Gas
Transmission

Annual Network Capability Assessment Report (ANCAR)

June 2022

nationalgrid

ANCAR Report
June 2022

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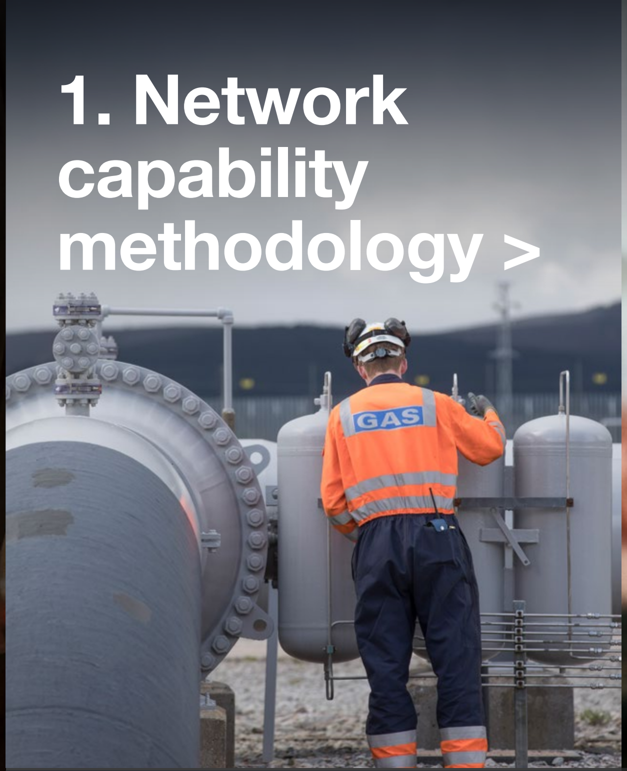

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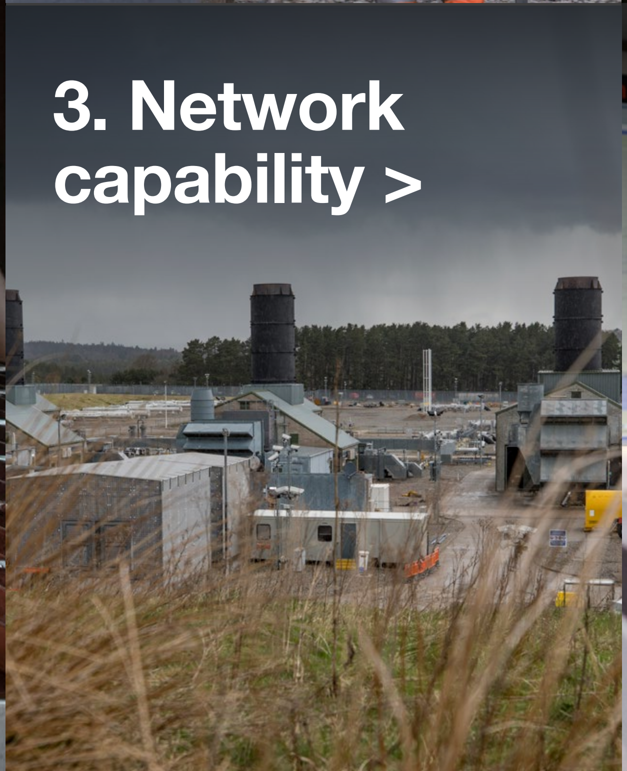

4. Development of the network capability process and analysis >

How to use this document

We have published the *Annual Network Capability Assessment Report (ANCAR)* as an interactive document.

Home
This will take you to the home page.

Enlarge/reduce
Hover over the magnifying icon to make charts bigger or smaller.

Arrows
Click on the arrows to move backwards or forwards a page.

'Linked' content
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Welcome and executive summary

Welcome and executive summary

Welcome to the second issue of the Annual Network Capability Assessment Report (ANCAR).

Network Capability refers to the process refined by National Grid during the RIIO-2 Business Planning process. It enables us to calculate and demonstrate the physical capability of the NTS and how that capability compares to the needs of our customers now and into the future. This assessment is carried out against a range of future supply and demand scenarios using the Future Energy Scenario (FES) outputs produced by the Electricity System Operator (ESO). The output of this assessment helps inform potential changes to market rules, commercial tools or physical assets, to ensure continued safe and economic operation of the NTS in meeting our customers' needs.

This ANCAR is based on the 2021 FES and does not account for the recent global situation and the consequential changes we are seeing in the export flows to Europe. We are working to develop our models to better reflect these changes for inclusion in the 2022 GTYS annex following the release of the 2022 FES in July.

The main findings of this year's ANCAR are:

- The entry and exit capabilities of all the zones, bar South Wales and the South East, are sufficient to meet all the supply and demand flows anticipated under all FES scenarios, over the next 10 years, assuming investment goes ahead as planned.
- South Wales' entry capability shows the strongest indication of all the zones that an increased capability may be required in future years, due to a greater reliance on the imports of liquefied natural gas (LNG). To address this the Western Gas Network project has been instigated.
- The South East's flows indicate the network has sufficient capability to meet most of the requirements put upon it now and over the next 10 years. For those scenarios where capability is insufficient, economical short-term operational and commercial solutions are available to manage flows. We estimate that, currently, one constraint a year is possible and, in 2031, this rises to possibly two per year.
- When considering Scotland's exit capability in 2031, as a sub-set of Scotland and The North zone, there are some low flow situations where constraints may occur on the system. This is brought about by having St Fergus flows reducing and the inability of the system to move gas into Scotland from the south. We will be monitoring this situation closely and when the need arises, we will make an appropriate recommendation.
- A greater reliance on imports, either LNG or through interconnectors, means that key compressor sites, impacted by the Medium Combustion Plant Directive, must be able to maintain their capabilities.

Out to 2031, the flame charts in this report support the proposals we made in our latest Business Plan. That is, the range of physical capability available to us via existing and planned assets is consistent with the requirements flagged by the supply and demand scenarios from FES as informed by our customers and stakeholders.

We continue to do exciting and innovative work on a number of important initiatives to improve future ANCARs. Informed by our extensive external engagement, we are focusing on projects that include a significant amount of work on resilience and compressor availability. The flame charts we show in this report reflect a perfect world, where compressors are fully available and 100% reliable. Whereas, in reality, outages do occur and we want to find clear ways of illustrating the real-world situation that are intuitive. We also continue to work on improving our commentary on interzonal flows and linepack management.

Lastly, and something that will develop rapidly in the future, we consider how we can contribute towards achieving the UK's net zero target and the steps we are taking to fill the hydrogen knowledge gaps that currently exist.

Collaboration with our stakeholders will remain a key focus in order to evolve and improve the information we provide in ANCAR, Ultimately, this is a document for the use of our stakeholders and we actively encourage feedback on its content in order to improve it in future years. We look forward to engaging with you soon.

Paul Sullivan
Head of System Capability & Risk Gas Transmission

1. Network capability methodology

1.1 The *Future Energy Scenario (FES)* backdrop

Figure 1

The *FES* process is delivered independently by the Electricity System Operator on behalf of the industry and creates a range of plausible energy pathways out to 2050. National Grid Gas Transmission (NGGT) is a stakeholder in the *FES* process.

For the first time, *FES 2020* introduced net zero as a target within its scenarios. Net zero by 2050 is the outcome achieved in three of the four scenarios, namely Leading the Way, Consumer Transformation and System Transformation. Steady Progression does not look to achieve the net zero target.

FES 2021 uses the same scenario framework as *FES 2020*[1].

We use the data from all four scenarios in *FES* to produce the visualisation of network capability in each zone, which we refer to as 'flame charts'. These charts are a visualisation of the range of potential flows into and out of the zones across the network and the physical capability we assess to be available. Section 1.4 gives a fuller explanation of this process.

1.1.1 The evolution of *FES 2021* from *FES 2018*

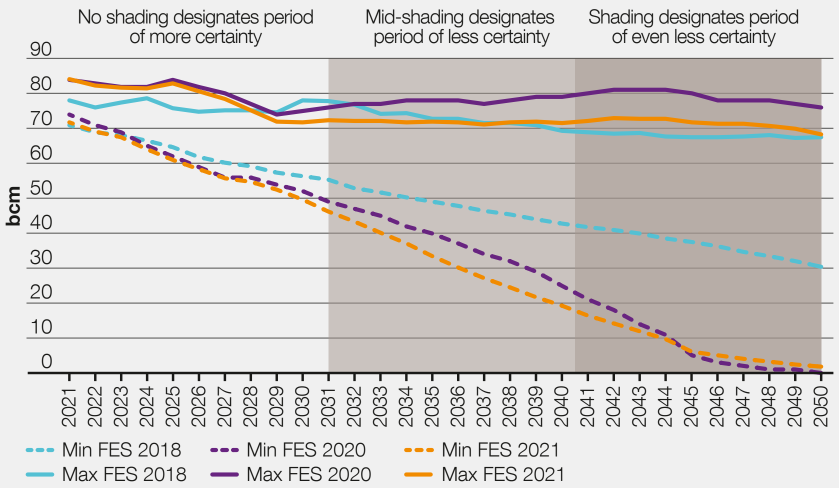
Our initial RIIO-2 Business Plan used the data from *FES 2018*. Because of this we have also included, in the following charts, *FES 2018* projections alongside both this year's and last year's *FES* predictions.

As the ESO note in their key changes' publication, "There is minimal change in natural gas supply and demand in *FES 2021*, compared to *FES 2020*. Natural gas is an important component of today's energy mix, primarily for heating and cooking, and remains so into the 2030's"[2].

Figure 1 illustrates the high and low annual gas demands that could evolve over the next 30 years for *FES 2018*, *FES 2020* and *FES 2021*. Figure 2 does the same for 1-in-20 peak gas demand.

For Maxima Annual Demand, there is little difference between *FES 2018* and *FES 2021* demands as expected for the next ten years, or even out to 2050. But, for Minima Annual Demand levels, there is a reduction, over the next ten years, between *FES 2018* and *FES 2020* & *2021* data. This reflects the potential introduction of the effects of net zero scenarios.

Figure 1
Minima and maxima Annual Demands for *FES 2018*, *FES 2020* and *FES 2021*



1. https://www.nationalgrideso.com/document/202281/download
2. https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2021/documents

1.1 The *Future Energy Scenario (FES)* backdrop

Figure 2 Figure 3

1.1.1 The evolution of *FES 2021* from *FES 2018* (continued)

For the 1-in-20 Peak Demand maximum values for *FES 2018* and *FES 2021* almost coincide for 2031, and again they are not dissimilar out to 2050. Like Annual Demand, the minimum values for *FES 2021* are significantly lower than *FES 2018* (and for *FES 2020*) out to 2031 (See Figure 2).

Consequently, for maximum values the flows in 2031, as indicated by *FES 2021*, are like those of 2018, on which our RIIO-2 plan was based. The minimum values do show earlier reductions in direct natural gas demand as each new *FES* is released.

1.1.2 Steady Progression

Steady Progression (see Figure 3) shows the least significant progress with decarbonisation – thus resulting in the highest carbon output.

In 2020, 75% of energy demand is supplied by natural gas. By 2030, the total energy demand will rise by about 7% from today's value and of this total demand, 65% will be natural gas; hydrogen will supply 0%.

Steady Progression continues the current energy pathway out to 2050. There is a continued improvement in energy efficiency for homes and appliances. However, these savings are offset by the effects of an increasing population.

Figure 2
Minima and maxima Gas 1-in-20 Peak Demand for *FES 2018*, *FES 2020* and *FES 2021*

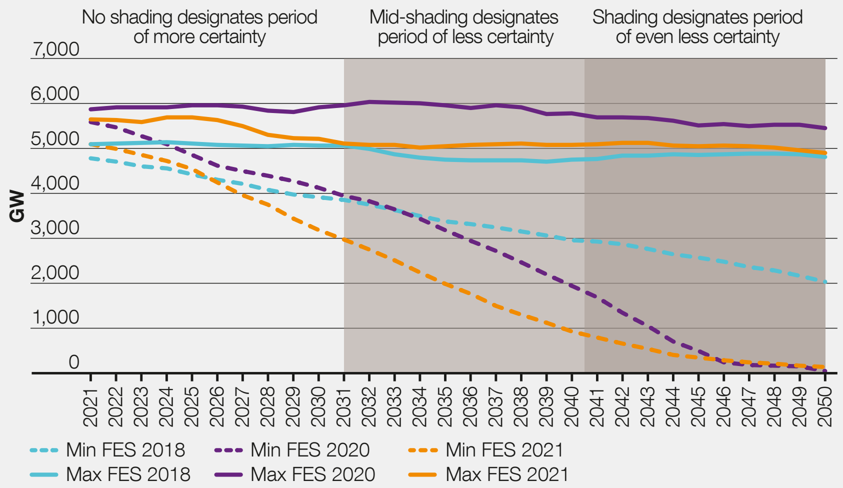
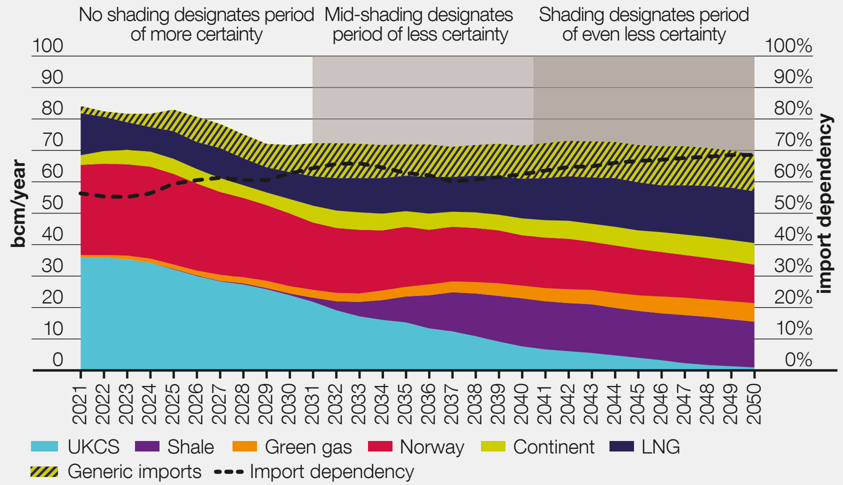


Figure 3
2021 FES's Steady Progression, gas supplies



1.1 The *Future Energy Scenario (FES)* backdrop

Figure 4 Figure 5

1.1.3 System Transformation

System Transformation (see Figure 4) meets the net zero carbon target in 2050 and shows a pathway that has the least consumer impact to do so. This scenario sees a high use of hydrogen for heating and other energy demands. Ultimately a self-sustaining hydrogen economy develops at a national scale.

In 2020, 75% of energy demand was supplied by natural gas. By 2030, the total energy demand will have decreased slightly to about 99% of today's value and of this, 63% will be natural gas; hydrogen will supply only 1%.

The demand for natural gas declines slowly out to 2040. There is then a resurgence as hydrogen production, predominately methane reformation with carbon capture usage and storage (CCUS), starts to pick up. The reliance on imports rises steadily throughout the period as the UK Continental Shelf (UKCS) production declines. By 2050, imports account for almost 100% of gas supplies.

1.1.4 Consumer Transformation

Consumer Transformation (see Figure 5) meets the net zero carbon target in 2050 and shows a pathway that has a relatively high consumer impact, compared to the System Transformation scenario. This scenario uses a high level of electrification for heating and other energy demands.

In 2020, 75% of energy demand was supplied by natural gas. By 2030, the total energy demand will drop to about 90% of today's value and of the total demand, 59% will be natural gas; hydrogen will supply 0%.

There are high energy efficiency gains in appliances in this scenario. Premises are also better insulated. The sale of natural gas boilers ends in 2035 and there is a move to the electrification of heating through the adoption of heat pumps and the electrification of cooking appliances.

A sustainable hydrogen economy fails to materialise but there are some hydrogen clusters which provide the fuel for the more intensive heating requirements, such as industrial processes. Hydrogen is also used for peaking plants, the majority of which is a product of electrolysis.

Figure 4
2021 FES's System Transformation, gas supplies

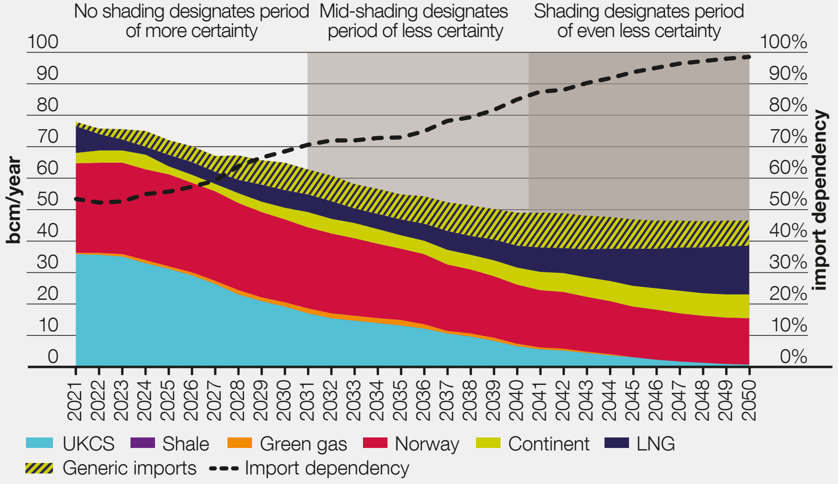
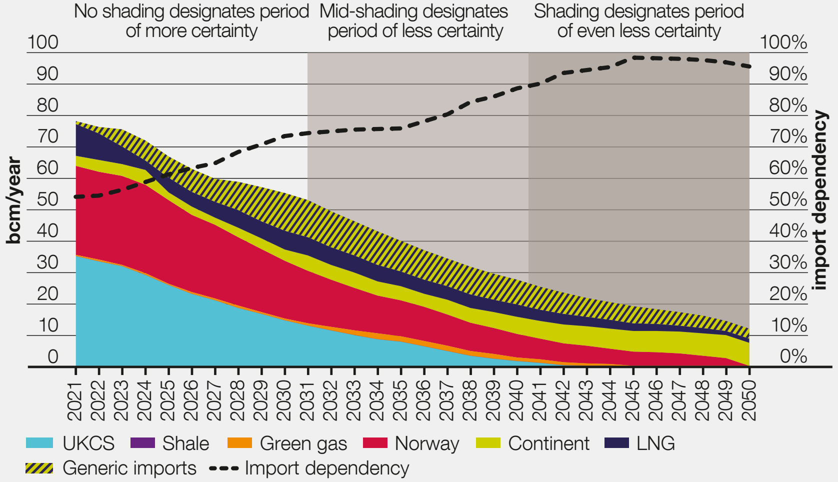


Figure 5
2021 FES's Consumer Transformation, gas supplies



1.1 The *Future Energy Scenario (FES)* backdrop

Figure 6

1.1.5 Leading the Way

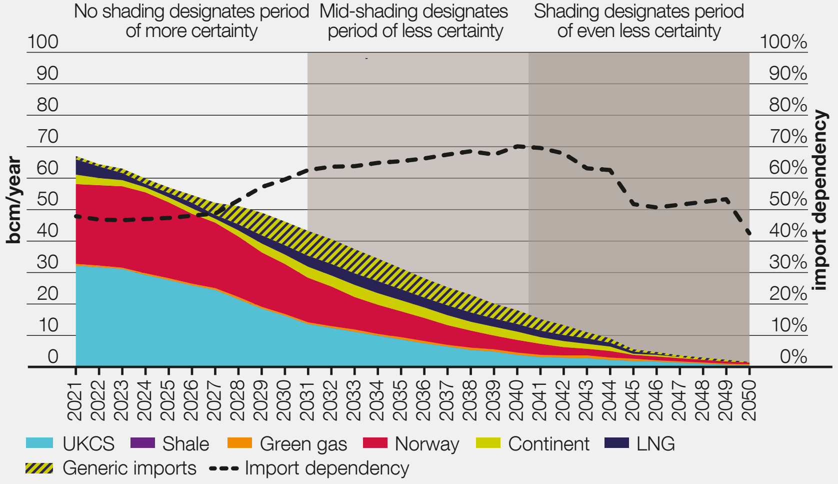
This scenario (see Figure 6) shows the earliest, credible date for when the net zero target is met. This comprises the most favourable carbon reductions from each sector. It is likely to have geographical variances as emission targets are set by communities and local and regional authorities.

In 2020, 75% of total energy demand was supplied by natural gas. By 2030, the total energy demand is expected to drop to about 87% of today's value and of this, only 55% will be natural gas; hydrogen will supply 0%.

