the options that were found to be optimal in the previous year's NOA can be adhered to if possible.

Basis for the cost estimate provided for each option

- 2.31. The forecast cost is a central best view. By Week 30, the TOs and ESO agree each year the cost basis to be used for NOA analysis. The information that will have to be agreed includes but is not limited to:
- price base, that is the financial year of the prices and should be current year prices.
 - annual expenditure profile reflecting the options' earliest in service dates.
 - delay costs.
 - the TO's Weighted Average Cost of Capital (WACC).

Environmental impacts and risks of options

- 2.32. Using the SRF the TOs provide views on the environmental impact of the options that they have proposed. This includes consideration of the environmental effects on the practicality of implementing each option. The ESO uses this information to help understand the background of proposed options, but the information does not form part of the NOA analysis.
- 2.33. As the TOs design and develop their options, their understanding of the environmental impacts of options improves. The more mature an option, its impact on the environment is better understood. Where appropriate, the TO indicates options that are relatively immature, which helps to highlight where the environmental impact needs further development. The ESO gives a similar indication on options that it is leading. As the NOA is the first step in an economic analysis of the need for reinforcement of the national electricity transmission system, it cannot provide an environmental assessment of those options. The TO will take any appropriate and timely environmental considerations into account as part of their investment process and according to relevant planning laws.
- 2.34. Different planning legislation and frameworks apply in Scotland from those in England and Wales. Where reinforcements cross more than one planning framework, this is highlighted if appropriate in the NOA report together with any implications. The TOs have the specialist knowledge for planning and consents and provide the commentary.

Checks of the costs that the TOs submit

- 2.35. The ESO reviews the costs that the TOs submit for each of their options and checks if they are reasonable. This is to ensure high quality data goes into the NOA process. The TOs submit the costs in SRF Part E, and this data is also to be used for assessing their eligibility for competition. Consenting costs are submitted through the same process but are made distinct from the construction costs.
- 2.36. The ESO checks the costs that the TOs submit against a range of data available. For similar plant and equipment, the ESO also uses knowledge gained from its own research using public resources. If any costs are outside of the range, the ESO will investigate it by asking more detailed information from the TO. If following discussions, the ESO still believes that the costs are outside of the expected range and will unduly affect the economic analysis, the ESO can omit the option from the economic analysis.
- 2.37. The costs check process the ESO follows is described in appendix C.

ESO assessment of options' outage requirements

- 2.38. ESO access planning assessment aims to identify the interactions that exist between the outage requirements of NOA options and other scheduled works or between the requirements of different NOA options. The assessment considers the NOA options' outage requirements submitted in SRF Part C together with the most recent long-term outage plan submitted by the TOs to the ESO Network Access Planning team. It takes place after the Final SRF Part C submission.
- 2.39. In more detail, the assessment will identify the interactions a) between outages required for the delivery of customer connections projects, asset maintenance or other works, and b) between outages required for the delivery of the NOA options.

- 2.40. The assessment will thus produce two sets of restrictions for each NOA option: a) available years and b) NOA-to-NOA options outage conflicts. The first term aims to capture the interaction between each NOA option, and the works specified in paragraph 2.39 point a). The second aims to capture interactions between the different NOA options.
- 2.41. The default position during the assessment is that customer connection works take priority ahead of NOA works and that NOA works take priority ahead of asset maintenance or other works.
- 2.42. ESO shares the output of the initial analysis with the TOs. The shared output is the identified interactions (paragraph 2.39) and the resulting restrictions (paragraph 2.40).
- 2.43. TOs must review the identified interactions and the resulting restrictions and raise a query for any request for amends within two weeks. A separate query should be raised by the TO for each considered option.
- 2.44. TOs must include in each query the justification for the requested amend. The justification can include any of the following but not limited to: why the TO believes that the identified interactions should be amended or why the identified interactions could be effectively resolved by the time construction for the option begins. TOs can also include revised outage requirements in their query.
- 2.45. If no query is received for an option, the output of the ESO access planning analysis for that option will be used in the CBA.
- 2.46. The ESO will examine each query separately and consider any amends to the identified interactions based on the data or justification provided by the TO. If applicable, the ESO will update the resulting restrictions for the considered options.
- 2.47. Following any TO query and the response from the ESO no further change in outage requirements should be considered for the current NOA CBA cycle.
- 2.48. The ESO will respond to all queries within two weeks of the date that the last TO query was received.

Build GB model

- 2.49. The TOs submit power system models to the ESO for each year being modelled. The ESO uses these along with FES data to produce complete power system models of the GB network and shares these for analysis. Additional models and modelling information for different scenarios and network options are also submitted such that the ESO and TOs have adequate information to carry out the necessary option analysis.

Boundary capability assessment for options

- 2.50. The ESO and TOs complete boundary capability assessment studies to feed into the cost-benefit analysis process. The TOs submit the results of their boundary studies for their own areas with their SRFs. TOs study neighbouring areas to ensure TO coordination between base capabilities and options' uplifts for those that cross TO areas. The ESO also performs studies of some of the same boundaries as the TO for the purpose of verification. For studies prior to the new SRF submission, the ESO studies reinforcements using information that the TO submitted the previous year. This assumes that many reinforcement proposals are the same or very similar from one year to the next. The TO will endeavour to provide any updates to the ESO on adjustments they make to their options that will allow the ESO to modify its studies. The ESO performs studies concurrently with the TOs to be able to perform a cross-check of some of the capability results, to the extent that the information on the options and any adjustments is available before the start of the economic analysis process. The ESO can ask the TOs for additional SRFs in the period June to August if it finds that its studies highlight a need for further reinforcement.
- 2.51. Thermal loading, voltage and stability boundary limitations are assessed to find the maximum boundary power transfer capability. The boundary capability is the greatest power transfer that can be achieved without breaching any NETS SQSS limitations. Sensitivities in background to represent different network conditions, such as generation patterns or time

of the year that may cause critical changes in boundary capability may be assessed separately.

- 2.52. In order to minimise unnecessary repetition whilst maintaining robustness, winter peak network analysis is carried out under the scenario that will stress the transmission system the most (in 2021 this was the Leading the Way scenario). This scenario has the highest electrical load and generation and therefore gives us the required stress on the system to test our boundary capabilities. Where there are significant differences in network conditions, either between scenarios or in time, additional sensitivity analysis is undertaken where appropriate to understand any network capability impact. For the purposes of any stability analysis (where required), year-round demand conditions are considered. The secured events that are considered for these assessments are N-1-1, N-1 and N-D as appropriate in accordance with the NETS SQSS.
- 2.53. The analysis is done in accordance with the ETYS/NOA study guidelines which describes the constraint type, scenario, season, and the years for the network assessment. The ETYS/NOA study guidelines are governed by the STC.
- 2.54. For the purpose of the boundary capability assessment, the baseline generation and demand dispatch conditions need to be altered to identify the maximum capability across the boundary. To make these changes, the generation and demand on either side of the boundary is scaled until the network cannot operate within the defined limits. The steady state flows across each of the boundary circuits prior to the secured event are summed to determine the maximum boundary capability.
- 2.55. The factors shown in Table 2. 3 below are identified for each transmission solution to provide a basis on which to perform cost-benefit analysis at the next stage.

Table 2. 3 Transmission solution factors

Factor	Definition								
Output(s)	The calculated impact of the transmission solution on the boundary capabilities of all boundaries, the impact on network security								
Lead-time	An assessment of the time required developing and delivering each transmission solution; this comprises an initial consideration of planning and deliverability issues, including dependencies on other projects. An assessment of the opportunity to advance and the risk of delay is incorporated.								
Cost	The forecast total cost for delivering the project, split to reflect the pre-construction and construction phases.								
Stage	The progress of the transmission solution through the development and delivery process. The stages are as follows: <table border="1" data-bbox="343 1624 1340 2036"> <tr> <td colspan="3"><i>Project not started</i></td> </tr> <tr> <td rowspan="2" style="writing-mode: vertical-rl; transform: rotate(180deg);"><i>Pre-construction</i></td> <td><i>Scoping</i></td> <td>Identification of broad Needs Case and consideration of number of design and reinforcement options to solve boundary constraint issues.</td> </tr> <tr> <td><i>Optioneering</i></td> <td>The Needs Case is firm; a number of design options being developed so that a preferred design solution can be identified.</td> </tr> </table>	<i>Project not started</i>			<i>Pre-construction</i>	<i>Scoping</i>	Identification of broad Needs Case and consideration of number of design and reinforcement options to solve boundary constraint issues.	<i>Optioneering</i>	The Needs Case is firm; a number of design options being developed so that a preferred design solution can be identified.
<i>Project not started</i>									
<i>Pre-construction</i>	<i>Scoping</i>	Identification of broad Needs Case and consideration of number of design and reinforcement options to solve boundary constraint issues.							
	<i>Optioneering</i>	The Needs Case is firm; a number of design options being developed so that a preferred design solution can be identified.							

Factor	Definition
	<i>Design/ development and consenting</i>
	Designing the preferred solution into greater levels of detail and preparing for the planning process including public consultation and stakeholder engagement.
	<i>Planning / consenting</i>
	Continuing with public consultation and adjusting the design as required all the way through the planning application process.
	<i>Consents approved</i>
	Consents obtained but construction has not started
<i>Construction</i>	Planning consent has been granted and the solution is under construction.

- 2.56. In order to assess the lead-time risk described in Table 2. 3, the ESO will consider, for a project with significant consents and deliverability risks, both 'best view' and 'worst case' lead-times submitted by the TOs to establish the least regret for each likely project lead-time.
- 2.57. It is possible that alternative options are identified during each year and that the next iteration of the NOA process will need to consider these new developments alongside any updates to known transmission options, the scenarios, or commercial assumptions.
- 2.58. If the TOs decide that there are insufficient options to cover the boundary requirement, they initiate further work to identify reinforcement options. The TOs aim for at least three options for each boundary requirement. The TOs can submit long-term conceptual options to ensure that there are enough options. The long-term conceptual options are high level and are developed only as far as their boundary transfer benefits and initial estimate of costs. Power system analysis is not conducted on the conceptual options.
- 2.59. Where there are boundaries affecting more than one TO, the TOs should work together to determine the options for inclusion in the economic analysis and in the NOA report.
- 2.60. The TOs use their boundary capability results in the SRF Part D that they submit back to the ESO.
- 2.61. Where specific boundary capabilities are not provided for spring, summer, autumn, or outage conditions by the TOs the following winter adjustment factors shall be used.

Seasonal boundary capability scaling

Spring and autumn thermal	85%
Summer thermal	80%
Summer outage thermal	70%
Summer outage voltage	90%

- 2.62. The ESO leads on commercial options in cooperation with the TOs. The economic analysis tool needs a MW value for the boundary capability which this analysis of commercial solutions must provide. In addition, the ESO must provide ongoing costs for the economic analysis such as intertrip arming fees as well as any capital outlay such as the cost of designing/ installing the intertrip.

Cost-benefit analysis

- 2.63. Cost-benefit analysis compares forecast capital costs and monetised transmission benefits over the project's life to inform this investment recommendation.
- 2.64. The NOA provides investment recommendations based on the Single Year Regret Decision Making process. If the ESO's NOA recommendation is to "Proceed - Critical" and triggers a LOTI / MSIP for a RIIO Needs Case, the ESO will assist the TOs to produce a Needs Case by undertaking a more detailed cost-benefit analysis.
- 2.65. The purpose of the Single Year Regret Decision Making process is to inform investment recommendations regarding wider transmission works for the coming year. The main output of the process is a list of recommended wider works reinforcement options to receive either a "Proceed - Critical" recommendation or a "Proceed - Maintain" recommendation for the next year. A secondary output is an indicative list of which options would be proposed at present if each of the scenarios were to turn out.
- 2.66. The methodology for a LOTI cost-benefit analysis follows the Large Onshore Transmission Investments (LOTI) Re-opener Guidance document published by Ofgem⁷. A Needs Case is submitted by the TO that proposes the option to the regulator, and which includes a cost-benefit analysis section that outlines the financial case for the option. The output of this process is a recommendation for the option to progress.

Cost-benefit analysis methodology

- 2.67. Since the number of transmission system reinforcement options proposed is quite large, the country is split into regions and each option is allocated to one of the regions. The cost-benefit analysis process for each region is conducted in isolation. The annual boundary capability outside the region is fixed to a pre-determined value, which may vary by scenario. This is usually based upon the recommendations of the most recent NOA report. The size and extent of a region (that is where region dividing lines are drawn) may change from year to year. An option may not appear in more than one region.
- 2.68. All the FES scenarios are considered; it is usual for sensitivities to be considered as described previously. Each scenario is studied in isolation; Each scenario is studied, and the process is repeated (in parallel since there is no dependency) for the other scenarios. The process is iterative and involves adding a single reinforcement at a time and then evaluating the effect that this change has had on the transmission constraint cost forecast.
- 2.69. To begin the process, all proposed options within the region are disabled, the output of the model is analysed to determine which boundaries within the region require reinforcement and when the option is required, this simulation is referred to as the base case. It is used to determine which option(s) should be evaluated first. The option that has been selected to be evaluated next is then activated in the constraint cost modelling tool (see Table 2.4 for a description) at its EISD. If a number of potential options have been identified as being candidates for the next option, then this process must be repeated with each option in turn. There are now two sets of constraint cost forecasts, the base case, and the reinforced case, which are compared using the Spackman⁸ methodology.
- 2.70. It is assumed that each transmission asset is to have a 40-year asset life. Since the constraint cost modelling tool only forecasts for the next 20 years the constraint costs for each year after that are assumed to be identical to the final simulated year (note that this limitation occurs because the scenarios do not contain detailed ranking orders beyond 20 years). Constraint cost forecasts are discounted using HM Treasury's Social Time Preferential Rate (STPR) to convert the forecasts into present values. The capital cost for the option is amortised over the asset life using the prevalent WACC and discounted using the STPR. This value is added to the constraint cost forecast for the reinforced case. The

⁷ https://www.ofgem.gov.uk/system/files/docs/2021/03/large_onshore_transmission_investments_loti_re-opener_guidance_-_clean_0.pdf

⁸ The Joint Regulators Group on behalf of UK's economic and competition regulators recommend a discounting approach that discounts all costs (including financing costs as calculated based on a Weighted Average Cost of Capital or WACC) and benefits at HM Treasury's Social Time Preference Rate (STPR). This is known as the Spackman approach.

present value of the base-case GB transmission constraint cost is then compared to the present value of the reinforced-case constraint cost plus the amortised present value of the capital costs to give the net present value (NPV) for this option.

- 2.71. This cost-benefit analysis process is carried out in a separate comparison tool which also automatically calculates the NPVs if the option being evaluated were to be delayed by a number of years. This list of NPVs allows the optimum year for the option, for the current scenario, to be calculated. If a number of alternatives have been identified, then the option that has the earliest optimum year should usually be chosen. The chosen option is then added to the base case and another option is chosen for evaluation. The process is then repeated until further options produce a negative NPV (which would indicate that the capital cost of the option exceeds the saving in constraint costs). There may be an element of branching if it is not immediately obvious during the process which option should be chosen to be added to the base case at any given point.
- 2.72. The cost-benefit analysis considers the outage restrictions when deciding the optimal delivery years of the options. The delivery years are chosen so that the combined economic benefit of all the options that were found to be required in each FES scenario is maximised in the presence of the identified interactions and resulting outage restrictions.
- 2.73. The outcome of this process is a list of reinforcement options, for the current region and scenario, and the optimum year for each. This is referred to as a 'reinforcement profile'.
- 2.74. Once the reinforcement profile for each scenario within a region has been determined the 'critical' options for that region may be chosen. The definition of a 'critical' option has some flexibility but the definition below must be considered.
- 2.75. An option's recommendation is 'critical' if its optimal year is in line with its earliest in service date under at least one of the FES scenarios.

Constraint cost modelling tool

- 2.76. The constraint cost modelling tool is used to forecast the constraint costs for different network states and scenarios. The high-level assumptions and inputs used in the tool are outlined in Table 2. 4.

Table 2. 4 Assumptions and input data for the constraint cost modelling tool

Input Data	Current Source	Description
Fuel price forecasts	FES	20-year forecast, varies by scenario
Carbon price	FES	20-year forecast
Plant efficiencies and season availabilities	Energy Exemplar (historic)	
Plant bid and offer costs	Historic data	See Long-term Market and Network Constraint Modelling ⁹
Renewable generation	Energy Exemplar (historic)	Wind, solar, and tidal profiles for zones around the UK
Demand data	FES	Annual peak and zonal demand
Demand profile	Energy Exemplar	Within year profiles

⁹ See <https://www.nationalgrid.com/sites/default/files/documents/Long-term%20Market%20and%20Network%20Constraint%20Modelling.pdf>

Input Data	Current Source	Description
Maintenance outage patterns	Historic data - TO	Maintenance outage durations by boundary
System boundary capabilities	Power system studies - TO	See text
Reinforcement incremental capabilities	Power system studies - TO	See text

- 2.77. The model is set to simulate 365 days per year, 20 years into the future with an appropriate time resolution. The year in which an option is commissioned can be varied. The primary output from the tool for the cost-benefit analysis process is the annual transmission constraint forecast; there are further outputs that help the user identify which parts of the network require reinforcement.

Selection of recommended options

- 2.78. At this point, all the economic information available to assess the options is in place. The ESO then uses the Single Year Least Regret analysis methodology to identify the recommended option or combination of recommended options.

Single year least regret decision making

- 2.79. The single year least regret methodology is to facilitate the decision making for options critical in some scenarios but not in all scenarios. It involves evaluating every permutation of the critical options in the first year (the year beginning in April following publication of the NOA report). For each critical option, there are two choices, either to give a “Proceed - Critical” recommendation for the option to be delivered on its EISD or to give a “Proceed - Maintain” recommendation for the option to be delivered one year after its EISD. It is assumed that information will be revealed such that the optimal steps for a given scenario can be taken from year two onwards – so only the impact of decisions in the first year are evaluated. If there is more than one critical option in the region then the permutations of options increase; the number of permutations is equal to 2^n , where n is the number of critical options.
- 2.80. Each of the permutations has a series of cost implications. These are either additional capital and constraint costs if the option is delayed (and further additional costs if the option is restarted at a later date) or inefficient financing costs if the project is progressed too early.
- 2.81. For each permutation and scenario combination the present value is calculated, taking into account operational and capital costs. For each scenario one of the permutations will have the lowest present value cost; this is set as a reference point against which all the other permutations for that scenario are compared. The regret cost is calculated as the difference between the present value of the permutation for a scenario and the present value that is lowest of all permutations for the scenario. This results in one permutation having a zero regret cost for each scenario.
- 2.82. The following section is a worked example of the least regret decision making process. Two options have been determined to be ‘critical’ in this region, the EISD for option 1 is 2022 and the EISD for option 2 is 2023. The optimum years for scenarios A, B and C are shown in Table 2. 5. Note that the scenarios are colour-coded; this is used for clarity in the following tables.

Table 2. 5 Example of optimum years for two critical reinforcements

Scenario	Option 1	Option 2
A	2022	2023
B	2022	2024
C	2027	N/A

Note: N/A means not required.

Table 2. 6 Example decision tree

Permutation	Year 1 Recommendations	Completion Date	NPV	Regrets	Worst regret for each permutation
i	"Proceed - Critical" Option 1 & "Proceed - Maintain" Option 2	Option 1: 2022 Option 2: 2024	£149m	£51m	£51m
		Option 1: 2022 Option 2: 2024	£100m	£0m	
		Option 1: 2027 Option 2: Cancel	£145m	£5m	
ii	"Proceed - Maintain" Option 1 & "Proceed - Critical" Option 2	Option 1: 2023 Option 2: 2023	£98m	£102m	£102m
		Option 1: 2023 Option 2: 2024	£65m	£35m	
		Option 1: 2027 Option 2: Cancel	£140m	£10m	
iii	"Proceed - Critical" Option 1 & "Proceed - Critical" Option 2	Option 1: 2022 Option 2: 2023	£200m	£0m	£15m
		Option 1: 2022 Option 2: 2024	£98m	£2m	
		Option 1: 2027 Option 2: Cancel	£135m	£15m	
iv	"Proceed - Maintain" Option 1 & "Proceed - Maintain" Option 2	Option 1: 2023 Option 2: 2024	£47m	£153m	£153m
		Option 1: 2023 Option 2: 2024	£68m	£32m	
		Option 1: 2027 Option 2: Cancel	£150m	£0m	

2.83. Table 2. 6 is an example of a least regret decision tree, since there are two 'critical' options there are therefore four permutations. From Year 2 onwards for each of the permutations the options are commissioned as close to the optimum year for each option for each scenario. For each scenario one of the four permutations is the optimum and therefore there is one £0m value of regret for each scenario. The table's NPV column indicates the net present value for each of the permutations in each of the scenarios.

2.84. The causes of the regret costs vary depending upon the optimum year for the reinforcement and scenario:

- If the option is delayed and cannot meet the optimum year, then additional constraint costs will be incurred.
 - If the option is delayed unnecessarily then there will be additional delay costs.
 - If the option is progressed too early, then there will be inefficient financing costs.
 - If the option is progressed and is not needed, then the investment will have been wasted.
- 2.85. The regret costs for each permutation under all scenarios are then compared to find the greatest regret cost for each permutation. This is referred to as the worst regret cost. The permutation with the least 'worst regret' cost is chosen as the recommended option and appears in the report's investment recommendation. In the example shown above the least 'worst regret' permutation is to give a "Proceed - Critical" to both options 1 and 2 which has a worst regret of £15m and is the least of the four permutations.
- 2.86. As the scenarios represent an envelope of credible outcomes it is possible that a reinforcement option is justified by just one scenario which doesn't always guarantee efficient and economic network planning if industry evolution were to follow a different path. In this event, the ESO would examine the single year regret analysis result to establish the drivers and then examine the scenario further. How we do this varies but an example would be to consider the sensitivity of the cost-benefit analysis to specific inputs. This informs our view on the robustness of the outcome and thus whether to make a recommendation based upon this scenario. The ESO supports all the TOs in this manner to optioneer and develop their projects to minimise the cost such as reducing any frontloading of expenditure if there is doubt about the need for the reinforcement option or downgrading the importance of the investment completely. The ESO examines any sensitivity studies in the same way to ensure that none skew the results unfairly. For example, if a change in policy were to occur after the publication of the FES document, significant amounts of generation in the scenarios may be affected and their connection may then be delayed or unlikely to go ahead. We would flag this kind of background update and identify in the single scenario driven investments where this is likely to be creating a skewed outcome. The ESO is investigating the development of probabilistic tools to deliver year-round network analysis on thermal and voltage network requirements, and further ensure that all sensitivities are covered. However, this is at an early stage and not yet ready for use with the NOA.

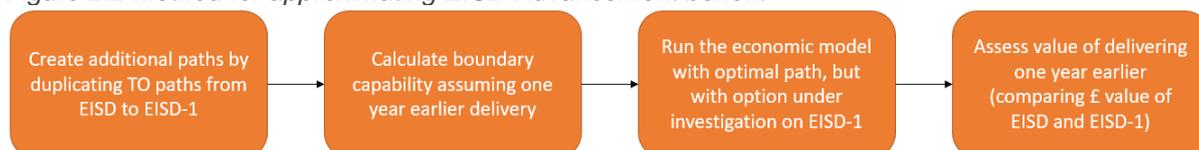
EISD Advancement Benefit

- 2.87. A recent improvement to the NOA process has been the implementation of an EISD advancement benefit methodology. The aim of this is to support a substantial reduction in network constraint costs and is an outcome of the 5-point plan¹⁰. NOA schemes are shortlisted that would provide significant constraint cost savings from earliest in service date (EISD) advancement. The purpose of this exercise is to stimulate early delivery, or at least highlight the importance of delivering schemes on their published earliest in service date. The results of the analysis are shared with the relevant TO but not included in the report.
- 2.88. The options for EISD advancement are selected individually by identifying bottlenecks to providing higher capability using our standard NOA toolset. These tools not only report boundary bottlenecks but also the cost associated with resolving these constraints. To be a candidate for advancement the option being considered should have precursors with earlier EISDs, such that bringing them forward poses no knock-on advancement of other options.
- 2.89. As an example, consider a path that has three reinforcements A, B, C, and A and B could be built in 2029, but C had an EISD of 2030, after B is built, we have to wait until 2030 before C can be built providing the next uplift. It is noted that C relieves several boundary constraints, causing constraint costs to decrease significantly. As such C would be identified as a potential candidate for advancement to 2029.
- 2.90. To establish the benefit of advancing schemes one or more years earlier than the EISD requires input including the capability that the scheme releases on boundaries and capital costs associated with delivering the scheme to this earlier year. To establish this for every

¹⁰ <https://www.nationalgrideso.com/news/our-5-point-plan-manage-constraints-system>

scheme requiring assessment would be resource intensive, and therefore a method that utilises existing data from the main NOA process was established. The following diagram highlights the main steps.

Figure 2.2 Method for approximating EISD Advancement benefit



- 2.91. Additional paths are added representing the capability released on each boundary by a scheme. The capability values are obtained from the EISD year's capability value, essentially duplicating this to a year earlier. This method focusses on quantifying the approximate constraint cost saving, and therefore other factors are considered equal.
- 2.92. Using these updated capability values an economic market simulation is performed to determine constraint costs. The potential benefit of bringing an option forward by one year is then calculated as the difference between constraint cost where the option is delivered on its EISD versus delivery one year earlier.
- 2.93. The findings are then communicated to the relevant Transmission Owner who can then use the evidence to either advance the option or to maintain an option on its EISD in the case where conflicting issues may cause delay.

Probability Analysis - LWWR

- 2.94. The effect of varying the probability of each scenario occurring is also explored using the technique called Least Worst Weighted regret (LWWR).
- 2.95. The LWR technique assumes that each scenario is equally likely to occur. The ESO does not assign probabilities to any of its scenarios, however, LWWR provides us with a technique to explore the effect of varying the probabilities. This can be used to see how stable a solution is to changes in the probabilities occurring, and hence aid in the discussion of particular options.
- 2.96. The LWWR technique works by taking the initial LWR results, which have implicit 0.25 weighting for each scenario, then changing these weightings between 0 and 1 for each scenario individually and performing the LWR technique at every possible permutation of weightings. At each permutation the option with the least worst regret is found, allowing us to see which options provide the least regret at every possible combination of weightings.
- 2.97. The LWWR technique is used alongside the implied probability technique to provide further insight into the marginal options following the single year least worst regret analysis. These results are presented to the NOA Committee for discussion.

