Gas
Transmission

A Gas Market Plan research project

‘GB Gas Balancing Regime Review’ final report

nationalgrid

Contents

Executive summary

To meet the ambitious target, the UK has set to reduce greenhouse gas emissions to net zero by 2050, action and change will need to be delivered across all sectors of society.

Decarbonising sectors such as industry, transport, and the provision of domestic and commercial heat, will require a mosaic of innovative solutions and technologies.

All future energy scenarios, as set out by National Grid ESO *Future Energy Scenarios*[1], where the 2050 carbon reduction target is met, use some form of a gaseous molecule as an enduring energy vector to varying extents. Be this methane, biogases, hydrogen, or some form of combination used in conjunction with other innovative technologies such as Carbon Capture and Storage, gas, in whatever form, has an important role to play.

As we move through the energy transition, the role that gas will play in a net zero future will become more clearly defined as technological innovations are tested and proven at scale, policy is deployed at central and local governmental level, and the price and level of disruption the end consumer is willing to accept in order to meet our net zero targets, as well as how far consumers are prepared to change their behaviours and lifestyles, becomes evident.

Whilst policy, technology, allocation of costs and tolerance to disruption are all causes for future uncertainty, what is evident is the part that gas will play, from sourcing, production and end usage, will be different in a net zero UK future. It is therefore important that the market framework and its associated tools are set up to handle these new dynamics.

This project has investigated the current UK gas balancing arrangements against the likely transformations, and their impacts, over the coming decade to ensure that balancing arrangements remain appropriate and are able to deliver upon their intended purpose. It has highlighted, through stakeholder engagement and analysis provided through the National Grid Gas RIIO-2 business plan[2] and *Gas Ten Year Statement*[3], that balancing arrangements are believed to remain appropriate in the short term (5 years+) without the requirement for any substantive change.

Geo-political events, arising from the conflict in Ukraine, close to the time of this publication have generated the potential for a tightening of gas supplies that could impact Great Britain as well as continental Europe. These developments may warrant the reconsideration of the means and mechanisms available to ensure gas security of supply which in turn could impact aspects of Great Britain's gas balancing regime. This report does not offer opinion or analysis in response to unfolding crises beyond the potential of tightening of gas supplies and the effects this has upon wholesale market prices.

With the above noted and turning to look towards the future, with the increasing nature of within-day linepack swing experienced within the gas system, predominantly driven by the mis-match between supply and demand at the within-day timeframe and the changing dynamics of gas-to-power moving from a

1 https://www.nationalgrideso.com/document/173821/download
2 https://www.nationalgrid.com/uk/gas-transmission/document/129016/download
3 https://www.nationalgrid.com/uk/gas-transmission/document/133851/download

predominately steady baseload provision to that of peaking activity, changes to the balancing regime may be required beyond this point. National Grid Gas 2019 GFOP study[4] into within-day behaviour also predicted an increase in the frequency of large linepack swings out to 2025, especially during the summer season, lending further rationale for the project's investigations.

Other initiatives, planned and future, could serve to increase the level of linepack swing even further, inter alia: National Grid Gas 'Project Union'[5] which is looking to establish a hydrogen backbone within the UK, linking its industrial clusters via a repurposing of ~25% of existing NTS[6] infrastructure; the government's ambitions to allow blending of up to 20% hydrogen into the gas distribution networks by 2023[7], and the establishment of a 'Hydrogen Village' to test hydrogen heating by 2025 with a further ambition to establish a 'Hydrogen Town' by 2030[6].

Therefore, this review has looked to provide several concepts, to start discussion and debate within industry, which could be deployed to mitigate the levels of linepack swing experienced at the within day timeframe in both the short and long term.

> The part that gas will play, from sourcing, production and end usage, will be different in a net zero UK future

4 https://www.nationalgrid.com/uk/gas-transmission/document/126251/download
5 https://www.nationalgrid.com/stories/journey-to-net-zero-stories/making-plans-hydrogen-backbone-across-britain
6 National Transmission System - the network of gas pipelines that supply gas to about forty power stations and large industrial users from natural gas terminals situated on the coast, and to gas distribution companies that supply commercial and domestic users
7 The Ten Point Plan for a Green Industrial Revolution – Point 2

Executive summary
(continued)

The concepts explored have been broken down into four main groups, which can be seen below.

Commercial optimisation

Communication, coordination and cooperation

Regime evolution

Linepack valuation and use

In the **short term** the project recommends:

1. **Improvements to balancing and capacity systems and services.** This is currently being explored by National Grid Gas along with industry partners, to determine future requirements of a potential replacement of the Gemini system.
2. **Improved communication and understanding between energy system parties** of the challenges faced by the gas and electricity system operators as well as the power generation sector and gas shipping community, with a view to reduce inefficiencies or avoid suboptimal outcomes through adapting market arrangements to fit the changing system/parties' needs.
3. **Continued monitoring of system capability to act as an indicator/trigger for future change.** This monitoring can be conducted by National Grid Gas through the production of its *Gas Ten Year Statement* and the newly established *Network Capability Annex* and *Annual Network Capability Assessment Report* or (ANCAR).
4. **Continued monitoring of governmental policy relating to net zero to act as an indicator/trigger for future change.** National Grid Gas has dedicated resource in this arena which undertakes continual review of policy as it is published to fulfil this recommendation.

In the **longer term** the project has explored various changes to the balancing regime, which could provide ways to manage an increased level of within-day linepack swing should it be identified that said linepack swing will have a negative impact upon the operation and use of the gas system, which include:

1. **Increasing the correlation between supply and demand at the within-day timeframe**
2. **Increasing the number of balancing periods**
3. **The determination of the value of flexibility provided by the system with a view to create new commercial products**
4. **The role of system operators in a future energy system**

Introduction
Gas Markets Plan

National Grid Gas, in collaboration with gas industry stakeholders and policymakers, has initiated the Gas Market Plan (GMaP) programme to help prepare the gas market for potential future transformations.

The GMaP programme has already published several reports on areas of interest to industry, links to which can be found below.