The need for heating homes is reduced due to much better insulation. The sale of natural gas boilers ends in 2035 and traditional boilers start to be replaced by district heat schemes, hybrid heating schemes and heat pumps.

Consequently, the supply of natural gas steadily declines. Hydrogen will replace an amount of the reduced natural gas requirements but only from 2040 onwards; and this will be mainly derived from electrolysis or importation.

Figure 6
2021 FES's Leading the Way, gas supplies

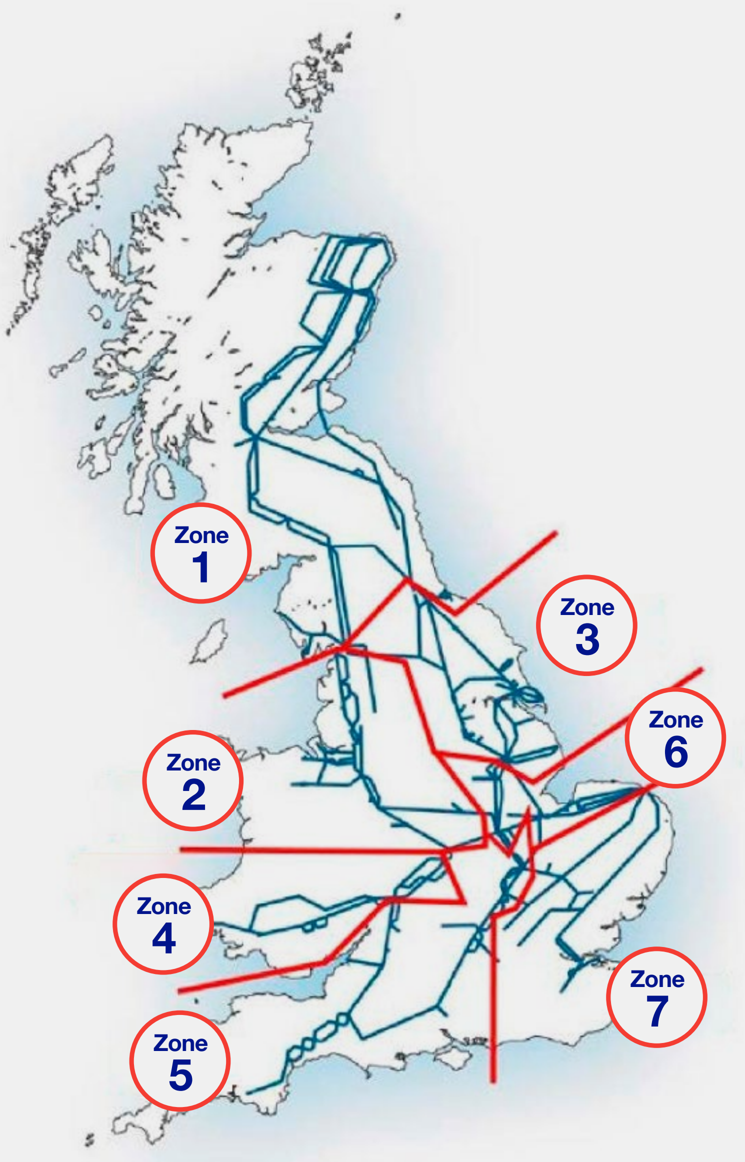


1.2 Network zones

As part of our capability analysis, we divide Great Britain into seven zones, as illustrated in Figure 7. These zones have been created to simplify a complex whole system into manageable parts, each of which have distinctive gas flow regimes. They are referred to as:

- zone 1 = Scotland and The North
- zone 2 = North West
- zone 3 = North East
- zone 4 = Wales
- zone 5 = South West
- zone 6 = East Midlands
- zone 7 = South East.

Figure 7
Simplified view of the NTS and the zones used



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1.3 Future Energy Scenarios to the network model

Figure 8

1.3.1 Future Energy Scenarios gas modelling

The latest methods used in creating the *FES* insights are described, in detail, on the ESO's *FES* website[3].

The outputs that are used from the *FES* process are Annual Demand and supply figures out to 2050 for each of the scenarios. The four scenarios (Leading the Way, Consumer Transformation, System Transformation and Steady Progression) are representations of four equally plausible views of the future GB energy landscape.

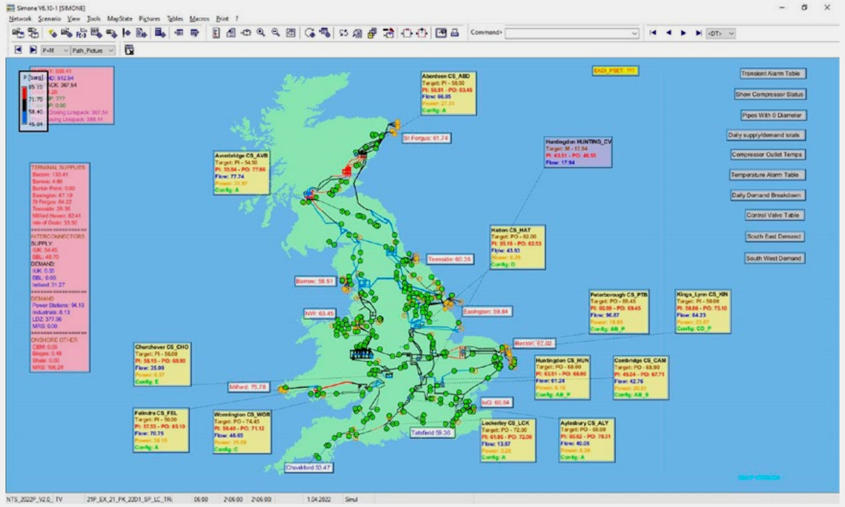
1.3.2 Network model

Section 9.12 of our Gas Transporter Licence Special Conditions[4] requires us to maintain an up-to-date simulation model of the Transmission System.

Our NTS models meet the Institution of Gas Engineers and Managers' (IGEM) requirements, as described in IGEM/GL/2[5]. That is, the models are validated against actual conditions.

For our network modelling we use pipeline simulation software called SIMONE (see Figure 8).

Figure 8
Screen shot of SIMONE 2022



3. https://www.nationalgrideso.com/document/199916/download
4. https://epr.ofgem.gov.uk/Content/Documents/National%20Grid%20Gas%20Plc%20-%20Special%20Conditions%20Consolidated%20-%20Current%20Version.pdf
5. https://www.igem.org.uk/technical-services/technical-gas-standards/legislation/ige-gl-2-edition-2-planning-of-transmission-and-storage-systems-operating-at-pressures-exceeding-16-bar/

1.4 Method

1.4.1 Capability analysis method

Analysts have to balance the system such that supply equals demand, all our obligations are met and all parts of the network are functioning within their working parameters. When undertaking this task, the analysts are guided by a set of principles which are laid out in our operating procedures and our Transmission Planning Code[6].

1.4.2 Inputs

Having established an up-to-date and validated network analysis model, appropriate supply and demand information is used. Unless there are specific reasons not to, we choose high (415 mcm), medium (300 mcm) and low (195 mcm) demand days. Figure 9 shows the actual flows seen in 2021 and setting into context how the values we choose equate to hypothetical winter extreme, shoulder months and summer demand levels.

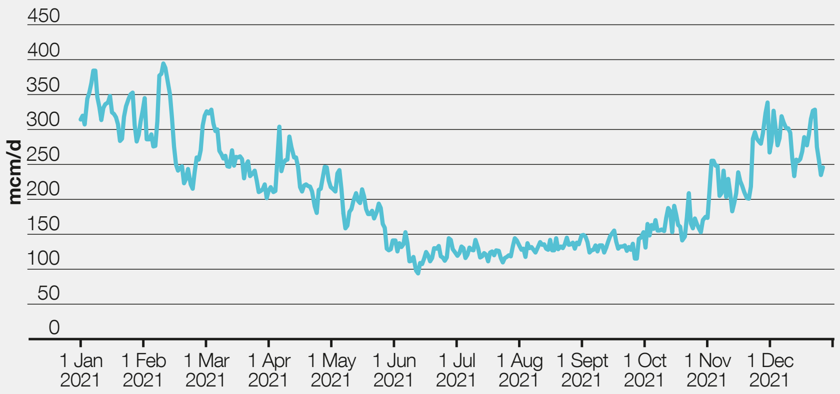
1.4.3 Assumptions

Network analysis follows a standard set of documented assumptions which must be used for all analyses carried out. These assumptions are reviewed and updated annually. Specific details include both physical and commercial requirements such as:

- Maximum Operating Pressures
- Entry (and Exit) Capacity Obligations
- Assured Offtake Pressures
- Anticipated Normal Operating Pressures
- compressor fleet assumptions, including amongst others:
  – priority of use
  – specific configurations
  – maximum flows
  – maximum discharge pressures.

Figure 9

Figure 9
Gas demand seen in 2021



6. https://www.nationalgrid.com/uk/gas-transmission/document/128221/download

1.4.4 Analysis approach

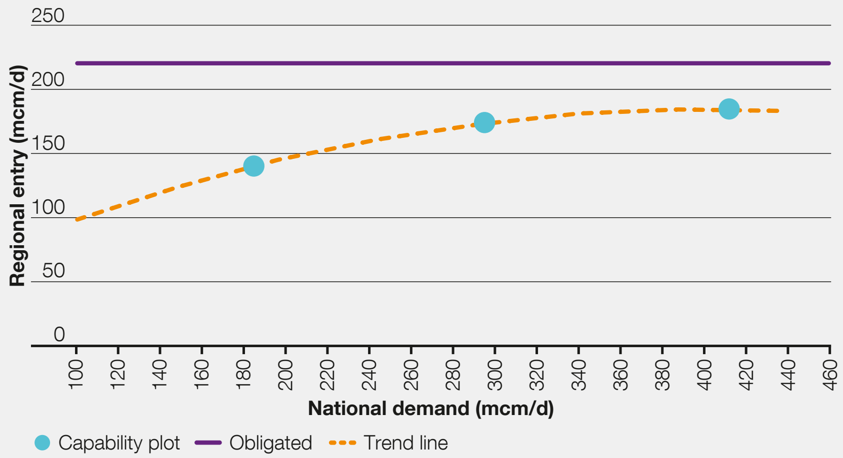
When analysing a particular zone, the analyst will increase the supply to that zone to the maximum possible before the required entry conditions cannot be met. They will also have increased the nearest supply point, to the zone under analysis, to its maximum flow rate for that year. However, as overall network supply and demand should remain balanced, it means that supplies in the rest of the network must be reduced by the same amount as the increase in the specified zone. This reduction is taken from the supply points of lowest interaction. Lowest interaction is determined by those points that are farthest away by pipeline distance. So, the supply point furthest away from the zone under consideration is deemed to be the least interactive.

The balancing supply can be reduced to its appropriate forecast minimum supply for the gas year being considered. After reducing supply at the least interacting point to the forecast minimum, the supply at the next least interactive point will be reduced. If it is not possible to reduce the supply to the forecast minimum without creating local exit constraints, supply will be reduced to as low a level as possible and then from the next least interactive point. If there is still too much overall supply, having reduced all interactive supply points to their minima, then the list of balancing points will be returned to, and the least interactive supply can be reduced to zero, or to a level just above where local exit constraints are created. The above steps will then be repeated.

The outputs from The Network Model analysis, for each zone, include every entry and exit point on the NTS in terms of gas flow as millions of cubic meters per day (mcm/d) rate. This data is then aggregated into supply and demands for each zone and nationally. The maximum attainable supply for the zone under consideration is plotted against the national demand – this is the capability.

The capabilities for each zone are plotted on a graph and a trend line is calculated between these points, see Figure 10. The line that is produced is referred to as the Boundary Line. We also add to the chart our obligated flow levels for the region (that is the level of flow that we must be able to release at entry and exit points on any given day). It should be noted that the obligated levels shown are undiversified, that is the sum of all our obligations.

Figure 10
Illustrative capability points, trend line (Boundary Line) and obligated level



1.5 Flame charts example

Figure 11

The flame charts evolved during the RIIO-2 Business Plan development process based upon extensive engagement with stakeholders. The data for the flame charts is derived both from the Boundary Line equations and an in-house statistical model. This probabilistic supply and demand model is used for several different processes as a constraint management tool and as a key contribution to our annual Strategic Business Plan.

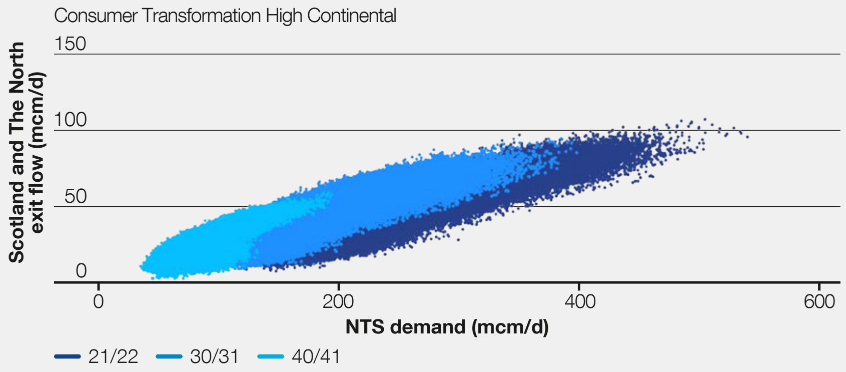
The probabilistic supply and demand model takes for every day of each chosen year, seven different composite weather variables[7] (CWV) to the distribution network exit points on the NTS. It randomises the demand from NTS connected power stations, and it uses regression analysis on the effects of CWV on interconnectors, storage and direct connect industrial sites. The result is a set of 980 unique data points covering the range of potential supply and demands for each day and 357,700 data points for any year. These points are mapped onto our flame charts as the blue dots.

We carry out this process for specific years out to 2050 and for each of the four *FES* scenarios. Figure 11 gives an example of a flame chart output for one region and one *FES* scenario. It encompasses every view of supply and demand that is plausible in the specified region.

1.5.1 Exit capability results

For Exit Capability we use, a single figure per zone which is the 1-in-20 Peak Demand Day level. However, we are working towards productions of capability lines, similar to entry and, where these have been produced, they are given in the following sections of this report.

Figure 11
Example of a flame chart for the years 2021, 2031, and 2041



7. CWV takes into account not only temperature, but also wind speed, effective temperature and pseudo seasonal normal effective temperature

1.5 Flame charts example

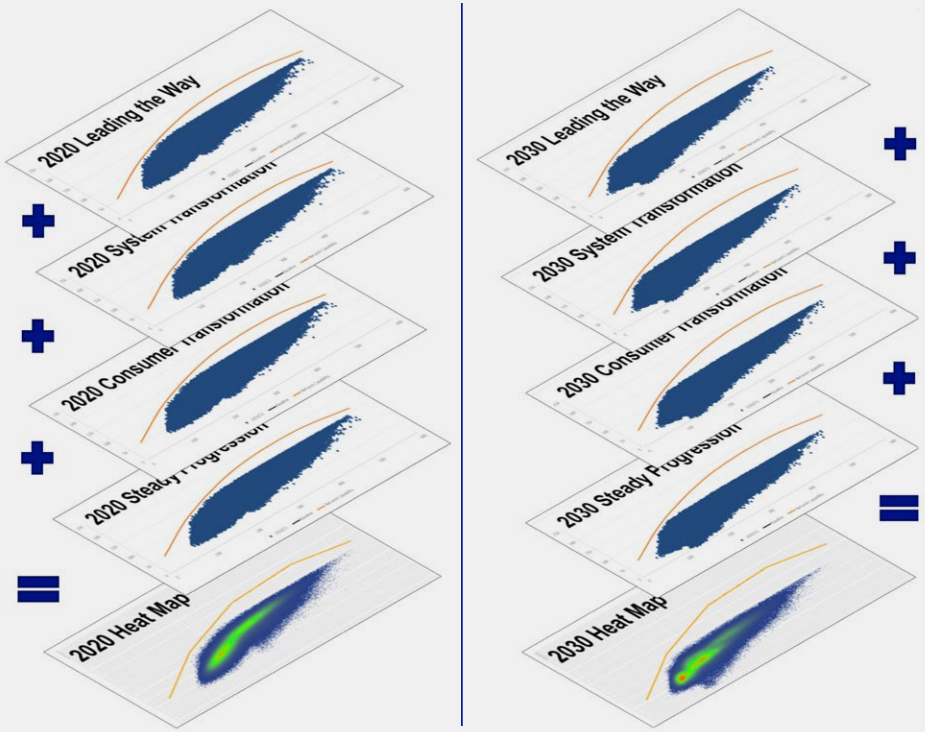
Figure 12

1.5.2 Network Capability visualisation

Stakeholders told us they wanted to see all the scenarios in one location to help inform their decisions. As each of the scenarios, within the Future Energy Scenarios, are equally plausible, and broadly similar, for the next decade, we have combined all the flame charts for 2020 into one heatmap and the flame charts for 2030 into a second heatmap. Every dot that was indicated on the four scenario charts for one year has been combined onto one chart. This allows for more insight as it now shows the frequency of the dots that make up the charts, see Figure 12 for an illustration of the process.

Within the *FES* output there are also two sensitivities – a High LNG and a High Continental – these too have been aggregated into the charts. So, for any one day, there are 7,840 flows represented. Therefore, in any one flame chart, in this ANCAR's zonal analyses, there are 2,861,600 different *FES* flow possibilities being illustrated.

Figure 12
Process behind creating the heat maps



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Stakeholder engagement

2. Stakeholder engagement

Figure 13

We have been engaging with stakeholders at a variety of forums and bi-laterals (see Figure 13), but we also encourage direct feedback that can be submitted to: Box.OperationalLiaison@nationalgrid.com.

Over the last 12 months, based on stakeholder feedback received, we've been working on three improvement projects to enhance the articulation of the existing flame charts, namely:

- network resilience and compressor reliability
- interzonal gas movements
- linepack management.

As a commitment to our stakeholders, we published, in the Gas Ten Year Statement (GTYS), a preview of the latest flow data that we received from the Future Energy Scenarios to enable feedback that might be incorporated into the next ANCAR. Therefore, about a fortnight after GTYS was published, we held a Webinar on the 15 December 2021. This was followed up by a second webinar on 21 April. The feedback we got from both these Webinars is given in Table 1.

Feedback has been received from sources such as the Operational Forum where there is a desire for future versions of ANCAR to give a better visibility of supply, demand and line pack data at a zonal level that can be clearly linked to national linepack swing.

Figure 13
Relationship of the Network Capability process and stakeholder engagement activities

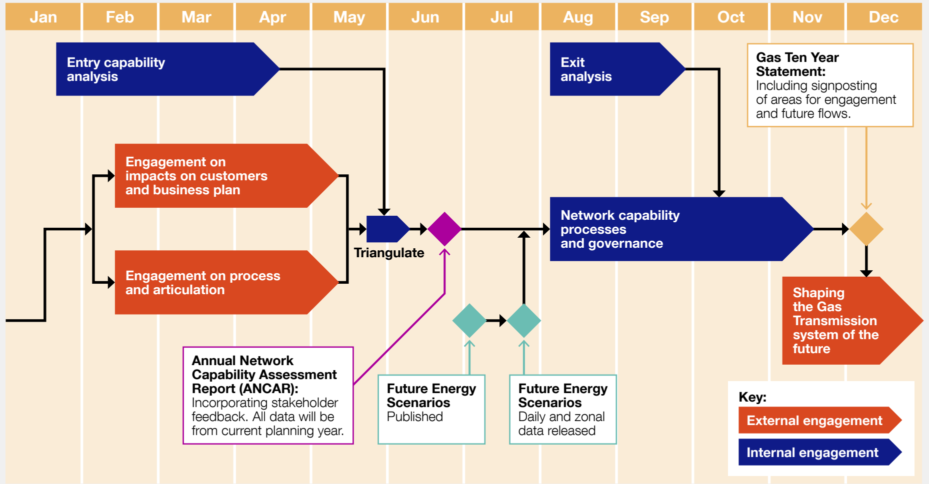

Table 1
Stakeholders' requests resulting from Shaping the Gas Transmission of the Future Webinar (15 December 2021)

	You said	We did
ANCAR	1. You liked the articulation of the capability of the network	1. Continued to use flame charts to articulate the network
	2. Different stakeholders want differing levels of detail	2. Developed varying levels of detail so stakeholders can get the level of information they want
	3. Articulating resilience and interzonal flows are still important	3. Established measures and articulations for resilience and interzonal flows that are being tested with targeted stakeholders.