Process output

- 2.98. Following Single Year Regret analysis, a list of investment recommendations for the region is presented.
- 2.99. The NOA process output recommendations are described below:
 - **“Proceed - Critical”**: This option is critical to our future planning. Investment should be made in the next financial year to ensure the option's earliest in-service date remains on course.
 - **“Proceed – Maintain”**: This option is important and recommended soon after its earliest-in-service date. Investment can be made in the next financial year to maintain project momentum and ensure its earliest-in-service date is delayed by at most one year.
 - **“Hold”**: This option is important and recommended for the future, however it is not on the earliest-in-service date submitted to NOA. Therefore, the delivery date of this option can be delayed by at least one year and the option can be reviewed in the next NOA cycle.

- **“Stop”**: This option is not currently recommended within the optimal path of any scenario; delivery should be stopped and not be continued.
 - **“Do not start”**: This option is not currently recommended within the optimal path of any scenario; delivery work should not begin.
- 2.100. The ESO has created the NOA Committee to challenge the single year regret recommendations. The Committee’s remit is to allow the ESO to review the investment recommendations that are marginal, or risk being driven by a single scenario. This will seek to identify any ‘false-positive’ investment recommendations that could come about as a result of the single year regret process and ensure that the recommendations are justified. In addition, the Committee will ensure the recommendations are supported by the holistic needs of the system. The Committee consists of ESO senior management who will challenge the robustness of the investment recommendations as well as provide holistic energy industry insight and take into account whole system needs to support or revise the marginal investment recommendations. Ofgem can also be present as observers to represent the consumers’ interests and provide regulatory oversight, as well as understand the driving factors behind recommendations. In preparation for the Committee meeting, the ESO will discuss the single year regret outputs with internal stakeholders and the TOs to ensure the final recommendations are robust. The TOs are invited to attend the NOA Committee to provide supporting evidence as the committee requires while maintaining the necessary commercial confidentiality.
- 2.101. The guiding principle behind the NOA Committee is that, on the marginal decisions the Committee reviews, the members should advise the investment recommendation they believe is most prudent, on the balance of evidence. This means that they believe, on the balance of probabilities, the recommendation (“Proceed - Critical”, “Proceed - Maintain” or “Hold”) is the best course of action for the GB consumer. This will take into consideration the many facets of the decision including, but not limited to: forecasted constraints in the scenario(s) advocating the option; the drivers behind the investment recommendation (e.g. specific generation build-up) and the latest market information on those drivers; what the regret is across the other scenarios; what next year’s expenditure is acquiring and what it will achieve (e.g. will the expenditure allow the TOs to learn more about the option); what the implied scenario weight of the decision is (that is what probability would have to be placed on the driving scenario to make the same decision under expected net present value maximisation); and wider system operability considerations including the availability of commercial solutions to congestion issues. The committee members should seek to have a risk-neutral outlook in their deliberations, that is they should seek to make decisions dispassionately, and on the balance of evidence, bearing in mind as much as possible the likelihood of future events.
- 2.102. The Committee’s aim is to reach a consensus on the marginal options. The outcomes will be recorded in minutes, and which will show the rationale behind the recommendations and highlight the challenges raised. The minutes will be made available to Ofgem and the TOs and published on the NOA webpage. Commercially sensitive information will be redacted from the published version.
- 2.103. If despite the process described in paragraphs 2.38 to 2.48, the optimal year or the recommendation for one or more options is primarily and adversely affected by the outage requirements the ESO will bring the options to the attention of the NOA committee. The ESO will present evidence to the Committee including: the outage interactions or restrictions that influenced the results; the expected economic impact and the steps taken during the process described in paragraphs 2.38 to 2.48 by the relevant TO if applicable. The ESO may request that the TO also provides evidence or technical details.
- 2.104. The ESO uses the output from the single year least worst regret analysis for the recommendation on whether a reinforcement option should receive a “Proceed - Critical” under the England and Wales Network Development Policy (NDP) framework.
- 2.105. If the investment signal triggers the TO’s Needs Case, the ESO will assist the TO in undertaking a more detailed cost-benefit analysis. The ESO reconciles the economy and

security results (in accordance with NETS SQSS Chapter 4) as mentioned previously in the section on sensitivities before making a final recommendation.

- 2.106. If a TO does not follow a NOA recommendation, it must inform the ESO at the earliest opportunity and tell the ESO about the effect on the option's EISD. If the TO has discretion over the change, it should fully involve the ESO in the decision process. The NOA Committee will monitor the process and the outcome.
- 2.107. EU/2019/943 Article 13 paragraph 5 of the Clean Energy Package covers the proportion of renewable generation being dispatched and redispatched in each year. There are two routes to compliance:
- Have total energy volumes of more than 50% renewables (including high efficiency cogeneration), or
 - Redispatch less than 5% renewable energy volumes.

We operate the NOA to meet this Clean Energy Package requirement as described below.

- For each scenario, we extract from Plexos the total energy volumes (TWh) for each year. We check the proportion of generation that meets the renewables criteria (under article 13, this includes high efficiency cogeneration, HEC) and record its value.
- For years and scenarios where this value exceeds the 50% threshold, the network is compliant with article 13, paragraph 5.
- For years and scenarios where the value falls below the 50% threshold, we take a further step described below.
- For years and scenarios where the renewable volume (with HEC) falls below 50%, we extract from Plexos the details of redispatched plant and record by fuel type. For years and scenarios where the redispatched volume comprises more than 5% renewables (this figure excludes HEC), we investigate the reinforcement profiles to see if changing the proposed reinforcements changes the plant and/or volume redispatched. The aim of this step is to bring the volume of redispatched renewables below the 5% threshold. We note the instances where amending the reinforcement profile is needed to meet the threshold in the NOA report. As compliance with article 13, paragraph 5 can also be achieved through mechanism outside of the NOA (broadly policy, or regulatory changes), and there may not be sufficient effective reinforcements in the NOA to achieve compliance, the situations where we do not meet the threshold will also be noted as appropriate in the NOA report. We will use the NOA Committee as our governance mechanism.

Cost bands

- 2.108. The ESO sorts reinforcement options with a "Proceed - Critical" recommendation after economic analysis and connections into cost bands which it then includes as appropriate in the NOA. The assumptions are that land costs are included in the costs but the cost of consents is excluded. The costs apply for new and separable elements only. Table 2.7 shows the cost bands that have been agreed.

Table 2.7 Table of cost bands

Cost bands
£100m - £500m
£500m - £1000m
£1000m - £1500m
£1500m - £2000m
Greater than £2000m

Report drafting

- 2.109. The ESO drafts the NOA report which focuses on the results of the ESO economic analysis. The TOs provide some technical information for onshore “build” options and the ESO provides equivalent technical information for alternative options and offshore options. Technical information includes an option’s status, nature of assets and equipment and boundary capabilities. The form of the report, covered by appendix D, is subject to consultation and to Ofgem approval.
- 2.110. The report presents the relevant information about the investment recommendations whilst maintaining appropriate commercial confidentiality. Information is presented to demonstrate the relative benefits of options while protecting commercial confidentiality. This is in consultation with stakeholders. The ESO passes outputs to the TOs to support its view of investment recommendations.
- 2.111. Report drafting is undertaken in the period late July to January.

Report publication

- 2.112. The ESO publishes the NOA report by 31 January of each year or as instructed otherwise by Ofgem.
- 2.113. On publication, the report is placed on the National Grid ESO website in a form that is widely readable and accessible. The ESO also provides a copy on request and free of charge to anyone who asks.
- 2.114. Standard Licence Condition C27 Paragraph 13 provides for delaying publication if the Authority (Ofgem) delay their approval of the NOA methodology or form of NOA report.
- 2.115. The Licence Condition allows for the omission of sensitive information.



3

Network Options Assessment for Interconnectors

Overview

- 3.1 This chapter provides an overview of the aims of the NOA with respect to interconnectors and details the methodology which the ESO will adopt for the analysis and publication within the 2022/23 NOA report (to be published in 2023).
- 3.2 Since the publication of the first NOA (2015/16), we have developed the NOA for Interconnector (NOA IC) methodology for each year. The developments have included:
- Use of our pan-European market model
 - Modelling of Socio-Economic Welfare
 - Inclusion of modelling of GB network constraints
 - Use of the baseline network reinforcement assumptions from NOA as the starting point for the NOA IC analysis
- 3.3 We wish to continue to develop the NOA for Interconnector methodology. This chapter represents our latest thoughts. Our goal is to produce a NOA for Interconnectors analysis that continues to be of increasing value for our stakeholders.
- 3.4 In August 2020, Ofgem launched an interconnector policy review (ICPR)¹¹, to review their regulatory policy and approach to new electricity interconnectors. Following a review of the consultation responses and additional evidence Ofgem decided to open an interconnector ‘cap and floor’ investment round in mid-2022. This will be a locationally targeted window for interconnectors that are able to connect by 2030.
- 3.5 Ofgem want future interconnector investment rounds to be more targeted than previous cap and floor application windows to incentivise those projects that are most likely in the interest of consumers and have a high chance of deliverability.
- 3.6 To support Ofgem we have been undertaking new forward-looking analysis on the system need for new interconnection, from a system operability perspective, on a regional basis across Great Britain. This analysis will look at the impact of new interconnection on thermal, stability and voltage and will consider the scope for new interconnection to provide system benefits through ancillary services, some of which are location dependent.
- 3.7 In the long-term, Ofgem want interconnector planning to be integrated within more strategic network planning processes, with outputs informing future investment rounds. This will link into the ongoing work on Ofgem’s proposals for a new ‘Centralised Strategic Network Planning’ model and process (CSNP) as part of the Electricity Transmission Network Planning Review (ETNPR)¹².
- 3.8 We plan to integrate the new analysis we have undertaken for Ofgem’s mid-2022 cap and floor window into subsequent NOA for Interconnectors work.
- 3.9 The primary purpose of NOA IC will continue to be to provide a market and network assessment of the optimal level of interconnection capacity to GB. This is undertaken by evaluating a range of factors, including social economic welfare, that is the overall benefit to society of a particular option, as well as constraint costs, capital expenditure costs, carbon costs and Renewable Energy Sources (RES) curtailment costs.
- 3.10 To achieve this, NOA IC does not attempt to assess the viability of current or future projects: the final insights are largely independent of specific projects currently under development and NOA IC does not provide any project-specific results.
- 3.11 Last year’s NOA IC only considered point to point interconnection between GB and potential European connecting countries. However, the potential for multi-purpose interconnectors, or hybrid interconnectors, that may include connections to more than two countries and/or also incorporate connections to offshore windfarms in the North Sea or Irish Sea are also being proposed by developers. We will consider the impact of MPIs for NOA IC 2022/23.

¹¹ <https://www.ofgem.gov.uk/publications/interconnector-policy-review-decision>

¹² <https://www.ofgem.gov.uk/publications/consultation-initial-findings-our-electricity-transmission-network-planning-review>

Structure of this section

3.12 This section consists of the ten sub-sections listed below:

- **Key changes to the 2022/23 methodology** - A summary of the potential changes for NOA for Interconnector methodology for 2022/23.
- **Key similarities to the 2021/22 methodology** - A summary of which areas of the methodology have remained the same from 2021/22 to 2022/23.
- **Factors for the assessment of future interconnection** - A justification of the factors to be considered in determining whether additional capacity would be beneficial.
- **Factors outside the methodology scope** – A summary of the factors that are not included within the scope of the methodology.
- **Cost estimation for interconnection capacity** – The costs associated with an interconnector and how these will be calculated.
- **Components of welfare benefits of interconnection** – This sub-section outlines the concept of Socio-Economic Welfare in relation to interconnection and the components of the calculation.
- **Constraint cost implications of interconnection** – An outline of how interconnectors could impact the operational costs on the network.
- **Plexos** – A description of the ESO’s current market modelling capabilities.
- **Options included within the assessment** – A description of what options will be included within the modelling.
- **Interconnection assessment methodology** – A description of the method by which the ESO proposes to meet the aims of the NOA in relation to optimal interconnection capacity.

Key changes for the 2022/23 methodology

3.13 We intend to develop NOA IC by building on the work undertaken for Ofgem’s mid-2022 cap and floor window. This will include a focus on the impact of new interconnection at a regional level, covering thermal and other system operability costs, as well as social economic welfare, capital costs, carbon and RES integration costs.

3.14 Previous NOA ICs have used an iterative step by step process, that determines the optimal level of interconnection based on maximising the Net Present Value of SEW, constraint savings and CAPEX costs. For the new analysis undertaken for Ofgem’s mid-2022 cap and floor window, we have developed a new process, which is not iterative. We intend subsequent NOA ICs to build upon both sets of work.

Key similarities to the 2021/22 methodology

3.15 We will continue to take into consideration the locational impacts on the GB transmission network in addition to the welfare and capital cost implications.

3.16 We will use the output from the latest NOA as the baseline network reinforcement assumptions for the NOA IC analysis: this provides greater consistency between the NOA and NOA IC.

3.17 We will continue to highlight the impact of interconnection on carbon costs and renewable energy curtailment.

3.18 We will continue to focus on providing greater insight and explanation into what is driving the results.

3.19 We will continue to improve NOA IC based on stakeholder recommendations.

Factors for the assessment of future interconnection

- 3.20 **SEW, CAPEX and Attributable Constraint Costs (ACC)** are the most significant criteria for identifying the optimal level of interconnection. Constraint costs refer to GB network congestion costs borne by GB consumers as a result of interconnection.
- 3.21 Therefore, these factors will be used in the analysis to determine the economically optimal level of interconnection.
- 3.22 We will also consider **System Operability impacts** This is an important area that is being analysed as part of our work to support the mid-2022 cap and floor window, and we will be incorporating new analysis in NOA IC 2022/23. The services that we will analyse include frequency response, short circuit level and reactive response.
- 3.23 Two further factors that will be analysed and have some accompanying commentary in the NOA report. They are intended to aid understanding of interconnection's potential impact to meeting GB's climate change goals. **Changes in carbon emissions** and the **use of Renewable Energy Sources (RES)** will be analysed but will not be used to optimise the level of interconnection. This is due to the complexity of combining Carbon/ RES estimates with welfare costs, especially where modelled welfare is already influenced by such factors through RES incentives and the European Trading System capping carbon emissions.
- 3.24 **Carbon costs:** modelling facilities allow for the extraction of total carbon emissions resulting from particular market states under different scenarios, thus the carbon savings or increases associated with various levels of interconnection can be presented with commentary.
- 3.25 **RES integration:** modelling facilities allow for the investigation of the impact of interconnection on renewable generation. This can be reviewed through investigating the reduction or increase in renewable generation curtailment driven by the optimal level of interconnection being in place in future years, rather than the currently forecast level.

Factors outside the methodology scope

- 3.26 There are further benefits and costs that could be considered, which are briefly outlined below; they are outside the scope of this methodology:
- 3.27 **Operational costs:** Various costs associated with the day-to-day operation of the interconnector, and the maintenance of its components, are currently omitted from the analysis. This is driven by the complexity of defining these costs, per market.
- 3.28 **Environmental/social costs:** In any large-scale construction project, the local environment may potentially suffer damage. This affects local stakeholders, as well as disruption associated with the construction (traffic, noise etc.). The severity varies with the site chosen and the construction methods used. These are not considered here as they are more relevant to the choice of sites for individual projects.
- 3.29 **Social benefits:** Depending upon the procurement for the construction, the project may offer a boom to the local economy. This again is a project specific benefit, so is not estimated in this work.

Cost estimation for interconnection capacity

- 3.30 The cost of building interconnection capacity varies significantly between different projects - key drivers are convertor technology, cable length and capacity of cable. Estimating costs for generic interconnectors between European markets and GB is therefore challenging. An exercise of a similar nature has been undertaken by various industry bodies to allow the generation of 'Standard Costs'. These are generic values that can be applied to estimate the cost of generic projects. In previous NOA IC analyses a report by ACER¹³ has been used to provide estimates of subsea cable, onshore connection, and wider reinforcement costs to different markets. Stakeholders have informed us that they believe these costs are now too old to be considered robust, as developments in interconnector technology have had a material

¹³ http://www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/UIC%20Report%20%20-%20Electricity%20infrastructure.pdf

impact on prices since the publication of the report. We now use additional information to validate and update the ACER report data, and we will continue to update our cost assumptions based on the most recent data available in the public domain.

- 3.31 Subsea cable costs will be identified by estimating the furthest and shortest realistic subsea cable length and taking the average distance for each market to GB zone permutation. The length of the cable will vary with the GB zone it is connecting to and the measurements will be taken between these to the nearest 5km.
- 3.32 Onshore connection costs will be excluded as the interconnector study cases are zone specific but not substation specific.
- 3.33 The convertor station assumed value will be drawn from an average of known HVDC project costs in the public domain.
- 3.34 We will investigate sourcing data to enable generic MPIs to be modelled.
- 3.35 As connection costs can occur across a range of years, discounting is employed to standardise each cost in Present Value. This is done with the Social Time Preference Rate (STPR) of 3.5%. Additionally, the cost of capital is accounted for by using Weighted Average Cost of Capital (WACC) of 6.8% for interconnectors, drawn from a publicly available Grant Thornton report.¹⁴

Components of welfare benefits of Interconnection

Introduction

- 3.36 This section outlines the definition of Social Economic Welfare. The purpose of this section is to give the theoretical background of assessing the impact of connected importing and exporting markets on consumers, producers and interconnectors triggered by another interconnector.

Social and Economic Welfare

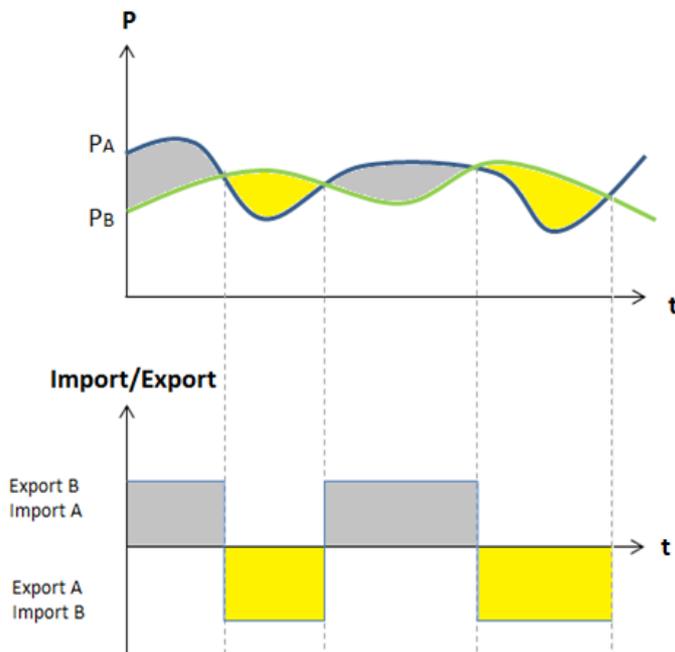
- 3.37 Social and Economic Welfare (SEW) is a common indicator used in cost-benefit analysis of projects of public interest. It captures the overall benefit, in monetary terms, to society from a given course of action. It is important to understand it is an aggregate of different parties' benefits - so some groups within society may lose money as a result of the option taken. The society considered may be a single nation, GB, or the wider European society, in which case the benefits to European consumers and producers would be a part of the calculation. We intend to calculate Social Economic Welfare (SEW) divided into GB and connecting country.
- 3.38 SEW benefits of an interconnector includes the following three components:
 - a) Consumer surplus, derived as an impact of market prices seen by the electricity consumers
 - b) Producer surplus, derived as the impact of market prices seen by the electricity producers
 - c) Interconnector revenue or congestion rents derived as the impact on revenues of interconnectors between different markets.

Effects on Interconnected markets

- 3.39 Power flow between two connected markets is driven by price differentials. Figure 3.1 shows the effects of such price differentials for two markets, A and B with variable prices over time. When the price is higher in market A, power will be transferred from B to A. When the price in A is lower than B power will be transferred from A to B.

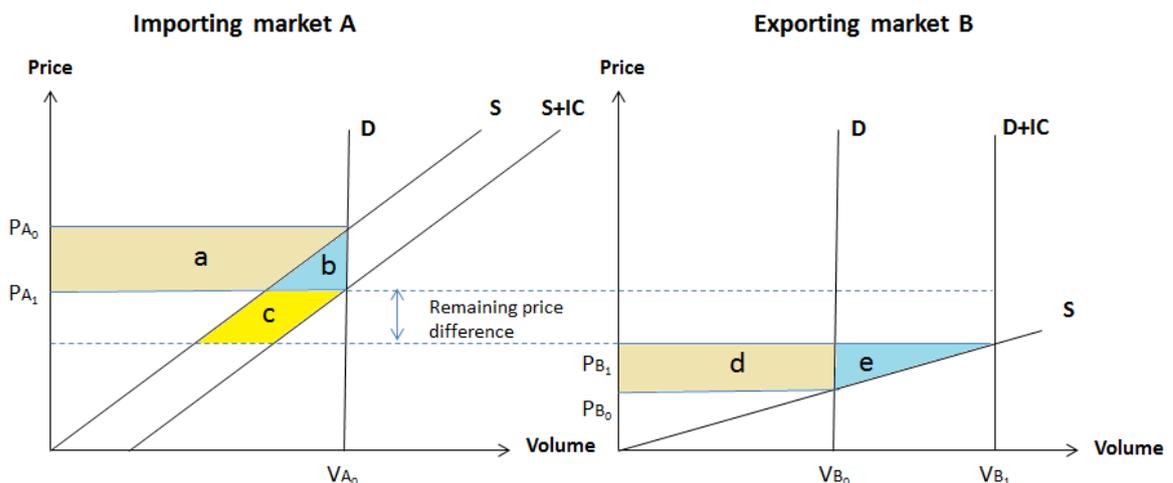
¹⁴ <https://www.ofgem.gov.uk/ofgem-publications/51476/grant-thornton-interest-during-construction-offshore-transmission-assets.pdf>

Figure 3. 1 Price difference as import and export driver



3.40 Figure 3.2 shows the impact of an interconnector (+IC) linking two markets on consumer (Demand D) and producer (Supply S) costs. When two competitive markets with different price profiles are interconnected, price arbitrage drives power flow from the low price market (B) to the high price market (A). Consumers in market A are likely to gain (a + b) as they benefit from access to cheaper power. Consumers in market B are likely to lose (d). Generators in market A must now also compete with generators in B and are likely to be forced by competitive pressures to reduce their costs. This may lead to a reduction in their profits (a). Producers in market B are likely to gain (d + e). Interconnector revenue (c) is derived from the remaining price difference.

Figure 3. 2 Consumer and Producer Surplus of connected markets



3.41 With greater interconnection, the price difference between markets will decrease thus the revenue of the interconnector will be reduced as well. This phenomenon is known as ‘cannibalisation’. There is an optimal level of interconnection between any two markets because price differential reduces as capacity increases, ie. area c in Figure 3.2 shrinks.

3.42 Forecasts of all components of SEW benefits will be key drivers to ascertain the optimum level of interconnection between GB and other European states. The outputs of this process will include monetised impacts on consumers, producers and considered interconnectors.

- 3.43 The Global SEW is the sum of the welfare of 5 parties (GB consumers, Europe consumers, GB producers, Europe producers and Interconnector owners). The British SEW is the sum of the welfare of all British parties. Using the ownership structure of existing GB interconnectors, assuming 50% of interconnector owner welfare remains in the GB economy is plausible.
- 3.44 Where the market is modelled with and without some additional interconnection capacity added, SEW is modelled in each year of a generic asset's lifetime (25 years is the standard assumption used here). As connection can occur across a range of years, discounting is employed to standardise each year's benefit in Present Value, also allowing comparison with the discounted capital spend. This is done with the Social Time Preference Rate of 3.5%.

Constraint cost implications of interconnection

- 3.45 The impact on constraint costs is dependent on the location of the interconnector on the GB network and the level of onshore reinforcement built to accommodate the interconnector. Further detail regarding optimal locations to connect will be output based upon the constraint costs calculated on the network with the interconnectors under consideration.
- 3.46 Constraint costs are incurred on the network when power that is economically "in merit" is limited from outputting due to network restrictions. In this event, the ESO will incur balancing mechanism costs to turn down the generation which is not able to output and offer on generation elsewhere on the system to alleviate the constraint.
- 3.47 The output of the ETYS and NOA reports provides information on the current state and ongoing developments of the network. This will be used to provide a general picture of the optimal network areas for accommodating interconnectors from certain countries. This will be based on constraint costs attributable to the interconnector under review. ETYS and NOA quantify the boundary limitations and present recommended options for reinforcement of the grid. This is intrinsically linked to the increasing presence of interconnection in the UK which can cause further strain on boundaries and potentially trigger investment in further reinforcements if the NOA process determines that to be the most economic and efficient course of action.

Plexos model

- 3.48 Plexos is the tool which will be used to perform the NOA IC 2022/23 and employed by the ESO to carry out a range of economic analyses.
- 3.49 Plexos is a pan European market model created by Energy Exemplar. Plexos will be used by the ESO to forecast the Socio-Economic Welfare (SEW) and the Attributable Constraint Costs (ACC).
- 3.50 It is an economic dispatch model which can simulate all ENTESO-E power markets simultaneously from the bottom up i.e. it can model individual power stations for example. It includes demand, supply and infrastructure and balances supply and demand on an hourly basis. Plexos models the hourly generation of power stations on the system, taking into account fuel prices, historical weather patterns, socio-economic welfare and operational constraints.
- 3.51 The GB electricity system in Plexos is represented by a series of zones that are separated by boundaries. Generators are allocated to their relevant zone based on where they are located on the network, and then the appropriate demand is allocated to that zone. The boundaries, which represent the actual transmission circuits facilitating the zonal connectivity, have a maximum capability that restricts the amount of power which can be securely transferred to across them.
- 3.52 The socio-economic welfare is calculated by summing the producer surplus, consumer surplus and interconnector revenue. The consumer surplus is the difference between the value of lost load and the wholesale price. The producer surplus is calculated and summed per plant based upon their Short Run Marginal Cost and the wholesale price.