- *GMaP Gas Quality Knowledge Share*
- *Implementing the proposed gas quality standards*
- *Hydrogen Gas Market Plan Scenarios*
- *Market considerations to support a hydrogen town*

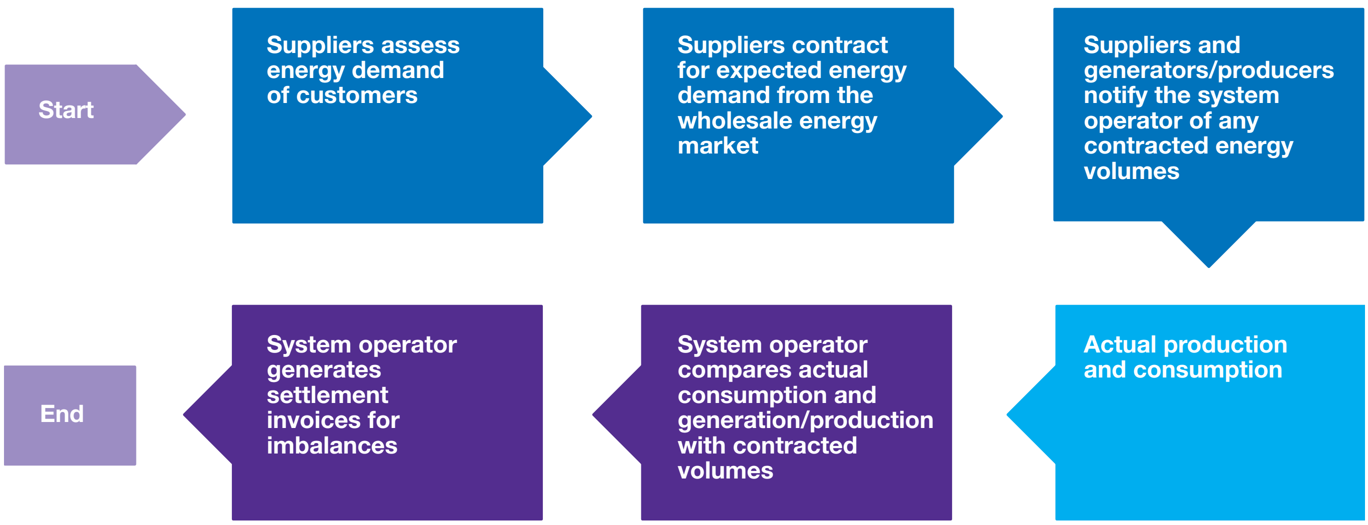
Gas terms and concepts

This report is focused around some key gas system concepts which feature throughout. We have included explanatory notes to provide additional context and support the readers' understanding in the glossary of terms at the end of this document.

UK gas balancing arrangements

Balancing arrangements within the UK have largely remained unchanged since the introduction of competition and liberalisation of the market which started in 1996. In 1999, under the *Reforms of Gas Trading Arrangements* (RGTA), market arrangements were established which remain largely as we know them today. Finally, in 2005, following the sale of National Grid's Gas Distribution Network businesses, the *Uniform Network Code*[1] (UNC) was created in order to prevent the inappropriate fragmentation of network code governance. The UNC defines the rights and responsibilities for users of gas transportation systems and provides for all system users to have equal access to transportation services.

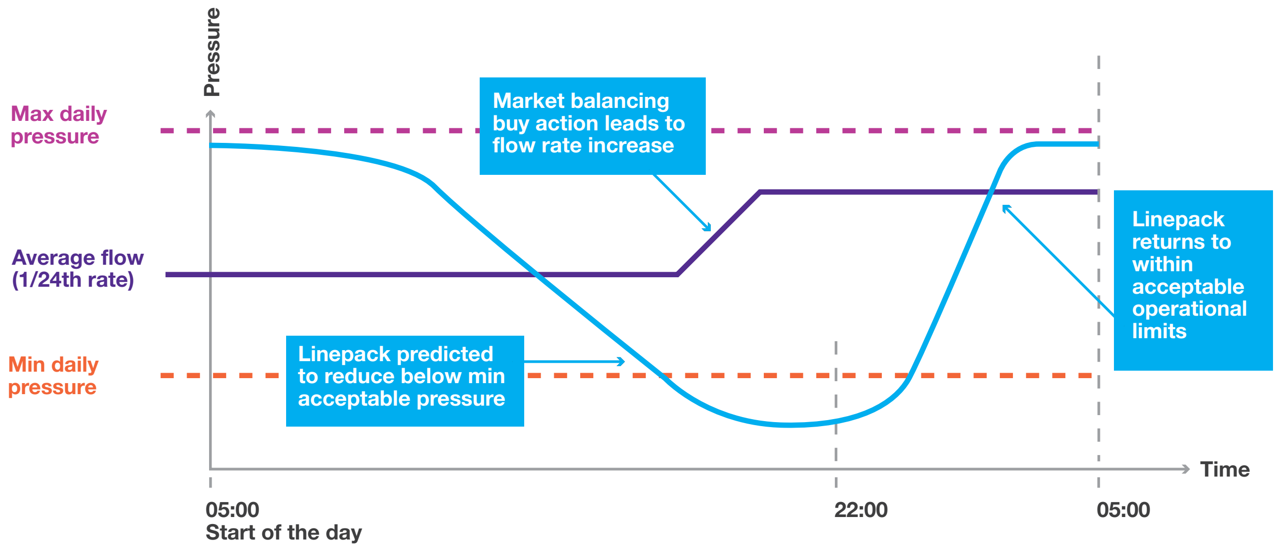
The concept of balancing is simple: gas which is taken off the system must be matched by gas delivered to the system. The responsibility for undertaking this action lies with gas shippers (shippers) and they are financially incentivised to do so through a mechanised process which calculates a shippers imbalance volumes and subsequent liabilities or provisions utilizing a formulated system average price[2]. This process is shown below:



Introduction
(continued)

Additional 'residual balancing' activity is undertaken by the Gas System Operator for operational balancing requirements. These take place where it is forecasted that the system or a specific locality within the network, taking into account the aggregated shipper imbalance positions, is likely to move outside of the acceptable range of balance between gas supplied onto and taken off the NTS, either during the day or by the end of the day. An example of this process is shown below:

These arrangements have served the market and system well, providing the UK with one of the most advanced and reliable gas systems in the world. This is even in the context of the gas system being very different as we see it today as compared to 25 years ago, when liberalisation occurred. The question is whether these rules will continue to serve us as well with the changes that are required to achieve a net zero future?