8. https://players.brightcove.net/2346984621001/default_default/index.html?videoId=6286994495001

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Network capability

3.1 Overview

The capability Boundary Line, which is overlaid onto the flame chart, shows the level of capability that can be delivered by the current network. It is based on the current network, including any confirmed changes, as laid out in our RIIO-2 Business Plan. In some zones, there is an opportunity to stop operating compressors that are non-compliant with emissions directives or units which are redundant for the operation of the network.

In some cases, these will be considered for decommissioning and not replaced. Those units, that have provided resilience to the main operating units at compressor sites, will be retained but with reduced running hour forecast as it may not be economic to replace them if this is their primary function. The network capability is not affected but the system resilience, how often that capability can be achieved, will be reduced. This issue is explored further in section 4.1 on resilience.

Over the next 10 years, it is proposed that our compressor fleet's operational units will reduce, mainly due to the Medium Combustion Plant Directive emissions legislation. This reduction will maintain the capability of the network, but it does remove some of the system's resilience back-up units and hence reduces the frequency at which we can achieve the network capability levels. For a more full account of this potential reduction see the Gas Ten Year Statement[9].

We are working to provide more effective ways of articulating resilience effects and we would welcome stakeholders' views on this, and contact can be made via: .Box.OperationalLiaison@nationalgrid.com

When we assess the network capability, we make the important assumption that all commissioned compressors are available. No planned or unplanned outages have been considered in relation to any of the compressors in our current flame chart visualisations. See section 4.1 for more information on asset availability.

As stated earlier, the Future Energy Scenarios contain three new Net Zero scenarios. Out to 2030, the updated flame charts continue to support the proposals we made in our RIIO-2 Business Plan i.e. the range of physical capability is consistent with the requirements demonstrated by the supply and demand scenarios from *FES* with the assets we have available in the network analysis. After 2040, some of the scenarios undergo fundamental changes, these are discussed further in section 3.9.3.

Declining supplies from the UK Continental Shelf (UKCS) mean that Scotland and The North zone will have less reliance on its compressor fleet to deliver the required entry capability, if flows reduce in line with predictions.

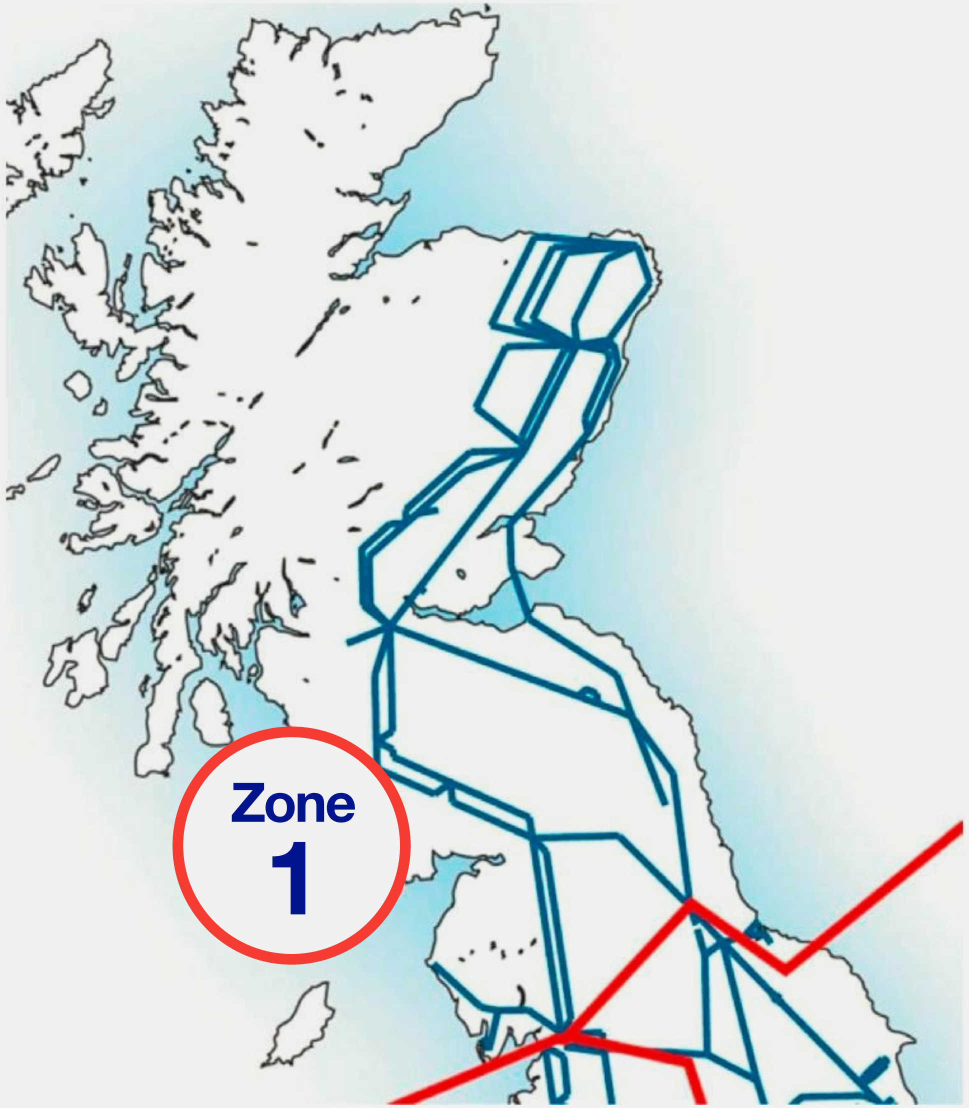
As well as delivering entry and exit physical capability, compressors are also essential for moving gas through a zone, as we discuss in section 4.3, in order to relieve pressure increases at entry points, to satisfy demand and to raise pressure at exit points across the network. Within all zones our investment and maintenance plans are under continuous review to ensure that the compressor fleet is resilient and delivers value to consumers.

We seek to optimise the operation of the system using rules, tools and assets to minimise the probability of constraints where it is economic to do so. In the longer-term, we can make trade-offs between investing in new assets, maintaining existing assets, decommissioning assets, using commercial contracts, and deploying constraint management actions.

However, at all times we have to ensure that we can maintain security of supply, such as the 1-in-20 obligation. Failing to meet these obligations has serious consequences for consumers and the network.

9. https://www.nationalgrid.com/gas-transmission/insight-and-innovation/gas-ten-year-statement-gtys

3.2 Scotland and The North (zone 1)



3.2 Scotland and The North (zone 1)

Figure 14 Figure 15

3.2.1 Scotland and The North entry

The Entry Capability for this region includes entry points at St. Fergus, Teesside and Barrow. Figure 14 indicates that Scotland and The North's entry capability is sufficient to meet the requirements asked of it over the next 10 years. There is a general reduction of supplies entering this zone as UKCS supplies are forecast to decline. This is reflected in the 2031 chart by the lowering of the flame's position, showing reduced inputs into the zone, and a greater concentration of flow frequency towards the lower demand levels as national demand decreases. This situation could, however, change as there are ongoing efforts to find new gas sources within the North Sea with future licencing rounds expected.

3.2.2 Scotland and The North exit

Figure 15 indicates that Scotland and The North's exit capability is sufficient to meet the demand requirements of it both now and in the next 10 years. However, the capability of the overall zone does mask an exit capability issue for Scotland which is dealt with in the next section (3.2.3). The range of the 2031 flow pattern is similar to the 2022 flow pattern. Whilst zonal demands remain only slightly reduced, there is a more pronounced concentration of flow frequencies towards the lower NTS demand levels and fewer flows at the extreme top end of NTS demand levels. These demand changes are believed to be due to the earliest signs of the net zero strategies taking effect.

Figure 14
Scotland and The North (zone 1), Entry Heatmap for 2021/22 and 2030/31

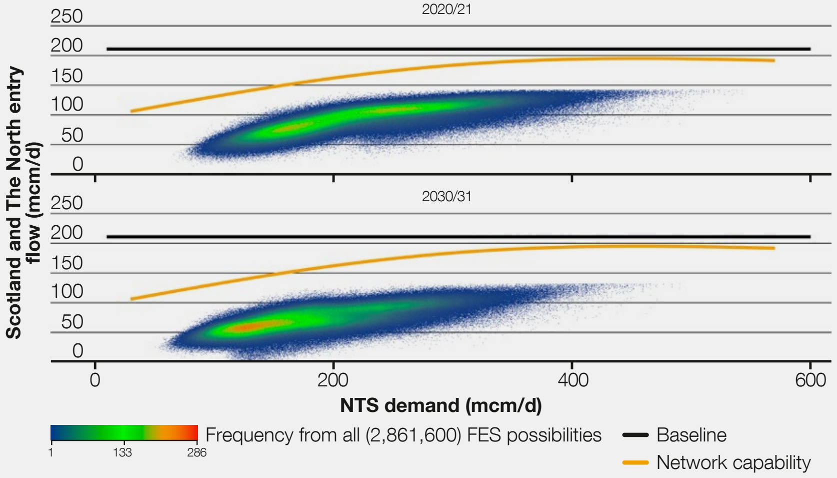
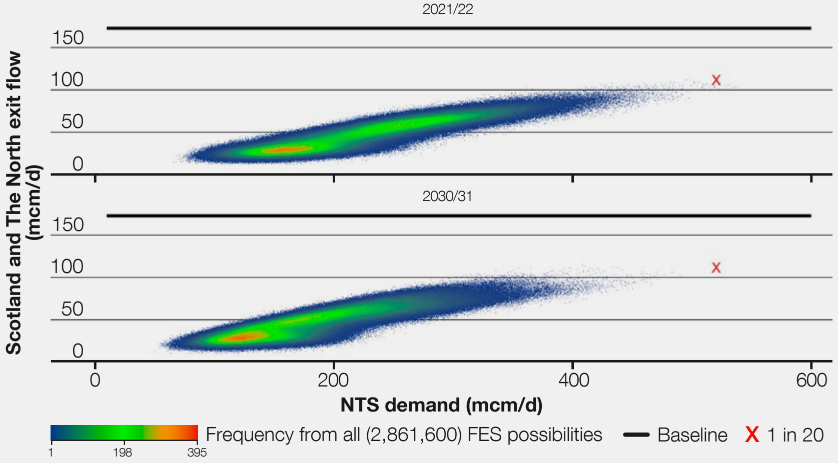


Figure 15
Scotland and The North (zone 1), Exit Heatmap for 2021/22 and 2030/31



3.2 Scotland and The North (zone 1)

Figure 16 Figure 17

3.2.3 Scotland's 1-in-20

With the network having limited capability to transport gas from south to north the decline in entry flows will make it difficult for us to meet our exit commitments in Scotland. To assess the required capability, we annually review just the supplies from the St Fergus terminal against the demand in Scotland. This is because we have no compression capability to move the supplies from Teesside, the North East and the North West towards the areas of high demand in Scotland. Flows from Barrow are expected to steadily decline to zero through to 2031. Figure 16, shows that in 2030/31 we still expect the maximum flow through the St Fergus terminal to be consistent to today's flows, but there are now a number of scenarios with very low or zero flows. A number of these are beyond our current levels of capability and would lead to constraints on the system without intervention. We continue to monitor any flow rate changes and, when appropriate, we will put forward recommendations to mitigate the constraints.

3.2.4 Medium Combustion Plant Directive and St Fergus

The St Fergus terminal receives gas from three sub-terminals (currently owned by Ancala, Shell and North Sea Midstream Partners (NSMP)/Gassco). Uniquely on the NTS, National Grid provides full time compression services for gas received from the NSMP terminal under the terms of the Network Entry Agreement.

There are nine units across three current compressor plants at St Fergus. The bulk of the compression is provided by two electric variable speed drive (VSD) compressor units which were commissioned in 2015. The remaining seven are gas powered compressors from the original site (commissioned in 1978) on two plants and they are not compliant with emissions legislation. These compressors currently provide the low flow capability, back up to the VSDs bulk flow and high capability when used with the VSD compressors.

Figure 17, shows that the range of flows thorough the NSMP sub-terminal are consistent in 2031/32 to those seen today. However, the *FES* scenarios indicate that the frequency of higher entry flows reduce.

Figure 16
Scotland 1-in-20 demand

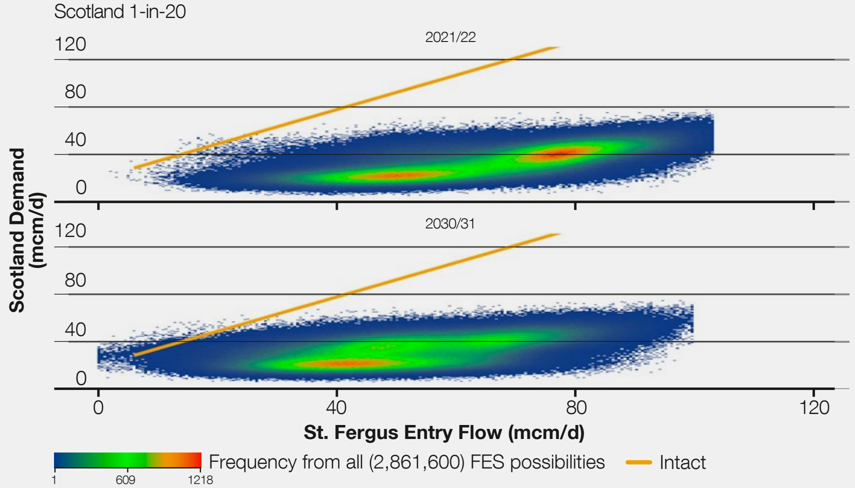
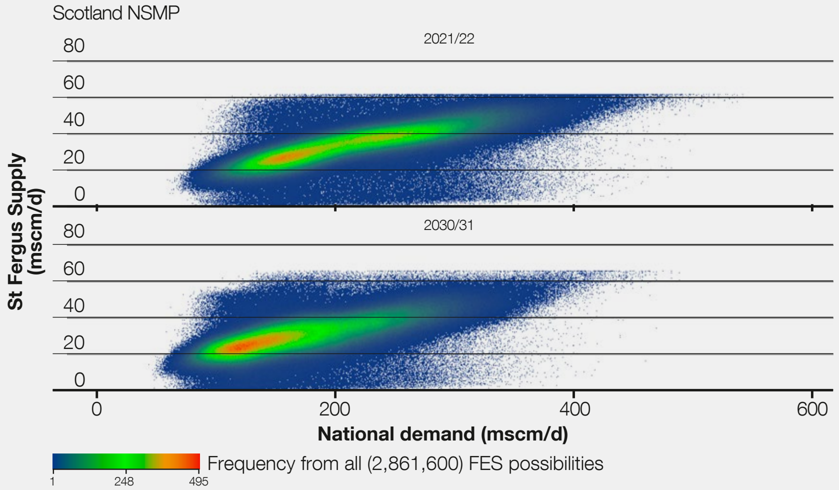


Figure 17
Flows through North Sea Midstream Partners' subterminal at St Fergus



3.2 Scotland and The North (zone 1)

3.2.5 Proposed developments

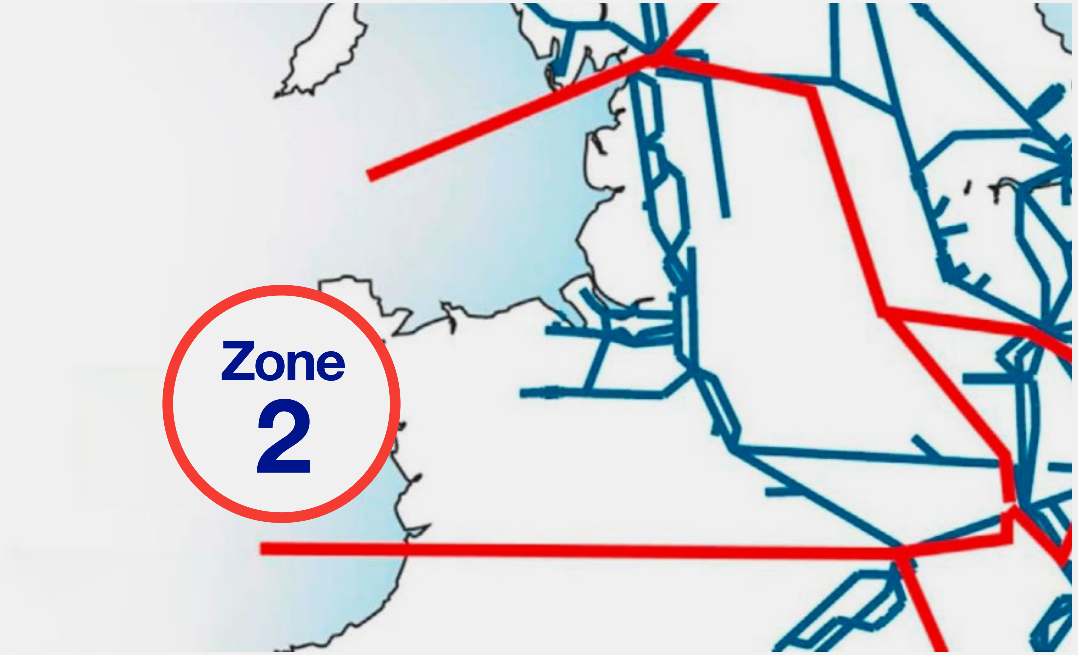
Within this zone, we are considering the decommission of compressor units during both RIIO-2 and RIIO-3[10]. Due to a significant reliance on compression to deliver this zone's capability, there are planned investments during RIIO-2 to improve the reliability of other key units in the zone that continue to provide the network capability required over the next ten years.

The final decision on the units to be decommissioned in the RIIO-3 period (2026 to 2031) will be reviewed during the RIIO-2 period (2021 to 2026) as network capability information and stakeholder requirements become available, and system resilience requirements further assessed.

Historically, entry flows into this region have far exceeded local demand therefore there has been a requirement to move the excess gas to the high demand areas further south. In 2020, at peak demand, supply approximately matches demand but in all four *FES* scenarios peak demand will exceed supply at some point in the future. Currently, all the compression in the zone is designed to move gas south, to the rest of Britain. We will continue to review our forecasts to identify the optimum time to deliver changes to some compressor sites to support flows from south to north when the depleting local supplies cannot support peak local demand. For more detail see Gas Ten Year Statement (GTYS)[11] section 3.3.

10. The RIIO periods are price control periods that are as follows: RIIO-1 (2013 to 2021), RIIO-2 (2021 to 2026) and RIIO-3 (2026 to 2031).
11. https://www.nationalgrid.com/uk/gas-transmission/insight-and-innovation/gas-ten-year-statement-gtys

3.3 North West (zone 2)



3.3 North West (zone 2)

Figure 18 Figure 19

3.3.1 North West Entry

Figure 18 indicates that the North West's entry capability is sufficient to meet the entry requirements required both now and in the next 10 years. As is illustrated, there is minimal change in the range of entry flows between the decades.

From the diagram it will be noted that the network's capability line is significantly above any of the expected supply and demand flows.

Part of this capability is required due to the North West being a transit zone for moving gas between zones with the use of compressors. This interzonal flow is not reflected in the entry capability charts which currently display only supply point flows and not pipeline flows from other zones. Consequently, these charts only illustrate part of the functional requirements of the assets. We continue to investigate this movement and how to effectively display it. Our current thinking is outlined in section 4.2.

3.3.2 North West Exit

Figure 19 indicates that the North West network has sufficient capability to meet the exit requirements required both now and in the next 10 years.

The range of the 2031 flow pattern is similar to the 2022 flow pattern, although the range of potential flows, at any given NTS demand level, has reduced slightly. There is a more pronounced concentration of flow frequencies towards the lower NTS demand levels and fewer flows at the extreme top end whilst zonal demands are only slightly reduced. These demand changes are believed to be due to the earliest signs of the net zero strategies taking effect as less natural gas is being used.

The 2022 North West exit capability chart includes a few data points where the exit flow is above the 1-in-20 level (the red cross on the charts), in this decade. Our modelling takes account of historic site flows, where network conditions occasionally allow some sites to flow at levels above the firm capacity release obligation. These flows do not form part of our 1-in-20 obligation and would be reduced to their firm capacity obligation if it was expected to create or exacerbate a network constraint. However, it should be remembered that each dot represents one of almost 8,000 possible outcomes for that day, which means it might occur one day in 22 years.

The unevenness seen in all the North West's exit flows below a national demand of 350 mcm is predominately a function of our storage site modelling that changes supply to, or from, demand flow patterns onto the NTS, as national demand changes.