Options included in the assessment

- 3.53 For this year's NOA IC, we want to build on the new analysis we have undertaken to support Ofgem's mid-2022 cap and floor window. As requested by Ofgem, this analysis is focused on

identifying the optimal location in GB of additional interconnection, independent of connecting country. We are intending to use a development of this analysis for NOA IC 2022/23.

- 3.54 The search is just for interconnection to GB. The level of interconnection between European markets will remain fixed throughout the scenarios (though could vary across future years). These levels are defined by the FES European scenarios.

Interconnection Assessment Methodology

- 3.55 The starting point of the process will be National Grid ESO's FES 2022 which includes generation plant ranking orders and demand forecasts across Europe for each scenario. Output from NOA 2022/23 will be used to determine the high-level boundary capacities which form the zones included in the analysis.
- 3.56 The FES make forecasts of the future interconnection capacities in GB, per scenario. The FES level of interconnection is calculated on a project-by-project basis, reviewing all axioms from economic, political, environmental etc. An important distinction between the FES and this process, therefore, is that the NOA IC aims to find what would be economically optimal rather than being based on specific projects.
- 3.57 Previous year's NOA ICs have used an iterative optimisation for each scenario. The iterative optimisation approach attempts to maximise present value, equal to SEW less CAPEX less Attributable Constraint Costs (ACC), using a search strategy. The whole process is repeated four times to arrive at an optimal development of capacity in each of the four FES. Based on strong stakeholder feedback, there will be no Least Worst Regret calculation at the end of each iterative step, resulting in four optimal paths: one per FES and hence a range for the optimal solution will be produced. A balance between computing resource and rigour in each step of the process must be found.
- 3.58 Timing of capacity increases can affect the SEW generated and Attributable Constraint Costs (ACC) by the interconnection across the study window. Within each search step, therefore, timing combinations will be considered. The use of spot years will be necessary to allow a solution to converge, wherein the commissioning of additional projects would be evaluated only in a finite number of years. This means for each iteration, the welfare of the interconnectors in every spot year will be calculated.
- 3.59 In recent years the levels of interconnection within FES and NOA IC have started to converge. This is understandable as the FES scenarios are already partially optimised with respect to the levels of interconnection within each scenario. Each scenario within FES is modelled within Plexos to ensure that a detailed within-day supply demand match can be achieved across all modelled years.
- 3.60 Last year we found that the levels of SEW being generated within the FES could result in unrealistically high levels of interconnection within the NOA IC analysis, hence we limited the levels of interconnection we modelled within NOA IC 2021/22.
- 3.61 For our new analysis to support Ofgem's mid-2022 cap and floor window, we have developed a new methodology to help identify where additional interconnection can add value. As in previous NOA IC analyses, we consider study cases where interconnectors connect at various geographical locations across GB. A key difference is that the modelled interconnector does not connect to a specific connecting country. This enables the analysis to be focussed on GB and not the effects of the connecting country market. The interconnector is modelled at 100% import, 100% export, and various import/export mixes.
- 3.62 For NOA IC 2022/23, we intend to build upon the modelling undertaken for Ofgem's mid-2022 cap and floor window, but also investigate incorporating elements from previous NOA IC analyses, such as setting a baseline level of interconnection and using an iterative approach. We will continue to focus on constraint costs and SEW, but also investigate system operability impacts, as well as carbon costs and impact on RES curtailment.



4

**Suitability for third party
delivery and tendering
assessment**

Introduction

- 4.1 BEIS and Ofgem would like to introduce competition to build and own transmission assets. This intention was set out in the [Energy White Paper](#)¹⁵ in December 2020 and confirmed in the Energy Security Bill in July 2022¹⁶. If passed in its current form, this legislation will enable Competitively Appointed Transmission Owners (CATOs) to compete to build, own and operate onshore transmission network. In preparation for this new competitive regime Ofgem introduced a licence requirement, C27, which placed a clear role on the ESO to facilitate the introduction of such competitions. This role requires the ESO to assess major network reinforcements against the competition criteria that Ofgem have deemed appropriate before construction (known as 'late competition'). This methodology describes the process for assessing both wider network reinforcement and connections.
- 4.2 In March 2022, Ofgem also confirmed its intention to implement an early model of competition (competition to design, build and own assets), as set out in the ESO's Plan. Ofgem asked the ESO to progress this implementation.

Overview

- 4.3 The ESO's role applies to NOA wider network reinforcements that we recommend and also new connections or modifications to existing connections that arise from applications. The ESO assesses the suitability of projects for competition in accordance with published tendering criteria¹⁷. The single year regret analysis process identifies the options most economic to consumers. For each set of options, the ESO identifies the most relevant options and assesses these options against the tendering criteria. For late competition, these criteria are:

- new,
- separable and,
- high value.

In order to undertake the assessment, the TOs will provide information to the ESO via the SRF form (see appendix B) for wider works. The ESO then carries out the following activities:

- Reviews the information provided for each option.
- Assesses the options against the criteria for competition.
- Provides a recommendation to Ofgem for the options on how they meet or do not meet the criteria for competition and hence the options' suitability for competition.

- 4.4 In addition to wider network reinforcement, the NOA also examines connections for eligibility for competition. For each NOA, the ESO assesses transmission connections against the same criteria as wider work options (described above) and publishes the conclusions in the NOA. The assessment does not mean that investments meeting the criteria will be subject to competitive tendering. Any decision for competitive tendering lies with Ofgem.
- 4.5 It should be noted that, in the current NOA, when the TOs submit the delivery dates for their wider transmission reinforcements or enabling works¹⁸ for connection projects, the time for the competitive tendering process for late competition is not considered.

¹⁵ <https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future>

¹⁶ <https://www.gov.uk/government/collections/energy-security-bill>

¹⁷ https://www.ofgem.gov.uk/system/files/docs/2018/01/competition_update.pdf and https://www.ofgem.gov.uk/system/files/docs/2019/02/criteria_guidance.pdf

¹⁸ For the definition of 'enabling works', please refer to section 13 of the Connection and Use of System Code (CUSC) <https://www.nationalgrid.com/sites/default/files/documents/Complete%20CUSC%20-%20%20%201%20April%202018.pdf>

Connections

- 4.6 Prospective users can apply at any time to connect to the transmission network or to modify a connection whereas the NOA process runs annually. As a result, the ESO assesses connection projects when it receives them. Few connection projects meet the late competition value criteria of £100m and of those that do, many provide wider network benefits and hence are of interest and already included in the NOA process. The ESO uses the connection contract between the ESO and the prospective user to take a view of the likelihood of meeting the value criteria.
- 4.7 For a new connection, the ESO identifies the projects where there is the possibility of the required enabling works (not including works already covered in the NOA) meeting the value criteria. The ESO identifies the projects to the relevant TO(s) and provides a summary of the work proposed and the costs. This is in time for the ESO to perform the assessment in October.
- 4.8 If the TO states that a project reinforces the wider network, it can use the SRF at the usual time in the NOA process to submit the information for the competition assessment process for NOA options.
- 4.9 The TO(s) responds to the ESO's summary of the projects and the ESO then uses the summary together with any input from the TO(s) for the process to assess eligibility for competition.

Bundling / splitting of work packages

- 4.10 The first step in the ESO's competition assessment of larger projects, is to provide an opinion on bundling projects into larger packages, or splitting projects into smaller packages, to form a recommendation in the NOA. There are two aspects to the ESO's consideration of bundling and splitting as follows:
- a. The costs and size of the component aspects of projects to ensure that they can be most appropriately packaged.
 - b. Where the ESO can identify opportunities or benefits from repackaging of projects.

The core process is to apply the three late model competition criteria that Ofgem determined. Checking for splitting or bundling beforehand is to investigate its relevance to the core process. However, recommendations to split or bundle do not prevent projects being assessed against the three criteria. The check happens again at the end of the process if an option has met the criteria to see if changes for instance for separability have affected our earlier conclusions on splitting or bundling.

If projects can be changed by splitting or bundling, they are assessed in the changed state. A comment about any change is included in the NOA report along with information submitted to Ofgem.

Bundling

- 4.11 The ESO considers whether combining one or more projects into a single tender could be appropriate (if they have common needs/drivers or it makes technical or commercial sense) and whether it is in the interests of consumers (e.g. economies of scale for procuring large quantities). If the ESO believes that there is benefit from bundling (and where the constituent projects have not been challenged or corrected), then each constituent project should meet the high value threshold. Where work is bundled as part of this process, the component parts must each meet the competition criteria to be eligible.

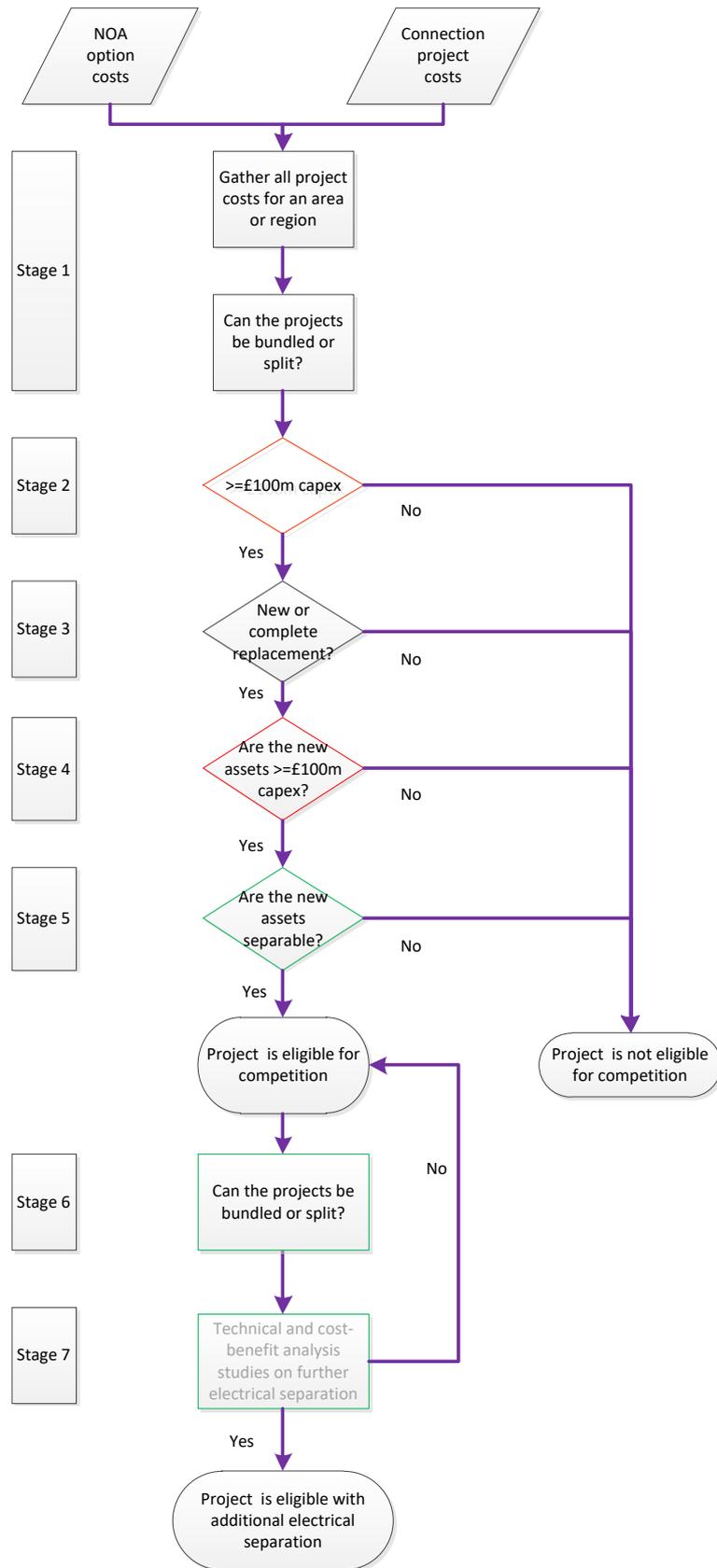
Splitting

- 4.12 The ESO is expected to recommend splitting a project into more than one tender package if it is in the interest of consumers (for example if a project constitutes new assets and refurbishment of existing assets these could be split so new assets could be competed). When it considers splitting a project, the ESO will consider the impact this could have on project delivery. Each resultant package should meet the high value threshold if these are to be competed.

Late model competition criteria

- 4.13 Ofgem has stated that there are significant benefits to consumers in introducing competition into the delivery of transmission projects that meet defined criteria. For late competition, these criteria are:
- **New** – completely new transmission assets or complete replacement of transmission assets,
 - **Separable** – ownership between these assets and other (existing) assets can be clearly delineated and,
 - **High value** – at or above £100m in value of the expected capital expenditure of the project.
- 4.14 Figure 4. 1 shows the process for assessing whether reinforcement projects meet the late model competition criteria.
- 4.15 Note that there are two stages in the high value assessment (red outline) and two stages in the separability assessment (green outline).
- 4.16 Process stages - the names of the process stages below match those in the diagram. The numbered stages below correspond to the boxes on the left side of the diagram.

Figure 4. 1 The process for assessing suitability for competition



Stage 1

Can the projects be bundled or split?

- 4.17 Aim – to carry out a first check to ensure that sensible packages of work are developed together by assessing the proposed work to see if it should be split (broken into more than one smaller bundle) or whether work across more than one project should be bundled together.
- 4.18 Considerations when assessing potential for splitting:
- Does the project involve different technologies that suggests different skills and procurement are needed for the separate elements?
 - Is there a variety of works involved? For example:
 - Are there one or more new substations?
 - Does the proposed project comprise OHL and cable sections and how do they affect existing networks?
 - Are there one or more cable tunnels?
 - Are the project phases adjoining or in naturally separate timeframes?
 - Could the resulting work package lead to stranded investments?
 - Considerations when assessing the potential for bundling:
 - Are there multiple projects with common needs / drivers?
 - Are there several individual projects in a relatively self-contained area or corridor?
 - Are there scheme works that are very similar?
 - Is it one of several smaller projects that could be efficiently or more efficiently developed with other projects?

Stage 2

>=£100m capex

- 4.19 Aim – to assess whether the project or bundle of projects meets the high value criteria and include only projects that exceed the threshold within a 10% margin for consideration at the next stage.
- 4.20 *Table 4. 1* lists the factors that affect the high value figure.¹⁹
- Criteria – this is the first of a two-stage process (the second, stage 4 is below). The ESO uses the costs that the TO(s) have provided and conduct an independent cost checking (see Appendix C). For connection works the costs that appear in the connection contract are used to calculate the cost. The ESO will query any costs that cannot be explained with the TO. The trigger threshold is set at £90m to highlight projects that are marginally below the £100m figure. This produces a straight yes/no output.

¹⁹ As applied to the current framework for cost allocation under the RIIO-T1 framework.

Table 4. 1 List of factors that the high value figure includes or excludes

The £100m capex 'high value' figure	
includes	excludes
<ul style="list-style-type: none"> Costs of acquiring land Costs of complying with consents conditions 	<ul style="list-style-type: none"> Costs of gaining consent

Stage 3

New or complete replacement

- 4.21 Aim – to test the projects against whether they are new assets or complete replacement assets rather than, say, refurbished assets. This test has the practical benefit of checking for complicated examples. For example, where a new double circuit crosses an existing double circuit and because of routing and the existing circuits, the existing circuits need modification leading to new assets integrated into existing circuits. Often new double circuits employ sections of existing circuits for local reasons, such as, environment / amenity. Thus, the affected existing circuits would become a mix of old and new assets. The consenting process might also change a simple double circuit route into a complicated one that includes mixed ownership because of old and new assets being integrated. As the project will be assessed annually in the NOA process, this might lead to a change in the project's eligibility from one year's assessment to another. For example, some replacement work could become refurbishment or the reverse as the project evolves, it might tip the project one way or the other over the value threshold.
- 4.22 Criteria – is a project delivering completely new assets or complete replacement assets that fulfil the same function as the assets to be removed or replaced? This produces a straight yes/no output. For example: if an overhead line double circuit is completely rebuilt including towers and their foundations, it would count as complete replacement.

Stage 4

Are the new assets \geq £100m value?

- 4.23 Aim – to test whether the new assets reach or exceed the high value threshold.
- 4.24 Criteria – this is the second part of a two-stage process (the first, stage 2 is above). If the project has a very high proportion of new assets and high value, the project will pass this stage. For more marginal projects (where the value of new assets is around the threshold), the ESO uses the breakdown of costs from the TO to calculate the value of the new assets. This produces a straight yes/no output.

Stage 5

Are the new assets separable?

- 4.25 Aim – to test whether the project details indicate that the new assets are readily separable from the existing assets.
- 4.26 Criteria – this is to check if the project already has points of connection to existing assets that can be clearly delineated, in other words, clearly identified. Disconnectors are obvious points that can be delineated but Ofgem suggest that other points such as clamps on busbars would also be acceptable as long as the point can be clearly identified. This produces a straight yes/no output.

Stage 6**Can the projects be bundled or split?**

- 4.27 Aim – having gone through the process to check for eligibility, this stage is a recheck that sensible packages of work are developed together. The eligibility process especially for separability sometimes changes a project package of works and this stage is to check if bundling or splitting is still appropriate or has become appropriate.
- 4.28 Criteria – these are the same as for stage 1 (above). Note that projects that are split must have component parts that meet or exceed the £100m value threshold.

Stage 7**Based on technical and cost-benefit analysis studies, is it appropriate for the ESO to recommend additional electrical separation for the projects that have met the competition criteria?**

- 4.29 If the ESO concludes that the project proposals already have adequate electrical separation, it is not necessary to carry out this stage.
- 4.30 Aim – use cost-benefit analysis studies to test technical solutions and determine if it is worth extra investment in assets or amending the design to further delineate ownership boundaries to provide adequate electrical separability.
- 4.31 The ESO believes that the electrical separation assessment will be needed by exception only. As a result, the ESO treats any such instances on a case by case basis for options that pass the earlier stages and look likely to go to tender. The ESO will consider factors such as safety and operability as well as cost and record outcomes along with method used in a summary report.
- 4.32 The ESO maintains a log of connection projects that meet the competition criteria and liaises with the TOs about the outcomes of the competition eligibility assessments. This log forms the basis of the list that is published in the NOA.



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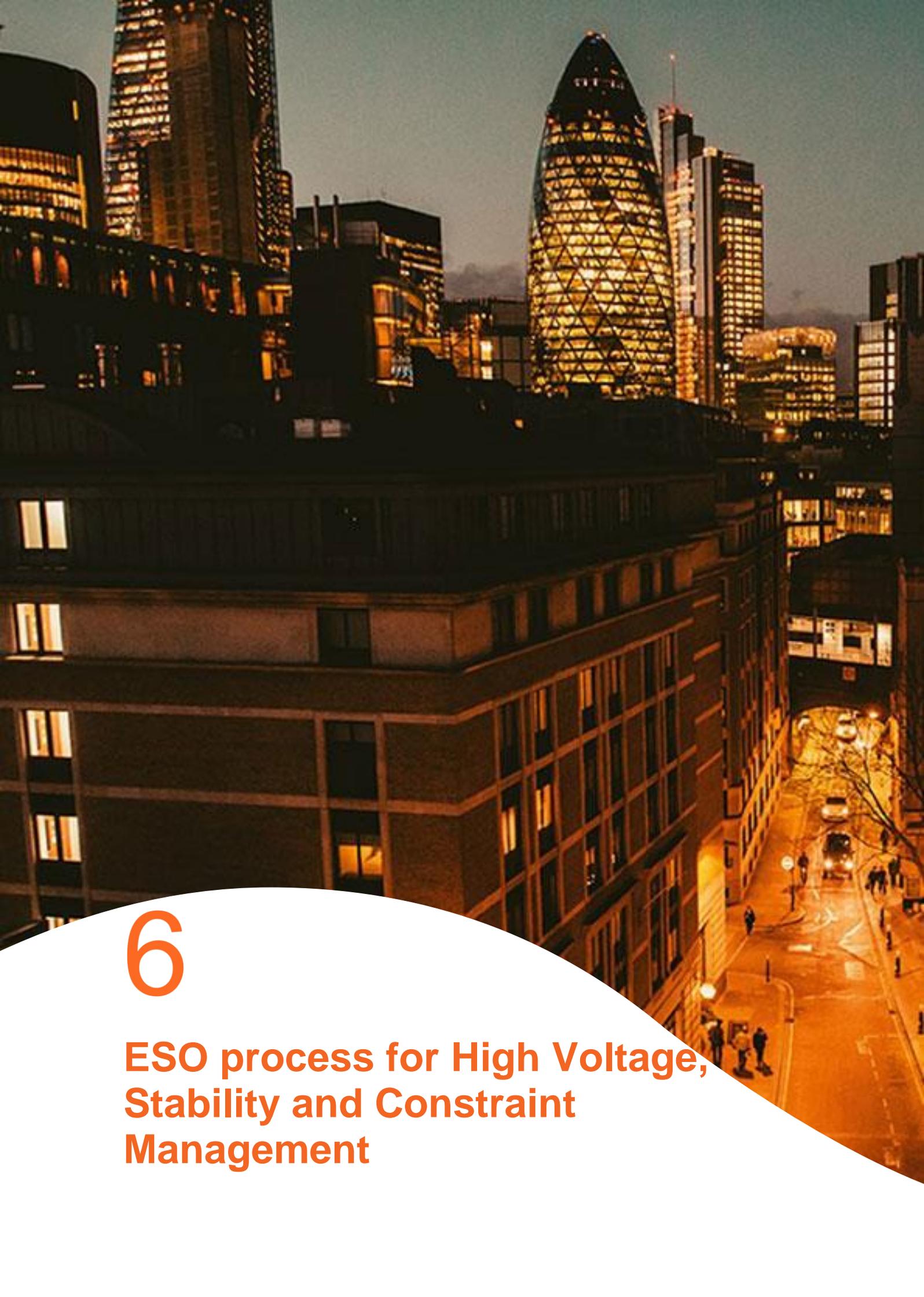
ESO process for Offshore Wider Works

Foreword

- 5.1 The process for offshore wider works (OWW) is evolving to use more shared or integrated connections for offshore generation, instead of point to point. This is necessary due to the high volume of new wind connections required to meet the UK Government target of 50 GW of offshore wind by 2030. This is a significant increase in the present installed capacity²⁰. To support this objective, BEIS and Ofgem are leading the Offshore Transmission Network Review (OTNR) which looks at how to improve the way that offshore generation is connected to the onshore network²¹. OTNR has four workstreams, one of which is 'Pathway to 2030'.
- 5.2 A significant part of the 'Pathway to 2030' workstream is the Holistic Network Design (HND) which is led by NGENSO. This identifies the requirements for network capacity in the onshore network, so that new offshore windfarms connect efficiently. This large volume of offshore wind has significant impacts on the network which are complex to evaluate. One potential effect is that reinforcements, previously categorised as '*wider works*' now become essential to enable the planned offshore connections. HND is developing a new approach to network design, which is likely to form the template for future design for offshore connections.
- 5.3 The ESO led network planning review is currently evaluating the best approach to develop onshore and offshore transmission network. When this work has been completed the process for aligning the onshore network design (currently NOA) with the offshore design and integration (currently HND) will be clearer and this section will be revised.

²⁰ <https://www.gov.uk/government/news/major-acceleration-of-homegrown-power-in-britains-plan-for-greater-energy-independence>

²¹ <https://www.nationalgrideso.com/future-energy/projects/offshore-coordination-project/latest-news>



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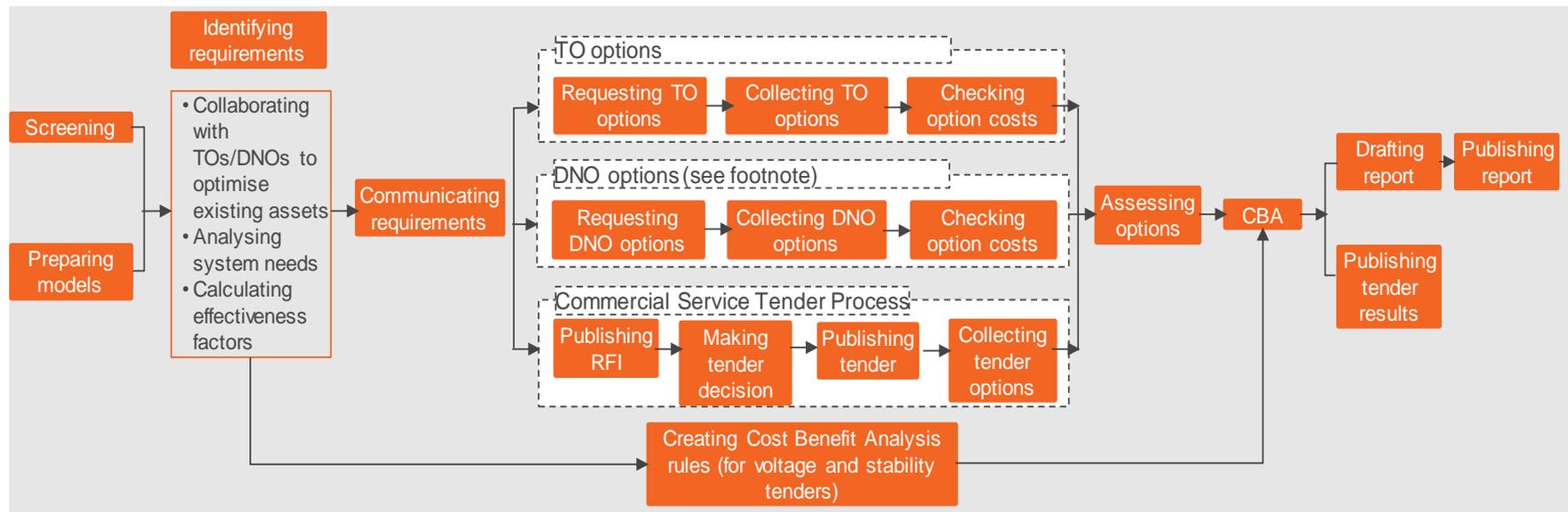
ESO process for High Voltage, Stability and Constraint Management

This chapter outlines the scopes, principles and processes for the High Voltage, Stability and Constraint Management pathfinder projects.