Industry stakeholders, subject matter experts and the gas system operator itself have articulated that, in their opinion, balancing arrangements remain appropriate for the short term (~5 years). Beyond this point, the certainty that balancing arrangements will continue to deliver upon their intended purpose becomes less certain and therefore, it was agreed that an exploration of potential changes to the regime to ensure it continues to perform as desired was prudent.

> These arrangements have served the market and system exceptionally well, providing the UK with one of the most advanced and reliable gas systems in the world

Gas system dynamics – 25 years of evolution

The nature of gas supply and demand, the parties active within the gas value chain as well as the physical system itself and technologies employed, have steadily evolved over time.

With ambitious government targets now in place[1], the amount of change the industry will need to deliver is vast and complex. Given this and the pace of change required to achieve these targets, as an industry we can no longer wait, and exploration of the potential future market changes required to facilitate a net zero future must start now.

Over the next few paragraphs, we will explore how the system has changed over the last 25 years and what we may expect to change over the coming decade that would impact upon balancing arrangements. This has been broken down into three broad areas: Supply, Demand, and the Physical System.

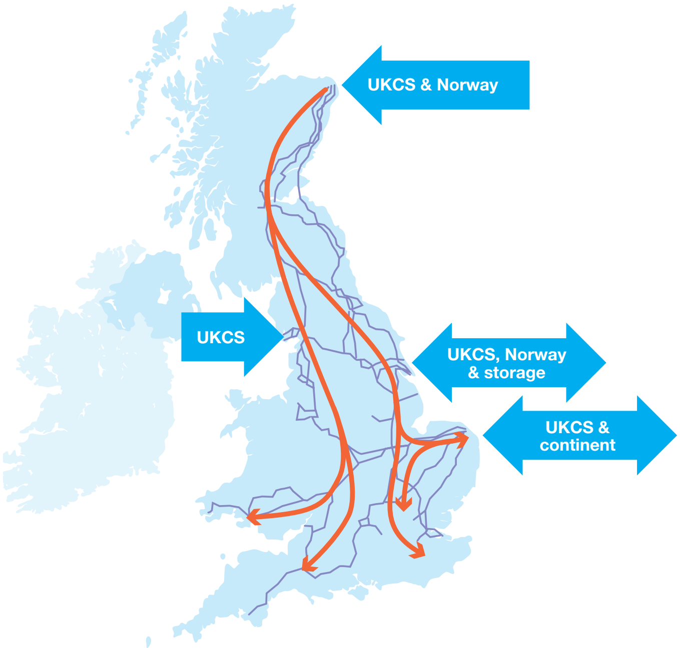
Gas supply

The supply of gas into the UK has diversified significantly over the last two decades. The UK was entirely self-sufficient for its gas needs with gas produced in the North Sea; in 2000 98% of all gas used within the UK came from this source.

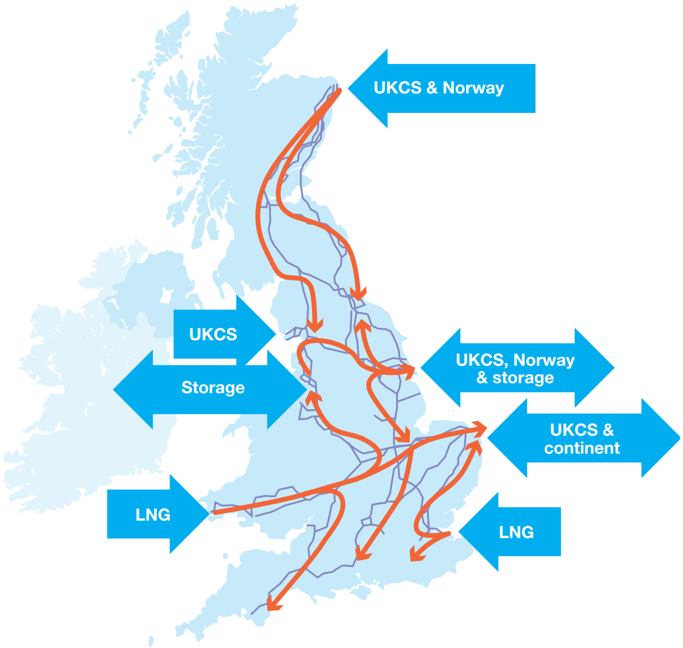
Today, this landscape is very different with the North Sea providing significantly less gas for end use within the UK as gas fields are depleted and come to the end of their operational lifecycle. This has resulted in the UK's increasing reliance on imports of gas from Norway, interconnectors to Belgium and the Netherlands, and global supplies into LNG terminals to meet the nations' demands.

This has served to change the nature of gas supply from what was once a local steady supply to what we see today where gas comes from multiple international sources with fluctuating, less predictable deliveries of gas into the National Transmission System (NTS). Indeed, current projections show that the UK could reach an import dependency for gas of ~75%, by 2030 and 100% by 2050, under certain future energy scenarios[2].

Mid-1990s to mid-2000s



Mid-2000s to 2016



1 Energy White Paper – Powering our Net Zero Future

2 National Grid ESO – Future Energy Scenarios 2020 publication – Consumer Transformation Scenario

Gas system dynamics
– 25 years of evolution (continued)

Over the coming decade, supply is set to diversify even further as we transition to a net zero energy system. Activity is already underway to expand the gas quality range limits placed upon the composition of gases that are eligible to enter the UK's gas networks[3] which will in turn help facilitate the introduction, and remove the current barriers, for alternative, low carbon gases such as biomethane, bioSNG and hydrogen.

Hydrogen, and its use, has been highlighted by government and industry as of particular interest for decarbonisation in various sectors of society. Whilst hydrogen production methods and its ultimate end use is still a matter for much debate, all agree that hydrogen has a role to play in a net zero future. This will serve to diversify supplies even further with new production and injection sites located around the UK.

Recent events have seen a particular spotlight shone upon the supply of gas globally, at European level and at a national level for supplies entering the UK. With the UK now more reliant upon the importation of gas as to supply our indigenous demands in comparison to the turn of the millennium where the UK was entirely self-sufficient for its gas needs, the UK has been exposed to the ongoing energy crisis. The reasons for the current energy crises are myriad and complex but include a cold winter across Europe in 2020/21 which put pressure on gas supplies and resulted in a drop of stored gas. A relatively windless summer further compounded this as gas was used for electricity generation when renewable wind sources were unable to produce and gas storage was difficult to replenish. An increase in demand for LNG from Asia in conjunction with the re-opening of industry following Covid-19 having the effect of squeezing global gas supplies further. Other technical and geopolitical factors are also at play which means many countries across Europe are facing similar difficulties.