Figure 18
North West (Zone 2), Entry Heatmap for 2021/22 and 2030/31

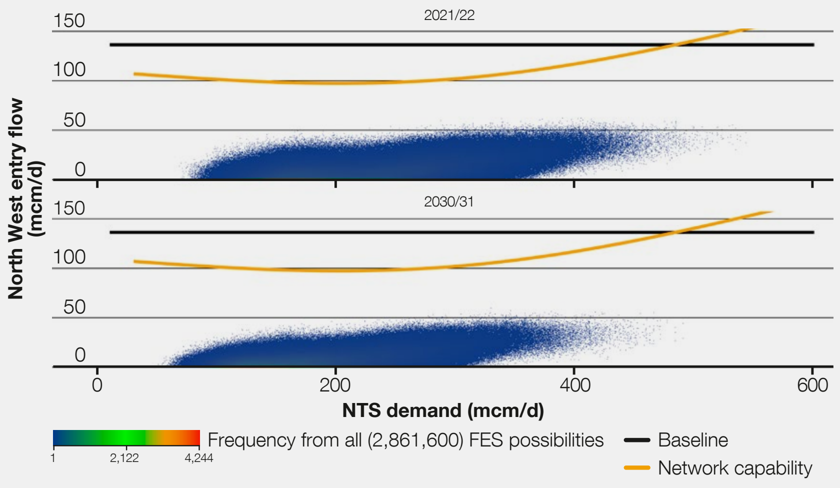
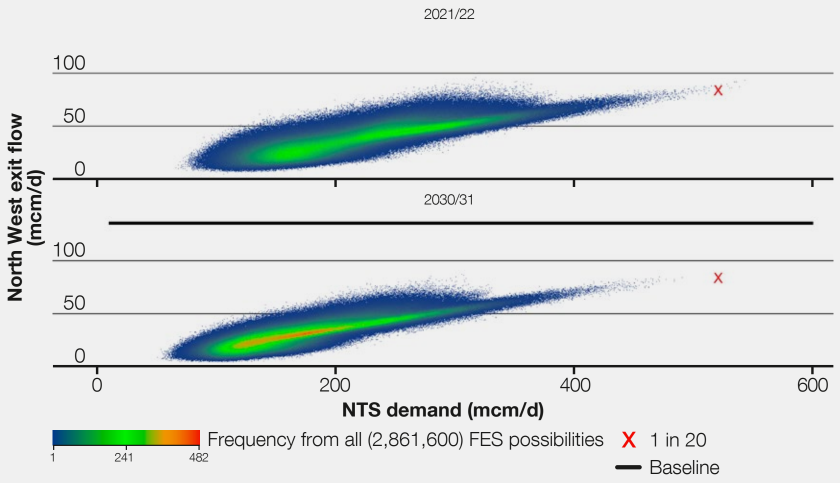


Figure 19
North West (Zone 2), Exit Heatmap for 2021/22 and 2030/31

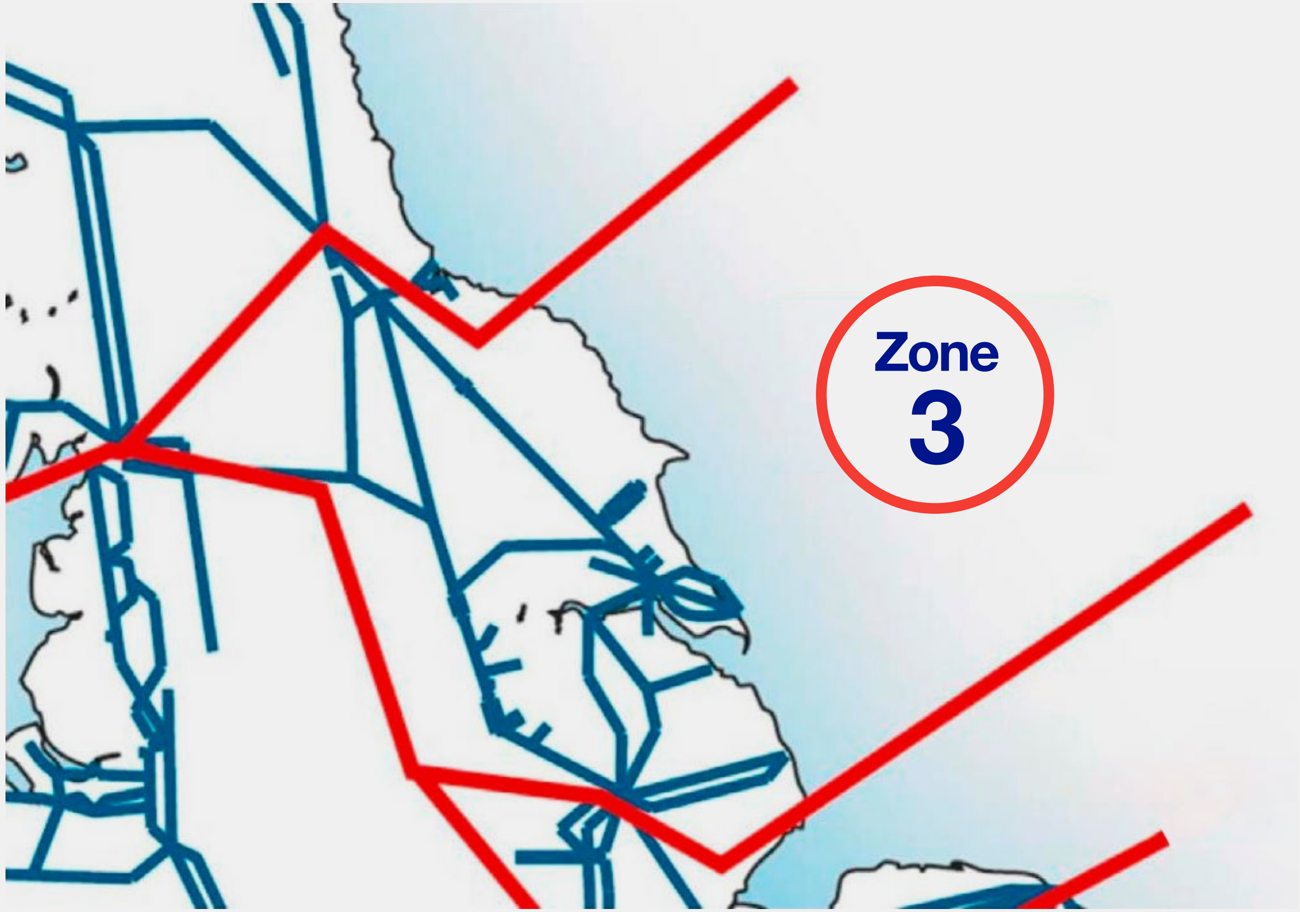


3.3 North West (zone 2)

3.3.3 Proposed developments

During RIIO-2, we are considering the decommissioning of two compressors in this zone. The capability of the zone will not be compromised but the resilience will be affected i.e. the frequency with which we can achieve the capability. See section 4.1 for how we discuss resilience of the NTS. The final decision on the units to be decommissioned in RIIO-3 will not be made until nearer the time and will be under review during the RIIO-2 period. These decisions reflect the forecast reducing need to transport gas from the north to the south due to the potential reduction in UKCS reflected in *FES*.

3.4 North East (zone 3)



3.4 North East (zone 3)

Figure 20 Figure 21

3.4.1 North East Entry

Figure 20 indicates that the North East's entry capability is sufficient to meet the entry requirements both now and in the next 10 years.

The range of the 2031 flow pattern is similar to 2022 flow pattern. There is a more pronounced concentration of flow frequencies towards the lower NTS demand levels and fewer flows at the extreme top end of NTS demand levels, whilst zonal demands remain only slightly reduced. These demand changes are believed to be due to the earliest signs of the net zero strategies taking effect.

The entry capability line for this region is above the expected flows in all the scenarios. Some of this is accounted for by the removal of Rough storage site which supplied up to 45 mcm per day at peak periods. Part of this capability is required due to the North East being a transit zone for moving gas between zones with the use of compressors. This interzonal flow is not reflected in the entry capability charts which currently display only supply point flows and not pipeline flows from other zones. Consequently, these charts only illustrate part of the functional requirements of the assets, that is entry and exit flows and not interzonal flows. We continue to investigate this attribution and how to display it. Our current thinking is outlined in section 4.2.

3.4.2 North East Exit

Figure 21 indicates that the North East network has sufficient capability to meet the exit requirements required both now and in the next 10 years.

The range of the 2031 flow pattern is broadly similar to 2022 flow pattern, although the range of potential flows, at any given NTS Demand level, has reduced slightly. There is a more pronounced concentration of flow frequencies towards the lower NTS demand levels and fewer flows at the extreme top end of NTS Demand levels, whilst zonal demands remain only slightly reduced. These demand changes are believed to be due to the earliest signs of the net zero strategies taking effect.

3.4.3 Proposed developments

During RIIO-2, we will consider the decommissioning of two compressor units in this zone following the commissioning of one new unit to ensure the current capability is retained, although the resilience will be reduced. This reflects the importance of retaining interzonal capability in this zone, especially given the similar potential loss of resilience in the North West region.

Figure 20
North East (Zone 3), Entry Heatmap for 2021/22 and 2030/31

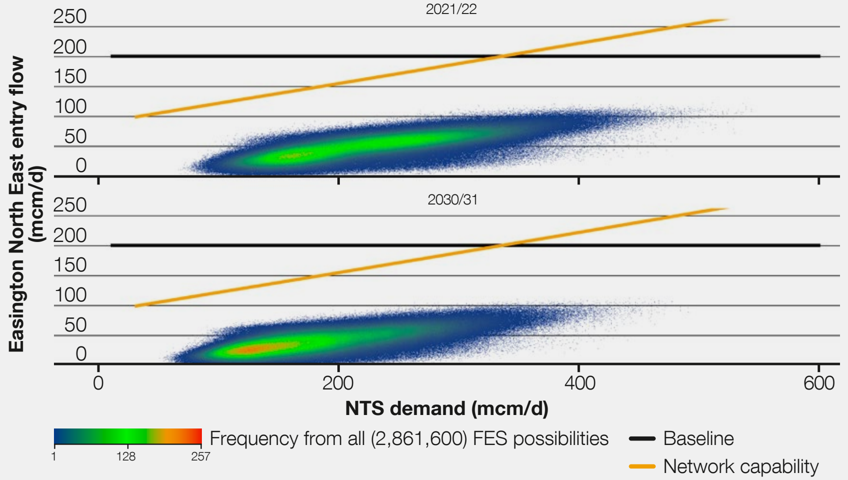
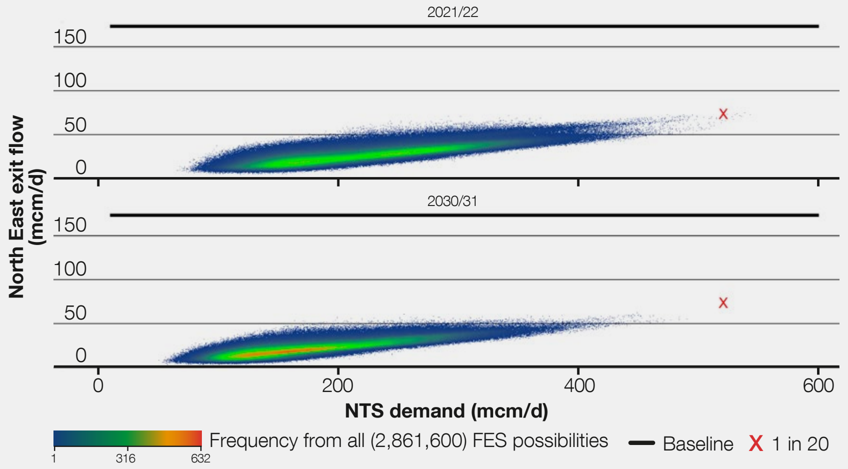


Figure 21
North East (Zone 3), Exit Heatmap for 2021/22 and 2030/31



3.5 South Wales (zone 4)

3.5 South Wales (zone 4)

Figure 22 Figure 23

3.5.1 South Wales Entry

The entry capabilities for South Wales in *FES 2021*, Figure 22, continue to show an increase in periods where supply is above capability. This is consistent with the 2021 ANCAR and shows the strongest indication of all the zones for an increased capability requirement. Historically, within this zone, the use of short-term physical and commercial actions (constraint management contracts and locational sells on the open market) have been used to manage flows above physical capability. Currently, we do not hold any constraint management contracts for this or any other zone, although we have held such contracts during RIIO-1.

Based on global events and the subsequent impact on the UK and global gas markets, for the period June to October '22, the amount of capacity made available at Milford Haven was reduced (with potential flows being more likely to exceed network capability). Although this did not impact the physical capability of the network given this heightened risk of entry constraints and associated potential costs, which would have impacted customers and consumers in this period, a consultation was undertaken to reduce the available capacity at Milford Haven for this period and this was subsequently approved by Ofgem. We are engaging with industry on the forward-looking risk at Milford Haven in subsequent years.

In 2031, there are more periods where supply is above the capability than in 2022. This is caused by increased flows as a result of greater reliance on imports of LNG to offset the declining UKCS supplies. The number of flow dots above the capability line averages out to about three constraint days in one year.

3.5.2 South Wales Exit

Figure 23 indicates that the South Wales network has sufficient capability to meet the exit requirements now and in the next 10 years.

The range of the 2031 flow pattern is broadly similar to the 2022 flow pattern, although the range of potential flows, at any given NTS demand level, has increased slightly.

There is a more pronounced concentration of flow frequencies towards the lower NTS demand levels and fewer flows at the extreme top end of NTS demand levels, whilst zonal demands remain only slightly reduced. These demand changes are believed to be due to the earliest signs of the Net Zero strategies taking effect.

Figure 22
South Wales (Zone 4), Entry Heatmap for 2021/22 and 2030/31

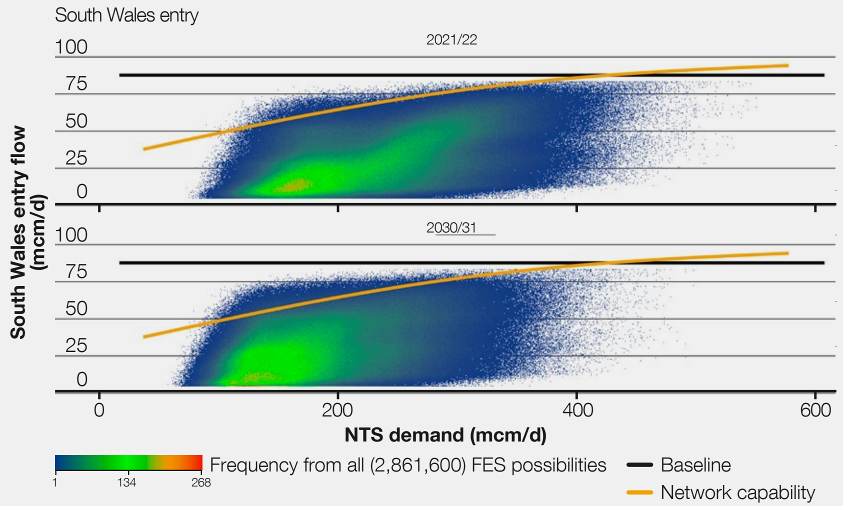
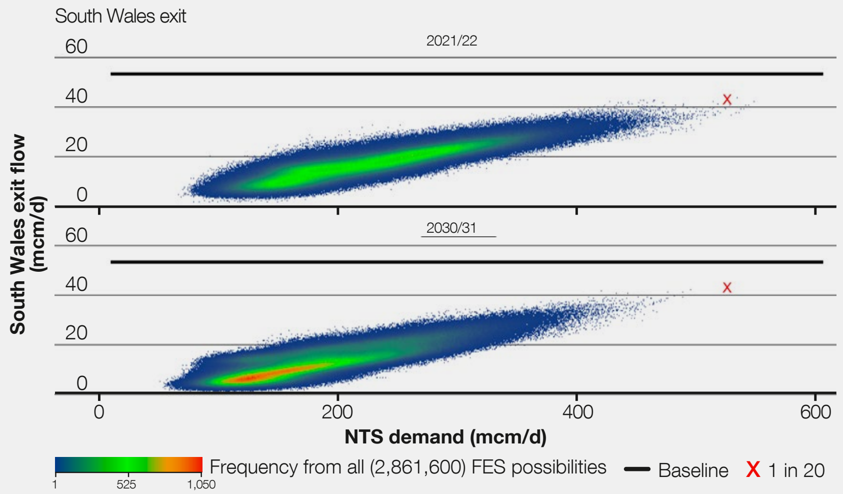


Figure 23
South Wales (Zone 4), Exit Heatmap for 2021/22 and 2030/31



3.5 South Wales (zone 4)

Figure 24

3.5.3 Proposed developments

3.5.3.1 Tirley Above Ground Installation

During RIIO-1, we delayed filter maintenance at Tirley to avoid causing constraints on the network due to the inability to isolate individual filters for maintenance. Isolating the whole site restricts flow in South Wales, reducing entry capacity to about 20 mcm/d. The restriction would also impact gas flows out of England and into South Wales to meet demand, should Milford Haven not be exporting LNG into the network.

Funding was awarded through our RIIO-2 Business Plan to install new isolation valves. This will allow for individual filters at the Tirley site to be isolated and maintained without limiting capability.

3.5.3.2 Western Gas Network (WGN) project

In 2018 a PARCA application was received for the Milford Haven South Hook Terminal. The application was to increase the current entry baseline from 88 mcm/d to 103 mcm/d. Figure 24, shows our current view of the new flow distribution that could result from the WGN project. Overlaid on these flows are the current Network Capability (orange line) and the expected new capability from the preferred option (pink line), once the proposed upgrade has been completed.

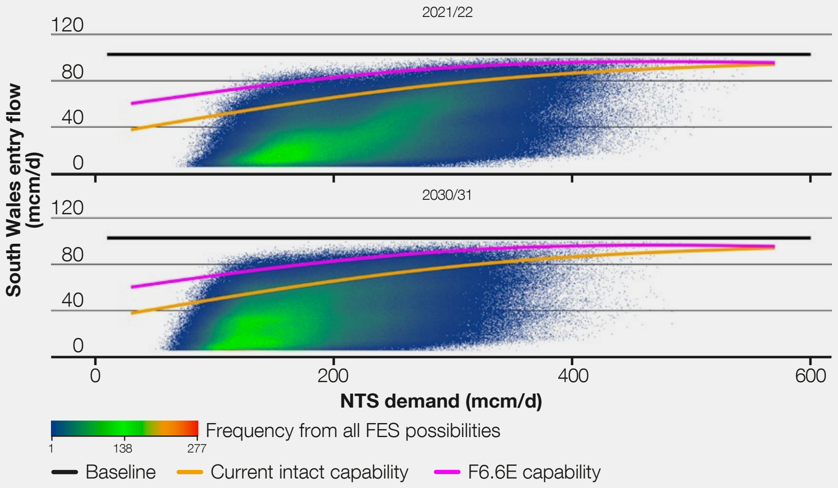
Following the increase, the number of supply/demand scenarios (notated by flow dots) above the current capability make it no longer possible to manage the increased flows with the use of short-term physical and commercial actions (constraint management contracts and locational sells on the market). For this reason, Funded Incremental Obligated Capacity has been triggered.

In 2031/32 the preferred option (pink line) begins to see an increase in flow dots above the new capability. These flow dots only occur in one of the four *FES* scenarios. If this scenario occurs, additional investment will be required during RIIO-3. We will continue to monitor the flows and review the need for further investment in this zone during RIIO-2.