Overview of the High Voltage and Stability Management Process

6.1 High voltage and stability management are two separate processes with different technical assessments. However, they share a number of similarities in the economic assessment and tender processes. The objective of the process is to ensure economical and efficient options for high voltage and stability management to be available when required. This Electricity System Operator (ESO) led process is designed to identify high voltage and stability issues in the transmission system, the causes, requirements and the preferred options to solve these issues. The process is designed to work with all expected option providers including Transmission Owners (TO), Distribution Network Operator (DNO) and Commercial Service Providers. *Figure 6.1* gives an overview of the high voltage and stability management process.

Figure 6. 1 Overview of the high voltage and stability management process²²

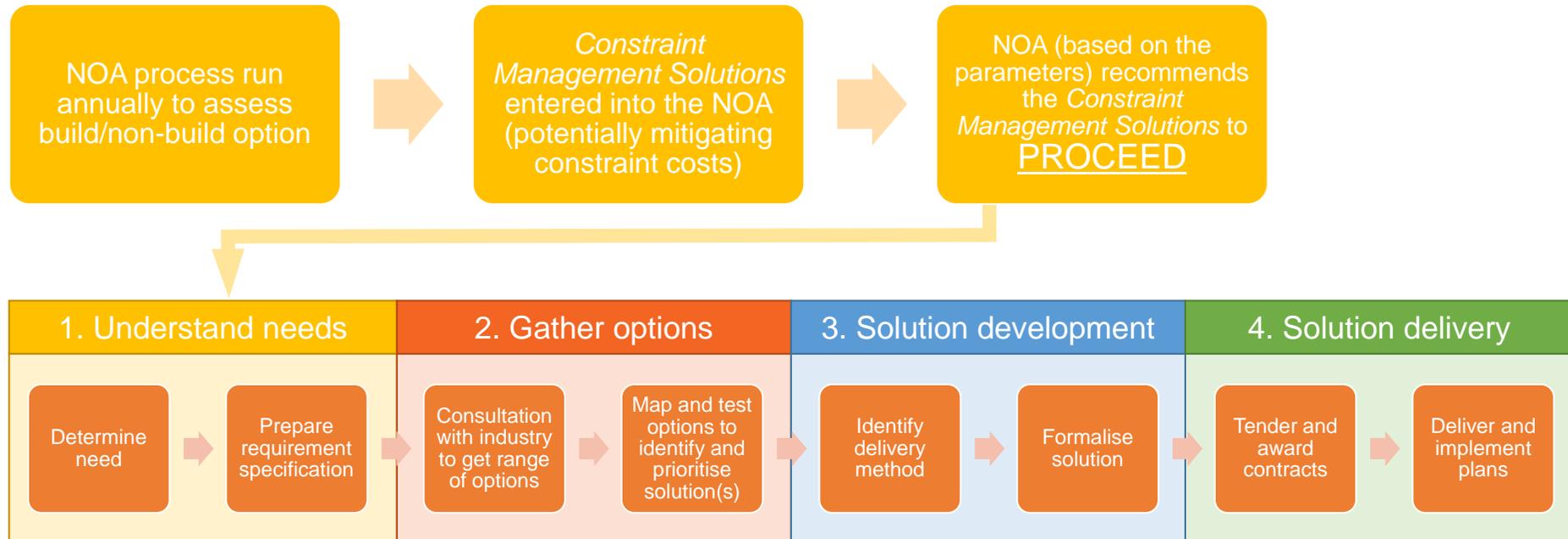


²² In the long term when a regulatory funding mechanism for DNO options is agreed, it is expected that DNO options will follow a similar route to TO options, but presently a suitable regulatory funding mechanism is not in place for the DNO options. Until a suitable funding mechanism is established it is expected that the DNO options will be paid via the Balancing Service Contract; hence DNO options will follow the same route as Commercial Service options in the short term. The stability solutions are expected to be more effective at the higher voltage levels due to network impedance and therefore the DNO options may not be applicable.

Overview of the Constraint Management Process

6.2 The NOA Constraint Management Pathfinder (CMP) looks for options to reduce the cost of managing constraints in various regions in the electricity system. Constraints can be of three types - thermal, voltage or stability on the transmission system. The CMP process is designed to develop commercial options in the NOA that could be used to relieve residual constraints depending on the need and delivery of network reinforcements. *Figure 6.2* shows an overview of the CMP process. The detailed process is described in the Constraint Management Process section (6.22).

Figure 6. 2 Overview of the constraint management process



Programme

6.3 The ESO carries out the screening process annually. The ESO expects to carry out the screening process for high voltage and stability management after the annual technical analysis of boundary capabilities for ETYS & NOA. Constraint management solutions are assessed as part of the annual ETYS/NOA analysis, however the ESO only carries out more detailed CMP assessments in the regions with a “Proceed – Critical” recommendation from the constraint management NOA.

6.4 A detailed assessment of any prioritised regions will be initiated on demand and as agreed between the ESO and the relevant TOs and DNOs.

- 6.5 The timeline of the detailed assessment of any prioritised regions will vary depending on the complexity and the size of requirements. The ESO will agree the timeline with the relevant TOs and DNOs involved.

Roles and responsibilities

System Operator

6.6 National Grid Electricity System Operator (ESO) leads the high voltage, stability and constraint management processes. ESO shall be responsible for:

- Plan develop and operate the NETS in accordance with the SQSS
- Selecting and prioritising regions by screening
- Preparing network models for analysis
- Collaborating with TOs and DNOs to identify requirements
- Communicating requirements to providers
- Collecting options from providers
- Assessing options
- Collaborating with DSO²³ to carry out the technical assessment of distribution-connected options
- Recommending most economic options based on cost-benefit analysis (CBA)
- Communicating process conclusions to providers
- Procuring Commercial Power Services via Balancing Service Contract
- Procuring Constraint Commercial Services via the Constraint Management process
- Publishing the high voltage and stability management process Reports.

Transmission Owners

6.7 Transmission Owners (TO) shall be responsible for:

- Plan and develop their networks in accordance with the SQSS
- Providing feedback on regions which they think should be prioritised in this process
- Preparing network models for analysis
- Collaborating with ESO to explore options from existing assets of their networks for analysis
- Collaborating with ESO to identify requirements
- Supporting the assessment of options which could have an impact on their network
- Proposing options using the System Requirement Form – Voltage/Stability.
- Collaborating with ESO to deliver the feasibility studies and infrastructure work required to facilitate tender options.

Distribution Network Operators

6.8 Distribution Network Operator (DNO) shall be responsible for:

- Compliance of their networks
- Preparing network models for analysis
- Collaborating with ESO to explore options from existing assets of their networks for analysis.

DNOs shall also be responsible for the following, while the relevant DSO does not yet exist:

- Collaborating with ESO and the relevant TO to identify requirements
- Supporting the calculation of effectiveness factors for their networks
- Collaborating with ESO to carry out the technical assessment of distribution-connected options which connect to their networks.

DNOs will be invited to respond to any Request for Information and/or participate in any Tender Process. They can propose options which meet requirements set out by ESO via the Tender Process²⁴.

²³ Where a relevant DSO function does not yet exist, it is expected that the relevant DNO will take responsibility.

²⁴ In the long term when a regulatory funding mechanism for DNO options is agreed, it is expected that DNO options will follow a similar route as TO options, but presently a suitable regulatory funding mechanism is not in place for the DNO options.

Reactive Power and Stability Commercial Service Providers

- 6.9 Reactive Power and Stability Commercial Service Providers will be invited to respond to any Request for Information and/or participate in any Tender Process. They can propose options which meet requirements set out by ESO via the Tender Process.

Constraint Commercial Service Providers

- 6.10 Constraint Commercial Service Providers will be invited to respond to any consultation and Expression of Interest and/or participate in any Tender Process of the Constraint Management Pathfinder projects. They can propose options which meet requirements set out by the ESO during the Consultation phase.

Principle of assessment for high voltage, stability issues and constraint related investment

- 6.11 The ESO plans, develops, and operates the transmission system so that voltage and frequency levels stay within the normal operating ranges defined within the National Electricity Transmission System Security and Quality of Supply Standards (NETS SQSS)²⁵. The specific voltage and frequency limits used in planning and operating the transmission system can be found in chapter 6 of the NETS SQSS.
- 6.12 To ensure the ESO can plan the system to operate securely and safely while managing voltages and system stability both economically and efficiently, a Network Options Assessment (NOA) style methodology is proposed. This will facilitate the assessment of options to develop the electricity networks to meet future voltage and stability control requirements.

High Voltage Assessment

- 6.13 High voltage assessments seek to identify and address high voltages needs. This process currently runs in parallel to the existing NOA process which primarily focuses on thermal and low voltage issues that are typically seen when power transfer across the network is high. This is normally assessed at peak demand periods. High voltage issues, are typically encountered during periods of light system loading or minimum demand.
- 6.14 Other voltage control concerns may be present at other periods of the year but to avoid increased complexity and delay they are not being addressed in this methodology. As the NOA methodology continues to evolve, the ESO will expand the methodology to cover further voltage control concerns in the future.
- 6.15 High voltage issues are typically localised and voltage control solutions are usually ineffective over long distances so the ESO will apply a regional approach to the assessment.
- 6.16 The ESO uses cost-benefit analysis (CBA) to provide investment recommendations. Cost-benefit analysis compares the cost of a proposed solution and the monetised benefits over the project's life to inform the investment recommendation. To effectively meet the future voltage control requirement, the ESO also considers system operability when recommendations are made. The two primary factors that will drive an ESO recommendation are:
- a. Monetised benefits, when monetised benefits are higher than the forecast solution cost. This implies investing in the proposed solution will provide a more economical and efficient way to manage voltages in the long term when compared to the ESO paying for reactive power service in real-time via the Balancing Mechanism (BM).

Justification based on monetised benefits

The monetised benefits are the cost saving achieved by investing in a proposed solution compared to using existing services such as Obligatory Reactive Power Services (ORPS)²⁶. The ESO currently relies heavily on the reactive power capabilities of generators for managing voltage. The ESO hopes to see savings on constraint cost and, in some cases, utilisation cost as well. To estimate this saving, the ESO forecasts the constraint and utilisation costs they will pay for accessing and using the ORPS via the BM.

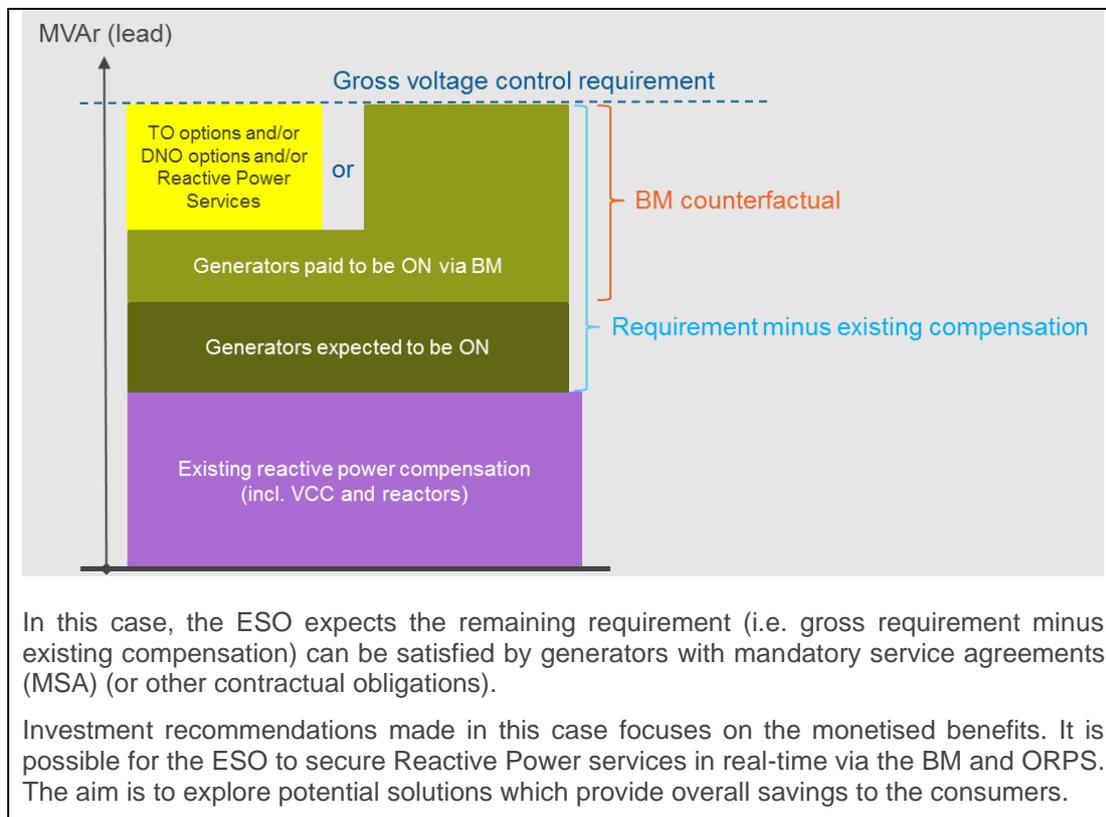
Constraint cost refers to the bid and offer price the ESO pays (for the MW) to get a generator onto the system to provide reactive power support, together with another generator reducing its generation or turned off elsewhere on the system to maintain the balance of supply and demand. Utilisation cost refers to the payment the ESO makes (for the MVAR) to generators for using their reactive power capabilities, the more being used the higher the cost.

²⁵ Transmission Licence Standard Conditions C17: Transmission system security standard and quality of service, paragraph 1.

²⁶ The Obligatory Reactive Power Service (ORPS) is the provision of varying reactive power output. At any given output generators may be requested to produce or absorb reactive power to help manage system voltages close to the point of connection. All generators covered by the requirements of the Grid Code are required to have the capability to provide reactive power.

The aim here is to find the solutions which deliver additional benefits to the consumers, in the form of net savings. This is achieved by replacing services which will need to be procured via the BM with lower cost proposed options. *Figure 6.3* shows how proposed options replace services from the BM to meet the voltage control requirement. The ESO uses cost-benefit analysis (CBA) to compare forecast investment costs and monetised benefits over the duration of the system need to inform this investment recommendation.

Figure 6. 3 Proposed options replacing services from the BM to meet voltage control requirement

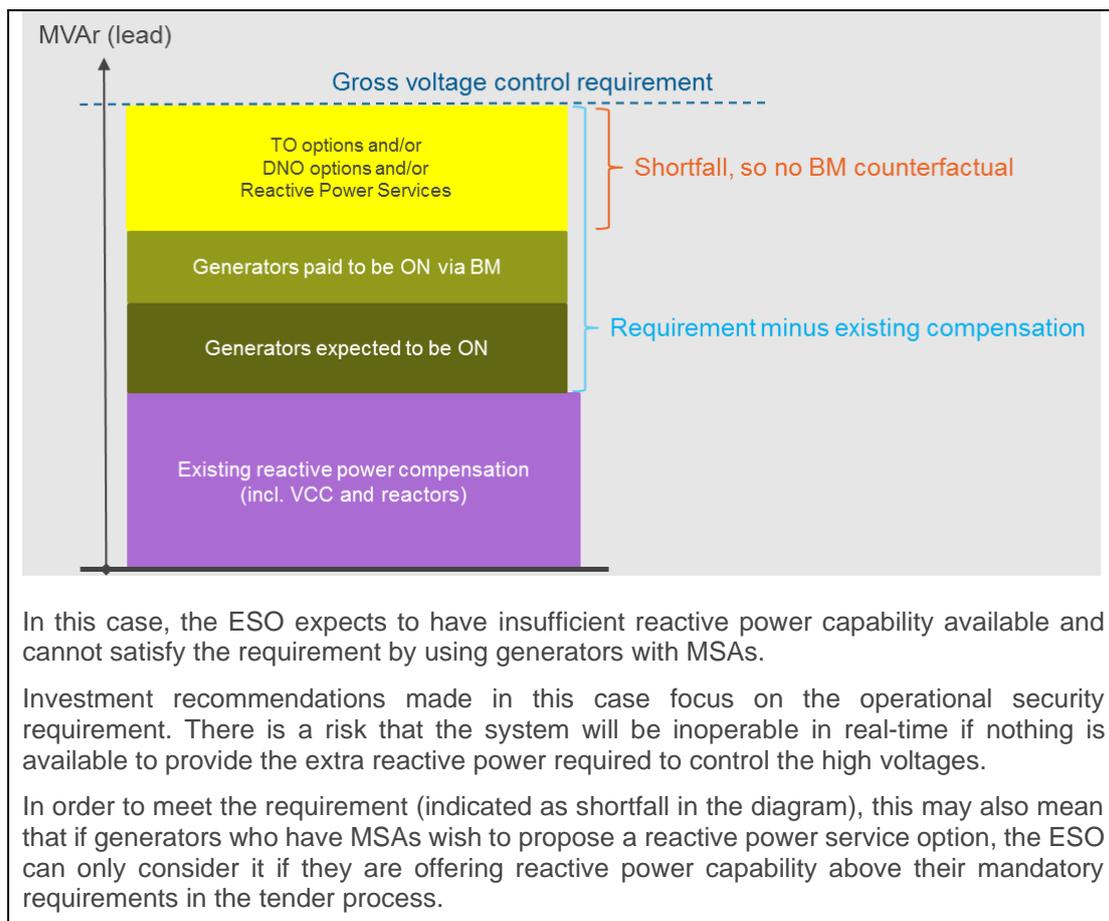


- b. Operational security requirement, when there are insufficient means to provide reactive power to contain high voltages and securely operate the network. This implies the forecast reactive power required in the future is higher than is forecast to be available via the BM or other means.

Justification based on security and operability

Given the rapid changes in generation and demand backgrounds, there may be times in the future where there will be insufficient reactive power compensation or services available to meet the voltage control requirements within a region. If such situation is observed in the analysis, the ESO will then focus on verifying the credibility of the assumptions leading to such a situation. If deemed credible, the most cost-effective solution to resolve the situation will be pursued. *Figure 6.4* shows how proposed options provide the reactive power needed to meet voltage control requirement as sufficient services cannot be procured from the BM.

Figure 6. 4 Proposed options providing the reactive power needed to meet voltage control requirement as sufficient services cannot be procured from the BM



Stability Assessment

- 6.17 Voltage and frequency limits used in planning and operating of the transmission system are stated in the NETS SQSS. The GB Grid code defines performance requirements for different users connected the National Electricity System for different system conditions (eg. fault ride through requirements, voltage and frequency withstand variations).
- 6.18 The ESO considers stability at national and regional levels. Where a solutions' ability to provide stability support is independent of its electrical location, it is considered at a national level. The ESO also considers stability on a regional basis where both the need and the solutions are location specific. There will be some interaction between these two types of needs that the ESO will manage in communicating the requirements.
- At a national level, ESO maintains system frequency within limits by consideration of frequency response/reserve market products and maintains Rate of Change of Frequency (RoCoF) within limits by consideration of largest generation/ demand loss on the system and planning for national levels of inertia.
 - At a regional level, the distribution of regional inertia, short circuit level, dynamic voltage support can influence the stability of the local network and its users.
- 6.19 Similar to Voltage assessment, in order to ensure the system is planned in a way that it could be operated securely and safely while system stability is managed both economically and efficiently, a Network Options Assessment (NOA) style methodology is proposed. This will facilitate the assessment of options to develop the electricity networks to meet future stability requirements.

- 6.20 The ESO uses a cost-benefit analysis (CBA) to provide investment recommendations. The cost-benefit analysis compares the cost of a proposed solution and the monetised benefits over the length of the system need to inform the investment recommendation. The two primary factors that will drive an ESO recommendation are:

Monetised benefits, when monetised benefits are higher than the forecast solution cost. This implies investing in the proposed solution will provide a more economical and efficient way to manage stability in the long term when compared to the ESO paying for the equivalent services in real-time via the Balancing Mechanism (BM).

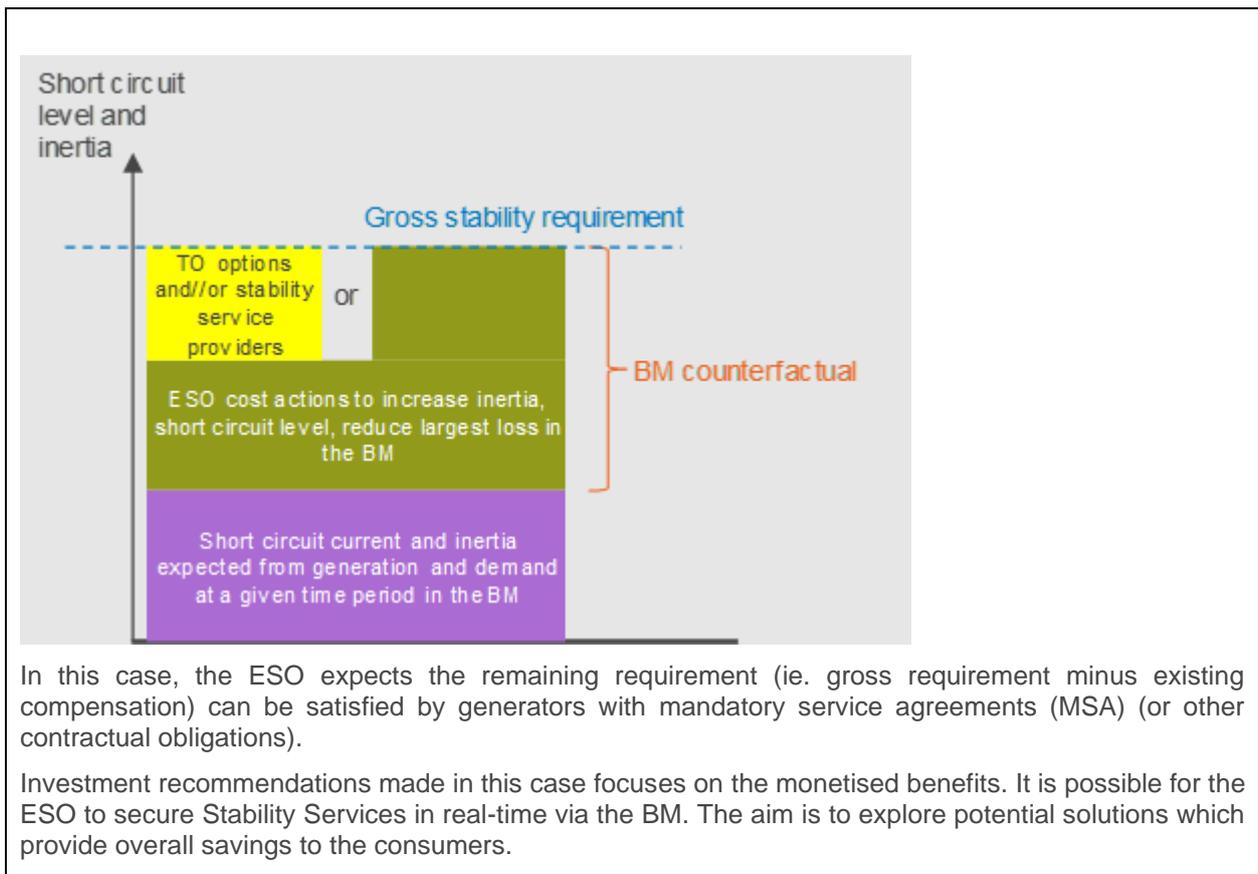
Justification based on monetised benefits

The ESO currently relies on the inherent capabilities of synchronous generators participating in the BM to provide inertia, short circuit current and dynamic voltage support. The ESO takes actions in the BM to address any shortfall which would lead to system instability. The ESO hopes to see savings on constraint costs. To estimate this saving, the ESO forecasts the constraint and utilisation costs they will pay for accessing and using the short circuit level and inertia via the BM.

Constraint cost refers to the bid and offer price the ESO pays (for the MW) to get a generator onto the system to provide stability support, together with another generator reducing its generation or turned off elsewhere on the system to maintain the balance of supply and demand.

The aim here is to find the solutions which deliver additional benefits to the consumers, in the form of net savings. This is achieved by replacing services which will need to be procured via the BM with lower cost proposed options. In some future instances, the ESO expects a shortfall in the BM to procure for stability. Figure 6.5 shows how proposed options replace services from the BM to meet stability requirement. The ESO uses cost-benefit analysis (CBA) to compare forecast investment costs and monetised benefits over the solution's life to inform this investment recommendation.

Figure 6. 5: Proposed options replacing services from the BM to meet stability requirement

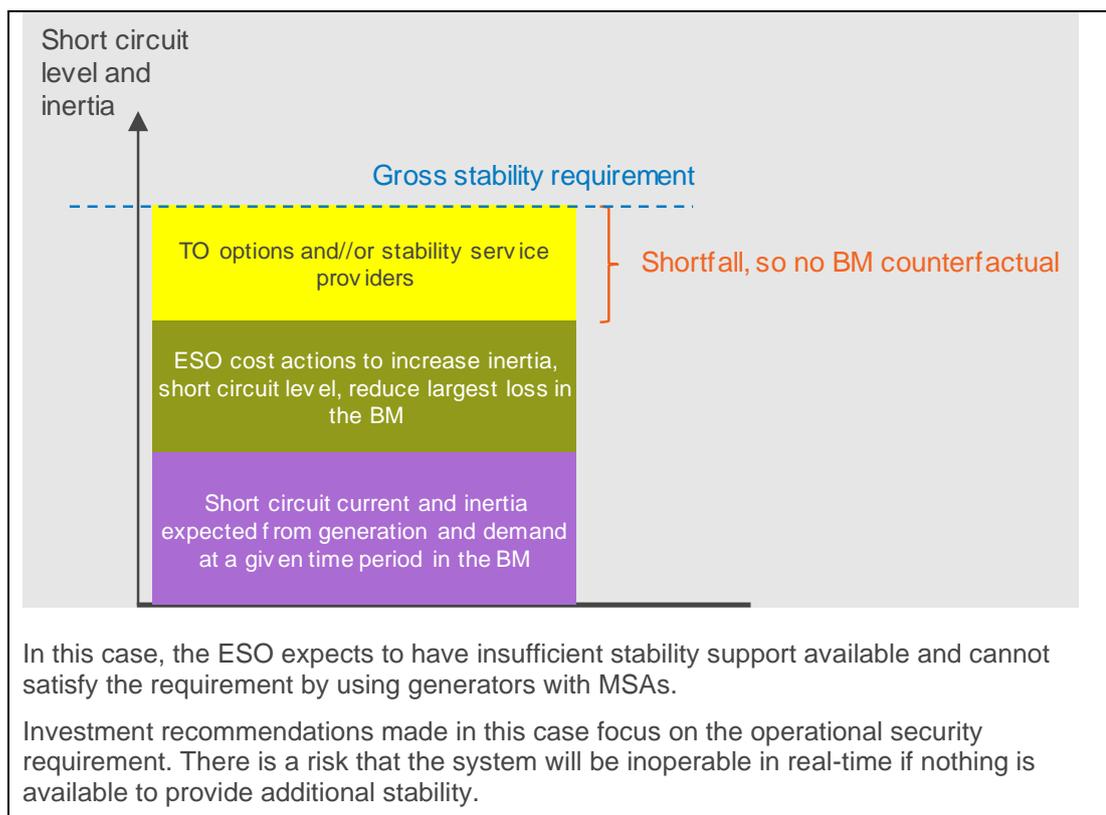


- c. Operational security requirement, when there are insufficient means to provide stability support and securely operate the network. This implies the forecast stability requirement in the future is higher than is forecast to be available via the BM or other means.