The unfolding conflict between Russia and Ukraine has resulted in the potential tightening of gas supplies in European markets resulting in further volatility within the natural gas wholesale markets and, has also served to push wholesale gas prices up further.

The UK has been exposed to these issues as one of Europe's largest consumers of natural gas with some ~85% of homes using gas for central heating and ~40% of electricity production[4] coming from gas fired power stations. The UK also has lower gas storage capacity than compared to other European countries.

> Over the coming decade, supply is set to diversify even further as we transition to a net zero energy system

This has resulted in unprecedented volatility within the wholesale commercial markets and has seen the price of gas spike to their highest levels since liberalisation of the market back in the 1990's. The shock of this price volatility has seen a record number of energy suppliers exit the market over the last 12 months. The exit of these market participants has had an impact upon the commercial arrangements surrounding balancing which has led to the introduction of new UNC modifications as to ensure the continued proper functioning of market arrangements. All consumers of gas have also been impacted by the increase in gas wholesale prices with domestic customers facing a potential ~50% increase in their annual energy bills and business and industrial consumers facing increased costs of operations resulting in lower production and investment.

The changes in how the gas networks were supplied some 25 years ago to how they are supplied today has not required any substantive change to balancing arrangements during this same period. However, possible future changes such as the potential for multiple gas systems to emerge, or the repurposing of NTS infrastructure to facilitate hydrogen transportation, are likely to result in a smaller system that has to be balanced with an increased exposure to supply fluctuations. It is for these reasons that balancing arrangements need to be continually considered to ensure they continue to fulfil their intended purpose.

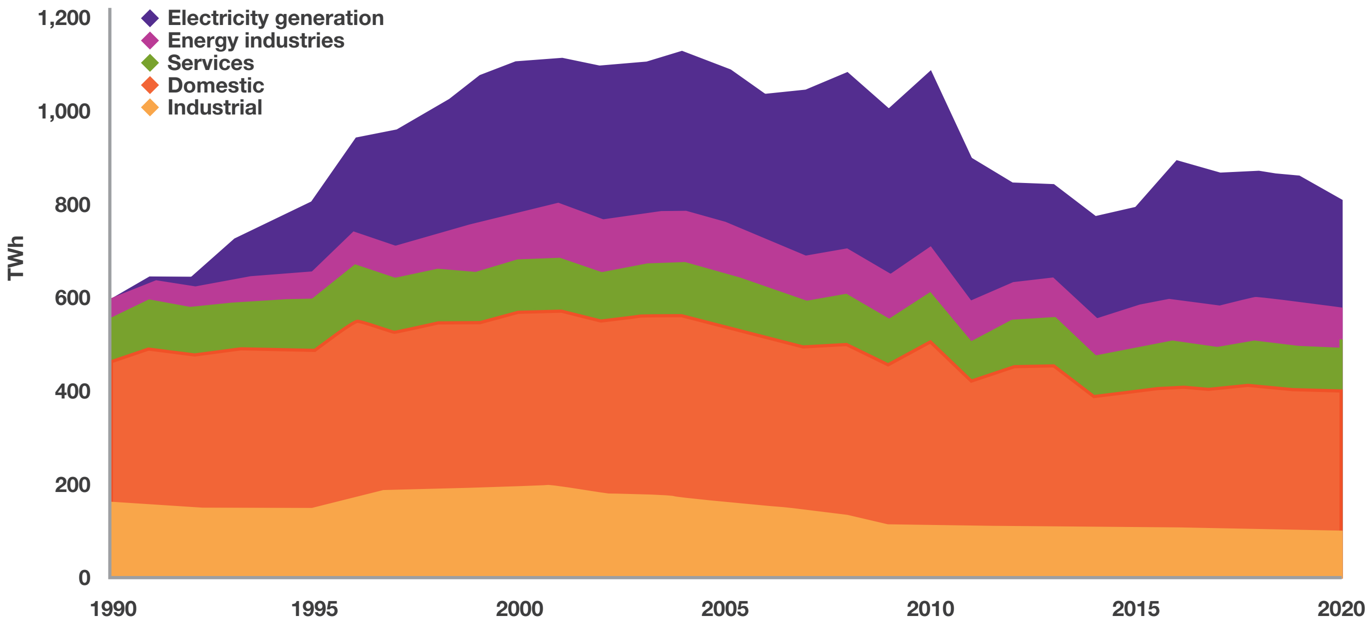
3 https://www.igem.org.uk/technical-services/gas-quality-working-group/
4 Based upon electricity generation during 2019 – UK Energy in Brief 2020 – Gov.uk

Gas system dynamics
– 25 years of evolution (continued)

Gas demand

The overall demand for gas has declined when compared to levels in 2000, with a reduction of 248TWh of gas demand seen over this period. This can be seen in the below graph and table

Natural gas demand, 1990 – 2020

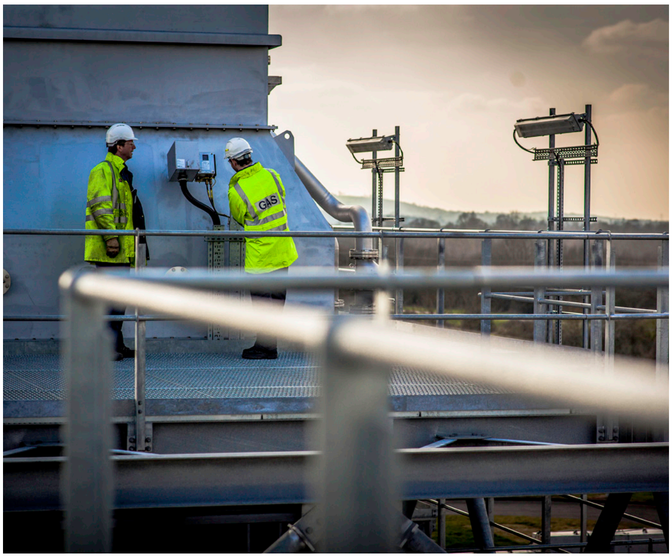


	1990 TWh	2000 TWh	2010 TWh	2018 TWh	2019 TWh	2020 TWh
Electricity generators	6.5	324.6	376.5	273.4	272.3	231.6
Energy industries	39.2	102.1	95.9	88.4	91.2	88.6
Industry	164.6	198.5	118.0	109.2	108.0	99.3
Domestic	300.4	369.9	389.6	305.3	294.9	299.3
Services	86.4	110.5	101.6	92.3	93.2	89.6
Transport	–	–	–	0.1	0.2	0.3
Total	**597.0**	**1,105.5**	**1,082.2**	**868.7**	**859.8**	**808.7***