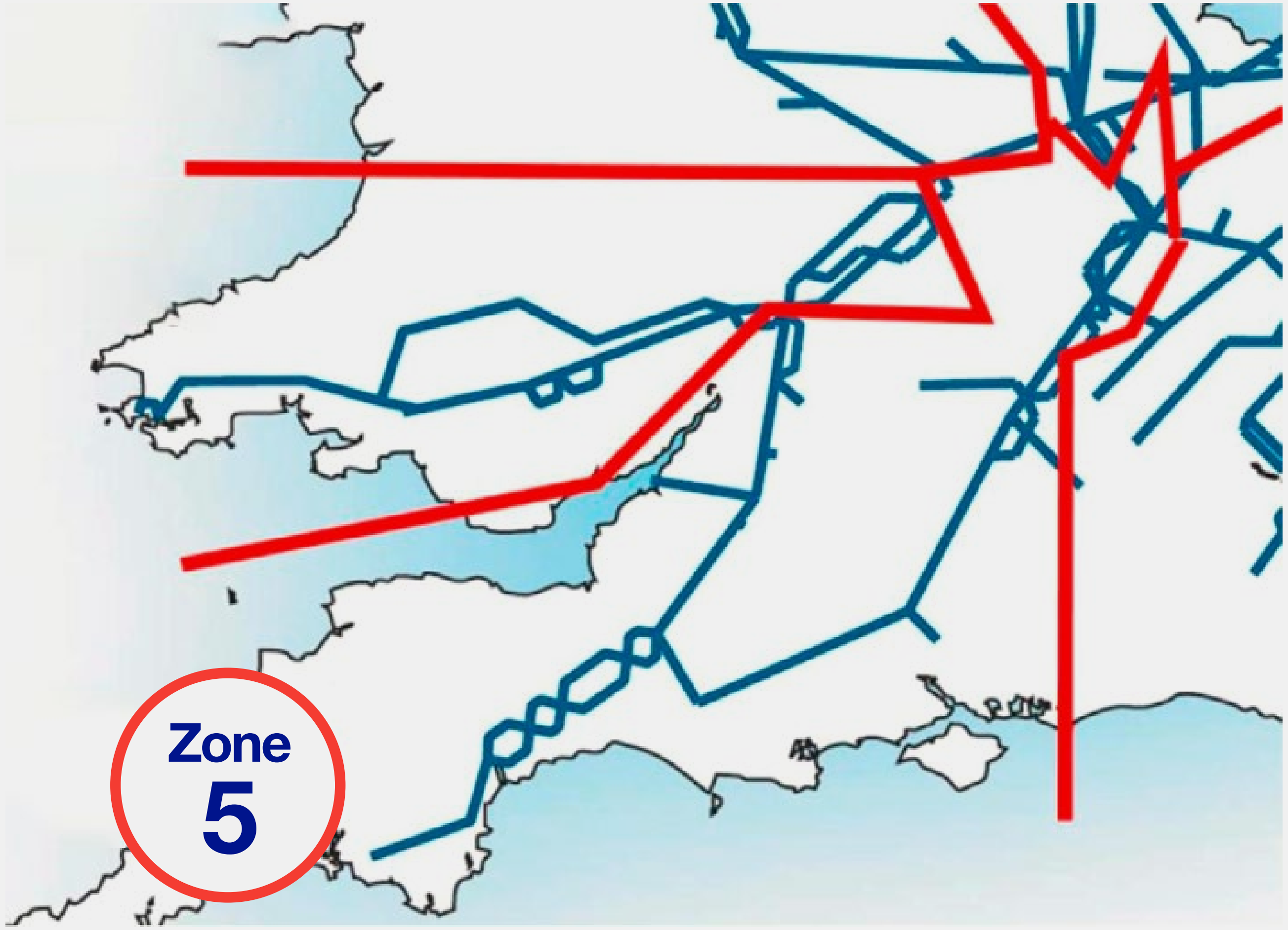
3.5.4 Medium Combustion Plant Directive and Wormington

To provide the current level of entry capability both today and following completion of the PARCA, two units operating in parallel at Wormington are required. Two of the three units on site are impacted by the MCPD and if we choose to "do nothing" they will be placed on a limited run hour derogation. Those derogations will impact how often we can provide the full Network Capability and will drive the level of investment needed to support future entry flows from the terminal. From current cost benefit analysis, two new units is the lead option. We are seeking funding to ensure MCPD compliance through an Uncertainty Mechanism in August 2022.

Figure 24
South Wales (Zone 4) entry Heat Map 2021/22 and 2030/31 with WGNU proposal



3.6 South West (zone 5)



3.6 South West (zone 5)

Figure 25

3.6.1 South West Entry

There are no entry sites, excluding storage which contributes less than 5% of local winter demand, in the South West. Therefore, there is no Entry Capability heatmap for this zone.

3.6.2 South West Exit

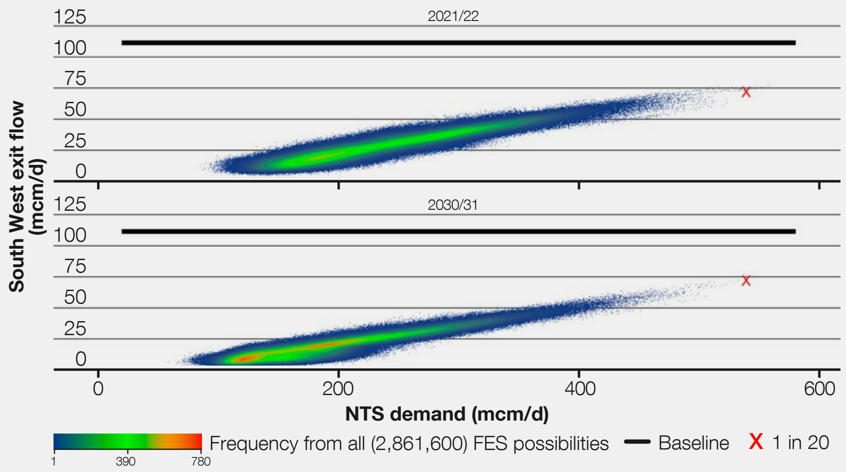
Figure 25 indicates that the South West network has sufficient capability to meet the exit requirements, as they are below the 1-in-20 Peak Demand, required both now and in the next 10 years.

The 2031 flow pattern is broadly similar to 2022 flow pattern, although the range of potential flows, at any given NTS demand level, has increased slightly. There is a more pronounced concentration of flow frequencies towards the lower NTS demand levels and fewer flows at the extreme top end of NTS demand levels, whilst zonal demands remain only slightly reduced. These demand changes are believed to be due to the earliest signs of the net zero strategies taking effect; that is power stations needing to cover the intermittency of the renewable electricity supplies.

3.6.3 Proposed developments

The outcome of how we use two units at Wormington, which fall under the MCPD as described in section 3.5.4, will have an impact on this zone, particularly if the predicted flows in Steady Progression become a reality. These two units straddle both South Wales and the South West zones.

Figure 25
South West (Zone 5), Exit Heatmap for 2021/22 and 2030/31



3.7 East Midlands (zone 6)

3.7 East Midlands (zone 6)

Figure 26

3.7.1 East Midlands Entry

There are no entry sites in the East Midlands zone, therefore there is no entry capability flame chart or heatmap produced.

3.7.2 East Midlands Exit

Figure 26 indicates that the East Midlands network has sufficient capability to meet the exit requirements required both now and in the next 10 years. Although, currently, there are a few data flow points above the capability line this amounts to less than one constraint a year.

The 2031 flow pattern is broadly similar to the 2022 flow pattern, although the range of potential flows, particularly above an NTS demand level of 225 mcm, has reduced. There is a more pronounced concentration of flow frequencies towards the lower NTS demand levels and fewer flows at the extreme top end of NTS demand levels, whilst zonal demand extremes remain only slightly reduced. These demand changes are believed to be due to the earliest signs of the net zero strategies taking effect.

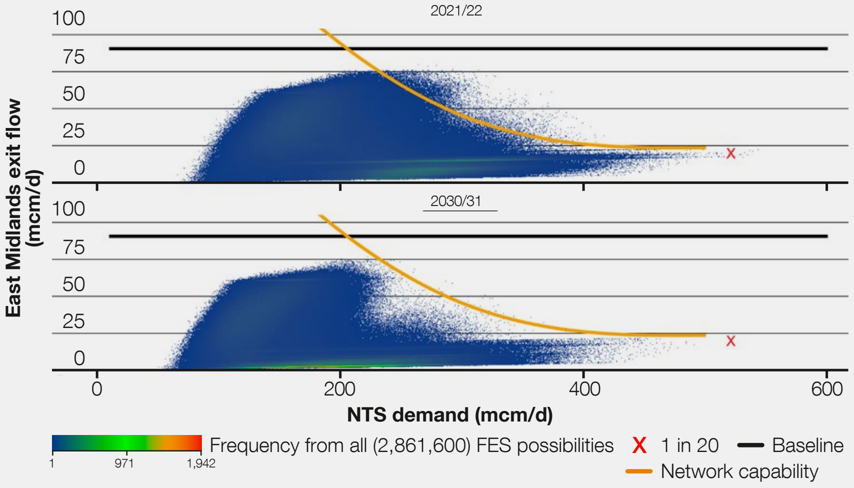
Bacton is considered as an exit point for the East Midlands, as the gas it exports, via the interconnectors, is largely supplied by moving gas from the East Midlands by using the King's Lynn compressor station. In the winter of 2021/22 Kings Lynn has been used more frequently to facilitate winter exports including meeting exit pressure requirements at Bacton.

The plateau shape present in the charts, as national demand increases, is caused by the transition of interconnection flows to the continent from exit to entry via Bacton.

The highest level of exit capability in the East Midlands is when Bacton is exporting to Europe. The chart shows that there will still be the need for Bacton to be able to support baseline levels of exit capability in 2030/31. Further optimisation of flows from LNG imports (from Milford Haven and Isle of Grain terminals) could potentially increase the exit capability at East Midlands, via Bacton.

There are a few data points on the 2022 heatmap where the exit flow is above the 1-in-20 level (the red cross on the charts). These exist for the same reasons as those explained for the North West (see section 3.3.2).

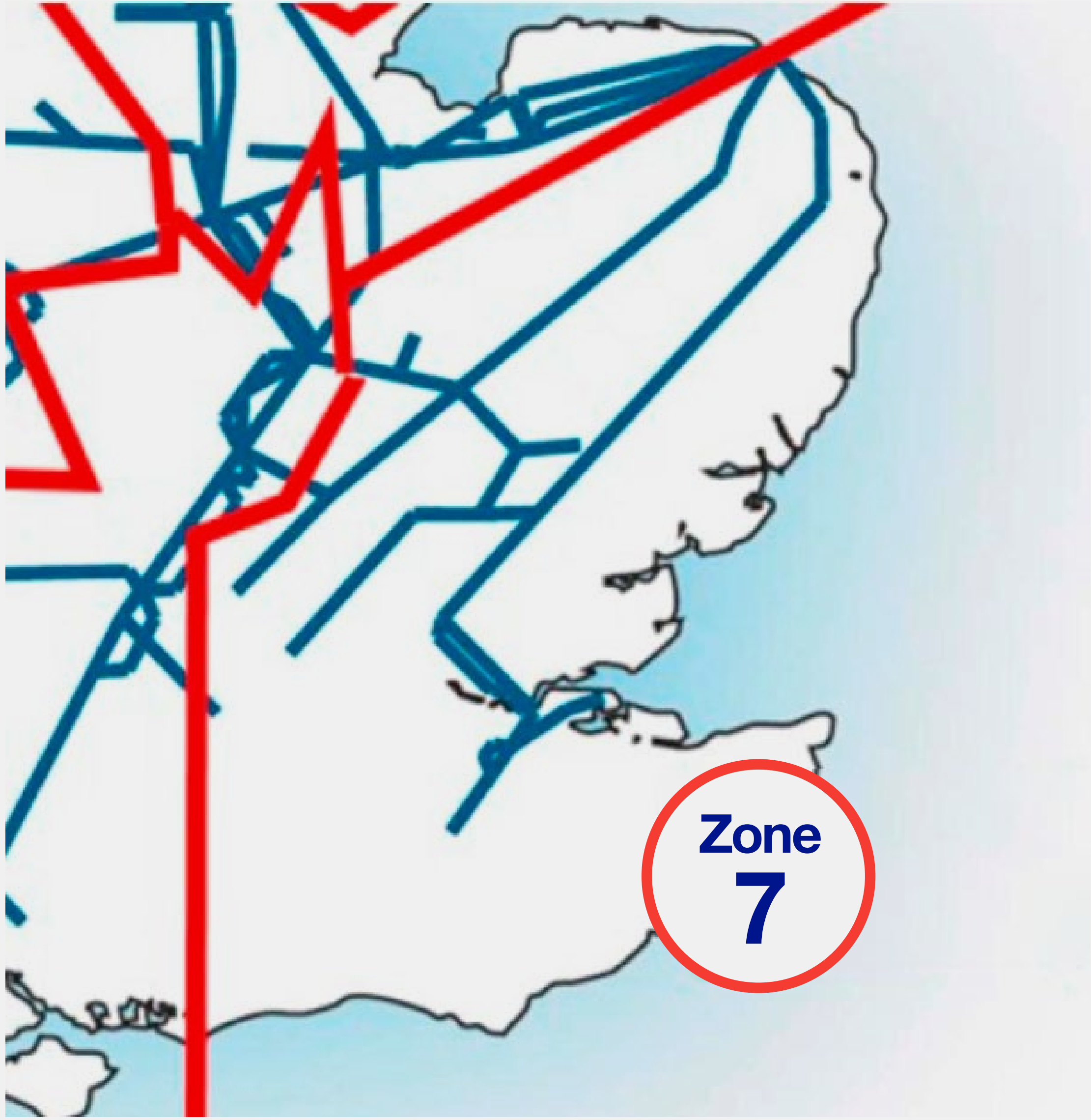
Figure 26
East Midlands (Zone 6), Exit Heatmap for 2021/22 and 2030/31



3.7.3 Proposed developments

During RIIO-2, we will continue to assess the compression requirement in this zone against the proposal to install two new compressors during RIIO-3 and decommission three others that are non-compliant with the Medium Combustion Plant Directive. These changes reflect the requirement to support exit capability at Bacton during the summer and entry capability in the South East zone in the winter.

3.8 South East (zone 7)



3.8 South East (zone 7)

Figure 27 Figure 28

3.8.1 South East Entry

Bacton is considered as an entry point for the South East, as the gas from the terminal is largely used to support the high demand centres in the zone. Figure 27 shows that we expect Bacton flows to remain high and close to the current capability levels. It is therefore important that we retain the current entry capability at the Bacton terminal.

Figure 27 also indicates that in the South East we have sufficient entry capability when entry flows are only seen from the Bacton terminal (orange line). However, if flows from the Isle of Grain terminal are also high (purple line) it would not be possible to maintain high entry flows at Bacton. Historically coincidental high entry flow from LNG and the interconnectors has been an unlikely scenario. But, as UKCS supplies decline and we become increasingly reliant on imports, this risk of high flows from both terminals increases. Although it appears that there are several flow data points above the Isle of Grain high flow capability line (purple line), these equate to, on average, about one day per year for 2021/22 and two days per year in 2030/31.

To provide the current level of entry and exit network capability in the two zones, we operate two units in parallel at King's Lynn. One of the three units onsite are impacted by the MCP Directive and if we choose to "do nothing" they will be placed on a limited run hour derogation in 2030. Those derogations will impact how often we can provide the full network capability and will drive the level of investment needed to support future entry flows from the terminal.

3.8.2 South East Exit

Figure 28 indicates that the South East network has sufficient capability to meet the exit requirements required both now and in the next 10 years. The orange capability line is based upon minimal entry from Bacton and none from Isle of Grain therefore giving a reasonable worst-case situation. However, the 1-in-20 point lies above this worst case capability line, thereby indicating a theoretical risk when both terminals are flowing at minimal entry levels. If either Bacton or Isle of Grain have more than minimal flows, then the capability line rises.

The 2031 flow pattern is broadly similar to the 2022 flow pattern, although the range of potential flows, at any given NTS demand level, has reduced slightly. There is a more pronounced concentration of flow frequencies towards the lower NTS demand levels and fewer flows at the extreme top end of NTS demand levels, whilst zonal demands remain only slightly reduced. These demand changes are believed to be due to the earliest signs of the net zero strategies taking effect.

3.8.3 Proposed developments

We are assessing the current resilience levels in this zone, in line with the method we are developing as described in section 4.1. The outcome of this assessment to be confirmed in 2022 *Gas Ten Year Statement*.

Figure 27
South East (Zone 7), Entry Heatmap for 2021/22 and 2030/31

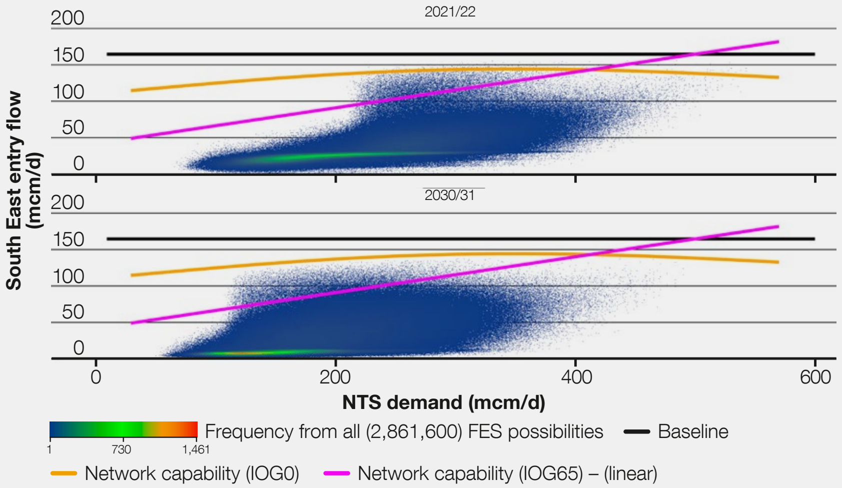
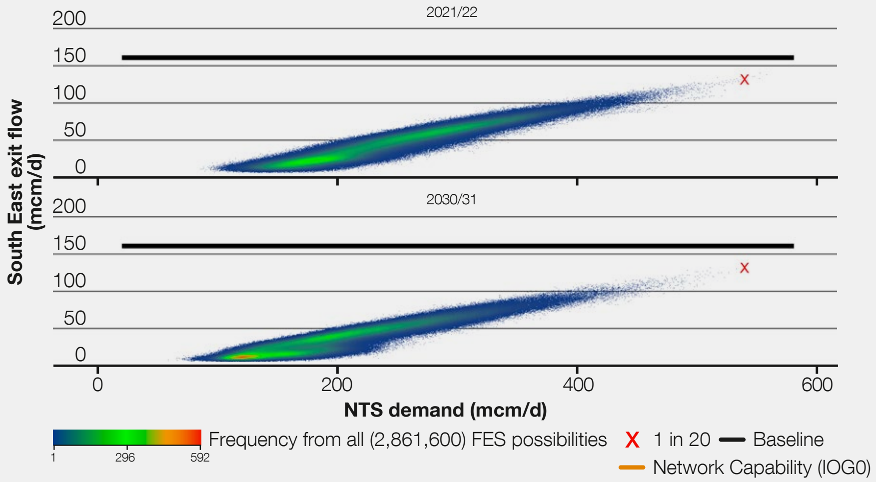


Figure 28
South East (zone 7), Exit Heatmap for 2021/22 and 2030/31



3.9 Beyond 2031

3.9.1 Entry 2031 to 2040

Post 2030, only Steady Progression preserves similar patterns of exit and entry flows that the 2020s display, Figure 29 shows a representative example.

In all scenarios, there is a continual shift away from supply flows from Scotland and The North (see Figure 30) towards a greater dependency of imported supply flows from the south (see Figure 31). This change of flow patterns will likely need to be managed by compressor alterations in order to maintain capability at key sites. This shift needs to be set against a backdrop of lower forecast national demand volumes in the three net zero scenarios.

The development of shale gas, reflected post 2030 in Steady Progression, may require a future reconfiguration of the network. *FES* currently has the North West as the main source of this supply. As and when shale gas evolves, we will monitor its development so that we better understand the implications for the NTS to enable us to consider any implications on network capability and investment.