Justification based on security and operability

Given the rapid changes in generation and demand backgrounds, there may be times in the future where there will be insufficient BM services available to meet the stability requirements within a region. If such situation is observed in the analysis, the ESO will then focus on verifying the credibility of the assumptions leading to such a situation. If deemed credible, the most cost-effective solution to resolve the situation will be pursued. Figure 6. 6: shows how proposed options provide the stability requirement as sufficient services cannot be procured from the BM.

Figure 6. 2: Proposed options providing the stability support needed to meet requirement as sufficient services cannot be procured from the BM



- 6.21 Investment recommendations will be based on the above mentioned two primary factors. As a general principle, if there are several options which meet the requirements and satisfy either of the two primary factors, the CBA chooses the most economical and efficient options. This is described in more detail in the section “Cost-benefit analysis”.

Constraint Management Solutions Assessment

- 6.22 The ESO must operate the system to the requirements set in the SQSS. When planning the network in operational timescales, the ESO Electricity National Control Centre (ENCC) would operate the system to a secure power transfer limit considering various network faults. If the transfer exceeds the capability, the ENCC must reduce the power flow pre-empting the worst network fault via Balancing Mechanism (BM) actions. Constraint costs are a factor of bid / offer prices and the amount of generation constrained.
- 6.23 The NOA process annually assesses options to increase boundary transfer capabilities as per system needs outlined in the ETYS. Non-build constraint management solutions (eg. system to generator intertrips) are assessed in the same way as asset-based options through the NOA process. The ESO uses cost-benefit analysis (CBA) to provide recommendations on balancing the costs of managing constraints and the cost of reinforcing the network. As constraint management solutions can be contracted flexibly and do not have a fixed asset life or duration, the NOA study assesses when to start commercial services to reduce constraint costs in short term and when to discontinue them considering delivery of asset-based reinforcements.
- 6.24 For the constraint management solutions given with “Proceed – Critical” NOA recommendations, the associated regions are prioritised based on the constraint cost and year recommended to start the commercial services. From the NOA outcomes to date, thermal constraints are the most common type of constraint for the regions identified with needs of constraint management solutions.

- 6.25 The ESO will select a priority region to carry out a regional constraint assessment by analysing technical and economic benefits of using commercial options. Constraint management solutions use operational measures from commercial providers to increase the volume of power that can be securely transferred across a boundary. For example, a commercial service enabling post-fault generation intertrip could be an effective way to relieve thermal constraints. The constraint assessment seeks to identify constraint issues and reduce associated costs. In addition to assessing winter peak demand periods, the constraint assessment carries out sensitivity studies for the interested region to investigate various power transfer scenarios, including periods of light system loading or minimum demand when the system might have stability issues.
- 6.26 The ESO uses a cost-benefit analysis (CBA) to provide investment recommendations. The CBA compares the cost of a proposed solution to procure commercial services and the constraint savings over the length of the system need to inform the investment recommendation. Balancing mechanism actions to bid off or buy generation in operational time scale are used as the counterfactual measure to address constraints.

The High Voltage management process

Regional approach – determining the most economical and efficient solution for High Voltage management Process

6.27 Voltage is a localised property of the system which means that requirements vary from one region to another. The voltage control requirements are determined by the configuration of the local network and the nature of generation and demand in that region. Since reactive power, unlike real power, cannot be sent across long distances due to the reactance of the transmission network, voltage control is most effective when applied close to the problem. Voltage issues can therefore be grouped into regions and assessment of each region conducted separately. The high voltage management process looks into the reactive power required for high voltage control on a regional basis.

Screening process – selecting and prioritising regions

6.28 The ESO uses a screening process to help identify and prioritise the region(s) which should be further explored through detailed power system and cost-benefit analysis. This should bring consumers the best value by ensuring that the secure, economical and efficient development of the network focuses on challenging regions first. The screening process considers four main factors which are in line with the NOA assessment principles – cost, network change, likelihood and lead time.

- **Cost:** The focus is on the historic spend in each region to procure Commercial services for managing high voltages. A high historic spend in a region suggests heavy reliance on the BM and ORPS, which suggests potential benefits of conducting an assessment to evaluate the best options to provide future reactive support in the region.
- **Network change:** This refers to any significant changes of the system in the future, including new generation (including embedded generation), major generator closures, commissioning of new cables etc. Regions which do not associate with a high historic spend, but which are set to see some significant changes that contribute to an increasing need for reactive support should be assessed.
- **Likelihood:** This is an assessment about how likely the above two factors will materialise. For example, if the high historic spend was due to a routine maintenance outage, it will be considered more likely than spend due to a long outage caused by a fault.
- **Lead time:** This refers to the length of time between the system need and the typical lead time to deliver an option in the region of interest. For example, if a compliance concern will arise soon after any options can be sourced to meet the requirements, there is an urgency to assess the region.

6.29 The ESO will request feedback from the TOs as to which region(s) they believe should be assessed. This includes any compliance concerns in their networks.

6.30 The ESO will discuss any compliance concerns raised by the TOs and agree a plan to assess these concerns. The discussion will consider when the compliance issue may materialise and the lead time of potential options to resolve the issue.

6.31 The four factors mentioned above, together with the TOs' feedback, will be used to help determine the region(s), as well as the backgrounds and conditions that the ESO will consider in the assessment. For example, conditions which are associated with high historic spend and are expected to persist or grow in severity will be analysed. The ESO will apply these conditions to future backgrounds which show similar characteristics to the system when those high historic spends arose.

Creating network models for analysis

6.32 In this high voltage Management Process, the ESO will use the GB system planning models produced in accordance with the SO-TO Code (STC). Future backgrounds based on Future Energy Scenarios (FES) and system conditions considered appropriate in accordance with the NETS SQSS will be applied to the models for assessment.

- 6.33 TOs and DNOs will provide relevant data to support the ESO in preparing the models for analysis.

Identifying requirement

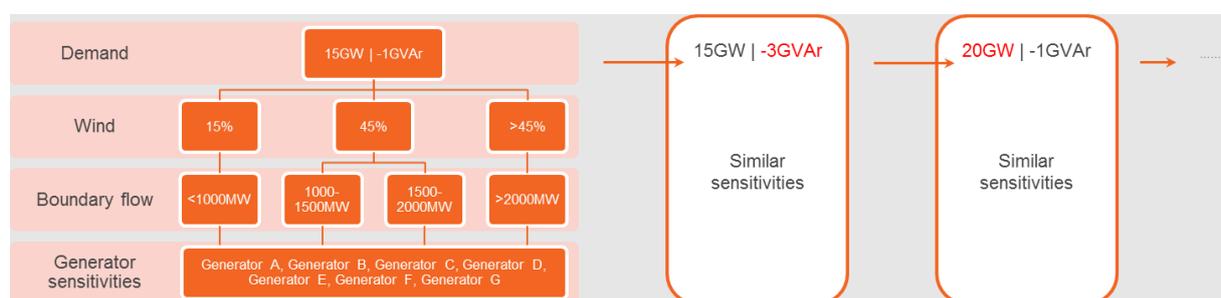
Collaborating with TOs/ DNOs to explore options from existing assets

- 6.34 The ESO will collaborate with Network Owners, TOs and DNOs, to ensure a consistent methodology is applied when it comes to planning and developing the transmission system. TOs are obliged by their transmission license to plan and develop their transmission network in accordance with the NETS SQSS. DNOs have a key role in enabling a whole system approach to address some of the future requirements in the transmission system while maintaining compliance of their distribution system.
- 6.35 The ESO will share the initial view of areas of priority with the relevant TOs and DNOs. The ESO aims to ensure consistent methodology, models, backgrounds and sensitivities are considered across all analyses. TOs and DNOs provide feedback about their networks in the relevant areas. The feedback will help the ESO to optimise existing and planned assets prior to quantifying the system needs in those areas in details. To ensure the transmission system is planned and developed in an economical and efficient manner, the ESO should only proceed with new requirements once existing and planned network assets are optimised.
- 6.36 Where available, the ESO will engage with the system operator function of the distribution companies.

Analysing the size of the reactive power requirement

- 6.37 The ESO identifies the reactive power required to control voltage based on system analysis results. The requirement varies depending on the future backgrounds and system conditions. It is not practical to fully analyse all combinations of backgrounds and conditions. Hence, the ESO selects snapshots using historic records assisted by data mining techniques and engineering judgement to represent a reasonable number of variations of backgrounds and conditions. The same four factors, which were considered during the screening stage (i.e. cost, network change, likelihood and lead time), are used to help with the selection.
- 6.38 The ESO collaborates with the TOs and DNOs to identify the reactive power required for the transmission networks.
- 6.39 The diagram below illustrates how the analysis to identify the reactive power required may be structured. The example shows variation in demand assumptions. The selection of the specific study backgrounds and system conditions, which set out the analysis, however, depends on the characteristics of the region of interest.

Figure 6. 3 Example of backgrounds and conditions considered for analysis



- 6.40 The reactive power required depends on what the ESO expects the system will need in the future to maintain voltages within the NETS SQSS limits. To determine the reactive power required for any region of the network the following steps are applied:
1. Set up analysis with selected credible backgrounds and system conditions
 2. Analyse to check if the NETS SQSS requirement can be met with existing reactive power compensation and generators which are predicted to run
 3. If the NETS SQSS requirement can be met, note the generators running in the region of interest and move on to the next sensitivity analysis

4. If the NETS SQSS requirement cannot be met
 - a. If applicable, consider using different combinations of generators in the region of interest which are accessible via the BM
 - i. Simulate constraint (bid and offer) actions until the voltage control requirement is satisfied
 - ii. Note the generators running in the region of interest
 - b. Consider suitable transmission solutions
 - i. Simulate investment in new transmission assets at different locations until the voltage control requirement is satisfied
 - ii. Note the size of new reactive power compensation plant(s) required and the location they are connected at. This is used to define the reactive power required and the most optimum location for solutions to meet the need in the region
 - c. Continue to the next analysis
- 6.41 The recorded generators running under each analysis will be used to formulate the voltage rules. This is described in more detail in the section *“Creating voltage rules”*.

Technical Assessment Approaches

- 6.42 Based on our latest pathfinder learning, we have found it necessary to adopt the technical assessment approach based on the unique characteristics of the relevant region.
- **Effectiveness Factor Approach:** In regions where there is a single worst-case contingency, and a single electrically optimal site, we apply an effectiveness factor approach.
 - **Joint economic and technical optimisation approach:** In regions where there are several critical contingencies and solutions are required across multiple sites, we will apply a joint economic and technical optimisation approach.

The two approaches are described in the following sections:

Effectiveness factor approach

- 6.43 In some network areas, there is a single site which is optimal for the installation of reactive absorption. However, physical factors such as land availability or even the amount of compensation required mean that potentially only some or even none of the compensation may be delivered at that site. To allow fair comparison of all potential options across different sites and allow combined and single options to be assessed, effectiveness factors are used when the ESO assesses options.
- 6.44 The effectiveness of an option is directly linked to its point of connection and determines the amount of reactive power required to meet the requirement. This will change the total volume expected to be invested or procured. For example, if a unit A was assessed to be 50% effective and unit B 100% effective, to resolve the same issue the system would need to use twice as much reactive power from unit A than B. Unit A would need to be significantly cheaper to have the same benefits.
- 6.45 Effectiveness changes with certain system conditions, for example with certain outages. The ESO calculates effectiveness factors for each point of connection against consistent (set of) background to ensure all providers are treated equally.
- 6.46 The examples below are all aimed to be illustrative and provides approximations of potential differences in effectiveness. This will change when specific technical assessment for each region is completed. Provider A in green, Provider B in red and represent any appropriate technology that can satisfy the reactive power requirements.

Example 1

Provider A and B are connected at the same site. The site is run solid. The two different providers have similar reactive ranges.

The providers would likely have the same effectiveness factor.

Note: If the site is run split, the providers would likely have different effectiveness factors.

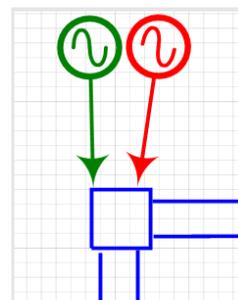


Figure 6. 4

Example 2

Provider A and B are connected at different, adjacent, sites, but sites that are geographically close together.

The providers would likely have similar effectiveness factors.

Note: Distance in the diagram is indicative only.

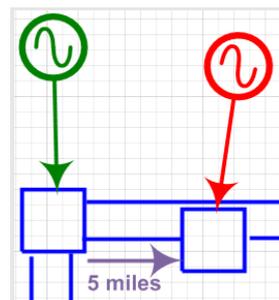


Figure 6. 5

Example 3

Provider A and B are connected at different, adjacent, sites, but sites that are geographically far apart.

The providers would likely have different effectiveness factors.

Note: Distance in the diagram is indicative only.

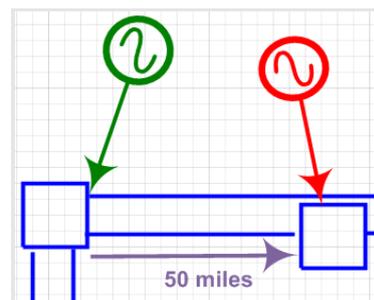


Figure 6. 6

Example 4

Provider A and B are connected at different voltage levels. Provider B is connected at 132kV in the DNO network.

The ESO expects the options close to the source of the issue will have higher effectiveness factors.

If, for example, the source of the issue is at the transmission network, then Provider B that is connected at a 132kV voltage level is likely to be less effective than Provider A. Providers connected at lower voltages than 132kV, in this example, would be expected to be even less effective.

Alternatively, if, for example, the source of the issue is at the distribution network²⁷, then Provider B is likely to be as effective (or more effective in some cases) than Provider A.

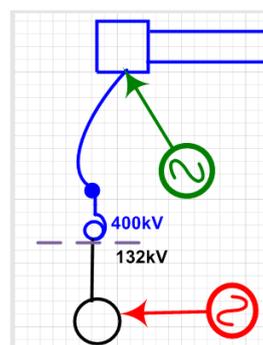


Figure 6. 7

²⁷ The [Power Potential Project](#), which aims to create a new reactive power market for distributed energy resources (DERs), will provide further insights into effectiveness of options connected to the distribution network. The ESO is learning from the Project and is improving their understanding of effectiveness.

Example 5

The reactive power required is set specifically for a defined region. The region has been defined based on potential effectiveness.

Provider A is inside the defined region and Provider B is outside the defined region.

Providers outside the region are assessed as only being ineffective at resolving the issue.

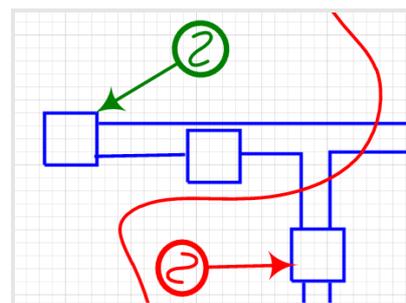
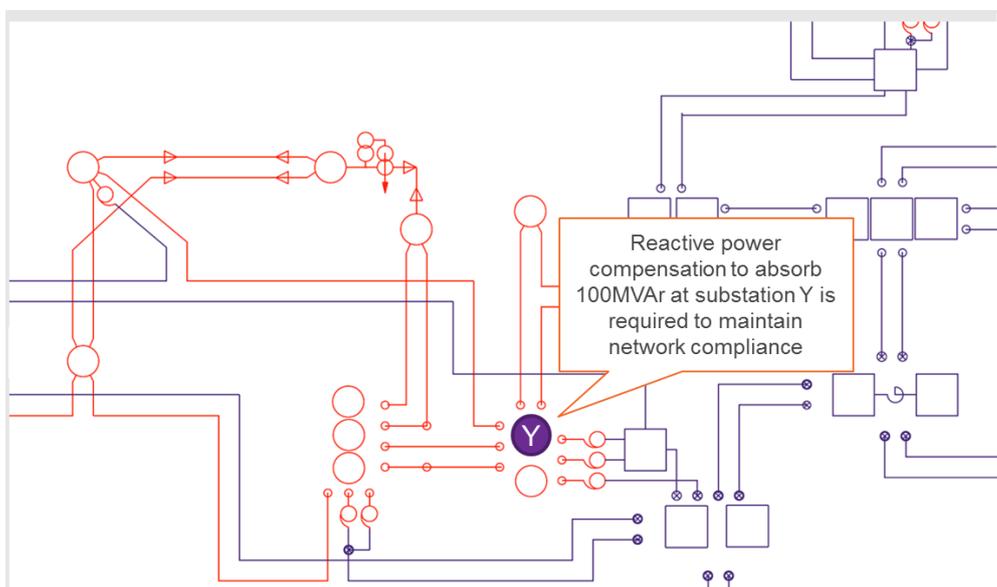


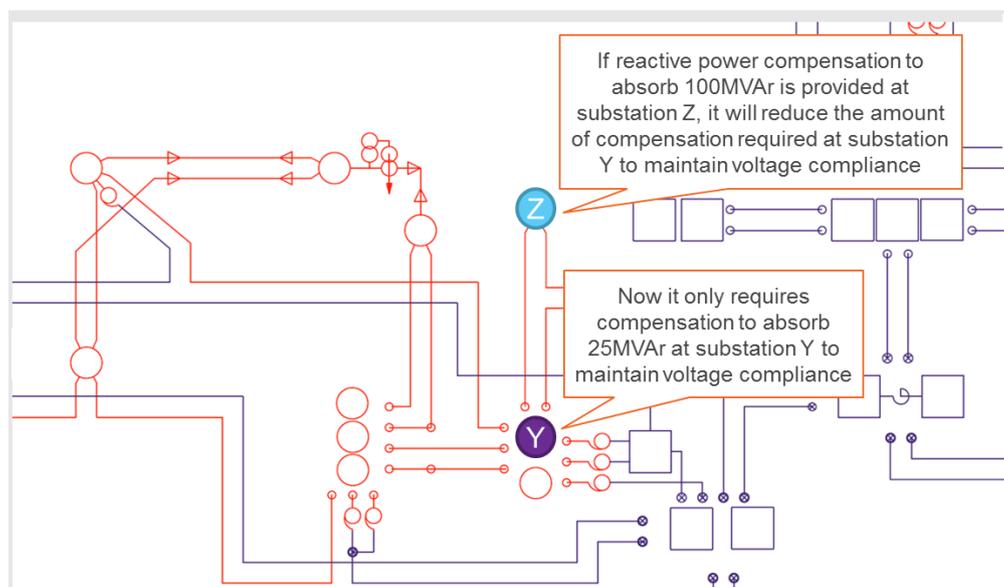
Figure 6. 8

- 6.47 Many factors affect the effectiveness of an option, such as its size, where and how it will connect to the network. Effectiveness factors are relative to a reference point in the network. The ESO chooses reference point(s) in the network based on where it is most effective to implement reactive power compensation to meet the requirement of the region of interest. Through system analysis the ESO calculates the effectiveness of various available transmission-level connection points with respect to the reference point(s).
- 6.48 For distribution-level connection points, the ESO works with the relevant DNOs to calculate the effectiveness factor of an option. The DNO will calculate the impact of a distribution-connected option to the closest GSP(s). With this information, the ESO can then calculate the effectiveness factor of a distribution-connected option with respect to the reference point in the transmission network. Where available, the ESO engages with the system operator function of the distribution companies.
- 6.49 In an example below, system analysis suggests it is most effective to implement reactive power compensation at substation Y and that 100MVAR of reactive power absorption is required to meet the system requirement.

Figure 6.13a Reactive power compensation



- 6.50 Next, the ESO calculates the effectiveness for options connecting at substation Z with substation Y as the reference point. The ESO models reactive power compensation to absorb 100MVAR at substation Z and test it with selected backgrounds and conditions. In this example, analysis results show that (on average) implementing a reactive power compensation to absorb 100MVAR at substation Z reduces the compensation required at substation Y from 100MVAR to 25MVAR.

Figure 6.13b *Reactive power compensation*

- 6.51 The ESO can then approximate the effectiveness for any options connecting at substation Z as $(100-25)/100 = 0.75$ with respect to the reference point.

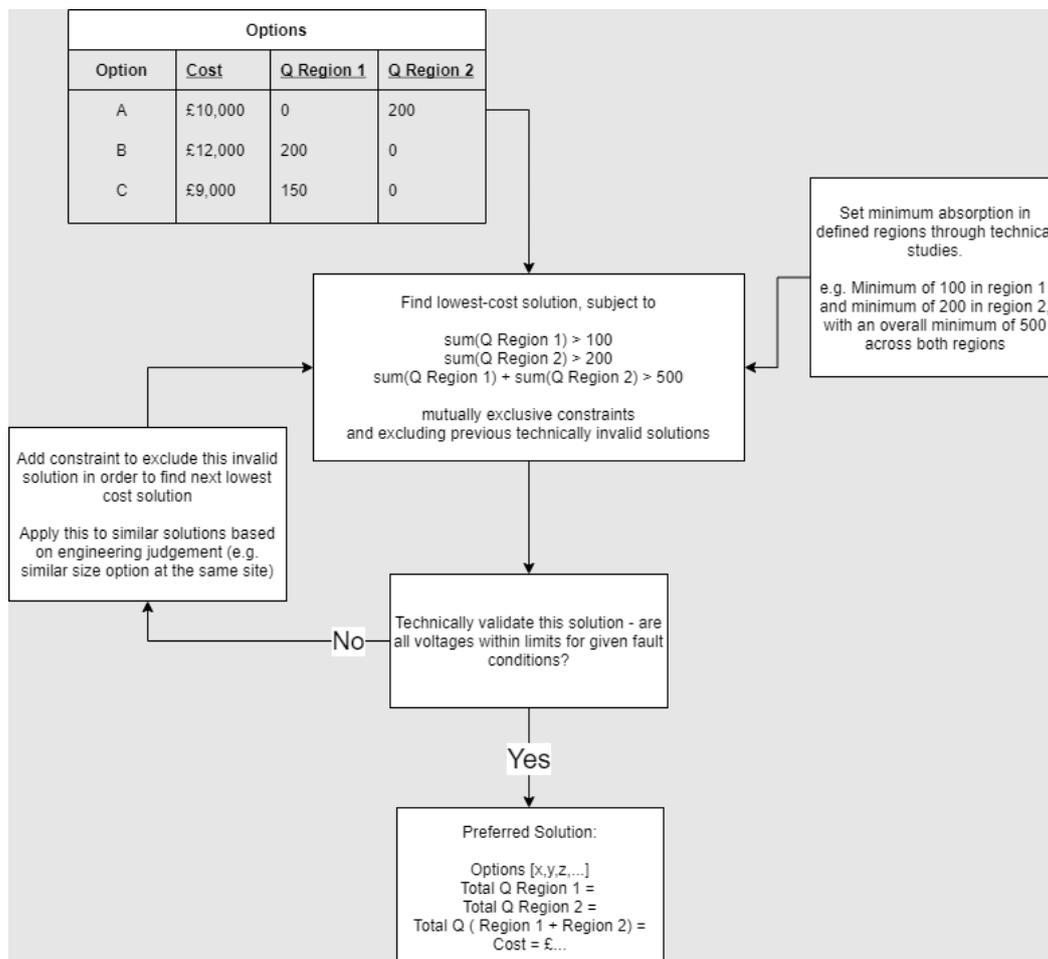
$$\text{Effectiveness factor} = \frac{\text{original compensation at ref. point Y} - \text{resulting compensation at ref. point Y}}{\text{size of option at Z}}$$

Joint Economic and Technical Optimisation approach

- 6.52 In some regions, it is not always possible to give a single effectiveness value for each site due to complexities in the network. In regions where there are several critical contingencies and solutions are required across multiple sites, we apply a joint economic and technical optimisation approach where combinations of all possible options must each be checked individually against the applicable criteria.
- 6.53 For cases where the requirement specifies any minimum criteria such as minimum amounts of MVar in a given region, the criteria will be applied when generating credible combinations.
- 6.54 The figure below illustrates an example process flow for a case where we have 2 regions under consideration (Region1 and Region2). In this example, technical analysis indicates some minimum requirements as follows.
- Minimum MVar in Region 1 = 100MVar (Q Region1)
 - Minimum MVar in Region 2 = 200MVar (Q Region2)
 - Total minimum MVar across Region 1 & 2 = 500MVar
- 6.55 In order to meet the total requirement of 500MVar, all possible combinations of all the submitted options will be generated. The minimum criteria applicable across the individual regions would be applied to further refine the list of option. All remaining options will be ranked from lowest cost.
- 6.56 The joint optimisation seeks to identify the lowest cost combinations of options which meet the minimum (region) requirements by creating a cost stack of feasible solutions. Technical analysis is then completed for each option combination, starting with the lowest cost combination to confirm if they are technically valid and result in a compliant network across both regions. If the first combination tested is not valid, the next lowest cost combination which meets the requirements is found and checked, moving to the third, fourth, and so on until a valid combination is found.

- 6.57 The preferred solution will be the most cost-effective combination of options which resolves all the high voltage issues in the region.

