Energy Networks Innovation Process

Annual Project Progress Form

Notes on Completion: Please refer to the NIA Governance Document to assist in the completion of this form.
Do not use tables

Step 1 - Initial Project Details

Project Title

Headroom – Whole System Thinking

Project Reference

NGED_NIA_073

Nominated Project Contact(s)

Laurence Hunter – lhunter@nationalgrid.co.uk

Project Start Date

09/23

Project End Date

04/25

Scope (15000 Characters max)

This project aims to evaluate the whole energy system to determine the benefit per unit of added headroom. This benefit will be quantified in terms of both the reduced cost of energy (£/MWh) and reduced grid carbon intensity (CO2/MWh) that can be attributed to increased distribution network headroom, for each voltage level, at critical times of year, and different constraint scenarios. By understanding this, we will be able to drive timely and cost-effective innovation towards these opportunities.
The project consists of two phases with increasing detail and granularity. We begin by quantifying the magnitude of benefit available from increasing headroom, then delve deeper into how different asset classes and archetypical variances will vary the benefit, providing greater rigor to the results.

To understand the benefit per unit of headroom, we will explore the difference between two scenarios - one where networks have sufficient headroom to allow distribution-connected assets to connect and dispatch freely, and one where there is a headroom shortfall that results in curtailed dispatch and - potentially - reduced or delayed connections.

- Consideration will be made of the voltage level and different constraint scenarios, including critical times of year when constraints are likely.
- We shall look across our network to identify illustrative instances (voltages, locations, network topologies, generation mixes) that we can study to understand the impact of headroom reduction, and to provide insights about how this varies across voltage levels.
- To quantify the benefit, the impact of headroom reduction on the capacity and dispatch behaviour of distribution-connected assets (generation, storage, demand) will be reflected as an input in PLEXOS and a Balancing Mechanism model, which will be run to model the impact on system prices and system carbon emissions.
- We shall review this benefit across two different time periods to be selected between today and 2035 that have different generation mixes and demand profiles.

Objective (15000 Characters max)

- Develop a methodology to calculate the whole system value of network headroom.
- Produce representative headroom archetypes that demonstrate where headroom provides value to the energy system
- Quantitatively understanding what parts of the network added headroom has the most significant financial benefit to the whole energy system. This will be discussed in terms of voltage level, types of connected generation, and types of connected demand
- Understanding the constituent parts of customer bills which are most impacted by added headroom, i.e. wholesale price savings, balancing market savings, carbon savings
- Collate information to give values for £/MWh and CO2/MWh headroom whole system benefit, which will vary depending on archetype grouping

Success Criteria (15000 Characters max)

Stage 1 Success Criteria

- A successful expert workshop is held, with attendance from National Grid DSO, ESO, and project partners. The outcomes of the workshop have successfully directed the project towards maximum value.
- A comprehensive methodology to understand the value of network headroom is produced. This should be completed in collaboration with National Grid, Baringa and EA Technology LTD.
- A conceptual translation of headroom into generation, storage, and demand is produced in Stage 1, which helps understand exactly how to model headroom availability.
- An understanding of how the value of network headroom availability differs according to voltage level, and according to time-based scenarios.
- Following detailed PLEXOS studies, understand how headroom availability changes the carbon intensity of the grid and consequently offers carbon savings.
- Incorporate constraints based on a national view into PLEXOS to understand the proportion of available low carbon generation that is curtailed, which otherwise supports the merit order effect.
- Develop an understanding of how the proportion of renewable generation affects the wholesale price. During Stage 1, this will be at a national level with only qualitative consideration of whether demand and generation assets are connected to the distribution network or transmission network.
- Provide an understanding of the scale of benefit increased distribution headroom may have in terms of £/MWh, and CO2/MWh. At Stage 1, this will explore what times of the year the benefit is largest.
- Detailed summary reports are produced for Stage 1 that outline the methodology in detail, the sources of any data used, and presents key findings in a clear and understandable way. This should incorporate the effect additional network headroom has on other aspects of the customer bill, including balancing system costs, network costs, and carbon accounting costs.