Figure 29
North East, entry Steady Progression 2020 to 2040

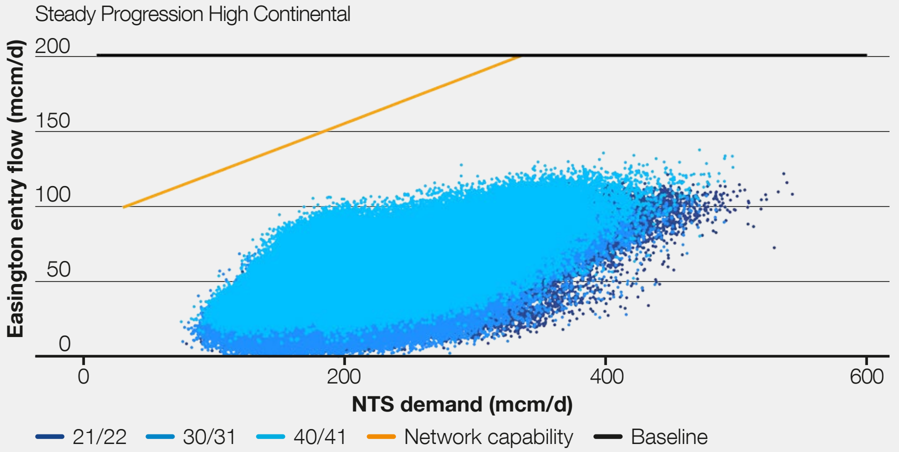
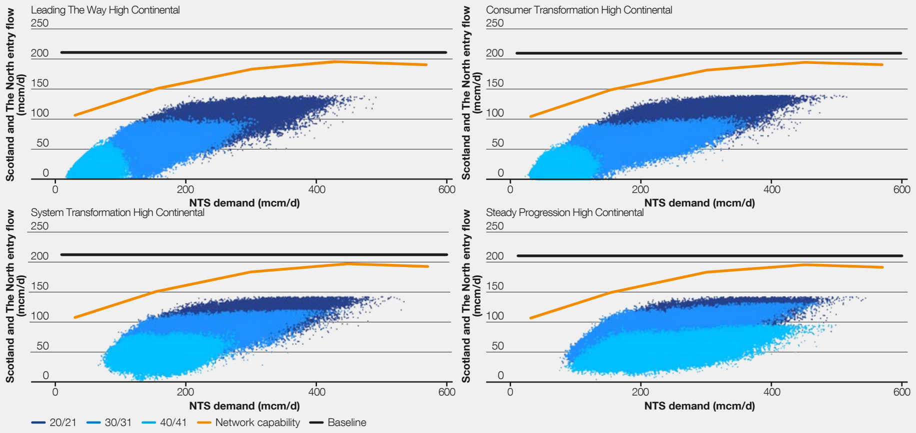


Figure 30
Scotland and The North, entry 2020 to 2040



3.9 Beyond 2031

Figure 31A Figure 31B

3.9.2 Exit 2031 to 2040

The change in exit flows for each of the Net Zero scenarios, Leading the Way, Consumer Transformation and System Transformation, is a reduction in demand, which is a continuation of what is seen in 2022 to 2031. The only non-Net Zero scenario, Steady Progression, shows little variation from today's flows, this is a result of increased domestic appliance efficiency being offset by population growth. Figure 32 illustrates typical exit flows for 2022 to 2041.

Beyond 2031, there is a marked divergence in the different flows in the four scenarios as each one continues to follow its own specific pathway. This is exacerbated by the uncertain nature of hydrogen deployment, which only starts to ramp up after 2035.

Figure 31A
South East entry 2020 to 2040

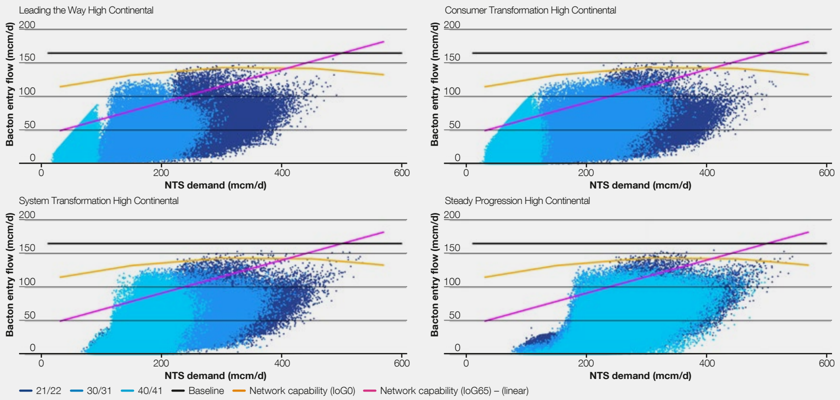
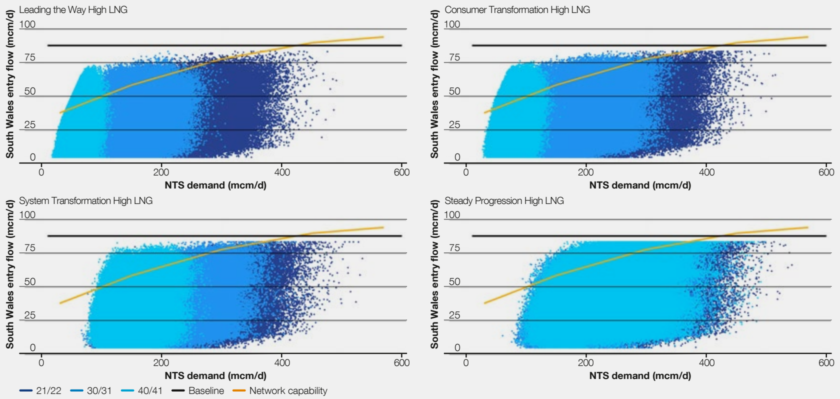


Figure 31B
South Wales entry 2020 to 2040



3.9 Beyond 2031

Figure 32

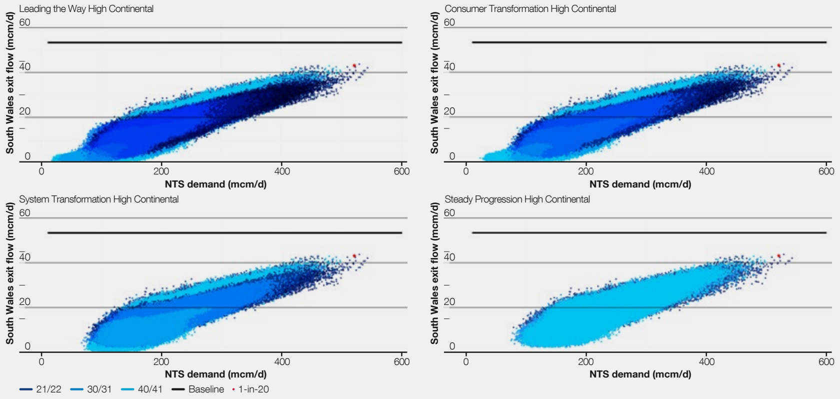
3.9.3 2041 to 2050

By 2050, the flows are expected to be substantially different to those of today. Consequently, the capability lines based on the current asset base will be of little relevance by 2050, with the exception of Steady Progression in which demand for gas stays the same, but the UKCS continues to decline.

Both Leading the Way and Consumer Transformation will have no, or negligible, gas flows. In System Transformation, as the scenario name suggests, the system will be transformed to a network that will primarily support hydrogen dependency using methane reformation, from natural gas, and electrolysis. This will need to begin from 2030 to achieve net zero by 2050. The NTS will have to transition to support both hydrogen and natural gas while maintaining system resilience. Much of the natural gas required in this scenario is forecast to be imported through existing terminals.

When, where and how these hydrogen generation processes take place is uncertain. There are a number of projects, in which we are currently participating, exploring the future of hydrogen that will better inform future analyses[12,13] (see section 4.4).

Figure 32
Typical example of exit flows for 2020 to 2040



12 https://www.nationalgrid.com/national-grid-explores-plans-uk-hydrogen-backbone

13 https://www.nationalgrid.com/uk/gas-transmission/insight-and-innovation/transmission-innovation/futuregrid

Development of the network capability process and analysis

4. Development of the Network Capability process and analysis

Figure 33 Figure 34

4.1 Resilience and compressor reliability

To shape and demonstrate an Analytical Framework, we have developed a Proof of Concept (POC) pilot study of the South Wales zone, one of the seven network capability zones.

4.1.1 Proof of Concept

We applied our Analytical Framework to understand more about network resilience in the South Wales zone. The findings of the study build upon previous ANCAR approaches by taking account of asset availability, providing greater insight into network resilience.

We carried out a POC pilot study in order to:

- see how the Analytical Framework can be used in a real-world scenario
- inform and refine the Analytical Framework and identify areas of development in the framework
- improve our understanding of potential use cases for the Analytical Framework
- understand the outputs of the Analytical Framework and their benefits to understanding network resilience.

We chose the South Wales zone (see Figure 33) as it represents the middle-ground of complexity in the NTS. Previous capability studies had identified it as requiring, potentially, additional entry capability. These entry flows are significantly influenced by imports of gas through the LNG terminals at Milford Haven.

The South Wales network Zone has three compressor stations (see Figure 34):

- Felindre
- Wormington
- Churchover.

To carry out the POC, we analysed the availability of the compressor units in these three stations based on reliability, availability and maintainability (RAM) study findings, historical data, and our expertise on the specific asset performances.

4.1.2 Understanding zone capabilities

To understand the impact of unit-level availabilities on zone resilience, we assessed what combinations of compressor units need to run together in a zone to be capable of delivering flows in the zone. In the POC, we analysed combinations for Intact Capability and High Confidence Capability.

Figure 33
NTS capability zones

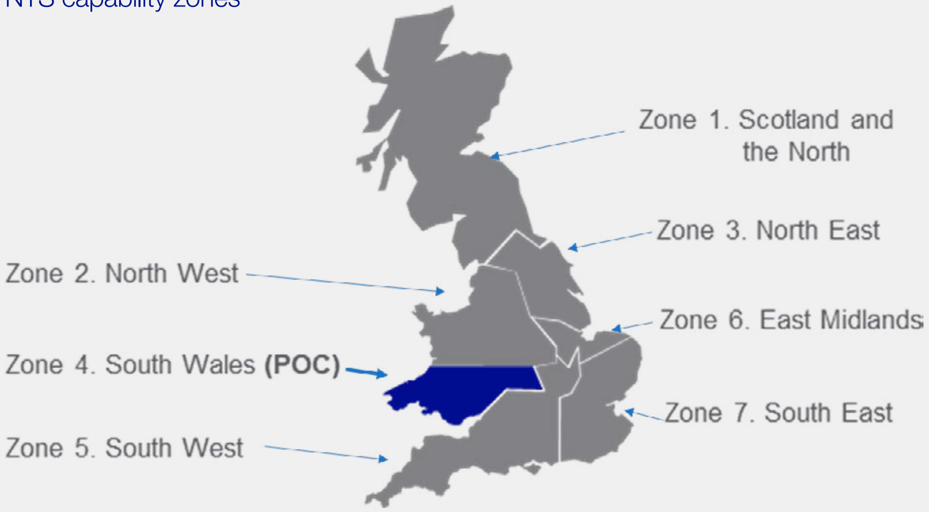
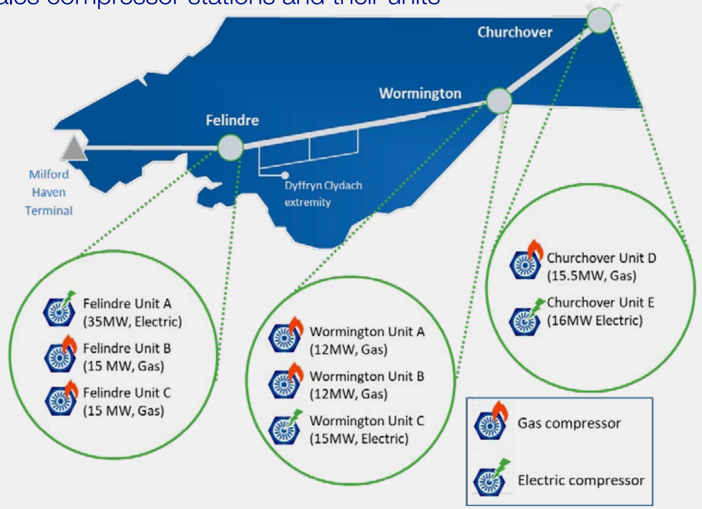


Figure 34
South Wales compressor stations and their units



4. Development of the Network Capability process and analysis

Figure 35 Figure 36

4.1.2.1 Intact Capability

Intact Capability is the highest compressor capability a zone is able to deliver. Because it requires more compressor units to run at one time, it may not be possible to achieve Intact Capability if one or more compressor units are unavailable.

The designed operation for South Wales is achieved by running Felindre compressors B and C (or A, but it is currently unavailable), two Wormington compressors, and one Churchover compressor (see Figure 35).

4.1.2.2 High Confidence Capability

High Confidence Capability is the compressor capability we expect a zone should always be able to deliver. It is calculated so that the likelihood of unavailable compressors preventing High Confidence Capability is below one percent. Because it requires less compressors to run at one time, High Confidence Capability cannot deliver the same flows as intact capability.

High Confidence Capability can be achieved through running multiple combinations of compressors (see Figure 36). This reduces the impact of unit-level availability on the likelihood of meeting High Confidence Capability.

4.1.2.3 Calculating zone availability

Unit-level availabilities were used to calculate High Confidence Capability, and the likelihood of achieving Intact Capability in South Wales.

The unit-level availabilities for the eight compressor units in South Wales currently, and at the end of RIIO-2, were calculated. The unit-level availabilities are calculated based on historic performance, RAM study findings, and unit-specific information (e.g. Felindre A being currently unavailable).

The combinations of units required to deliver Intact Capability or High Confidence Capability are used to translate unit-level availabilities in zone-level availabilities. Combinations of unit availabilities are calculated to provide station-level availabilities. These are then combined to produce an overall zonal availability.

Figure 35
Intact Capability combination – 57% availability

Figure 36
High Confidence Capability combinations – 99% availability

4. Development of the Network Capability process and analysis

Figure 37

4.1.3.0 Assessing resilience

To measure the impact of availability on network resilience, we modelled the number of *FES* flow scenarios in South Wales and analysed the likelihood that the network will be able to meet those scenarios.

Constraint days are the number of days in a year we expect the network will not be able to meet flow scenarios without commercial actions. The more resilient the network, the lower the constraint days.

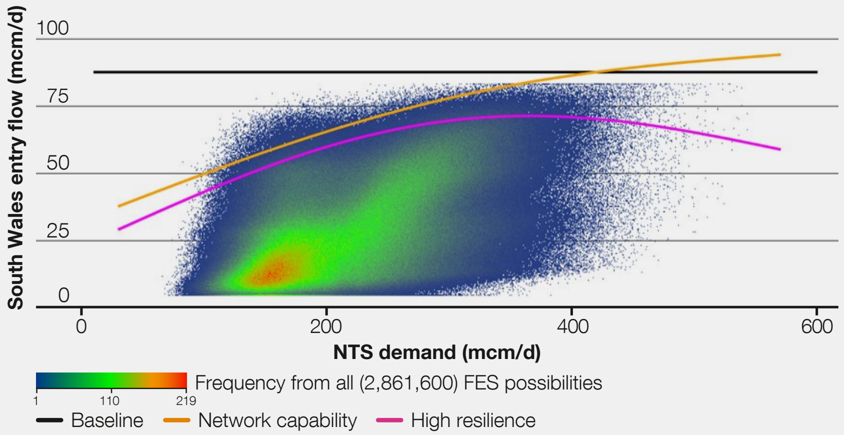
4.1.3.1 Mapping capabilities

We calculated the highest entry flows that the South Wales Intact Capability network and High Confidence Capability network are able to meet across increasing levels of demand, see Figure 37.

Intact Capability is represented by the orange line. It is relatively higher because it represents the most capable network operating scenario.

High Confidence Capability is represented by the pink line. It is lower because it uses less compressor units than the intact capability.

Figure 37
Zonal Flows, Intact and High Confidence Capabilities, for South Wales 2021/22



4. Development of the Network Capability process and analysis

Figure 38 Figure 39

4.1.3.2 Calculating resilience

See Figure 38. The network cannot deliver any of the flow scenarios above the Intact Capability (the orange line) but should deliver over 99% of the flow scenarios below the High Confidence Capability (the pink line). The ability to deliver scenarios between the two lines depend on the asset availabilities. The likelihood of achieving Intact Capability is used to estimate the average number of flow scenarios that will not be met. This number is then converted into days.

The total number of *FES* flow scenarios under the High Capability line (points in the blue area on the chart) is calculated. These represent scenarios that have a greater than 99% likelihood of being met.

The total number of *FES* scenarios under the Intact Capability line but above the High Capability line (the pink area) is calculated. Flows in the pink area have a 54% likelihood of being met in the Current South Wales example. Flows above the Intact Capability line (the orange area) cannot be met.

Estimating the number of constraint days is the number of scenarios that might be met (pink area) multiplied by the likelihood that the Intact Capability will not be available (46% in this example). This is added to the total number of scenarios that cannot be met (orange area) to produce an expected number of scenarios not met (see Figure 39).

We conduct a similar exercise for the years 2025/26 and 2030/31 to enable us to get a short-, medium- and long-term perspective.

Figure 38
2021/22 Current operating strategy example for South Wales

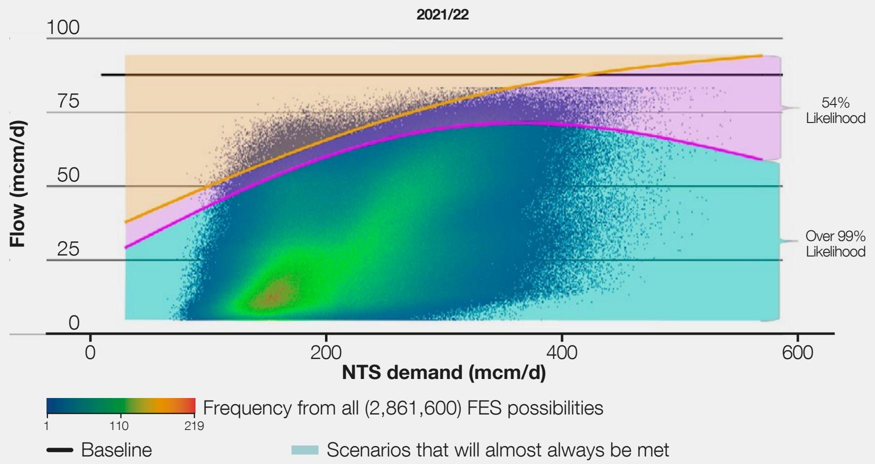


Figure 39
Constraint days calculation

$$\text{Flow Scenarios not met} = \text{Scenarios that cannot be met (orange area)} + \text{Scenarios that might be met (pink area)} \times \left(1 - \text{Intact network availability (\%)}\right)$$

4. Development of the Network Capability process and analysis

Figure 40 Figure 41

4.1.4 Proof of Concept findings for South Wales

4.1.4.1 Current Resilience

See Figure 40.

The current South Wales Zone is at risk of five constraint days a year on average.

The resilience is lower due to unit A at Felindre not being operational and the low levels of availability of the two Avon compressor units at Wormington.

4.1.4.2 Future Resiliencies

See Figure 41.

Planned RIIO-2 Investments

In 2025/26 the South Wales Zone, we expect three constraint days a year on average.

This is based on the current planned RIIO-2 investments, not including the Western Gas Network Project. Reliability is improved by control system upgrades at Felindre, commissioning of Unit A at Felindre, and asset health works at Churchover Unit E.

Western Gas Network (WGN) Project

In 2025/26, in the South Wales Zone we would expect to see two constraint days a year, on average.

This is based on the current planned RIIO-2 investments, including the Western Gas Network Project. The Western Gas Network Project reduces the likelihood of scenarios which would not be met by the intact network capability after planned RIIO-2 investments, reducing the likelihood of constraint days.

Figure 40 Current resilience for South Wales

2021/22 Current operating strategy example for South Wales

Constraint Days	10th Percentile	Expected Days	90th Percentile
Constraint days with Intact capability	0	1	2
Constraint days with High Confidence capability	5	9	13
Expected constraint days	2	5	7

Figure 41

South Wales' resiliencies at the end of RIIO-2

	Constraint Days	10th Percentile	Expected Days	90th Percentile
Planned RII0-2 Investments excl. WGN Project	Constraint days with Intact capability	0	2	4
	Constraint days with High Confidence capability	5	8	12
	Expected constraint days	1	3	5
Planned RII0-2 Investments incl. WGN Project	Constraint days with Intact capability	0	0	0
	Constraint days with High Confidence capability	5	8	12
	Expected constraint days	1	2	2

4. Development of the Network Capability process and analysis

Figure 42

4.1.4.3 Resilience Expectation in ten years' time without any additional investment post RIIO-2

See Figure 42.

In ten years' time we see the zone availibility drop from 82%, at the end of RIIO-2, to 72%. With the WGN project investment completed, this drop in availibility results in the average expected constraint days increasing from two to four days.

Without the WGN project investment, we also see the expected constraint days increase significantly from three to ten days. This increase is better explained by a need to increase network capability with the average constraint days above our capability increasing from two days to six.

Figure 42
South Wales' resiliencies in ten years' time

	Constraint Days	10th Percentile	Expected Days	90th Percentile
Resilience Expectation in 2030/31 excl. WGN Project	Constraint days with Intact capability	3	6	9
	Constraint days with High Confidence capability	14	19	25
	Expected constraint days	6	10	13
Resilience Expectation in 2030/31 incl. WGN Project	Constraint days with Intact capability	0	0	0
	Constraint days with High Confidence capability	9	14	19
	Expected constraint days	2	4	5

4. Development of the Network Capability process and analysis

Figure 43 Figure 44

4.1.5 Current and Future Resilience for Scotland and The North Entry

4.1.5.1 Current and Future Resilience

The current Scotland and the North Entry Zone availibility is 78% with risk of constraints low. Figure 43 shows both the intact and high resilience lines are above our current and future expected flows. However, without investment we see our zone availibility drop to 48% by the end of RIIO-2 and to 37% at the end of RIIO-3. This results in the high resilience line availibility decreasing to 96% in 10 years' time. We therefore need to reassess our high resilience line and consider our future compression strategy in Scotland and the North as we develop our RIIO-3 plans.