Figure 6.15: Example Joint technical and economic optimisation process



Communicating requirements

- 6.58 For regions where an Effectiveness Factor approach is applicable: The reactive power required to control voltage will be communicated to relevant parties in the form of “equivalent reactive power compensation to absorb X MVar at location Y”.
- 6.59 The ESO also provides information on the effectiveness of reactive power compensation or services installed away from location Y. This information could be presented in a heatmap. All effectiveness factors are relative to the same reference point(s). This is most likely to be the same reference point(s) stated in the requirement ie. “location Y” for consistency.
- 6.60 For regions where a Joint Economic and Technical approach is applicable: The reactive power required to control voltage will be communicated with reference to the total volume required within the region, with additional supporting minimum criteria as deemed necessary to support tender participants to locate their solutions appropriately.
- 6.61 The ESO will provide the same information on requirement to all potential option providers. Such information will be provided to the TOs using the System Requirement Form – Voltage (SRF-V). This uses a similar format and structure as the SRF used in the current NOA for network boundary flow. The same information will be provided to the DNOs and Commercial service Providers via the Tender Process.
- 6.62 For the avoidance of doubt, this does not imply other information which the TOs and DNOs currently have access to in accordance with the likes of SO-TO Code (STC) or Connection and Use of System Code (CUSC) for network planning purposes will be provided to all parties due to confidentiality reasons.

Requesting & collecting options

- 6.63 The ESO will invite potential solution providers including TOs, DNOs and Commercial Service Providers to propose options to meet the reactive power for voltage control requirements.
- 6.64 The ESO will ensure that reasonable timescales are provided for participants to submit their options.
- 6.65 Any parties interested to have their options considered by the ESO should respond to the invitation to tender for proposed options.
- 6.66 The TOs should respond using the SRF-V while the DNOs and Commercial service Providers should respond via the Tender Process.
- 6.67 For the avoidance of doubt, all options received will be assessed against each other using the same criteria. The different submission process reflects the difference in funding mechanisms - TO options will be recovered via the present transmission regulatory framework, while DNO and Commercial service options will be paid via the Balancing Service Contract. The ESO considers and assesses all options in the same CBA. See the section “Cost-benefit analysis” for more details.
- 6.68 The option collection process for each party is as follows:

Branch 1 – TO options

The exchange of option information between the ESO and the TOs will be by means of the System Requirement Form – Voltage (SRF-V). The outline of the SRF-V structure is shown in Table 6.1.

Table 6. 1 Outline of System Requirement Form - Voltage

SRF-V Part	Section title	Details
A	Requirement	Information on requirement in SRF-V Part A will be the same as the information published as part of the Request for Information (see Branch 3 for more details).
B	TO proposed options	TOs provide the information on their proposed options.
C	Outage requirement	TOs provide the expected outages required to connect new assets associated with their proposed options.
D	Not applicable	N/A
E	Option costs	TOs provide the costs on their proposed options. Information should include, but is not limited to: Capital cost, annual breakdown of cost, operation & maintenance cost, WACC etc.
F	Publication information	TOs specify the information which they give consent to the ESO to publish. The ESO will request consent from the TOs to publish the same level of information consistent with the way information from a DNO option or a Commercial service option will be published when the Tender Process concludes.

- 6.69 System requirements are sent to the TOs using SRF-V Part A. Unless stated otherwise, this also acts as the prompt to the TOs to propose options.
- 6.70 TOs are expected to submit their options to the ESO using SRF-V Part B, Part C and Part E. All costs supplied in the submission should be in current financial year base prices. SRF-V Part D is not used in the high voltage and stability management process.
- 6.71 The SO reviews the costs that the TOs submit with their options and check that they are reasonable. The SO checks the costs that the TOs submit against a range of costs for plant and equipment that the ESO has gained from recent experience. If any costs are outside of the range, the SO discusses the costs with the relevant TO. If, following discussions the ESO still

believes that the costs are outside of the expected range and will unduly affect the CBA, the ESO can omit the option from the CBA.

Branch 2 – DNO options

- 6.72 In the long term when a regulatory funding mechanism for DNO options is agreed, it is expected that DNO options will follow a similar route as TO options, but presently a suitable regulatory funding mechanism is not in place for the DNO options. Until a suitable funding mechanism is established it is expected that the DNO options will be paid via the Balancing Service Contract; hence DNO options will follow the same route as Commercial service options in the short term. Therefore, DNOs who wish to propose options should respond via the Tender Process.

Branch 3 – Commercial Service Tender Process

- 6.73 The ESO publishes the requirements to inform potential Commercial service Providers as part of a Request for Information (RFI). This includes the technical requirements which a Commercial service must meet to participate in the Tender Process. The ESO uses the RFI to gather information about options that could relieve the high voltage and stability issues. Where applicable, the ESO may directly proceed with a tender process without an RFI. In general, the ESO would like to understand the following before a decision to tender is made:
- The ability of the market to provide Commercial service options as alternatives to Network Owner options to control high voltage
 - The level of interest to provide a Commercial service to meet the identified long-term needs
 - The likelihood of achieving a more economical and efficient overall solution by considering a wider range of options
 - The delivery timescale of market-based options
 - Preferred contract options
- 6.74 The RFI information pack will include an indicative timeline for the Tender Process, including when a decision to tender will be made.
- 6.75 The ESO decides whether to tender based on the information received from the RFI. The decision will be published alongside a final timeline for the Tender Process.
- 6.76 If a decision is made to tender, the ESO will publish the Tender Process information pack with selected contract options. The ESO expects the requirements published in the Tender Process information pack to be the same as those published in the RFI information pack, and the assessment methodology to be consistent with this methodology document. Any exception will be stated in the Tender Process information pack. Details in the Tender Process information pack supersede the details from the RFI.
- 6.77 Any parties interested to have their Commercial service options considered by the ESO should respond to the Tender Process. Any responses should use the proforma published as part of the Tender Process information pack.

Creating voltage rules

- 6.78 Voltage rules are created to indicate the minimum number of generators required to meet voltage control requirements in a region. The voltage rules are formulated using system analysis results. This approach loosely simulates the close-to-real-time process for voltage management. Studies against generator sensitivities, as illustrated in the previous section, are carried out for each selected set of conditions to help determine the minimum number of generators required and define the voltage rules. Since generators differ in sizes, each generator will be assigned a size coefficient to reflect their different reactive power capabilities.
- 6.79 The ESO uses these voltage rules with the constraint cost modelling tool to simulate year-round system operation. The number of bid and offer actions required to maintain system voltages within the NETS SQSS can then be estimated.
- 6.80 The constraint cost saving for each proposed option can then be estimated. Representing those variations of study backgrounds and system conditions in the CBA is crucial to the credibility of the estimated constraint cost saving. These backgrounds and conditions will be built into the voltage rules and hence considered in the CBA.

Assessing options

- 6.81 When the ESO receives options from potential providers (TOs, DNOs, Commercial service Providers), these options need to be modelled and analysed so their actual impact to system voltages can be understood. The assessment often includes many options; and it may be necessary to group a few options together to create the solution which can meet the system requirement in a region. It may also be more economical and efficient to group options from various providers together ie. combining TO, DNO and Commercial service options, to meet the requirement. It is however inefficient and impractical to always assess – model and analyse - all possible groups of options. Therefore, the assessment process set out below is used to keep the modelling and analysis at a practical level.
- 6.82 The ESO will assess the options selected in the CBA and ensure those options satisfy the service and technical requirements before the final recommendation is made and the Tender Process concludes.
- 6.83 The ESO intends to analyse as many options and combinations as practically possible. Only if the number of options available means there are too many possible combinations, the ESO will perform a pre-assessment selection. For the avoidance of doubt, this pre-assessment selection is designed to keep the assessment practical for the high voltage management Process; the overarching principle of finding the most economical and efficient solution still applies.

Pre-assessment (applicable when a high number of options are available)

- 6.84 The ESO bases the pre-assessment selection on two main factors - effectiveness and cost. The pre-assessment aims at reducing the number of options to keep the number of possible combinations practical.
- 6.85 The ESO first calculates the equivalent effective MVAR compensation each option provides with respect to the same (set of) reference point(s) (effective MVAR). The relevant effectiveness factor is applied to each option according to its point of connection and its effective MVAR is calculated.
- 6.86 The ESO then considers the cost of the option. As the process considers options from TOs, DNOs and Commercial service Providers, it is expected that the costs of options will cover a range of service terms. Hence the cost per year of each option is used for comparison. See the section “Cost-benefit analysis” for more details on calculating the cost per year for each option.
- 6.87 The ESO considers the effective MVAR and cost per year of each option. A cost-effectiveness factor will be calculated for each option in the format £/effective MVAR per year.
- 6.88 Options are then ranked according to their cost-effectiveness factors. The options with greatest cost-effectiveness will be selected for the CBA.
- 6.89 For the regions where the Joint Economic and Technical Optimisation Approach is applicable, no pre-assessment is required, and all options will be placed in a price stack for evaluation starting with the lowest cost combination as discussed in the earlier section.

Cost-benefit analysis

- 6.90 The cost-benefit analysis, as mentioned in previous sections, provides investment recommendation based on two primary factors – monetised benefits or security and operability. As a general principle, if there are several options which meet the requirement and satisfy either of the two primary factors, the CBA chooses the most economical and efficient options.

How does the ESO estimate constraint cost?

To estimate constraint cost, the ESO uses the same constraint cost modelling tool as NOA – Energy Exemplar’s Plexos. This provides consistency with NOA. The ESO uses Plexos to model a European economic dispatch and a GB constrained dispatch (re-dispatch). More information on how we run the cost benefit analysis can be found in section 2 of the NOA Methodology.

The tool is used to work out constraint (bid and offer) actions required to maintain voltage compliance against future simulated scenarios. The criteria applied to evaluate constraint actions for high voltage control is different to those used by NOA to determine network boundary flow related constraint actions. The criteria are linked to the minimum number of local generators required on the system to maintain voltage compliance by means of voltage rules. This requirement is informed by analysis on credible future backgrounds and system conditions.

Plexos applies voltage rules to simulate the bid and offer actions required to maintain voltage compliance. The focus here is to represent the reactive power capability of generators while keeping the MW cost as low as possible, therefore the cost to move a plant to its minimum stable generation position is priced. Where applicable, footroom requirements will be considered.

The high-level process for estimating constraint cost using Plexos is outlined below.

1. Run an economic market dispatch
The Plexos model is dispatched for each future energy scenario.
2. Run a network constrained re-dispatch
Apply the forecast boundary capabilities and constraints based on the latest FES database and NOA investment recommendations. Re-dispatch the network as per the previous step.
3. Extract hourly data for pertinent plants for the voltage rules
For the areas under consideration and according to the voltage rules determined from the technical studies, extract the hourly data relevant for all options under consideration.
4. Examine the hourly data to see what is required to fulfil the rules
For each option, examine in turn the hourly data to see whether the rules are complied with or what actions need to be taken for them to be complied with. This then creates a list of actions for each option which need to be taken for every hour for the validity of the rules and for each scenario.
5. Cost the actions required based on bid and offer prices and minimum stable generation
The cost of the bid and offer actions is taken from the assumptions made within the Plexos model and the actions required to meet the voltage rules costed.

How does the ESO estimate utilisation cost?

Utilisation cost will be dependent on a range of factors, such as the following:

- Rate: The ESO applies the current ORPS rate²⁸ or the contracted rate where applicable.
- Point of connection: Utilisation varies depending on where an option is and the network topology at its point of connection.
- Service duration: Duration an option will be active ie. how often the ESO expects an option will be required to control high voltages.
- Equipment used: The different equipment used to provide the Commercial services affects how often and how long an option will be used.
- System needs: For example, whether the reactive power capability is required pre-fault and/or post-fault will impact how often and how long an option will be used.

It is impractical to calculate utilisation based on fixed point system analysis as utilisation varies with system conditions. To fairly recognise the utilisation cost, the ESO estimates it based on how the BM units or newly proposed options are anticipated to be used.

²⁸ The rate which the ESO pays BM providers for utilisation in £/MVAh under the default payment mechanism. The utilisation payment is updated monthly in line with market indicators as set out in Schedule 3 of the Connection and Use of System Code (CUSC).

- 6.91 The CBA considers various factors, including but not limited to:
- System requirements for controlling high voltages
 - Point of connection of option
 - Effectiveness
 - Assessment period
 - MVAR capability provided by proposed option
 - Flexibility to offer only part of the MVAR capability of proposed option
 - Earliest-in-service date (EISD)
 - Costs including costs to cover outages requirements for unavailability of the provider, either due to their own outages or network outages
 - Cost of electrical losses
 - Credible events that could give rise to loss of multiple providers
- 6.92 In previous sections, system requirements, point of connection and effectiveness have already been discussed in detail.
- 6.93 Assessment period is defined as the years over which the future voltage control requirements are reasonably clear and certain. This should be the same as the period for which the Tender Process requests for options.
- 6.94 Options may provide different MVAR capability in each year.
- 6.95 In some cases, a provider who can offer only part of the MVAR capability of its proposed option may help achieve an overall solution of lower cost to consumers. The ESO considers this flexibility when they select options to form the most economical and efficient solution(s).
- 6.96 EISD refers to the earliest date when an option will be available to provide the required reactive power.
- 6.97 The cost to provide the service can be split into capital costs and operational costs. All costs submitted should be in current financial year base prices. Table 6.2 below provides the various element of costs to be included as the capital cost and operational cost in TO options, DNO options and Commercial service options.

Table 6. 2 Details of capital and operational costs for each type of providers

Option providers	Capital cost	Operational cost
TOs	<ul style="list-style-type: none"> • Cost of the new assets associated with an option • WACC to be applied to regulated assets 	<ul style="list-style-type: none"> • Maintenance • System access • Other ongoing operational cost associated to the option
DNOs	<ul style="list-style-type: none"> • In the short term while the DNO options will be paid via the Balancing Service Contract, the cost of DNO options should be submitted via the Tender Process and in the same format as required by the Tender Process. 	
Commercial service Providers	Cost of connecting any new assets associated with an option to the electricity system (transmission or distribution)	<ul style="list-style-type: none"> • As per contract, which may include: <ul style="list-style-type: none"> ○ Availability payment ○ Utilisation payment

- 6.98 The capital cost is any infrastructure cost that will be incurred by a Network Owner (TOs or DNOs). The ESO applies the weighted average cost of capital (WACC) to any network infrastructure costs that will be incurred due to an option. The ESO will seek this information directly from the relevant Network Owner(s). The capital cost should be submitted as a spend profile, which indicates the financial year in which the capital will be spent. Costs should be in a single, specified price base year which is consistent with the base year used for tender bids.

Table 6. 3 Example of spend profile

Year	2020/21	2021/22	2022/23
Cost £m	5	10	8

- 6.99 The operational cost should include any maintenance, system access and other ongoing costs. The operational cost will be applied for each year that the option is utilised. The operational cost submitted may vary by year.
- 6.100 The benefits that each option provides will be discounted at the social time preference rate as laid out in the Treasury Green Book²⁹. This process results in the present value (PV) of each cost and benefit.
- 6.101 The ESO first calculates the equivalent effective MVAR compensation each option provides with respect to the same (set of) reference point(s) (effective MVAR). The relevant effectiveness factor to each option is applied according to its point of connection and its effective MVAR is calculated.
- 6.102 The ESO then calculates the cost of providing an effective MVAR for each option. The operational cost per effective MVAR will be calculated as the PV operational cost per year divided by the quantity of effective MVARs provided.

$$PV\ Op.\ Cost\ per\ eff.\ MVAR = \frac{PV\ Operational\ cost\ per\ year}{eff.\ MVARs}$$

- 6.103 The capital cost will be calculated as the PV capital cost divided by the product of the quantity of effective MVARs and the number of service years. Service years is defined as time that the option will be available and cost-effective within the assessment period.

$$PV\ Capital\ Cost\ per\ eff.\ MVAR = \frac{PV\ Capital\ Cost}{eff.\ MVARs \times Service\ Years}$$

- 6.104 The sum of the operational and capital costs per effective MVAR will be the cost per effective MVAR for the option.

$$PV\ Cost\ per\ eff.\ MVAR = PV\ Op.\ Cost\ per\ eff.\ MVAR + PV\ Capital\ Cost\ per\ eff.\ MVAR$$

- 6.105 The goal of the CBA is to find the most economic and efficient solution(s) to the problem for the GB consumer. An optimisation will be carried out across all years within the assessment period simultaneously to find the cheapest solution(s). This is to take into account the capital cost of each option which is independent of the number of years that the option is considered optimum.
- 6.106 With the cost per effective MVAR calculated, the bids will be stacked, with the lowest cost per effective MVAR at the top, and the highest at the bottom. In general, bids will be selected from the top first until the system requirement for effective MVARs has been met. The stack order may be altered if more cost-effective combinations become apparent.
- 6.107 The ESO may conduct this process for every year individually or across the entire assessment period as deemed appropriate.
- 6.108 A provider may submit an optimal bid in one year, but this does not guarantee the bid will be optimal in subsequent years if lower cost options are available. The lowest cost solution(s) over the entire assessment period will be chosen. Note that in some cases this may result in a more flexible or smaller option that is more expensive per MVAR to be chosen.
- 6.109 Within each yearly stack, the ESO forecasts the cost of procuring the system voltage need through the BM. This will be done by modelling future GB electricity markets using the latest future energy scenarios and assessing within each settlement period which generators will be able to provide a solution to voltage issues. The BM costs for procuring the need will be again converted into a cost per effective MVAR which will be placed within each yearly stack to compete against the submitted options.
- 6.110 An example of the stacks and the selection of winning bids (highlighted green) is shown below in Table 6.4. Please note that the costs shown are not reflective of any forecast, they have simply been chosen for demonstration purposes.

²⁹ <https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-government>

Table 6. 4 Example of selection of options based on cost per effective MVar to achieve a solution with most economical and efficient total cost

System need: 200MVar				
Provider name	Flexible?	Provider effective capability (MVar)	Cost per effective MVar (cost/MVar)	Cost
Provider 1	Yes	50	10	500
Provider 2	Yes	100	14	1400
Provider 3	No	25	15	375
Provider 5	Yes	50 (25 procured)	18	450
Provider 4	No	50	17	
BM	Yes	200	22	
Provider 6	Yes	100	30	

- 6.111 The total cost in Table 6.4 is $500+1400+375+450=2725$. Note that Provider 5 is selected ahead of Provider 4 even though Provider 5 has a higher cost per MVar. This is because Provider 5 is more flexible and allows the system need to be met exactly. Using Provider 4 would result in the system need being exceeded by 25MVar and result in a higher total cost ($500 + 1400 + 375 + 850 = 3125$). There is a cheaper (although not the cheapest) solution where Provider 4 is selected ahead of Providers 3 and Provider 5. This solution has a cost of $500 + 1400 + 850 = 2750$ and exactly 200MVar is procured. In some cases, the system operator may allow excess MVar to be procured if this would result in a lower cost for the consumer and pose no operational issues.
- 6.112 The CBA recommends the options which should be taken forward. Given the size of the investments and the short lead times, these recommendations are a single lifetime decision. This means that when an option is recommended, that recommendation persists until the asset or service contract expires. This is different to the normal annual NOA least-worst regret (LWR) recommendations which are reviewed annually. Where a recommendation is marginal, the decision may be to reassess at a later date when there is greater certainty of the need. This is only possible where the EISD of the option is ahead of the need and so the option can be delayed.

The Stability Management Process

Regional approach

6.113 At a regional level, the distribution of regional inertia, short circuit level, dynamic voltage support can influence the stability of the local network and its users. The regional stability requirements are determined by the configuration of the local network and the nature of generation and demand in that region. Since short circuit current and reactive power, unlike real power, cannot be sent across long distances due to the reactance of the transmission network, it is most effective when applied close to the problem. Stability issues can therefore be grouped into regions and assessment of each region conducted separately. The stability management process looks into the stability needs on a regional basis.

Screening process – selecting and prioritising regions

6.114 The ESO uses a screening process to help identify and prioritise the region(s) which should be further explored through detailed power system and cost-benefit analysis. This should bring consumers the best value by ensuring the secure, economical and efficient development focuses on challenging regions first. The screening process considers future trends of generation and demand and their potential impact of system operability due to decline in regional system strength (short circuit levels), regional inertia and regional dynamic voltage support.

6.115 The ESO will request feedback from the TOs as to which region(s) they believe should be assessed.

Creating network models for analysis

6.116 The ESO will start with the GB system planning models to produce and update elements within it to ensure the models are fit for this purpose. Future backgrounds based on Future Energy Scenarios (FES) and system conditions considered appropriate based on expected trends of decline in regional system strength (short circuit levels), regional inertia, regional dynamic voltage support will be applied to the models for assessment.

Identifying requirement

Collaborating with TOs/ DNOs to optimise existing assets

6.117 This part of the process is similar to the one from high voltage management project (please see paragraph 6.27-6.29).

Analysing the size of the stability requirement

6.118 The ESO identifies the stability requirement based on system analysis. The requirement varies depending on the future backgrounds and system conditions. It is not practical to fully analyse all combinations of backgrounds and conditions. Hence, the ESO selects snapshots based on data mining techniques and engineering judgement to represent a fair number of variations of backgrounds and conditions. For stability analysis, the ESO considers future outlook of FES scenarios on regional short circuit level, regional inertia and regional dynamic voltage. This allows ESO to choose a generation and demand background to be studied in detail. The ESO determines the regional stability requirements by running time series fault simulations in an RMS tool for a selected generation and demand background. The ESO carries out sensitivity scenarios to complete its detailed analysis. The ESO also considers how often such a need could arise in future.

6.119 The regional stability needs are determined by understanding regional voltage and frequency behaviours within a period of a transmission system disturbance (transmission system faults can last for up to 140ms), at fault clearance and immediately after a fault clearance and for at least 500ms after fault clearance. The stability of voltage and frequency waveforms allows ESO to understand the risks on the transmission system and to quantify the stability requirements.

Calculating effectiveness factors

6.120 To allow a fair comparison to be made for all potential options, effectiveness factors are used when the ESO assesses options. The general principle used to calculate the effectiveness of an option is similar to the one in high voltage project (please see paragraph 6.36-6.44), instead of calculating effectiveness of options to provide reactive support, the effectiveness of option to provide short circuit current and/or dynamic reactive support is calculated for stability management process. More details will be published in any stability tender based on regional stability needs.

Communicating requirements

6.121 Communicating process for system requirement between ESO and stakeholders is similar to the one from high voltage process (please see paragraph 6.51-6.55), instead of using SRF-V, SRF-S is used to exchange data.

Requesting & collecting options

6.122 This part of the process is similar to the one from high voltage (please see paragraph 6.56-6.70), instead of using SRF-V, SRF-S is used to exchange data.

Assessing options

6.123 Process is again very similar to high voltage management (please see paragraph 6.74-6.76), a cost-effective factor is calculated for each option in the format £/effective MVA per year (as opposed to the £/effective MVar per year used in high voltage management project) in order to compare and rank them in the CBA process later on.

Cost-benefit analysis

6.124 In principle, a similar methodology to high voltage is used (please see paragraph 6.83). The stability cost benefit analysis will be dependent on drivers behind each region's stability requirements. For example, in Scotland the ESO's stability needs are primarily driven by low short circuit level, whereas in other areas of GB there may be different drivers. The stability cost benefit analysis will also take account of active power export for each option and discount providers due to the cost of balancing their active power elsewhere. The ESO will publish detailed assessment methodology applicable to a stability tender as part of a tender process.

High Voltage and Stability Process conclusion

6.125 Based on the results of the CBA, the ESO recommends the solution which should be taken forward. The recommended solution could consist of only TO option(s), only DNO option(s), only Commercial Service Provider option(s), or any combination of these three types of options. If the CBA concludes that none of the options proposed in the process provides benefits against forecast BM cost to control high voltages, the ESO may accept no Network Owner options and/or Commercial Service Provider options.

6.126 If the recommended solution consists of TO option(s), the ESO will write to the relevant TO(s) to inform them of the recommendation to support an investment case.

6.127 If the recommended solution consists of Commercial Service Provider option(s), the ESO will contact the relevant provider(s) after publishing the tender outcome and proceed with procuring the selected option(s) using the Balancing Service Contract.

6.128 If DNO option(s) are recommended, in the short term while the DNO options will be paid via the Balancing Service Contract, the ESO will proceed with the DNO option(s) in the same way as with any Commercial Service Provider options.

Tender outcome

6.129 Tender outcomes will be announced as soon as reasonably practicable once the analysis and other relevant verification and approval process conclude. Tender outcomes will be published on the ESO website.

Tender documentation

- 6.130 All tender related documentation will be published on our dedicated website throughout the process. This will include any pre-tender, tender and post-tender documentation. This will include the technical and commercial methodologies, technical specifications, feasibility study guidelines, contractual terms and all other relevant data to support the tender activities. Tender outcomes will also be published on our website.

The Constraint Management Process

Annual NOA assessment of ESO Constraint management solutions

- 6.131 As part of the NOA process, the ESO can propose alternative options to be assessed. Constraint management solutions are an example of the Automatic MW redistribution options described in Chapter 2 of this methodology.
- 6.132 The ESO initiates the development of constraint management solutions during the NOA process by assessing the need for constraint management solutions across constrained system boundaries. Solutions that receive a “Proceed – Critical” signal from the NOA are then progressed for further development.

Prioritising regions

- 6.133 The regions with “Proceed – Critical” ESO-led constraint management solutions are prioritised based on their forecasted constraint costs, and timing of the system need.
- 6.134 The ESO engages with the relevant TO(s) on which region(s) the ESO is planning to deliver constraint management solutions following NOA recommendations.

Understanding needs

- 6.135 At this stage, the ESO will carry out both economic and technical analyses to clearly define the system needs for the region(s) prioritised. The economic analysis forecasts the constraint costs over the next ten years while taking account of the NOA optimal reinforcement path. For the years with high constraint costs, the technical analysis conducts system studies to identify the causes of constraints, eg. thermal, voltage or stability issues, under different operational scenarios.

Economic analysis

- 6.136 The ESO economic study uses the Plexos model and the FES background data to simulate the electricity market operation within the region. Following the NOA process outlined in Chapter 2, the study forecasts the number of periods in each year when the constraint is active, i.e. the boundary flow is higher than the boundary transfer capability. The study then calculates the associated constraint cost per year by taking balancing mechanism actions to re-dispatch generation to meet demand.
- 6.137 To demonstrate the business need of constraint management solutions, the economic study currently uses system to generator intertrip options with different MW volumes as a commercial service to increase the boundary transfer capability and alleviate constraints. An average effectiveness of commercial intertrip is used based on the technical analysis output. The economic analysis provides potential cost savings across the next ten years by taking account of the capital investment, arming fees and lead time of delivering intertrip services.