Stage 2 Success Criteria

- A successful expert workshop is held, with attendance from National Grid DSO, ESO, and project partners. The outcomes of the workshop have successfully directed the project towards maximum value.
- Incorporate constraints based on individual voltage levels into PLEXOS to understand the proportion of available low carbon distribution connected generation that is curtailed, which otherwise supports the merit order effect.
- Develop an understanding of how the proportion of renewable generation affects the wholesale price. During Stage 2, this will be at a national level with detailed consideration of whether demand and generation assets are connected to the distribution network or transmission network.
- Provide an understanding of the scale of benefit increased distribution headroom may have in terms of £/MWh, and CO2/MWh. At Stage 2, this will explore what times of the year the benefit is largest but also consider the relative split between GB wide free dispatch and the benefit gained from increased distribution network headroom.
- Detailed summary reports are produced for Stage 2 that outline the methodology in detail, the sources of any data used, and presents key findings in a clear and understandable way. This should incorporate the effect additional network headroom has on other aspects of the customer bill, including balancing system costs, network costs, and carbon accounting costs.

Stage 3 Success Criteria

- A successful expert workshop was held, with attendance from National Grid DSO, ESO, and project partners. The outcomes of the workshop have successfully directed the project towards maximum value.
- Incorporate constraints based on geographic zones and voltage levels into PLEXOS to understand the proportion of available distribution connected generation that is curtailed, which otherwise supports the merit order effect.
- Develop an understanding of how the proportion of renewable generation affects the wholesale price. During Stage 3, this will be at a zonal level with detailed consideration of whether demand and generation assets are connected to the distribution network or transmission network in different parts of Great Britain.
- Provide an understanding of the scale of benefit increased headroom may have in terms of £/MWh, and CO2/MWh. At Stage 3, this will explore the impact of geographic differences as explored in the PLEXOS GB zonal model.
- Detailed summary reports are produced for Stage 3 that outline the methodology in detail, the sources of any data used, and presents key findings in a clear and understandable way. This should incorporate the effect additional network headroom has on other aspects of the customer bill, including balancing system costs, network costs, and carbon accounting costs.
- Describe the potential impact of how locational marginal pricing may impact the modelling employed in this project. Identify how different wholesale market structures would vary the extent to which headroom benefits the wholesale market.
- Provide insight on how available distribution network headroom influences ESO/DSO dispatch strategies that seek to promote electricity consumption at least carbon intensive times.

Step 2 - Performance Outcomes

Performance Compared to Original Project Aims, Objectives and Success Criteria

Details of how the Project is investigating/solving the issue described in the NIA Project Registration Pro-forma. Details of how the Project is performing/performed relative to its aims, objectives and success criteria. (15000 Characters max)

At the time of authoring, Headroom – Whole System Thinking completed Stage 1 and has recently commenced the revised Stage 2 plan. As such, the performance against aims, objectives and success criteria shall be marked against our current position.

Stage 1 Success Criteria

A successful expert workshop is held, with attendance from National Grid DSO, ESO, and project partners. The outcomes of the workshop have successfully directed the project towards maximum value.
Completed - During Stage 1, two workshops were held with NGESO, NGED DSO, and project partners in attendance. Feedback from these sessions has shaped the project direction.

Following the October kick-off workshop, the following assumptions were made to the modelling methodology:

1. Demand reinforcement should be excluded from Stage 1 of the work. This was chosen as a means to calculate an upper bound for curtailment benefits.
2. The chosen study years should include 2023 as a baseline year, and the latest study year should be 2034 to be in line with BAU network planning horizons.

After the end of stage 1 workshop in February, several changes were made to the original project scope, to direct the project towards maximum value.

1. It was acknowledged in Stage 1 that the network curtailment modelling which forecasted generation curtailment volumes and profile had several assumptions which did not hold up to scrutiny. There is no known methodology to assess curtailment on a system-wide scale, as such the revised project direction for Stage 2 focuses on establishing 'cost-curves' to calculate the scale of expected benefit across a range of curtailment volumes. Further information on this change is detailed in the following section.

A comprehensive methodology to understand the value of network headroom is produced. This should be completed in collaboration with National Grid, Baringa and EA Technology LTD.
Completed - Stage 1 established a methodology to forecast the value of network headroom across UK DNOs. Collaboration between NGED, ESO and the project partners within Stage 1's workshop allowed for feedback on assumptions and the employed methodology. Specific detail on the methods used is captured in the Stage 1 reports accessible on the NGED website. National Grid - Headroom - Whole System Thinking

A conceptual translation of headroom on generation, storage, and demand is produced in Stage 1, which helps understand exactly how to model headroom availability.
Completed – Specific details can be found in the End of Stage 1 report. https://www.nationalgrid.co.uk/downloads-view-reciteme/660492

An understanding of how the value network headroom availability differs according to voltage level, and according to time-base scenarios.
Completed – EA Technology performed a sensitivity study using Transform and NGED's Simple Curtailment Tool. Further details can be found in the Stage 1 Network Modelling Report. https://www.nationalgrid.co.uk/downloads-view-reciteme/660491

Following detailed PLEXOS studies, understand how headroom availability changes the carbon intensity of the grid and consequently offers carbon savings.
Completed – The emission which could be avoided through headroom relief is forecast to range between 0.7 Mt ('Network Curtailment' scenario) and nearly 5 Mt ('Maximum Constrained Generation' scenario) accumulatively from 2023 to 2034. This amount of carbon saving is broadly equivalent to the level could be achieved by 20 to 170 thousand electric vehicles over their lifetime. Further details can be found in the End of Stage 1 report.