Figure 43
Scotland and The North Entry, Network Capability Chart with High Resilience

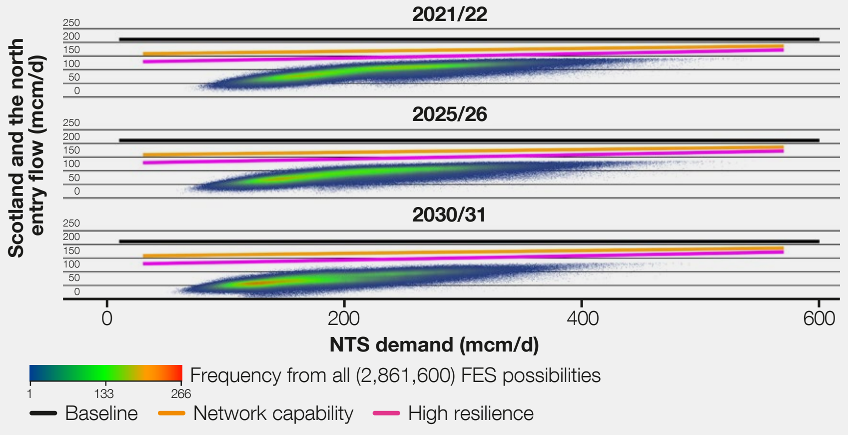


Figure 44
Scotland and The North entry resilience – Current, end of RIIO-2 and in ten years' time.

	Constraint Days	10th Percentile	Expected Days	90th Percentile
Current resilience	Constraint days with Intact capability	0	0	0
	Constraint days with High Confidence capability	0	0	0
	Expected constraint days	0	0	0
Resilience expectation end of RII0-2 period	Constraint days with Intact capability	0	0	0
	Constraint days with High Confidence capability	0	0	0
	Expected constraint days	0	0	0
Resilience expectation in 2030/31	Constraint days with Intact capability	0	0	0
	Constraint days with High Confidence capability	0	0	0
	Expected constraint days	0	0	0

4. Development of the Network Capability process and analysis

Figure 45 Figure 46

4.1.6 Current and Future Resilience Scotland Exit

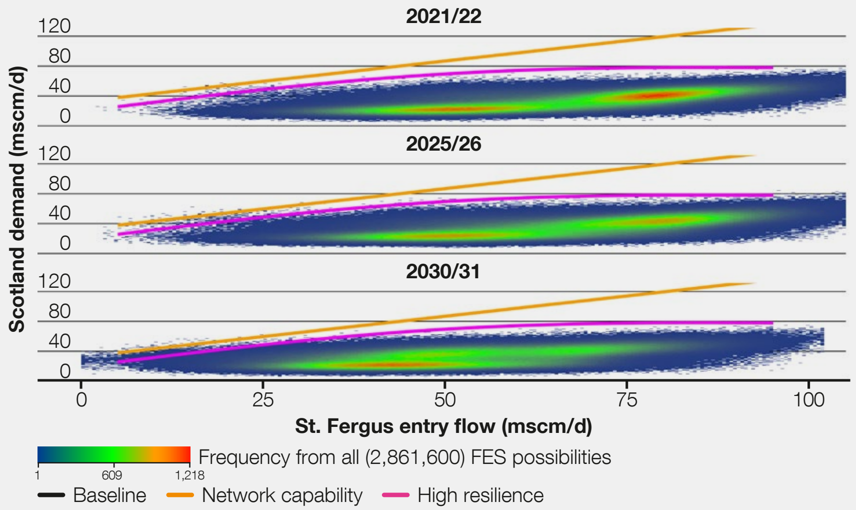
4.1.6.1 Current and Future Resilience

Current Scotland Exit zone availibility is 84% with the average constraint days forecast as zero now and in 10 years' time. However, in 10 years' time without investment we are no longer able to maintain the high resilience availibility above 99%. The impact of this will be considered as part of our RIIO-3 business plan.

Figure 46
Scotland exit resilience – Current, end of RIIO-2 and in ten years' time.

	Constraint Days	10th Percentile	Expected Days	90th Percentile
Current resilience	Constraint days with Intact capability	0	0	0
	Constraint days with High Confidence capability	0	0	0
	Expected constraint days	0	0	0
Resilience expectation end of RII0-2 period	Constraint days with Intact capability	0	0	0
	Constraint days with High Confidence capability	0	0	8
	Expected constraint days	0	0	0
Resilience expectation in 2030/31	Constraint days with Intact capability	0	0	0
	Constraint days with High Confidence capability	0	0	0
	Expected constraint days	0	0	0

Figure 45
Scotland and The North resiliencies in ten years' time



4. Development of the Network Capability process and analysis

Figure 47 Figure 48

4.1.7 Current and Future Resilience East Midlands Exit

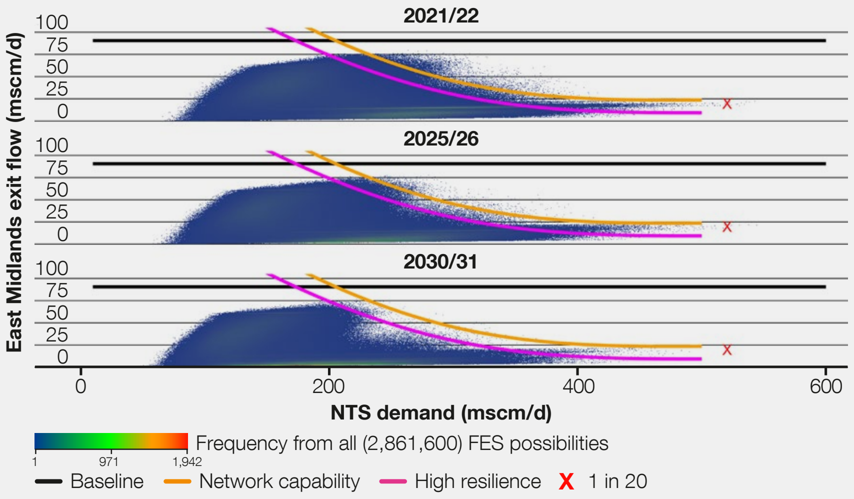
4.1.7.1 Current and Future Resilience

The current zone availibility in the East Midlands is 86% with an average expected constraint of two days. This is expected to reduce to 1 day by the end of RIIO-2 and with the decline of national demand seeing this reduce to zero days by 2030, even with zone availibility dropping to 55%.

Figure 48
East Midlands Exit Reslience – Current, end of RIIO-2 and in ten years' time.

	Constraint Days	10th Percentile	Expected Days	90th Percentile
Current resilience	Constraint days with Intact capability	0	1	2
	Constraint days with High Confidence capability	7	11	15
	Expected constraint days	1	2	4
Resilience expectation end of RII0-2 period	Constraint days with Intact capability	0	0	0
	Constraint days with High Confidence capability	2	5	8
	Expected constraint days	0	1	1
Resilience expectation in 2030/31	Constraint days with Intact capability	0	0	0
	Constraint days with High Confidence capability	0	1	2
	Expected constraint days	0	1	1

Figure 47
East Midlands Exit, Network Capability Chart with High Resilience



4. Development of the Network Capability process and analysis

4.2 Interzonal flows

For a gas system to remain balanced all inputs must be matched with corresponding outputs. On the NTS, terminal supplies are not perfectly matched with demand within each zone, therefore zonal transfer is necessary in order to maintain the correct safe pressures on the network.

The imbalance between a zonal supply and demand will cause areas with either:

- **A supply surplus (net supply zones)** thereby having higher pressures than areas with a demand surplus (net demand zones), this difference in pressure will cause gas to flow from the net supply zones towards the net demand zones.
- **A supply shortfall (net demand zones)** thereby having lower pressures than areas with a supply surplus (net supply zones), this difference in pressure will cause gas to flow from the net supply zones towards the net demand zones.

Figure 49 shows forecasts for 2021/22 average supply and demand balances within each zone, across three different national demand levels.

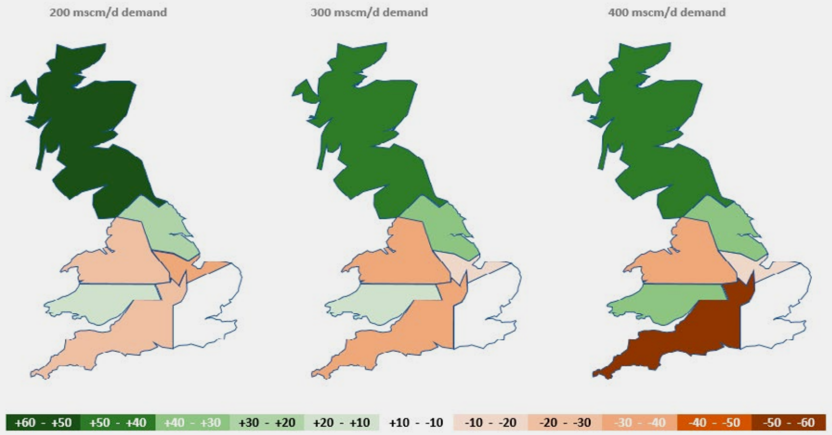
In order for the system to remain balanced, in terms of linepack distribution, any zone with a supply surplus (green) must have the amount of gas indicated transferred out of it into an adjoining zone over the gas day, conversely any area with a supply deficit (orange) must have that amount of gas transferred into it.

There is a general flow pattern across the network, with gas flowing from Scotland and The North, North East and South Wales towards the North West, South West and East Midlands. This gives an indication of the capability which may be required in order to keep the system balanced.

As an example of interzonal flow capability requirement, Scotland and The North is forecast to be a supply surplus area at all demand levels. Therefore, in order to stop Scotland and The North gaining linepack, gas must flow from that area into one of the adjoining zones i.e. North West or North East.

Figure 49

Figure 49
Average zonal supply balance on a low, medium and high national demand levels



4. Development of the Network Capability process and analysis

Figure 50 Figure 51

The North West, has a supply shortfall, that is, its demand is greater than its supply. Consequently, some of the excess linepack, transferred from Scotland and The North, will be absorbed. As the North West's supply shortfall is not as large as the Scotland and The North's supply surplus not all of this can be absorbed. What is not absorbed has to be passed through to another contiguous zone to maintain balance.

Alternatively, some, or all, of the excess stock from Scotland and The North may be transferred into the North East, but the North East is also in supply surplus. This implies that none of this excess Scotland and The North supply stock will be absorbed by the North East and the excess will be transferred out of the North East to a neighbouring zone. In this scenario the NTS must have the capability to transfer both the Scotland and The North supply surplus as well as the North East supply surplus out of the North East.

Thus, we can demonstrate that on an average day both the North East and North West will need to have the capability to move gas that they receive from other zones further onto an additional zone. This makes the North East and North West typically transit zones. These zones will require additional capability above that required for their local supplies (as shown on the flame charts).

Figure 50 is based on average flows but the network is more nuanced than that. We expect to see variance on a zone's supply surplus, or deficit, across all demand levels. Figure 50 and Figure 51 illustrate two dissimilar examples.

Figure 50 illustrates the supply flows in the South West, this zone has one relatively small storage site with no other supplies that are external to the NTS. Consequently, the zonal demand is strongly correlated with national demand and it is always expected to be in supply deficit. In this case the average figure is an accurate representation of the capability requirement.

Figure 51 shows the supply flows for the South East. This zone has two supply terminals, Bacton and the Isle of Grain. The Isle of Grain is an LNG terminal and so the flows are not strongly correlated with national demand. Therefore, unlike the South West, it is on average, neutral with neither a strong surplus nor deficit. We can reasonably expect days where there is a supply deficit or surplus of up to 50 mscm/d. We must be capable of dealing with both extremes in order to avoid constraints.

Figure 50
Supply flows for South West zone

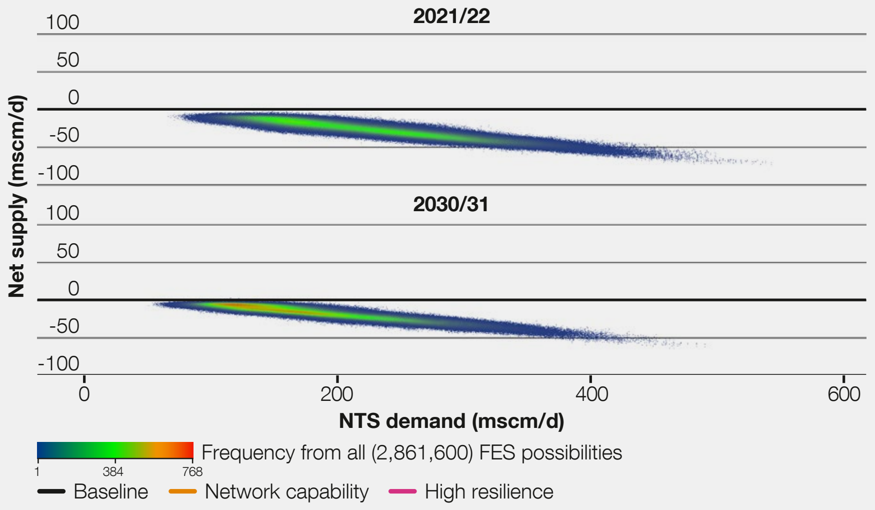
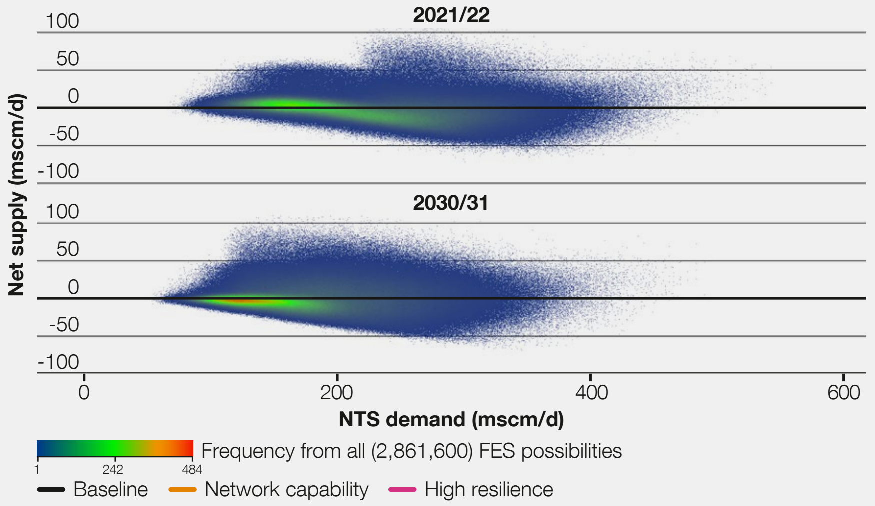


Figure 51
Supply flows for South East zone



4. Development of the Network Capability process and analysis

Figure 52

4.3 Linepack management

Linepack management is the practice of adjusting the amount of linepack (gas held within the pipeline) in a zone for operational reasons, which may require the use of compression in order to manage risks. There are several risks which can cause an unexpected or large variance in the amount of linepack within any zone. These risks include:

- zonal linepack swing
- national linepack swing
- asset failure
- supply and demand volatility.

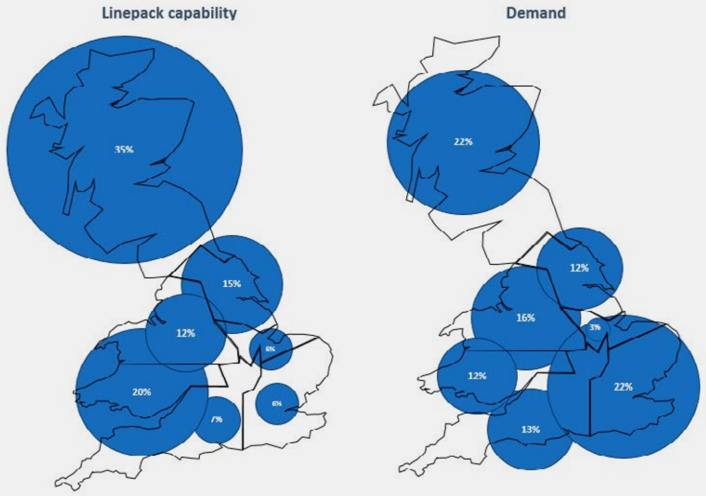
4.3.1 Zonal linepack swing

Each zone has the capability to store linepack. If the linepack within a zone goes too high it will eventually result in an entry constraint, too low and there will be an exit constraint. The difference between the highest and lowest amount of linepack a zone can hold can be referred to as linepack capability. In reality this figure constantly varies according to the instantaneous supply and demand pattern as well as other factors such as network configuration or temperature, however we can define illustrative maxima and minima by analysing a likely scenario.

Figure 52 illustrates linepack capability within each zone on an average forecast demand day (Day 150), alongside a view of demand levels within each zone. High levels of demand are associated with many risks which can cause unexpected zonal linepack swings.

As is shown, the high demand areas are not correlated with the areas which can facilitate large linepack swings. This forms the basis of active linepack management. Linepack changes within day are inevitable and therefore we use linepack management to ensure that each zone stays within its operational limits to avoid constraints.

Figure 52
Linepack capability and demand



4. Development of the Network Capability process and analysis

Figure 53 Figure 54

4.3.2 National linepack swings

National linepack swings occur due to imbalances between overall supply and demand which accumulate over the gas day. Typically, demand is higher than supply during the day causing the linepack levels in the NTS to drop, supply is higher than demand overnight causing the linepack levels to recover to close to their original position. The linepack swing is the amount of linepack lost during the day before recovery. Large linepack swings can occur for several reasons e.g. market conditions, inaccurate demand forecasts, unexpected supply losses, large swings in instantaneous demand.

Any linepack swing must be absorbed by the NTS. Linepack management is used to ensure that it is absorbed within zones which have the capability. As shown in Figure 53, 11% of days have a linepack swing of greater than 20 mcm, this is approximately the entire linepack capability of the South East, South West and East midlands combined, so even if these zones were at their absolute maximum at the start of the day there would be a risk of exit constraint if the linepack swing was experienced entirely in these areas.

Whereas Scotland and The North has a linepack capability of approximately double this, we can use linepack management to ensure that zones like Scotland will lose stock during the day rather than the South.

Figure 54 shows how linepack swings in winter (when we expect to experience higher linepack swings) are generally increasing both in terms of average linepack swing and maximum linepack swing experienced. This increases our reliance on linepack management in order to avoid constraints on the NTS.