Source: UK Energy in Brief 2021 – BEIS

** 2020 annual gas demand impacted by COVID 19*

Gas system dynamics
– 25 years of evolution (continued)



The UK has already achieved almost the complete removal of unabated coal use for electricity production, seeing reliance on this method reduce from 70% in 1990 to just 3% today, and will see the remaining use eliminated by October 2024, pending government consultation on this matter[5].

Other factors, such as the thermal efficiency of housing stock, new home technologies for the provision of heat, new embedded Biogas production facilities, alternative fuels for industrial processes and other energy efficiency measures, have served to add additional downward pressure on the demand for natural gas.

The increase in renewable generation sources for electricity has also served to alter the role that traditional thermal generation plays within the UK energy mix, changing the nature from providing long-form, stable baseload output for the electricity grid to that of providing intermittent, peaking activity.

Looking to the future, how much further this role alters is dependent on several factors, but will primarily be driven by the emergence, or not, of long-term storage solutions to help balance the intermittent nature of electricity production.

The UK is continuing to expand its renewable generation base with ambitious targets set out over the next decade, detailed in the government's key commitments in the December 2020 Energy White Paper publication[6]. This is in addition to the use of carbon capture and storage technologies and the production and use of hydrogen, as well as further biogas sources, as alternative low-carbon fuels of the future.

As with supply, the changes in the demand for gas are set to alter significantly over the coming decade and beyond, and therefore balancing arrangements need to be continually considered to ensure they continue to fulfil their intended purpose.

5 https://www.gov.uk/government/consultations/early-phase-out-of-unabated-coal-generation-in-great-britain
6 Energy White Paper - Powering out Net Zero future

National Gas Transmission System (NTS)

The NTS has remained largely static in size over recent history, however, there have been changes to the compression technologies used to move gas around the system to where it is needed, as well as the number of compressor units deployed.

There has been the introduction of gas interconnection points, linking our system with those of our European partners, primarily for the importation of gas, as well as the introduction of LNG regasification terminals and landing ports at Milford Haven and the Isle of Grain, and the connection of the first biomethane production facility to the NTS based in Cambridgeshire.

In addition to these changes, we have also seen the closure of the UK's largest gas storage facility 'Rough', which accounted for more than 70% of the UK's working gas volume[7] and 25% of daily deliverability [8].

Looking to the future we can expect further compressor reconfiguration on the network[9], more connections of biogas production facilities on both the NTS and gas distribution networks and, pending the outcomes of various pilot projects, the repurposing of parts or the entirety of the NTS to transport blends[10], as well as pure hydrogen[11].

This will be in addition to the conversion of LNG terminals and ports, with expanded gas quality parameters for gas that can be delivered via interconnectors and injected to the grid, to facilitate and accept the delivery of hydrogen from global market supply chains as well as domestic production sites.

Whilst the extent of future developments is still unknown, these potential future changes to the physical system itself realistically represent the main grounds to amend current balancing arrangements as we move through the energy transition.

> The increase in renewable generation sources for electricity has served to alter the role that traditional thermal generation plays within the UK energy mix

7 The working gas volume (WGV) is the amount of natural gas that can be injected, stored, and withdrawn during the normal commercial operation of a natural gas storage facility. The definition of WGV is the total volume of a gas storage minus the cushion gas.
8 Daily deliverability is a measure of the amount of gas that can be delivered (withdrawn) from a storage facility on a daily basis. It is also referred to as the deliverability rate, withdrawal rate, or withdrawal capacity and is usually expressed in terms of millions of cubic feet of gas per day that can be delivered.
9 National Grid Gas Transmission's business plan 2021–26 - Chapter 12. Network Capability
10 National Grid - FutureGrid programme
11 https://www.nationalgrid.com/stories/journey-to-net-zero-stories/making-plans-hydrogen-backbone-across-britain

Potential evolutions to the UK gas balancing regime

Having explored how the energy landscape has changed over the last 25 years and how this landscape could potentially develop into the future, we will now look at several concepts of how balancing arrangements may need to evolve or change as we move towards net zero.

What are the potential challenges the concepts are looking to address?

Through engagement activity the project has undertaken with industry experts, the main potential challenge over the coming decade was identified as increasing levels of within-day volatility, expressed as linepack swing experienced within the NTS, and the ability of shippers and the system operator to manage this volatility.

What is linepack, linepack flexibility and why is it important?

The amount of gas contained within the higher-pressure tiers of the UK's gas transmission and distribution network is termed 'linepack'; literally, it is the amount of gas held within the pipelines.

Linepack is proportional to the pressure of the gas in the pipelines; increasing the pressure increases the amount of gas, and thus the energy contained therein. The amount of linepack changes throughout the day due to the varying levels of pipeline pressure, which is caused by the differential between supplies to, and demands from, the network. This flexing of pressure, or use of linepack flexibility, provides a method to help match the supply and demand for gas at the within-day timeframe.