Incorporate constraints based on a national view into PLEXOS to understand the proportion of available low carbon generation that is curtailed, which otherwise supports the merit order effect.
Completed – Curtailment profiles for distribution connected generation assets were incorporated into PLEXOS within Stage 1.

Develop an understanding of how the proportion of renewable generation affects the wholesale price. During Stage 1, this will be at a national level with only qualitative consideration of whether demand and generation assets are connected to the distribution network or transmission network.
Completed – A sensitivity study was performed in Stage 1. A more granular assessment producing cost curves illustrating the scale of impact at different volumes of renewable curtailment will be produced in Stage 2.

Provide an understanding of the scale of benefit increased distribution headroom may have in terms of £/MWh, and CO2/MWh. At Stage 1, this will explore what times of the year the benefit is largest.
Completed - The accumulated system cost saving could range from ~£330m to ~£17bn between 2023 and 2034 (£27.5m to £1.4bn annually); this represents a saving of 0.2% to 7.0% of the total system cost by 2034. The carbon cost saving that could be achieved in each year is between £5m and £125m, making an impact on annual carbon costs at 0.2% (2023) to 40% (2034). This is equivalent to reducing the emission from 17,000 (2023) to 120,000 (2034) Internal Combustion Engine vehicles over their lifetime. The impact on wholesale price is between £0.70/MWh and £6.00/MWh, of which a material proportion could be used to reduce customer bills.

Detailed summary reports are produced for Stage 1 that outline the methodology in detail, the sources of any data used, and presents key findings in a clear and understandable way. This should incorporate the effect additional network headroom has on other aspects of the customer bill, including balancing system costs, network costs, and carbon accounting costs.
Completed – Details of the methodology, data sources, and findings can be found in the two Stage 1 projects available on the Headroom – Whole System Thinking project page.

Stage 2 Success Criteria
A successful expert workshop is held, with attendance from National Grid DSO, ESO, and project partners. The outcomes of the workshop have successfully directed the project towards maximum value.
Complete

Incorporate constraints based on individual voltage levels into PLEXOS to understand the proportion of available low carbon distribution connected generation that is curtailed, which otherwise supports the merit order effect.
In progress

Develop an understanding of how the proportion of renewable generation affects the wholesale price. During Stage 2, this will be at a national level with detailed consideration of whether demand and generation assets are connected to the distribution network or transmission network.
In progress

Provide an understanding of the scale of benefit increased distribution headroom may have in terms of £/MWh, and CO2/MWh. At Stage 2, this will explore what times of the year the benefit is largest but also consider the relative split between GB wide free dispatch and the benefit gained from increased distribution network headroom.
In progress

Detailed summary reports are produced for Stage 2 that outline the methodology in detail, the sources of any data used, and presents key findings in a clear and understandable way. This should incorporate the effect additional network headroom has on other aspects of the customer bill, including balancing system costs, network costs, and carbon accounting costs.
In progress

Required Modifications to the Planned Project Approach During the Course of the Project

The Network Licensee should state any changes to its planned methodology and describe why the planned approach proved to be inappropriate. Please confirm if no changes are required. (15000 Characters max)

During the Stage Gate Review between Stages 1 and 2, the scope of Stages 2 and 3 were updated based on the feedback provided in the End-of-Stage 1 workshop.