Figure 53
Linepack swings

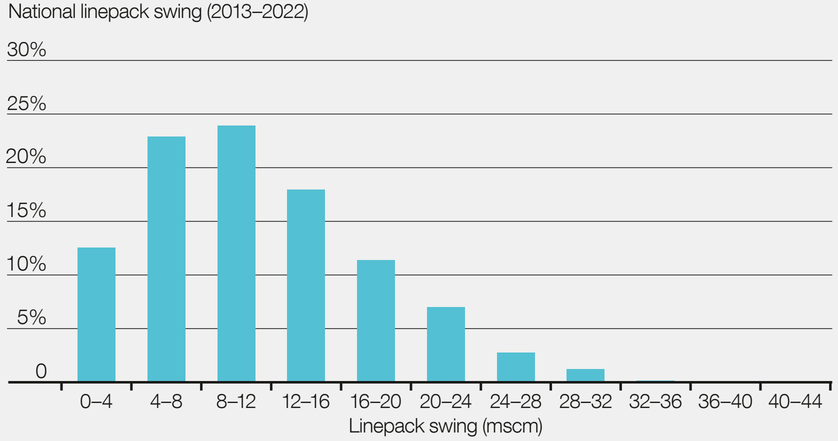
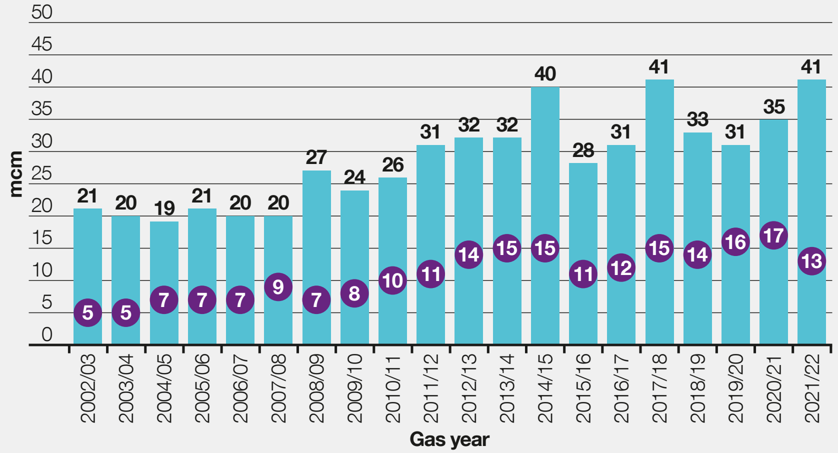


Figure 54
Linepack swing during winter months



4. Development of the Network Capability process and analysis

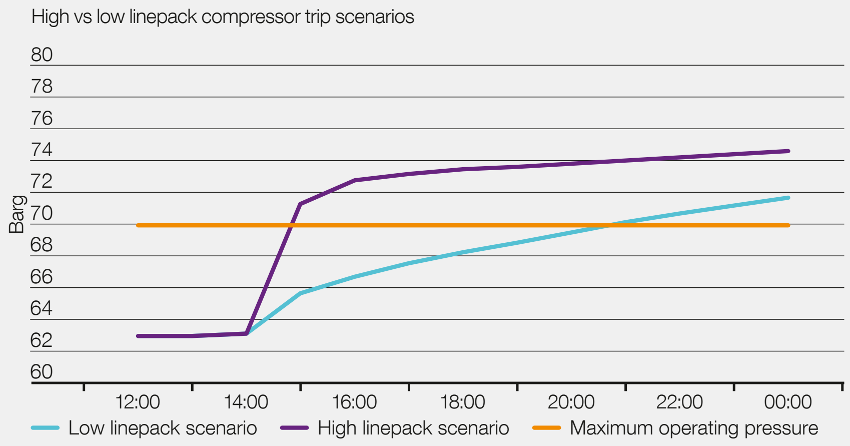
Figure 55

4.3.3 Asset Failure

Assets such as compressors are relied on to maintain operational pressures on the NTS. This is because given the supply and demand profiles on any given day it is likely that the linepack levels within some zones will be too high or low to maintain operational pressures otherwise. Assets will never be 100% reliable and therefore linepack management is used to reduce the risk of constraint in the event of a failure.

Figure 55 shows the pressure at St Fergus terminal in the event of a compressor trip at 14:00 hrs when Scotland and The North zone's linepack is at 128 mcm (a high linepack) and 117 mcm (a low linepack). In the high linepack scenario the maximum operating pressure (70 bar) is breached after 45 minutes, in the low linepack scenario the pressure is breached after 7 hours even though at the time of the trip the pressure at the terminal is identical. The low linepack scenario gives much more time for the compressor to be restarted, alternative compression to be started or commercial actions to take place. This modelling demonstrates how keeping a lower level of linepack in Scotland and The North zone can reduce the risk of entry constraint.

Figure 55
St Fergus compressor failure scenarios



4. Development of the Network Capability process and analysis

Figure 56 Figure 57

4.3.4 Supply-demand volatility

Supply and demand patterns change within day and can do so unexpectedly. Active linepack management can again mitigate this and prevent causing an entry or exit constraint. An example being, the South East zone, which contains Isle of Grain terminal.

In Figure 56 (pressure) and Figure 57 (linepack) we have considered three scenarios where the Isle of Grain is flowing a steady 30 mcm until 14:00 hrs, at which point either it ramps up to 55 mcm, ramps down to 0 mcm, or remains steady 30 mcm flow. This demonstrates that while the site is flowing 30 mcm, consideration has to be given that this situation can change, and within an hour the pressure could increase by 6.1 bar or decrease by 5.4 bar, giving a potential 11.5 bar range around the current projected pressure. After 2 hours this range is up to 14.6 bar, this variation could mean we are approaching the maximum or minimum linepack levels and pressures.

The potential risk of supply or demand changes vary according to a number of factors such as gas price, balance position and prevailing flow rate (e.g. if a site is offline it cannot flow any less), it is up to us to continually assess the risk of an unexpected increase or decrease in linepack, and therefore potentially use active linepack in order to adjust the linepack levels within a zone to mitigate this risk, if necessary.

Figure 56
South East scenarios – pressure

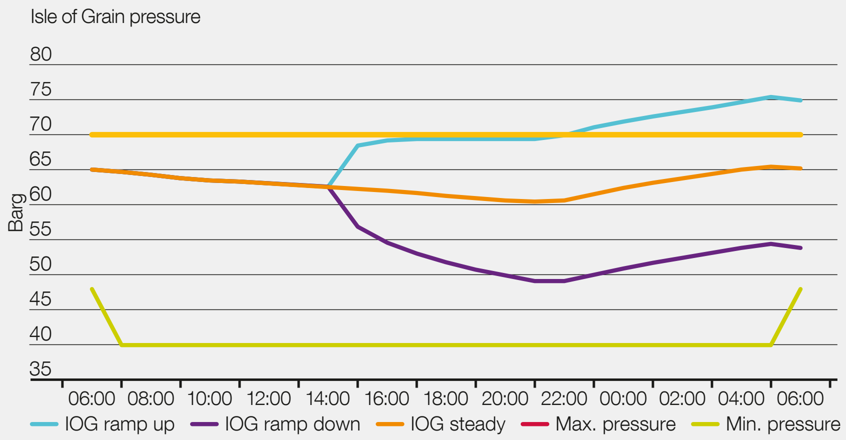
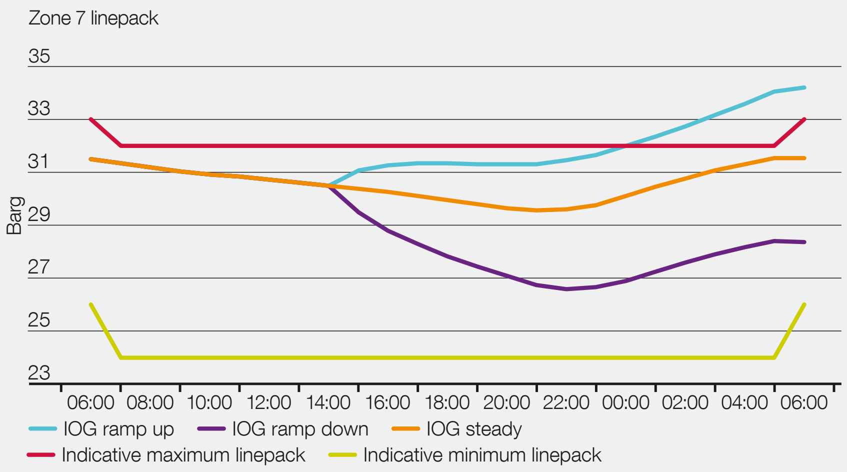


Figure 57
South East zone scenarios – linepack



4. Development of the Network Capability process and analysis

4.4 Hydrogen

Achieving the UK's net zero targets will require decarbonisation across the whole energy system.
The importance of the NTS to the UK's current energy supply means that we need to consider how to deliver low carbon energy, reliably and safely to all consumers. Existing research suggests that hydrogen could be an alternative to natural gas, but there are several knowledge gaps that need addressing.

We have been awarded funding through the Network Innovation Competition, for our FutureGrid project. This project will look at the possibility of converting the NTS to transport hydrogen and assessing the impact of hydrogen on our assets.

Additionally, National Grid Gas Transmission, in collaboration with industry, decision makers and stakeholders, is working on the Hydrogen Gas Markets Plan (GMaP)[14]. We want to make sure the gas system and markets continue to deliver consumer value throughout the UK's potential transition to a full (100%) hydrogen future.

We want to enable the transition to hydrogen in support of achieving net zero by 2050, and to do this in a way that continues to provide safe, secure, and affordable energy for all.

There are a range of projects that we are involved with that are exploring the transition to hydrogen. The overarching project is Project Union that is looking into the initial feasibility of this transition to support the governments hydrogen targets of 10 GW by 2030 and ensuring Scotland's 2045 and the UK's 2050 net zero targets are met. Projects currently being supported are:

- Project Union (HyNTS) – UK hydrogen transmission backbone[15]
- System Transformation in collaboration with gas distribution networks (GDN) and BEIS
- Project Acorn – repurposing of a pipeline from St. Fergus to the Grangemouth Hydrogen hub[16]
- East Coast Hydrogen – connection of Teesside to Humber hydrogen hubs initially and further repurposing of the region (including Merseyside hydrogen hub)[17].
- Capital Hydrogen – looking at hydrogen supply to London[18].

The following range of modelling scenarios are required to investigate the options that may be available for the introduction of hydrogen into the NTS, in order to support the pathway to net zero and the creation of a hydrogen transmission backbone, whilst understanding and mitigating the resulting impact on the NTS:

- Identifying Project Union options across a range of supply and demand levels
  - What is the optimal route?
    - repurposing of current assets
    - where repurpose isn't possible what is the preferred asset solution
  - Working with GDNs and other customers/stakeholders for production/demand volumes/ locations.
- ANCAR assessment:
  - What is the impact on current network capability assessment?
  - Does the level of risk change and, if so, how?
- Security of Supply impact:
  - Ensuring security of supply of the methane network as a key principle
  - Maintaining current levels of risk on the NTS.
- Operability impact on NTS:
  - During the transition to hydrogen, when can that begin?

14. https://www.nationalgrid.com/gas-transmission/document/135546/download
15. https://www.nationalgrid.com/gas-transmission/document/139641/download
16. https://theacornproject.uk/wp-content/uploads/2020/05/Hydrogen-Coast-DIGITAL.pdf
17. https://www.nationalgrid.com/gas-transmission/document/138181/download
18. https://www.sgn.co.uk/news/london-study-kick-start-hydrogen-vision-capital-support-of-net-zero-carbon-target

4. Development of the Network Capability process and analysis

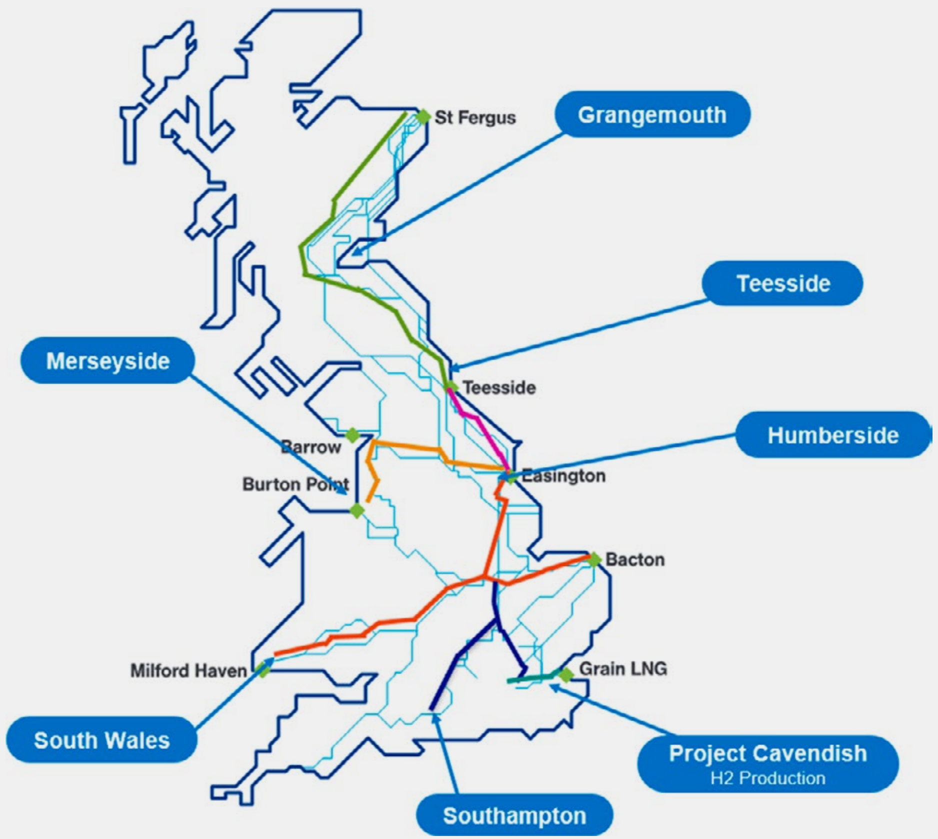
Figure 58

4.4.1 Project Union

The network modelling principles used to deliver Project Union will be the same as current network modelling obligations, rules and tools. Figure 58 gives a summary of Project Union's illustrative UK hydrogen backbone. The modelling will help determine the routing and phasing. The aim will be to repurpose existing feeders where possible. To achieve the required objectives, whilst highlighting any additional risks and opportunities, our network modelling will go through a range of scenarios and iterations working with GDNs and other stakeholders, including governing bodies, to ensure a one system approach solution.

Additionally, we are developing our current suite of modelling tools to increase their functionality to inform stakeholders and to input to forthcoming business decisions. This will enable us to find the optimal solution for the introduction of hydrogen alongside methane.

Figure 58
Project Union illustrative routing (a combination of repurposed and new build pipeline)



4. Development of the Network Capability process and analysis

4.4.2 Project Acorn assessment

Project Acorn is initially planning the construction of a large-scale hydrogen production plant at St Fergus, in the North East of Scotland. This would allow for hydrogen to be blended into the NTS and the possibility of part of the NTS being dedicated to pure hydrogen flows. The emissions from the hydrogen production would be captured, transported, and stored in a depleted hydrocarbon reservoir, reusing current oil and gas infrastructure.

Project Acorn requested us to undertake a network modelling assessment of the potential for repurposing to hydrogen, one or two NTS pipelines, between St. Fergus and Grangemouth between 2025-2035. Repurposing of these pipelines (or any potential alternative new build option) would support the transition to net zero for Scotland on a cost optimal basis.

The network modelling assumptions that we used for this study were:

- 2020 Future Energy Scenarios
  - All four *FES* scenarios
  - Snapshot years 2025, 2030 and 2035
  - Three supply and demand days; Peak Day, a winter day and a low summer day
- all feeders are available for repurposing
- all current methane entry and exit locations are required
- all current methane assets are available (as per the year being assessed).

During this network modelling assessment, a total of 7,461 scenarios and sensitivities were assessed within our Network Modelling team using SIMONE and a newly developed tool called NetStrat. NetStrat is run on ten servers and has the computing power equivalent to 80 analysts. This tool allows us to analyse a wide range of scenarios which would have taken significantly longer without its capability.

4. Development of the Network Capability process and analysis

The preliminary desktop network modelling results showed that repurposing one-pipeline has significantly less impact than two-pipelines. Both options have identified risks that would need to be further investigated to enable a hydrogen transition. These are highlighted within the Project Acorn report and centres around resilience, operational issues, entry and exit network capability and capacity baselines all on the remaining methane network. We have set out what we believe to be the next steps required to start to find mitigations to these risks.

A result of these assessments is the demonstration of a reduction in network capability, within the timeline assessed, if one or more of the pipeline feeders in Scotland are repurposed for use with Hydrogen. Such effects are something that would need to be agreed with wider industry, BEIS, Ofgem, Scottish Government and HSE. We believe there needs to be a consensus to determine the pace, risk and cost of removing capability from the methane market and transitioning to hydrogen and how this is achieved while ensuring UK energy security of supply.

Changes to the methane regulatory framework may also be required as they would need to allow hydrogen to enter and flow through the network and this would result in a reduction in methane capability and potentially require a change to methane capacity baselines.

Our assessments have also highlighted the operability impacts of making these changes. Further investigation is required into the effects of hydrogen on current NTS assets and their operation, such as compressors and pipelines, and the changes that would need to be made. There is research taking place in the wider industry looking into these factors some of which we are directly involved with, such as Future Grid[18] at Spadeadam.

We want to enable the most cost-effective transition pathway to hydrogen use in GB, in support of achieving net zero by 2050 and we want to do this in a way that continues to provide safe, secure, and affordable energy for all.

18. https://www.nationalgrid.com/gas-transmission/insight-and-innovation/transmission-innovation/futuregrid

4. ANCAR FAQs

1. Why is Britain divided into seven exit and entry zones for capability analysis?

a. Because the NTS is an integrated network we have broken it down into zones. Each zone has its own gas flow behaviour which, although part of the whole, means it can generally be treated separately for analysis purposes. This makes it easier to model and make decisions to balance the system on a day-to-day basis.

2. What is mcm, mscm or mscm/d?

a. These are standard unit of measurement for gases and they stand for; a million cubic metres, million standard cubic metres or million standard cubic metres per day.

3. What is a network asset?

a. This is any physical part of the network and includes such things as compressors, pipelines, flow valves and regulators.

4. Does NGGT have any contracts to control flows above network capability?

a. Currently we have no long-term contracts in place. However, if flows of gas look as if they might exceed the network's capability, we have a number of short-term physical and commercial tools to manage this.

5. What is resilience?

a. Resilience is the ability of the network to recover from unforeseen conditions such as asset failure. If, at a compressor site, there is a back-up unit, the site resilience is much higher.

6. How is resilience accounted for when planning the network?

a. Planned and unplanned maintenance is part of our cost benefit analysis (CBA) process and the full implications of the resilience of our units is described in an Engineering Justification Paper which is a required part of the network development process. Resilience is not accounted for within the network capability flame charts.

7. What is capability?

a. Capability is the maximum amount of gas that the network can physically flow at specific locations without going outside any of its pressure obligations, or equipment's safe operational tolerances.

8. How do you model network capability?

a. We use network modelling software called SIMONE. Within this model we have used the NTS configuration, which we validate regularly to ensure it accurately reflects the real NTS. SIMONE is widely used by other network operators across Europe.

9. What factors affect capability?

a. There are many factors that affect the network's capability including supply and demand flows, gas in the network, network asset availability, upstream and downstream gas movements, ground temperature, etc.

10. How will a move to hydrogen affect the network?

a. Planning for how hydrogen will be deployed is embryonic, but we are working with partners to better understand the implications of the various possibilities.

11. Why does the ANCAR go out in detail for the next 10 years?

a. Ten years is our primary planning horizon, and the timescale within which definitive network development proposals need to be made. The *FES* data beyond this becomes significantly more variable, thus no meaningful analysis or conclusions could be drawn.

12. Why is the entry network capability line the same in the 2020 charts as in the 2030 charts?

a. The network capability line shows the network capability as it is now and with any confirmed changes. By overlaying the 2030 flow data we can see the relationship of today's network and expected future flows. That way we can anticipate how the network needs to evolve.

4. *ANCAR* FAQs

13. Why are there so many dots on the flame charts?

a. For each future forecast day we look at 980 possible flow outcomes that are likely, and their consequences. We then use the four scenarios and this gives us 3,920 flows for each day. When we include the two sensitivities of High LNG and High Continental flows, this goes up to 7,840 for each day. So, on each zonal flame chart, which covers a year, there are 2,861,600 *FES* flows represented.

14. Why do you have a line for entry capability?

a. How much gas the network can accommodate changes with the demand on the network. With more gas coming off the network closer to the entry point, the network is capable of moving additional gas away from the entry zone.

15. Why do you use the '1-in-20' demand level as your exit capability?

a. The 'Pipeline Security Standard' is one of our key licence obligations. We are obliged to plan and develop the network to meet the 1-in-20 level, this being the highest level of gas demand that we should expect to experience only once in every 20 years.

16. What is a constraint?

a. A constraint is where the pressure or flow required to meet customer needs cannot be met by the physical capability of the network. On entry flame charts the potential of this is represented by a dot above the capability line.

17. What is linepack?

a. Linepack is the amount of gas physically contained within the NTS. Ideally the amount of linepack at the start of the day should match that at the end of the day. Throughout the day it will vary as a result of changing supplies and demands.

18. What are RIIO-2 and RIIO-3?

a. RIIO (Revenue = Incentives + Innovation + Outputs) is a price control mechanism that is set by Ofgem. The RIIO periods are as follows; RIIO-1 (2013 to 2021), RIIO-2 (2021 to 2026) and RIIO-3 (2026 to 2031).

19. What is a derogation in terms of the Medium Combustion Plant Directive:

a. Under MCPD, plant which does not comply with the emissions limit levels may be derogated, this allows them to continue to operate under certain restrictions.

Continuing the conversation

We will be engaging with stakeholders at a variety of forums and bi-laterals, but we would also encourage direct feedback to be submitted to: .Box.OperationalLiaison@nationalgrid.com

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