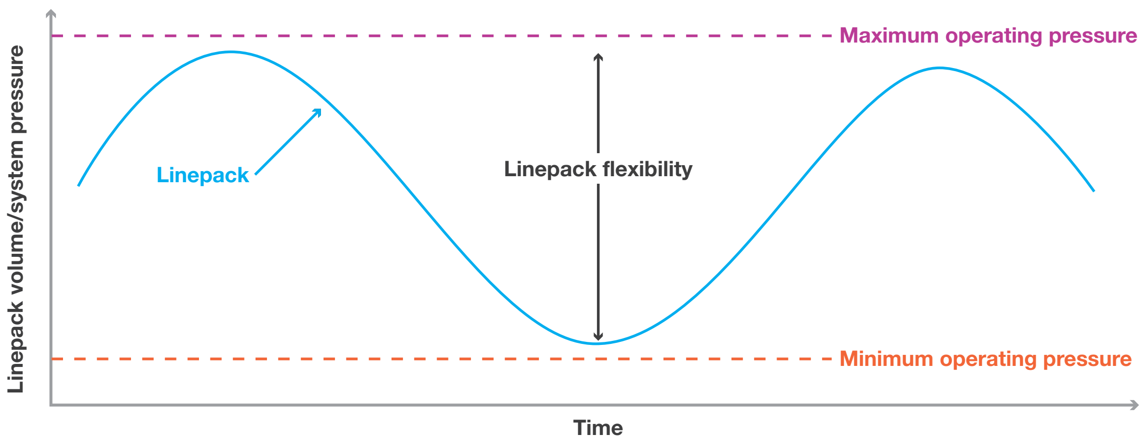
This is one of the key differences to the electricity system which requires real-time balancing with an associated balancing market in order to ensure the system always maintains balance. One of the key benefits to the gas system is that it can absorb differences in supply and demand, utilising linepack flexibility, unlike the electricity system. This is one of the reasons why the balancing regime is not believed to require immediate change as set out in this document.

Linepack arises from the fundamental design of a gas transportation system. Natural gas moves through the NTS from entry points to exit points at speeds up to 25mph depending on the pressure within the system and the diameter of the pipes carrying the gas. As gas is supplied into the system at its extremities and travels at a certain speed to its end use location, there is always an inventory of gas held within the system which is known as linepack.

The system is also designed to work between a range of minimum and maximum pressures as to ensure there is sufficient pressure to flow gas out of the system and allow gas into the system, as well as maintain its safety. These technical limits of the system determine the linepack flexibility that the system can provide.

Linepack is the total volume of gas present within the system, whereas linepack flexibility is the amount of gas that can be managed by controlling the pressure levels within the system between the minimum and maximum operating levels. This can be seen in the visualisation below:

The scale of energy that can be stored and released by varying linepack highlights its importance as a means of operational flexibility, helping to balance the changes in national primary energy demand.



Potential evolutions to the UK gas balancing regime (continued)

Drivers of linepack swing

National Grid Gas GFOP[1] publications have completed several analyses[2] over recent years exploring the drivers and outlook for this system dynamic. These studies have highlighted that linepack swing is forecasted to increase over the near term[3]. This is despite the overall level of gas demand having decreased since 2000 and, as set out in National Grid ESO *Future Energy Scenarios* 2020 publication, is forecast to fall further over the coming decade and beyond. The key drivers for this increase in linepack swing have been attributed to:

Supply-driven

- Reductions in UK Continental Shelf (UKCS) supply being replaced by sources whose within-day delivery rates are typically less constant (interconnectors and LNG)
- Further refinements in interconnector and storage compressor fuel usage and gas spot price spread optimisation potentially leading to more within-day volatility in delivery rates

Demand-driven

- Increased proliferation of renewables could lead to more frequent increases and decreases in gas-fired generation within-day demand. Ultimately, this would increase within-day linepack swings
- Increases in small-scale gas-fired power stations connected to distribution networks could lead to higher contributions to linepack swing

With the continued importance of gas-fired power stations to the UK's energy mix, having provided around ~40% of all electricity generation during 2019[4], and the continued expansion of renewable electricity production which is weather dependent, it is anticipated that gas-fired generation behaviour will become increasingly variable as to support the more intermittent nature of electricity supply.

Therefore, gas has an important role to play as a facilitator of further renewable generation deployment in the short to medium term, which is the reasoning behind the exploration of concepts that deal with the management of within-day linepack swing/volatility by the system operator and those with primary responsibility for balancing the system, gas shippers.

It is worthy to note that the NTS has recently experienced some days with significant swings in linepack. In November 2021 and January 2022, the NTS saw swings of ~41mcm and ~38mcm respectively over the course of the gas day. Linepack swings of this magnitude can provide operational difficulties for the NTS with the physical strategy having to be largely focussed on distributing gas stocks evenly across the system, continued meeting of pressure requirements and the active management of compressors to avoid trips and the associated system issues these outages could potentially cause. In both these instances the gas system operator maintained the uninterrupted supply of gas to all customers but provides a timely example of how the trend of linepack swing continues to increase.

Balancing concepts

The concepts which we will explore have been presented at a high level and are intended to act as a starting point for industry to discuss and debate further. It is recognised that further work and analysis would need to be undertaken to fully explore each of the concepts to derive cost, impacts and benefits.

However, with industry in agreement that arrangements are not believed to require any substantive change over the coming five years, there is sufficient time for this work to be completed where concepts are identified as being of particular interest to the industry.

These concepts have been grouped into four categories with theories set out for discussion under each one, these are:

1. Commercial optimisation

a. Improvements to capacity and balancing systems and services

b. Introduction of arrangements to allow a shipper to carry an imbalance position between days

2. Communication, coordination and cooperation

a. Improvements to communication and understanding between system parties

b. Identification and improvements to data sharing between system parties

c. The role of system operators in a future energy system

3. Regime evolution

a. Application of the implied nomination flow rate rule

b. Increasing the correlation between supply and demand at the within-day timeframe

c. Increasing the number of balancing periods

4. Linepack valuation and use

a. How linepack can be valued and used as a commercial product/tool

> ...gas has an important role to play as a facilitator of further renewable generation deployment in the short to medium term

1 Gas Future Operability Planning
2 https://www.nationalgrid.com/uk/gas-transmission/insight-and-innovation/gas-future-operability-planning-gfop
3 https://www.nationalgrid.com/uk/gas-transmission/document/126251/download
4 UK Energy in Brief 2020 - Gov.uk

Balancing concepts – Commercial optimisation

The first two concepts we will look at are concerned with a shipper's ability accurately to reflect their commercial position.

Context

An example of the issue that these concepts are looking to address is where shippers have customers who own and operate gas-to-power assets which participate in the electricity balancing mechanism.

The customer of the shipper may receive instruction to alter their assets' output, either by increasing or decreasing the energy it is providing to the electricity grid, something which has become more prevalent with the increase of intermittent generation coming from renewable sources.