- Additional Stage 2 Network Modelling:
  - Refinement to EATL's Transform modelling to increase the number of representative days used in generating a forecasted annual curtailment profile driven by network constraints, inclusion of abnormal running arrangements within transform, development of more realistic battery storage profiles, and benchmarking against historic and forecasted curtailment volumes.
  - Use of NGED's Simple Curtailment Tool to better forecast curtailment across 30 Grid Supply Points within NGED's licence areas.
- Additional Stage 2 Power Market Modelling:
  - In addition to the work agreed previously for Stage 2, Baringa will conduct more thorough PLEXOS analysis in order to create representative cost curves detailing the magnitude of system wide benefit when considering the spectrum of curtailment, which may be incurred.
  - Provision for 22 additional PLEXOS runs to determine Headroom cost curves using multiple sensitivities.
  - Increased Subject Matter Expert (SME) involvement within the Ancillary Services modelling team to establish cost curves.
  - Provision for increased costs incurred in Stage 1 of the project.
- National Grid Project & Programme Management
  - Due to the increased stage duration required to undertake the additional modelling (23 weeks compared to the original 10), additional project and programme management time is required.
- Reduced Scope in Stage 3
  - Based on feedback from the NGED Project Sponsor, the overall objectives of the project will be met within the revised Stage 2 plan.
  - Stage 3 originally involved moving towards a Zonal Market model within PLEXOS, to understand the relative benefit of headroom on a geographic basis, along with an understanding of how the value Headroom can bring will be affected by a move to locational marginal pricing.
  - Following feedback, and changes in National Policy regarding Locational Marginal Pricing (LMP) the priority of these features has been reduced.
  - Considering the increased workload of Stage 2, it is proposed to de-scope several aspects of Stage 3 and re-utilise the budget for the additional work proposed in Stage 2.

Lessons Learnt For Future Projects

Recommendations on how the learning from the Project could be exploited further. This may include recommendations on what form of trialling will be required to move the Method to the next TRL. The Network Licensee should also state if the Project discovered significant problems with the trialled Methods. The Network Licensee should comment on the likelihood that the Method will be deployed on a large scale in future. The Network Licensee should discuss the effectiveness of any Research, Development or Demonstration undertaken. (15000 Characters max)

Network Modelling Lessons:

- Using 4 representative days to model generation profiles across 12 months fails to capture an accurate profile of generation curtailment.
- Curtailment of distributed renewable generation across the LV, HV and EHV networks is expected to increase over time, as more distributed generation is installed.
- Curtailment across the distribution network is expected to be primarily driven by PV generation, under the bottom-up methodology and seasonal profile assumptions utilised throughout this project.

Power Market Modelling Lessons:

The output of the market model shows that releasing Headroom between now and 2034 could bring significant benefits for the GB system in terms of cost and carbon reduction:

- The accumulated system cost saving could range from ~£330m to ~£17bn between 2023 and 2034 (£27.5m to £1.4bn annually).
- The carbon emissions which could be avoided through headroom relief will range between 0.7 Mt and nearly 5 Mt, which is equivalent to nearly 200 thousand electric vehicles' carbon savings over their lifetime.
- The impact on wholesale price is likely between £0.70/MWh and £6.00/MWh, some of which may be used to reduce customer bills.
- The highest price impact would happen in January when the system has little generation margin with high demand and limited solar PV generation.

Outcomes of the Project

When available, comprehensive details of the Project's outcomes are to be reported. Where quantitative data is available to describe these outcomes it should be included in the report. Wherever possible, the performance improvement attributable to the Project should be described. If the TRL of the Method has changed as a result of the Project this should be reported. The Network Licensee should highlight any opportunities for future Projects to develop learning further. (15000 Characters max)

Outputs from Stage 1 of the project are available on the project webpage. This includes:

- Stage 1 Network Modelling report: Produced by EA Technology Ltd, this report details the network modelling work undertaken in Stage 1. EA Technology's Transform tool was used to study the LV to 33kV networks, and NGED's Simple Curtailment Tool which was used to evaluate 4 Grid Supply Points' 132kV networks.https://www.nationalgrid.co.uk/downloads-view-reciteme/660492.
- End of Stage 1 report: Produced by Baringa, this report explains the methodology and results from the Power Market Modelling aspect of the work. https://www.nationalgrid.co.uk/downloads-view-reciteme/660492.

Outcomes of Stage 2 and 3 of the project will be reported in subsequent annual progress reports.

Step 3 - Outputs And Implementation

Data Access Level & Quality Details

A description of how any network or consumption data (anonymised where necessary) gathered in the course of the Project can be requested by interested parties. This requirement may be met by including a link to the publicly available data sharing policy. (15000 Characters max)

All reports and supporting work are published on the National Grid – Hole System Thinking project page. Additional data can be requested by contacting us directly.
NGED data can be requested via the National Grid Connected Data Portal (https://connecteddata.nationalgrid.co.uk/).
(/www.nationalgrid.co.uk/innovation/contact-us-and-more)

Foreground IPR

A description of any foreground IPR that have been developed by the project and how this will be owned. (15000 Characters max)

The Relevant Foreground IPR is:

- All deliverable reports and documents produced during the project delivery.

The Relevant Background IPR required to produce this is:

- National Grid's network modelling data
- The PLEXOS model used by Baringa
- The Transform tool used by EA technology