Technical analysis

- 6.138 The ESO study aims to define the technical requirement for a constraint management solution by assessing the thermal, voltage and stability criteria as per the NETS SQSS. In addition to the ETYS/ NOA boundary capability assessment, the analysis will:
- focus on the earliest year expected to deliver a constraint management solution, which is usually the year when the constraint cost starts increasing significantly due to the high uptake of generation in the year as forecasted by the FES.

- study a range of snapshot scenarios by taking a joint view of long-term network development and day-ahead planning. The scenarios cover winter peak and summer minimum demands with various generation and interconnector backgrounds.
 - utilise the latest NOA reinforcement options expected to be delivered in the region, and model intertrip as an example of constraint management solutions to resolve any thermal, voltage and stability issue encountered in each scenario.
- 6.139 The ESO will start with the GB system planning models to update and produce elements within it to ensure the models are fit for this purpose. Future backgrounds based on FES and system conditions considered appropriate in accordance with the NETS SQSS will be applied to the models for assessment.
- 6.140 The study calculates the effectiveness of using intertrip as a potential constraint management solution to relieve constraints. The effectiveness indicates how effectively tripping off generation helps increase the power flow through a constrained boundary, expressed as a percentage of the total volume of the intertrip service.

$$\text{Effectiveness} = \frac{\text{Change in the boundary transfer capability (MW)}}{\text{Total volume of commercial intertrip (MW)}} \times 100\%$$

For example, an effectiveness of 70% means allowing post-fault intertripping 1GW generation would increase the boundary transfer capability by 700MW. The effectiveness factors are calculated for all scenarios and provided to the economic analysis. The study also assesses the effectiveness of intertrip options with different amounts of active power, up to the largest infeed loss that can be securely tripped off the system without leading to instability or large disturbances on the network.

Gathering options

- 6.141 Once the economic driver and technical requirements for a constraint management solution are defined, the ESO can decide whether to adopt an existing solution such as setting up a commercial intertrip market or request information from the market. The latter would be via Request for Information (RFI) to seek options that could better meet the need.
- 6.142 If a commercial intertrip service is being considered as an option, the ESO will collaborate with TO(s) to check the current status of any Operational Intertrip Scheme (OTS) that already exists in the region. Depending on the issues identified, the existing OTS (if any) might be able to be adopted for the commercial intertrip, or it needs to be upgraded with additional functionalities, e.g. fast reactive switching to help maintain post-fault system stability.

Solution development

- 6.143 Based on the options received, the ESO will validate the solutions to see how they fulfil the technical and commercial requirements. A cost-benefit analysis will be carried out to prioritise a solution or a range of solutions to progress.

Commercial Assessment/ CBA

- 6.144 The ESO will conduct a cost-benefit analysis to commercially evaluate solutions. To assess the most economic solution, potential savings will be analysed. These will be calculated via simulating the costs of the balancing mechanism with the solution in place (which includes the boundary transfer capability of the intertrips) and comparing them to the ones of the counterfactual case. The cost of the solution will be then subtracted, and the result will be discounted using the rate provided by HM Treasury in the Green Book, resulting in the present value of the solution savings. In particular tenders, we may need to limit the number of options which can be awarded an agreement. The details will be part of the tender documentation, but this is likely to be by accepting a certain number of options or MW capability based on the lowest submitted prices.
- 6.145 If a commercial intertrip service is recommended to be developed, the ESO will launch a public consultation on the draft service requirement and contract, following with an Expression of

Interest (EOI) to collect information on participants which are interested in offering an intertrip service. The ESO will conduct a feasibility study to assess the interested participants against the technical criteria of delivering the service. The feasibility study requires studies from TO(s) to confirm if the service providers could be connected to the existing OTS by the requested service period and hence can participate in the tender.

6.146 In the commercial tender stage, participants are expected to submit arming and utilisation (tripping) prices to the ESO. To determine the cheapest MW volume available to provide the service, the following process will be used:

1. Identify all possible unit size combinations across the available number of channels in the intertrip scheme.
2. If required, apply an average outturn factor to the submitted output capacity of the relevant units. This is important as a significant proportion of generation can come from wind, which rarely achieves 100% output. Therefore, the outturn factor helps to ensure that the MW volume is always achieved.
3. Filter and remove the combinations that do not meet the MW volume requirement. To ensure no single unit (N-1) being unavailable leaves the remaining MW volume under the requirement, the largest unit on a stack of generators shall be removed from the combination to see if the requirement is still met/exceeded.
4. The arming and utilisation (tripping) fees will be used to identify the lowest cost combination of units. The lowest priced combination will be awarded the contracts.
 - For the arming assessment, appropriate arming assumptions will be made. The ESO will assume H-hours (2H settlement periods) of arming per annum (units are expected but not guaranteed to be armed between H-hours a year).
 - The ESO expect the fault to be a rare occurrence. Subject to all involved units adhering to network policy for asset and maintenance and assumed historical weather conditions, the fault is expected to occur once every 25-years.
 - From the previous assumptions, the utilisation (tripping) fee will be calculated on a pro-rata basis and added to the arming fee per settlement period.

$$\text{Combination price} = \sum_{i=1}^n \left(\text{Arming fee per SP} + \left(\frac{\text{Tripping fee}}{2H \times 25} \right) \right)_i$$

TO Feasibility Studies

6.147 The ESO will initiate feasibility studies with the relevant Transmission Owner(s). The ESO will provide the EOI responses to the TOs who will thereafter advise the ESO:

- If a service provider meets the ESO's requirements of the commercial intertrip service.
- If the service provider can be connected to any existing OTS by the requested service start date.
- The TOs will be looking to ensure that there is no disruption to another party connected behind the identified transmission circuit breaker. If another party is connected behind the same transmission circuit breaker or downstream of the interested party, then the outcome of the TO Feasibility Studies will be a failure if the other party is not in agreement with the conditions of being tripped off post fault or participating in the commercial intertrip service.

Solution delivery

6.148 A tender will be conducted at this stage to procure the constraint management solution.

6.149 The ESO will develop and publish the commercial assessment principles, service specification and contracts, tender platform with a clear timeline for delivery of the project.

6.150 Once contracts are awarded, the ESO will start to implement the infrastructure needed to deliver the solution, e.g. network, IT, training and resources. In the case of implementing a commercial intertrip service, the ESO will engage with the successful service providers and relevant TO(s) to commence the service.

Constraint Management Process Conclusion

- 6.151 Tender outcomes will be announced as soon as reasonably practicable once the analysis and other relevant verification and approval process conclude. Tender outcomes will be published on the ESO website.
- 6.152 The developed constraint management solution will be considered in background when assessing boundary capabilities in the next NOA annual process.
- 6.153 As constraint management solutions are currently being designed to be flexible around when the system needs emerge and decline, the contractual periods are expected to be short term. This allows flexibility for the ESO to revise the need and make improvements to deliver constraint management solutions that maximise consumer benefits.



7

**Early development of options
and Interested Persons' process**

Early development of options and NOA Interested Persons' process

Introduction

7.1. Licence condition C27 obliges the ESO to undertake the early development of options (see paragraphs 23 and 24 of licence condition C27) and assess options from interested persons (see paragraph 16(a)(viii) of licence condition C27) among others. This methodology section describes how the early development of options and the Interested person' processes work:

Early development of options

7.2. The ESO undertakes the early development of options where early development is not carried out by another transmission licensee or an option is suggested by other interested persons. The ESO will assess whether the option has demonstrable benefit. A demonstrable benefit would be where the mitigation of a constraint is in a credible range and at a competitive cost. The ESO might do development by, for example, modelling the network and/or options. The ESO must do the early development to such a standard that it can perform economic studies on the options to adequately compare the relative suitability of options.

7.3. The ESO publishes the System Requirements Form that provides the information to the industry about system needs and hence opportunities for them to invest.

7.4. Note that early development of options is different from ESO-led options such as commercial solutions. A 'commercial solution' is a contract with a generator for the output of that unit to be reduced or disconnected following a system fault.

7.5. The ESO accepts that its limited capability to study options' costs and earliest in-service dates may limit the accuracy of its view of the costs of options it is developing. The consequence of this could be that an early development option has unduly favourable results at first which displaces and delays alternative options. The ESO may make its costs and earliest in-service dates available for scrutiny which could lead to it revising the data put into the NOA economic process.

7.6. Following the review of options submitted for the NOA process, the ESO will consider the following aspects when determining whether to undertake early development of options:

- **Insufficient NOA Options:** Where there are not enough options to meet the requirements on each boundary, the ESO may undertake early development. We assess whether the options are sufficient by comparing the capabilities against unconstrained flows modelled in Plexos. This will be followed by initial screening to test if options are technically effective with some consideration of the cost.
- **Abandoned Options:** If an option has been initially devised in NOA but then not re-submitted in a subsequent NOA, the ESO will seek to understand why the option has been abandoned and may/ may not decide to pursue the option.
- **Options not progressed by relevant TO:** The ESO may develop an option that the TO or relevant party has declined to adopt and develop.

Interested Persons' Process

7.7. The purpose of Interested Persons' options is to increase the diversity of options considered within the NOA process through academic and industry participation. Options submitted through this process are required to be new and innovative and not currently assessed in NOA.

7.8. Interested persons can suggest options and where they can give demonstrable evidence of benefit to meet system needs, the ESO, and TO as required, can support them with further analysis or studies. In some cases, the ESO might conclude that previous work, perhaps by

a TO, has found that a particular option is impractical or not worthwhile in which case there is no further action.

7.9. The ESO will apply a screening stage to filter options from interested persons if there are many and it is clear that some are more beneficial than others. This may be found by engineering judgement based on the following factors:

- Genuine network need.
- Operability.
- Practicality, for instance delivery date.
- Understanding of the costs.
- Whether the same or similar option has been considered before and ruled out for good reason.

During the filtering process the ESO will also check to see if the Interested Persons option is better suited to alternative processes such as our voltage and stability procurement events or Innovation projects. If this is the case, the option may be recommended to be put forward to the alternative process.

7.10. When the ESO carries out early development of an option, it needs to be able to determine the option's benefit, for instance how much it improves boundary capability, the cost and also the earliest in-service date. These are the key factors in the cost-benefit studies. The ESO forms a view on these using the following considerations:

- What the ESO's aim is, for example to improve capability when all other options have been exhausted. This provides an introduction to the nature of the option and the ESO's thinking such as new reactive compensation and new circuit(s).
- The existing parts of the network that are affected, such as connection points for new circuits as well as other network topology changes.
- Technical parameters of the solution to allow technical studies of the option and determine, for instance, boundary capability and related effects such as fault levels. This might affect the overall benefit of the option as the net gain might be reduced or an investment like circuit breaker replacement might be needed elsewhere if fault levels exceed existing ratings. An estimate of the capital cost and earliest in service date based on public cost data and making certain assumptions such as the proportion of a new route that is cable. The ESO consults with the relevant TOs about such examples for their views about an option's practicality.

7.11. The early development of Interested Persons' options will be an ongoing collaborative process between the provider, NGE SO and the incumbent TO, as appropriate. This will ensure proposed options are fully understood and sufficiently developed whereby it is demonstrated they can provide a benefit ahead of inclusion in the NOA CBA. For an Interested Persons' option to be considered for the forthcoming NOA, it must be considered technically competent, mature and submitted before the start of technical analysis.

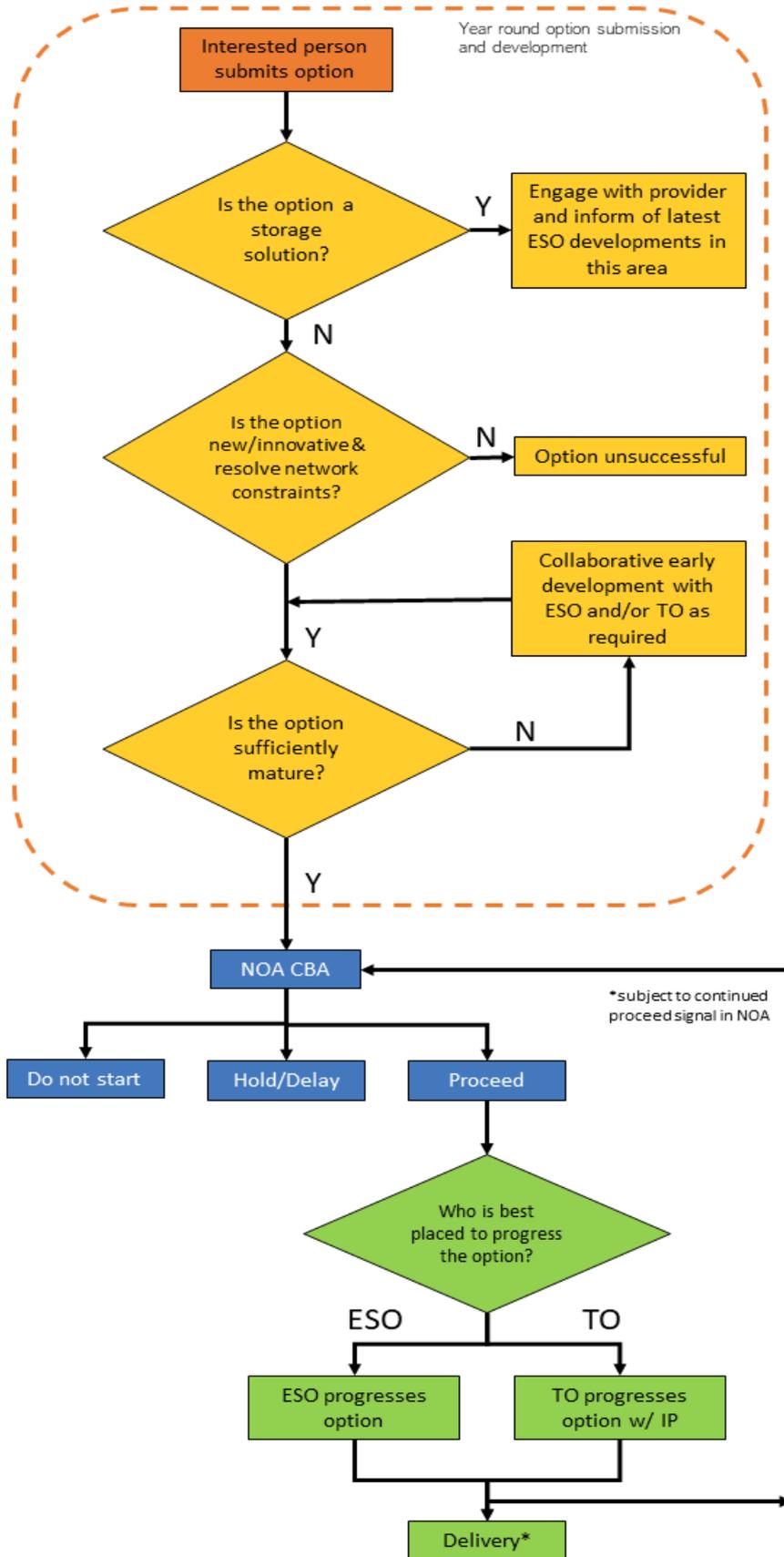
7.12. Providers will be able to submit options year-round through a publicly available System Requirement Form (SRF).

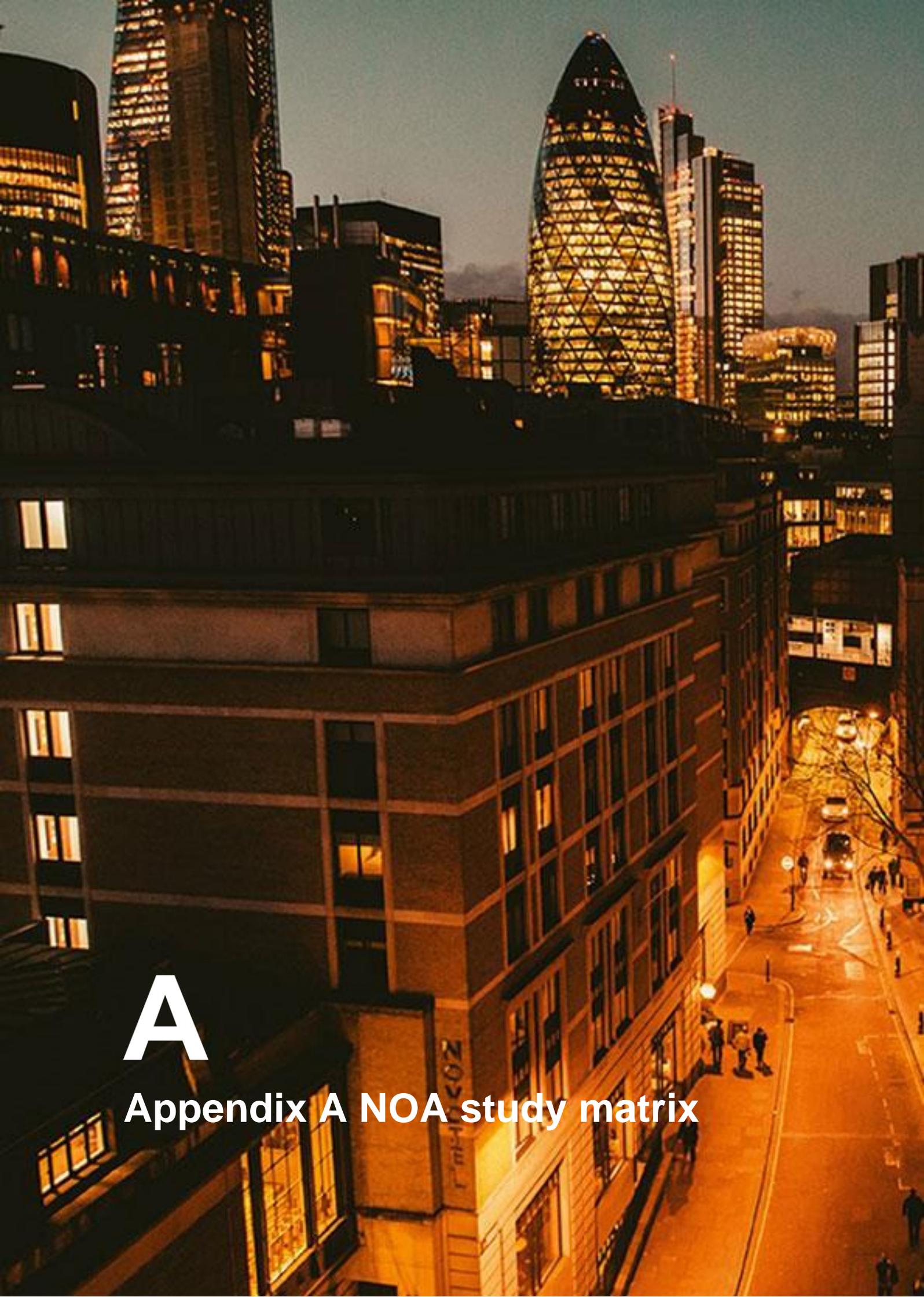
7.13. Interested Persons' options must be a response to system needs and deemed sufficiently mature before the ESO will grant their inclusion for assessment in the NOA CBA. Where deemed insufficiently mature, the option(s) will be developed in collaboration with the third party and incumbent TO until such time that all parties agree the option is ready for NOA assessment or until the need is met or no longer required. If an option's benefit cannot be clearly demonstrated, then the ESO can either work with the Interested Person if the ESO

believes there could be some benefit or the ESO explains to the Interested Person why the option is being rejected.

- 7.14. At present the Interested Persons process will not assess storage options, this includes pumped storage, battery storage, compressed air, and all other storage technologies. Due to complexity challenges (see [Storage in NOA supplementary note - Methodology 2021](#)) we believe the benefit of this technology is best assessed through a separate process rather than the NOA. The benefits of using storage to reduce constraint costs are being investigated within a separate workstream under our [5-Point Plan](#) to manage constraints in the system. The outcome from this will feed into how storage can be utilised for the purpose of boundary benefit and whether storage can be taken forward within the NOA.
- 7.15. The framework to enable non-TO entities to deliver NOA reinforcements was set out in the Energy White Paper. This would enable third parties to compete to become Competitively Appointed Transmission Owners (CATOs). The introduction of legislation to enable this is underway and the ESO is establishing a tender process to run early competitions. These are competitions for the design, build and operation of reinforcements. The ESO envisages that the interested person's process will evolve to enable third party input into the initial solution development for projects that may be completed.
- 7.16. In advance of the frameworks described above, it is anticipated that all successful non-ESO led Interested Persons' options will be developed and owned by the relevant TO. The development will require close collaboration with the Interested Persons.
- 7.17. The ESO may seek the input of the relevant TO(s) to help it understand the factors that might affect an option. The ESO will not undertake consenting engagement work on options – this will be carried out at the appropriate development stage, by the relevant party, following a "Proceed - Critical" recommendation. Following a NOA "Proceed - Critical" signal, the Interested Persons' options will be delivered by the incumbent TO(s) or, if appropriate via the ESO, through standard procurement and regulatory frameworks. Figure 7.1 shows the Interested Persons' process in a flowchart.
- 7.18. Year on year progression of Interested Persons' Options will be subject to continued "Proceed - Critical" signals in the annual NOA CBA.

Figure 7. 1: Interested Persons' Process flowchart.





A

Appendix A NOA study matrix

Assumption/Condition		Comments
Generation and Demand Scenarios	Leading the Way	Technical and economic assessment of the reinforcement options; sensitivity studies where appropriate
	Consumer Transformation	Economic assessment of the reinforcement options and technical assessment as required; sensitivity studies where appropriate
	System Transformation	Economic assessment of the reinforcement options and technical assessment as required; sensitivity studies where appropriate
	Falling Short	Economic assessment of the reinforcement options and technical assessment as required; sensitivity studies where appropriate
Seasonal Boundary Capability	Winter Peak	Technical and economic assessment of the reinforcement options
	Spring/Autumn	Technical and economic assessment of the reinforcement options. Technical assessment of boundary capabilities can be calculated based on agreed scaling factors from winter peak capabilities which are validated against benchmarked results. Benchmarking is subject to availability of the model and agreement on generation despatch
	Summer	Technical and economic assessment of the reinforcement options. Technical assessment of boundary capabilities can be calculated based on agreed scaling factors from winter peak capabilities which are validated against benchmarked results. Benchmarking is subject to availability of the model and agreement on generation despatch
Boundary Capability Study Type	Voltage Compliance	
	Thermal	
Contingencies	N-1-1	
	N-1	
	N-D	
Network Reinforcements	Build reinforcements	
	Reduced-build reinforcements	Assessment of reduced-build reinforcement options

Assumption/Condition		Comments
	Operational reinforcements	Assessment of operational options
Study Years	Year 1	Assessment of alternative reinforcement options subject to availability
	Year 2	Assessment of alternative reinforcement options subject to availability
	Year 3	Assessment of alternative reinforcement options subject to availability
	Year 4	Assessment of build and alternative reinforcements options excluding those subject to Ofgem agreement
	Year 5	Assessment of build and alternative reinforcements options excluding those subject to Ofgem agreement
	Year 7	Assessment of build and alternative reinforcements options excluding those subject to Ofgem agreement
	Year 10	Assessment of build and alternative reinforcements options excluding those subject to Ofgem agreement



B

Appendix B System requirements form

The System Requirements Form template is in an electronic form for parts B, C, E and F using a dedicated data room. The table below gives an overview of the SRF parts and a summary of the data content.

SRF Part	SOFI Content?	Description	Data content
Part A – Boundary requirement and Capability	Yes	ESO states the requirements for each boundary which triggers the TO's response in providing options to meet the capability requirement level for that boundary. The form includes the Plexos unconstrained boundary transfers. Each boundary will have its own Part A.	The requirements listed are the transfer capabilities for each energy scenario for each of economy and security criterion in tabulated and chart form. An example is given below in this appendix.
Part B – TO Proposed Options	Yes	TO responds with an option that may partially or wholly meet the requirements set out by Part A. Each option will have its own Part B.	Technical description of the option including: <ul style="list-style-type: none"> • physical works • summary of included assets • diagram • what requirement the option solves and how • earliest in-service date • any environmental impacts • other reference information including option name, status, reference number
Part C – Outage Requirements	Yes	TO responds with outage requirements for that option. Each option will have its own row in Part C.	Outage requirements to deliver the option: <ul style="list-style-type: none"> • The circuit or apparatus that needs to be on outage and the required duration of outage (in weeks) in each calendar year if the option is to be delivered on its EISD. The number of distinct calendar years that works take place in. • Restriction in sequence of works.
Part D – Studied Option combinations	Yes	TO and ESO supply how the options' capabilities have been studied to ensure that the ESO accurately and faithfully reproduces the options' order and capabilities in the economic analysis. Part D is a separate online form. Each boundary will have its own Part D.	Boundary benefit data is captured in the handover tool: <ul style="list-style-type: none"> • The options that provide boundary benefit on their own or together with other options and the combinations they can be used in. • The sequence of the reinforcements in each combination. This includes

			<p>alternative sequences for the same combination.</p> <ul style="list-style-type: none"> • The resulting absolute boundary capability in MW in each stage of each sequence. • Whether an option must follow or is an alternative to certain reinforcements.
Part E – Options’ Costs	Yes	TOs supply asset and cost information to allow the ESO to proceed with ‘cost reasonableness’ check (See Appendix C). Each option will have its own Part E.	<p>The data recorded includes:</p> <ul style="list-style-type: none"> • WACC used. • A limited break down of costs. • The cost profile for the option. • Delay, remobilisation and cancellation costs.
Part F – Publication Information	No	TOs supply names and descriptions of options for publication use. Each option will have its own row in Part E but only if it has featured in Part D.	<p>The information includes:</p> <ul style="list-style-type: none"> • The NOA code agreed with the ESO. • The option name to appear in the NOA report. • The description of the option to appear in the NOA report.

SOFI stands for System Operator Functional Information. NGESO interprets ‘SOFI’ as, ‘*all information owned, received or created by the ESO related to its licence activities which is not in the public domain and which could confer an unfair commercial advantage or create a real or perceived conflict of interest if disclosed out of line with one of the legitimate licence exemptions.*’³⁰

Interested Persons

The SRF template for Interested Persons’ will be publicly available on the ESO website. The template will include sections for parts B, E and F of the SRF. Parts C and D will be determined in collaboration with the ESO and incumbent TO as required. In future cycles this may be superseded by an online portal as per the TO submission data room.