If this action is taken during the periods where capacity and balancing systems and the traded markets are unavailable, then the shipper who is the party supplying the gas to the customer has no way to reflect their commercial position and either sell or buy more gas, dependent upon the instruction received by their customer. This in turn potentially exposes the shipper to higher costs incurred through the end-of-day gas balancing mechanism.

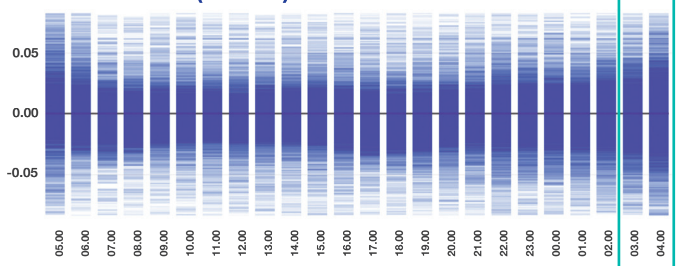
Improvements to capacity and balancing system and services and OCM availability

The current system, Gemini,[1] that is used by National Grid Gas and its business associates for the commercial management of transportation of gas through the NTS is currently not accessible between the hours of 2am and 5am for capacity bookings[2] and 3am and 5am for renominations. As a result of the unavailability of the Gemini system during these periods, shippers are unable to reflect any changes to their commercial position that may have occurred during this period and could be potentially exposed to higher costs[3] due to the market systems end of day outage.

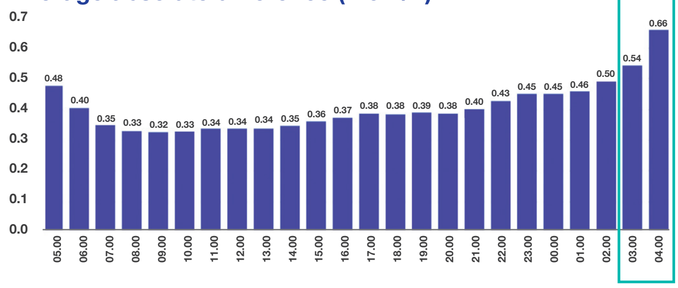
Preliminary analysis[4] undertaken by National Grid Gas, as shown in the graph opposite, indicates that flows of gas deviate away from the nominated position at a greater level during the period the Gemini system is unavailable than at any other time of day. Further analysis would need to be carried out to fully determine the drivers of this deviation as it could be attributed to other system and commercial dynamics in addition to the system and market closure times.

> By extending the hours that systems and markets are available until the end of the gas day, it would allow shippers to manage potential imbalance positions

Site differences (mcm/h)



Average absolute difference (mcm/h)



In addition to the Gemini system end of day outage, the OCM[5], where within-day trading activity takes place and is the only platform the gas system operator may use for residual balancing activity, also has a daily outage between 2:35am and 5:00am. This can also result in the shipper potentially being exposed to higher costs due to the inability to trade gas during this period.

By extending the hours that systems and markets are available until the end of the gas day, it would allow shippers to manage potential imbalance positions that are incurred during this current closure window and mitigate the risk of being exposed to higher costs. With the increase in information provision that this would bring about, and the improvements to data accuracy, it should also allow the gas system operator to avoid taking unnecessary balancing actions and manage levels of linepack within the system more effectively had this information not been available.

1 The Gemini System wholly administered by Xoserve on behalf of National Grid
2 As a result of UNC modification 0759S
3 Further information on costs and incentives can be found in National Grids "End to End Balancing Guide"
4 Analysis based upon data for the period of 01/01/2020 – 31/12/2020 comparing nominated flows to observed physical flows

5 On the Day Commodity Market operated by the ICE Endex exchange as appointed by National Grid

Balancing concepts – Commercial optimisation (continued)

National Grid Gas in December 2020 issued notice[6] to the market asking for expressions of interest from suppliers to provide future capacity and balancing systems and services. The project has proceeded since this time and is now at the stage of reviewing proposals from prospective suppliers before moving on to potential detailed contract negotiations.

One of the key recommendations was that future systems should be available on a 24/7 basis, or as close to 24/7 as possible, as to improve the efficiency of the of the market to respond to changes up to the end of the gas day. This view was also taken by the wider industry where it was expressed as desirable through stakeholder workshops conducted by National Grid Gas. This recommendation has been taken into the project with the future requirements of capacity and balancing systems and services reflecting the ambition for systems to be available on a 24/7 basis, or as close as is practicable possible.

Introduction of arrangements to allow shippers to carry an imbalance between days

An alternative option to increasing the availability of systems and markets is the ability to allow shippers to carry a level of imbalance between days. The level of imbalance that could be carried between days would need to be limited and it is suggested that it should directly correlate to imbalance incurred during system and market closure times.

Should this be explored further, one outcome would be that the shipper could receive an allocation equal to their last re-nomination before the end of the gas day with any difference to the physical flow borne by the system until compensated in the next gas day.

A comparison of how this could work in practice can be gleaned from the use of operational balancing accounts employed at the UK's gas interconnector points. These arrangements concern operator to operator arrangements rather than operator to shipper, however, the arrangements do allow a level of imbalance to be carried between days known as the steering difference, which is derived through an 'allocate as nominate' process. These arrangements therefore could be used as a basis for designing a new type of balancing account for shippers rather than having to design a new mechanism from the ground up.

However, given that improvements to current systems and services represent a way in which shippers and system operation can be optimised to the benefit of all system parties, it is National Grid Gas view that improvements to capacity and balancing systems and services is the preferable option to explore further with industry.

> ...it is National Grid Gas view that improvements to capacity and balancing systems and services is the preferable option to explore further with industry

6 Periodic Indicative Notice

Balancing concepts – Communication, coordination and cooperation

The next three concepts relate to the communication between system parties and their ability to work optimally for the benefit of all energy system users. These concepts are closely related and could be viewed as a potential roadmap for action to be taken in the coming years.

Context

There currently exists limited industry fora that bring together the parties responsible for both the Gas and Electricity Systems within the UK which reflects the separate regulations and incentives placed upon these parties. In fact, there are deliberate restrictions on their communications based on market competition grounds. This can mean that decisions taken by one party may not necessarily take into the account the impacts those decisions have upon other energy participants and, as a result, may not be the optimal solution for the energy system as a whole or the decarbonisation agenda.