³⁰ NGESO Business Separation Compliance Statement, Version 1.4, May 2021, <https://www.nationalgrideso.com/document/222386/download>

SRF Part A: Boundary Requirement and Capability

This is an example of the data and plots provided by NGESO.

[BACK to Contents](#)

ESO Required Transfer

Boundary under Analysis: **B6**

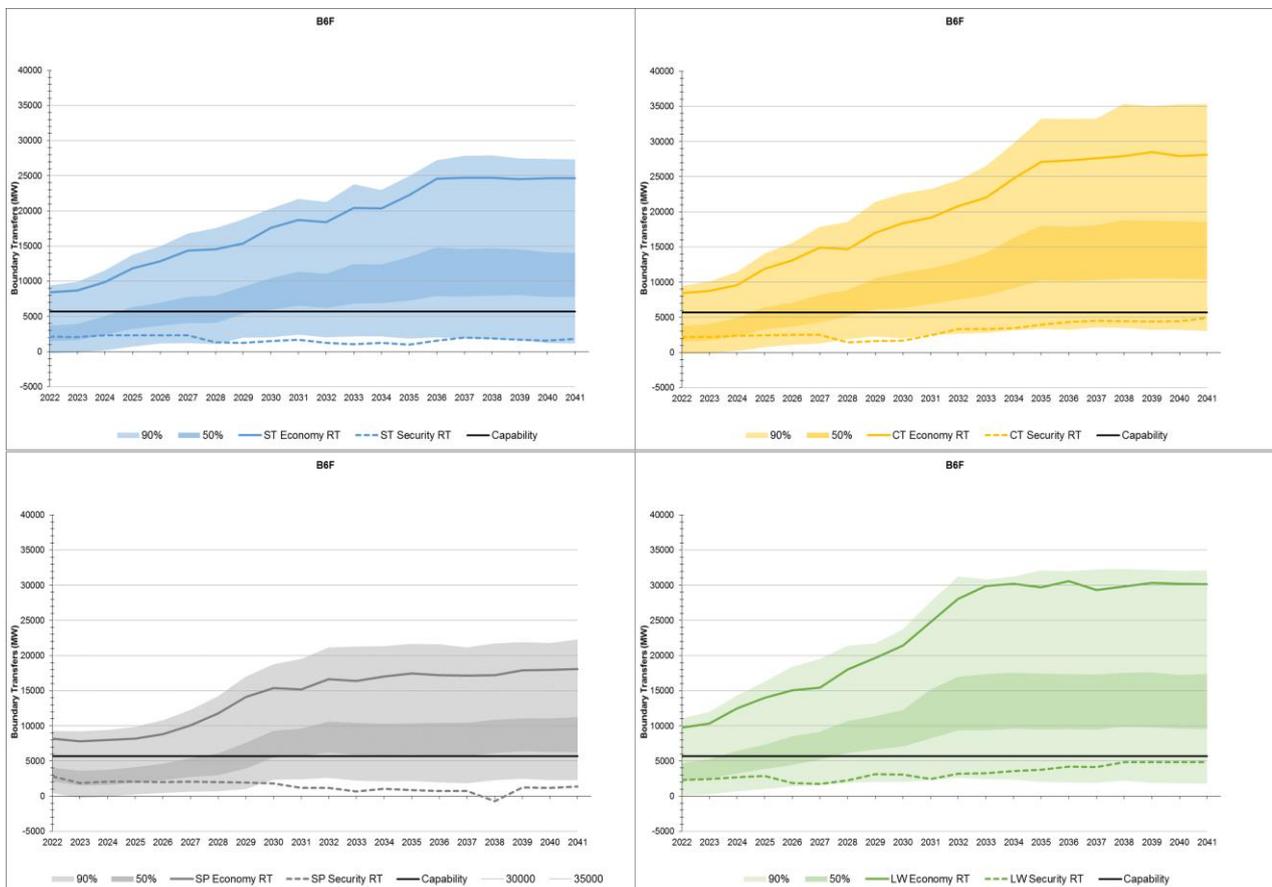
Winter Peak Boundary Required Transfer Summary:

Year 1 Winter Peak Base Capability from previous year (2020): **5700MW**

	Economy	Secured Event	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32
Winter Peak Required Transfers in accordance with NETS SQSS Chapter 4 Economy Background (in MW)	Leading the Way 2021	N-D	9,077	9,847	10,453	12,572	14,189	15,275	15,641	18,245	19,920	21,676	25,045
	Consumer Transformation 2021	N-D	8,518	8,530	8,880	9,709	12,114	13,293	15,152	14,909	17,220	18,660	19,392
	System Transformation 2021	N-D	8,333	8,502	8,815	9,977	12,066	13,050	14,574	14,746	15,542	17,812	18,953
	Steady Progression 2021	N-D	7,580	8,242	7,937	8,091	8,351	9,017	10,305	12,004	14,335	15,599	15,386
Winter Peak Required Transfers in accordance with NETS SQSS Chapter 4 Security Background (in MW)	Security	Secured Event	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32
	Leading the Way 2021	N-D	3,007	2,303	2,458	2,831	2,917	1,996	1,866	2,355	3,468	3,378	2,763
	Consumer Transformation 2021	N-D	2,921	2,292	2,322	2,397	2,468	2,515	2,530	1,645	1,894	1,937	2,757
	System Transformation 2021	N-D	2,814	2,235	2,196	2,288	2,318	2,332	2,303	1,295	1,233	1,755	1,971
Steady Progression 2021	N-D	2,743	2,874	1,977	2,208	2,196	2,150	2,178	1,970	2,070	1,969	1,403	

Unconstrained Boundary Flows

The section below details the unconstrained flows across the boundary. The 90th percentile and 50th percentile ranges have been highlighted for each scenario, and this has been shown together with the NETS SQSS required transfers and 2020 base boundary capability.



Seasonal scaling factors can be submitted using the following template. Otherwise, default ones mentioned in Section 2 will be used or actual seasonal boundary capabilities can also be submitted separately.

Boundary Name	Seasonal Scaling Factor				Number of circuits crossing boundary	Number of outage days
	Winter	Spring/Autumn	Summer	Summer Outage		
Example	100%	85%	70%	50%	4	
B0						
B1						
B2						
B4						
B5						
B6						
B7						
B8						
B9						
B13						
EC5						
SC1						
SC1rev						
NW1						

Please enter data into column H OR column I. The number of outage days will be calculated based on the number of circuits crossing the boundary unless the number of outage days is specified.

Lock/unlock

Use this page to enter seasonal scaling factors for boundaries studied.

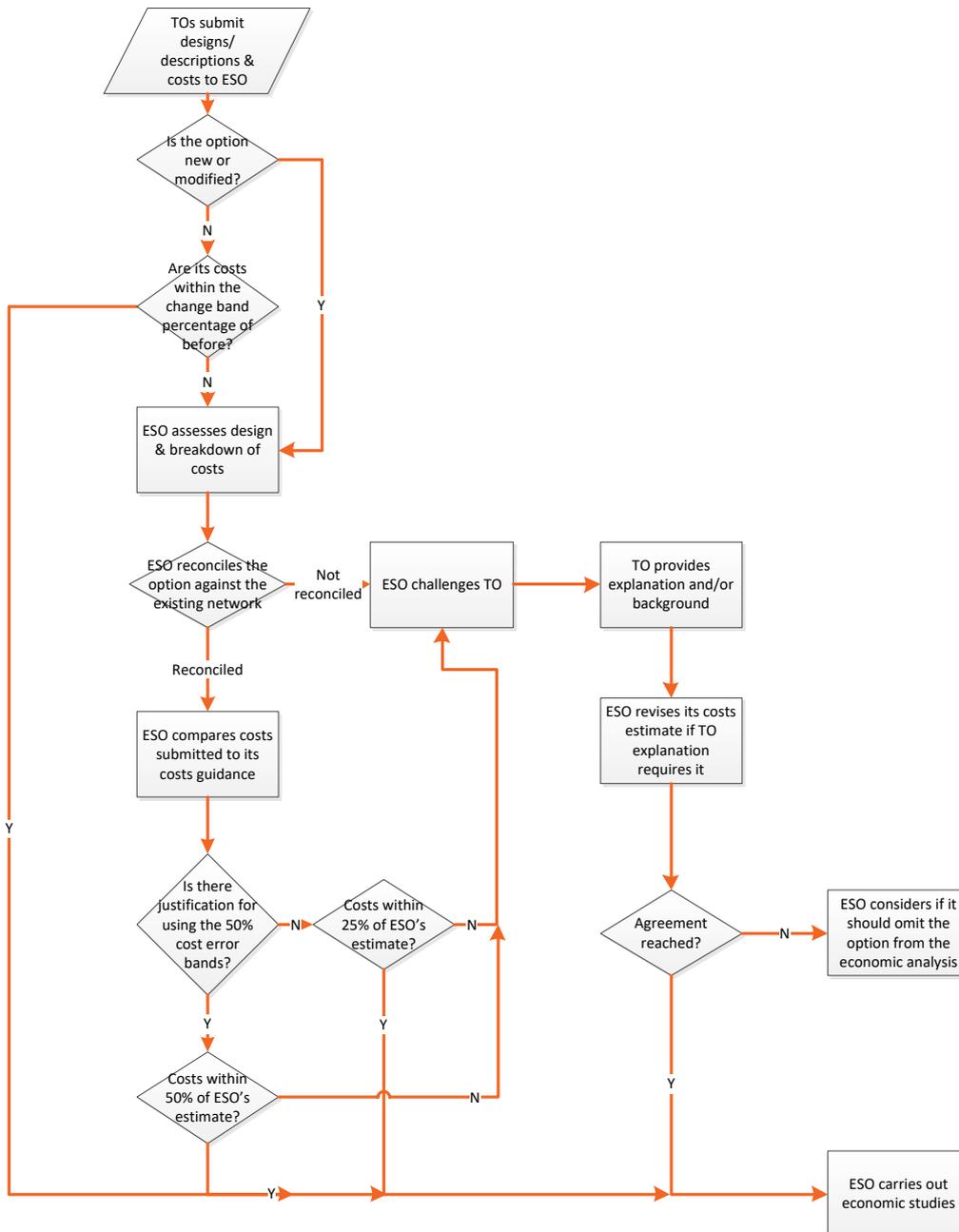


C

Appendix C Process for checking NOA option cost reasonableness

This appendix describes the process that the ESO uses to check the NOA option cost data that the TOs provide. This cost data will be used as an input to the NOA economic assessment process. The costs are also used for the suitability for third party delivery and tendering assessment process.

Figure C1 cost reasonableness checking process map



The input to the above process is the costs that the TOs submit for their NOA options. The output of the process is the TOs' cost submissions to be deemed valid and act as an input into the NOA economic process. The TOs may modify their costs following discussions with the ESO as part of this process. If following discussions, the ESO still believes that the costs are outside of their expected range and will unduly affect the economic analysis, the ESO may omit the option from the economic analysis.

The ESO maintains independent cost guidelines which are derived from RIIO unit costs and external public domain market intelligence. Depending on the type of equipment/ technology, the ESO either compares the costs of each option against previous years (allowing for inflation) or against its cost guidelines.

The headings below match the stages in the process map.

TOs submit designs/ descriptions & costs to ESO

Having received the SRFs that the TOs submitted, the ESO gathers the following information from Part B – work description and Part E – cost information from the SRF:

- Detailed technical breakdown of the reinforcement option
- Cost data for the option.

Is the option new or modified?

Are its costs within the change band percentage of before?

The first step is for the ESO to identify which options should proceed through the full cost reasonableness process. New or modified options always proceed through the full process. Options where the designs are unchanged from previous years' submissions, as they have already had their costs approved through previous years' cost checks, may be exempt from the rest of the checking process provided any increase in costs falls within an expected range, i.e. if the increase of the costs value is within the band of $\pm 5\%$ of previous submissions, then the cost checking process for such an option ends here. Options where the costs have changed outside this range, or options that have been modified or evolved with new designs, should be taken through the process as normal.

ESO assesses design & breakdown of costs

The aim of this step is for the ESO to understand the option, how it is intended to deliver the benefit and the components of the option. The ESO analyses the technical breakdown from the descriptions of the option and builds up their understanding of the reinforcement option:

The ESO checks the descriptive text with any diagrams that the TO has provided.

The ESO checks that equipment requirements are consistent and complete. For instance, where a new circuit is proposed, does the SRF explain how it will connect to the existing transmission system? Are new bays proposed and how many, or will it reuse existing bays?

The ESO checks environmental factors. For example, whether the option needs consents and whether the option is in a mainly urban or rural setting.

It is expected that the level of detail of each option and the accuracy of its costs will vary with the maturity level of the option, i.e. options that have been developed over several years will have more accurately estimated costs as they can usually be broken down into more detailed aggregate components, while for options that are still in their initial stages of conception, the design and costs are more approximate.

The ESO reconciles the option against the existing network

Having built up its understanding of the option, the ESO checks the existing part of the network that the option affects. This is to identify any parts of the option that might have been omitted and which may affect the cost estimate. The ESO notes any omissions or discrepancies in the SRF and seeks clarification from the TO. An example might be that the SRF describes using a spare bay so the ESO compares against the latest system diagram to confirm the availability of the bay and its details. For detailed explanation, go to the **ESO challenges TO** stage.

ESO compares costs submitted to the range of costs in its guidelines

The ESO performs the checks by the following two ways for each option at this stage as applicable.

- 1) Having developed its understanding of the option, the ESO compares the option's costs against the ESO's cost guidelines.
- 2) The ESO identifies similar options within a TO's portfolio and checks the cost consistency between them. For instance, where the option includes similar reconductoring work (e.g. same voltage level of the circuits), the ESO estimates the unit costs based on the existing TO's data and compares with the submitted data, to see if the cost is consistent.

Is there justification for using the 50% cost error bands?

Some aspects of options add a lot of uncertainty to the forecast cost of a project and so it allowed a larger cost error. For this reason, the ESO measures against a 50% cost error band for any option affected by the following:

- consents
- new technology with high uncertainty.

Costs within 25% of ESO's estimate?

For most options the wider cost error bands are not applicable, the ESO conducts the check via the following steps:

- If the TO's submitted costs, are within 25% difference when compared against the ESO's estimated costs based on its own guidelines, the ESO will then
- check that a TO's costs are consistent with other similar options' costs across its portfolio. If this is the case, then the ESO sets the option costs as 'agreed' and the costs are used in the economic process.

If the costs are outside of the 25% band and/or the costs are not consistent, the ESO asks the TO for justification. For more detailed explanation, refer to the process map from **ESO challenges TO** stage.

Costs within 50% of ESO's estimate?

This step applies **only** to options where there is justification for wider cost error bands and is a similar two stage approach.

Firstly, the ESO takes the TO's submission and compares it with its own estimate of costs. If the differences are within 50%, the ESO progresses to the cost consistency check against the TO's portfolio.

If the costs are consistent with other similar options' costs in the TO portfolio, then the ESO sets the option costs as 'agreed' and the costs are used in the economic process.

If the costs are outside of the 50% band and/or the costs are not consistent, the ESO asks the TO for justification. For more detailed explanation, refer to the process map from the **ESO challenges TO** stage.

ESO challenges TO

If the ESO finds that an option's costs lie outside of the range that it estimates, it approaches the TO for a more detailed understanding.

TO provides explanation and/ or background

In response to the ESO's challenge, the TO provides more information to resolve the query. This information might be:

- adding information, for instance including the details of cable section lengths
- correcting assumptions about assets, for instance the amount of plant involved in work on a substation bay
- clarifying the detailed works involved. If necessary, this may require sending a clear list of components being costed and the costs breakdown. This is to allow the ESO to compare with their original estimates and review the reasonableness.
- amending a cost submission due to an error

If the TO provides more information to the ESO, the ESO will revise its cost estimation accordingly to check if the costs are within the 25% bracket or 50% bracket as applicable. If the cost falls within these brackets, the ESO sets the option costs as 'agreed' and the TO's costs are used in the economic process. If the TO provides more information to the ESO, the ESO will revise its cost estimation accordingly to check if the costs are within the 25% bracket or 50% bracket as applicable. If the cost falls within these brackets, the ESO sets the option costs as 'agreed' and the TO's costs are used in

the economic process. If the TO's response does not resolve the ESO's concerns, the ESO will review its concern, clarify if necessary, and refer it back to the TO.

If ESO cannot agree to the costs and explanations that the TO provided, the ESO engineer escalates the matter within ESO management. The ESO management decides whether to include the costs for the option in question at this stage or to omit it from the economic analysis.

ESO revises its costs estimate if TO explanation requires it

The discussion between the ESO and the TO might mean that the ESO has to recalculate its estimate of the costs. The ESO notes the revised costs.

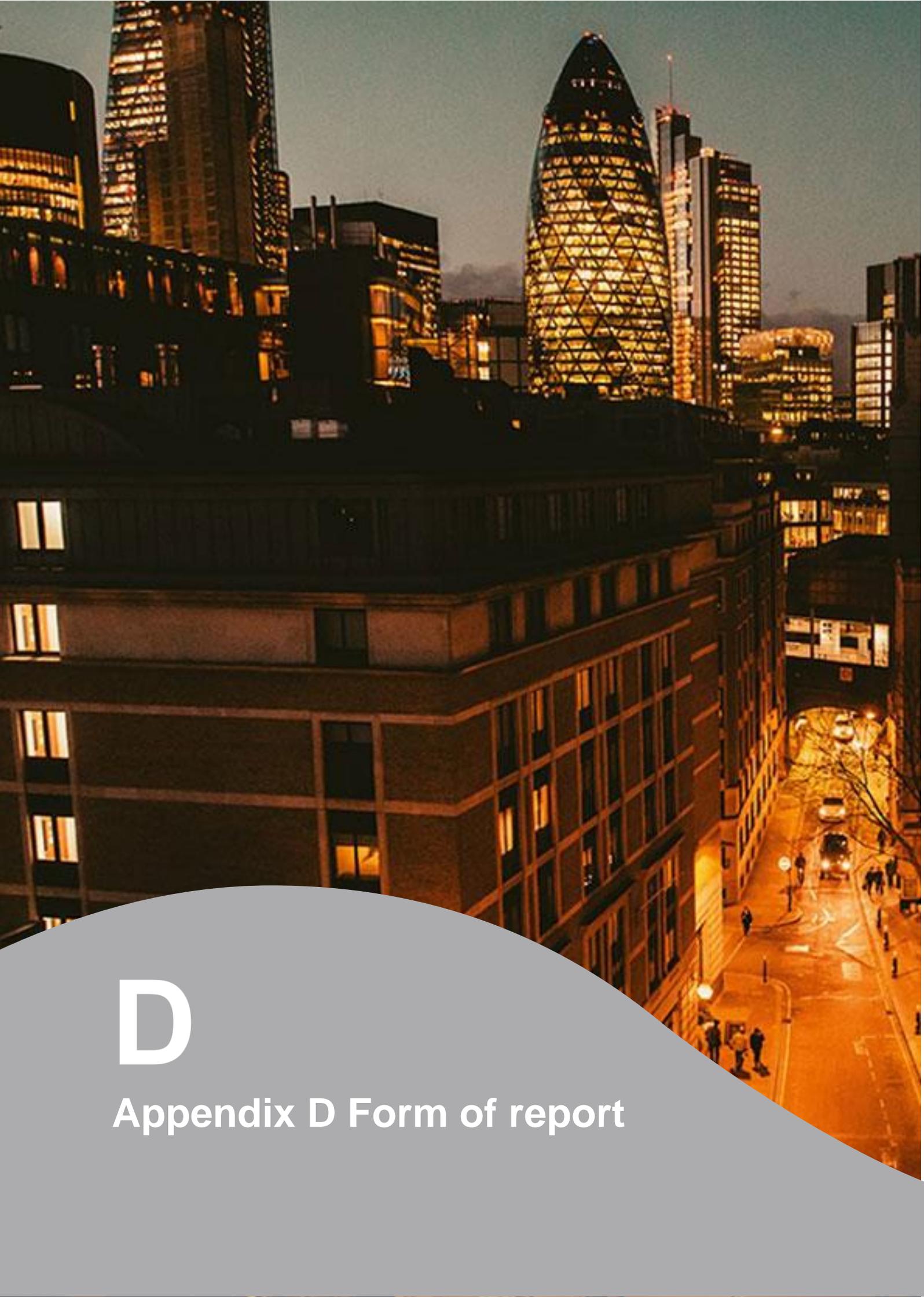
Agreement reached?

The ESO engineer conducting the checking process passes the 'agreed' TO costs for use in the NOA economic process.

General points

The ESO keeps the cost information for all options submitted by each TO and uses them to do consistency checks of similar options in future years. In the consistency check, the ESO will only compare options submitted by the same TO.

In general, the ESO assumes that the TO cost submissions include the project development costs. There might be occasions where this part of the cost is not included, in which case the TO and ESO will discuss further to decide how to treat this option in its economic analysis.



D

Appendix D Form of report

The Electricity System Operator (ESO) will produce the NOA report. The body of the report will be public and its contents are outlined below. The costs of options are confidential and will be described in appendices with circulation restricted to stakeholders such as Ofgem. We will provide Ofgem with justification for the redactions. Extracts of this report will go to the relevant Transmission Owners (TO). This appendix describes the contents and chapters of the report. The ESO reserves the right to add or change chapters and utilise the NOA webpage, to better represent the information

Foreword

Contents Page

Executive Summary

The executive summary will include headline information on options listing those that meet LOTI or SWW criteria.

Introduction

This chapter will describe the aim of the NOA report, provide the reader with the context such as its relationship with the Electricity Ten Year Statement (ETYS) and introduce the types of options reflecting *table 2.2 Potential transmission solutions* of this methodology.

Investment recommendations

After a short introduction linking the reader to the NOA methodology webpage area and a high-level view of the energy scenarios and their effect on transfer requirements, this chapter will cover the economic benefits of each option. The data will be tabulated and to support the comparison will include the earliest in service (EISD) and optimum delivery dates. An explanation of the regrets for the options and combinations of options where the options are critical will be included as an appendix of the report, i.e. those that need a decision to proceed (or otherwise) imminently. The chapter will detail the ESO recommendation whether to proceed with each option. In some instances, there might be a recommendation to proceed with more than one option. Such an instance could be at an early stage when two options are closely ranked but there is uncertainty about key factors, for example deliverability.

The chapter will indicate options that are likely to meet the competition criteria.

The chapter will finish with a summary of the options for the boundary. It will provide:

- Any differences in preferred options between annual NOA reports where the ESO has carried out similar analysis in the past.
- How the scenarios have different requirements and how they affect the options.
- A comparative view as appropriate of each option's deliverability and how it affects the choice of the preferred options.

The chapter will meet the ESO obligation to produce the recommendations for the Network Development Policy for Incremental Wider Works.

Certain details will be in the appendices such as details on the options descriptions and previous NOA recommendations.

Interconnector analysis

This section of the report will introduce the method of analysing GB's potential for interconnectors to other markets and publish the analysis.

Glossary

NOA webpages

The NOA webpages will contain:

- Broadly fixed and unchanging information such as what the NOA can and cannot do.
- Headline results figures.
- Summary information on NOA Interconnector analysis and the NOA methodology.
- Information on how readers can be involved in the NOA.

The ESO reserves the right to add or change these webpages to better represent the NOA information.



E

Appendix E Summary of stakeholder feedback

This appendix summarises the views the ESO has on the comments that we received. We would like to thank the organisations for their feedback and contribution.

Area of feedback	Feedback	ESO response
Timing of methodology consultation	Significant work has been done on HND and NOA 7 refresh. A large-scale review is underway on ETNPR with unconfirmed changes. We suggest it would be better to delay any update to the NOA Methodology until new planning processes are agreed and can be reflected in the updated document. This would reduce duplicated effort and support consistent messaging to stakeholders.	We understand that consulting on the NOA methodology ahead of HND and NOA 7 refresh being published makes this consultation difficult to respond to. The NOA methodology was consulted as per the ESO's licence obligation which requires submission to Ofgem by 1st August. The aim of this consultation is to have a process that explains how we implement the economic analysis of reinforcement options to maximise value for consumers in preparation for CSNP.
Validity of annual NOA process	The annual NOA process with its 'stop /start' assessment risks timely delivery, in the context of significant growth in transfer requirements. There is a need for certainty in the network investment to meet net zero. The annual NOA process does not provide the certainty required. We propose we refine the strategic reinforcement package instead of comparing on an annual basis with alternatives.	We understand the need for certainty in order to achieve timely delivery of projects. We will review this aspect of the annual NOA process as part of CSNP.
TO & ESO resource to deliver annual NOA process	The resource to run the annual NOA process is increasing. A better use of this resource is to ensure that the network needed for net zero can be delivered on time.	We appreciate the efforts of our TO colleagues in developing network reinforcement options and delivering them during a period of increasing uncertainty. The options are evaluated in the annual CBA process; this being an important part of ensuring best value for the consumer.
EISD	Do not recommend each option based on its EISD. Instead identify a strategic package of works, which could be developed. The 'hold' recommendation does not fit in this context.	This will be considered in the CSNP which may base the future recommendations on a more strategic approach.
Agreed definition of EISD	A definition of EISD agreed by all stakeholders is needed and a consistent approach to determining the EISD of an option.	We will review how and when we communicate how reinforcements are needed as part of the network planning review.
Holistic Network Design	1.8 This doesn't read well. Should this not be "NGESO and BEIS, alongside Ofgem's ETNPR project, have initiated the OTNR project"?	Agree. We have amended the text.

Area of feedback	Feedback	ESO response
Impact of HND on NOA	1.13 Again, this doesn't read well to me. Suggest: "As the work on the ENTPR develops, we will review, update and consult, with the industry, on our network planning methodologies where appropriate"	Thank you for the comment. Text amended.
Cost benefit analysis	2.65 Could be RIIO-3 also? Do we need to specify RIIO-2?	Amended to just refer to 'RIIO'.
EISD Advancement benefit	2.91 word missing in figure 2.2	Thank you. Text in 1st box, of figure 2.2 amended to: 'create additional paths by duplicating TO paths from EISD to EISD-1'.