One of the authors of a 2018 Imperial College Paper[1], Dr Aidan Rhodes, summed this situation very succinctly stating: "The thing is, much of our energy system is interdependent but not integrated… We have come a long way from the mid-20th century, but everything is still designed to operate independently….". This problem is truly fundamental: the energy industry, its respective governing rules and their markets have all developed along siloed lines meaning that there can be little understanding of gas and electricity issues, as well as operations, across the energy industry, and even within the same company.

An example of this siloed approach with regards to system operation, associated markets and effects, can be seen in the electricity balancing mechanism (BM). The BM includes gas-to-power generation assets (gas fired power stations), as well as other forms of power generation such as wind and solar, where generators of electricity are paid to perform balancing actions for the electricity grid as instructed by the Electricity System Operator.

As a hypothetical situation, imagine an unpredicted, particularly cold day in winter, which is overcast with little to no wind blowing. The Electricity System Operator issues a notice through the BM asking for additional generation to come online as wind and solar generation is unable to meet the energy demand within the country. Coincidentally, the Gas System Operator has issued a Gas Balancing Notification for this particular day and is asking for gas demand to be reduced within the country, which is usually fulfilled by the curtailment of large connected sites to the NTS such as gas-to-power generators (gas fired power stations).

Now we have a situation for a gas-to-power generator where they are being asked to increase output by the electricity system operator but simultaneously to reduce their demand by the gas system operator. The commercial implication for the generator is that they will be rewarded by the electricity system operator for increasing output but penalised by the gas system operator for not reducing demand.

Currently commercial incentives within the BM far outweigh the penalties imposed by the gas system operator, therefore the generator would in theory increase its output to receive the financial benefit of doing so, as the overall benefit minus the penalty is still a net positive, however, this would be the exact opposite of what the gas system operator was trying to achieve and would further impact upon the gas system.

Were this siloed approach not taken and, parties were able to communicate, understand the operations of each other's systems and design market rules with this knowledge and understanding, the above example could potentially be avoided. The following concepts provide some ways in which this dichotomy could start to be resolved and move us towards a more integrated energy future.

Balancing concepts – Communication, coordination and cooperation (continued)

Improve the communication and understanding of the challenges faced by gas and electricity system operators as well as other industry participants (Step 1)

By bringing together the parties responsible for the various aspects of the UK's energy system to discuss the challenges they face, it is hoped that solutions could be found to current and future issues which take into account the integrated nature of energy systems as they stand today and as we move through the energy transition.

For the gas system, and balancing activity therein, discussions around the intermittent nature of power generation, and the stress this places upon the gas network to provide backup generation at times of low wind and solar generation, may lead to new market arrangements to minimise these impacts. Conversely, a better understanding of the needs of the electricity grid in times of low intermittent generation could again allow for new market arrangements to be introduced to support the ever-increasing share this type of generation has within the UK energy mix.

Work has been started in this arena by National Grid Gas through the 'Review of the Impact of a Gas Supply Shortage on the Electricity Network' (RIGSSE) project. This is an entirely separate project to this review of balancing arrangements and is looking at understanding the issues faced by the electricity and gas systems at times of stress.

This encapsulates how communication and data sharing between the system operators can be opened up in times of system stress to ensure the most appropriate actions are taken for the energy system as a whole, as well as the market incentives behind the actions taken to ensure that sub-optimal decisions are not taken by market participants, such as those as described in the example given in the previous section.

A particular strand of the RIGSSE project is looking at communication and information between system operators and energy participants before a system stress event/emergency takes place (pre-emergency communication), and may start to bring these separate parties together and illuminate optimisations to the ways these parties have traditionally operated and communicated with each other.

It should be noted that the RIGSSE project is separate to the concept put forward here of increasing communication and understanding between energy participants whilst accepting there is some overlap with the pre-emergency communication strand of the project. It is also separate to the discussion surrounding the establishment of an Independent System Operator (ISO), which is currently being investigated by Ofgem and BEIS, and which we will discuss later in this document.

> ...communication and data sharing between the system operators can be opened up in times of system stress...

It is also worth noting the recent report that has come from the Energy Data Taskforce[1]. Established by the Department for Business, Energy, and Industrial Strategy, Ofgem and Innovate UK, the Energy Data Taskforce was run by Energy Systems Catapult and was created to advise Government, Ofgem and industry on how to unlock value from data within the UK energy system. The report provides 5 key recommendations:

Recommendation 1: Digitalisation of the Energy System – Government and Ofgem should direct the sector to adopt the principle of Digitalisation of the Energy System in the consumers' interest, using their range of existing legislative and regulatory measures as appropriate, in line with the supporting principles of 'New Data Needs' 'Continuous Improvement' and 'Digitalisation Strategies'.

Recommendation 2: Maximising the Value of Data – Government and Ofgem should direct the sector to adopt the principle that Energy System Data should be Presumed Open, using their range of existing legislative and regulatory measures as appropriate, supported by requirements that data is 'Discoverable, Searchable, Understandable', with common 'Structures, Interfaces and Standards' and is 'Secure and Resilient'.

Recommendation 3: Visibility of Data – a Data Catalogue should be established to provide visibility through standardised metadata of Energy System Datasets across Government, the regulator and industry. Government and Ofgem should mandate industry participation though regulatory and policy frameworks.

Recommendation 4: Coordination of Asset Registration – an Asset Registration Strategy should be established to coordinate registration of energy assets, simplifying the experience for consumers through a user-friendly interface in order to increase registration compliance, improve the reliability of data and improve the efficiency of data collection.

Recommendation 5: Visibility of Infrastructure and Assets – a unified Digital System Map of the Energy System should be established to increase visibility of the Energy System infrastructure and assets, enable optimisation of investment and inform the creation of new markets.

With the above noted, it is believed that through communication and understanding, the coordination of activities and market arrangements, as well as market alignment where possible and enhanced cooperation between all energy participants, the challenges society faces in transitioning to a net zero future can be approached collectively and resolved collaboratively. This must involve not just the electricity and gas system operators, at both national and distribution level, but also the shippers, generators, terminal, and interconnector operators in order to ensure a whole system view is represented and considered.

Project RIGSSE is a good initiative to start the review of where enhanced communication and data sharing between system parties can be developed as the UK targets a net zero, integrated and interdependent whole energy system future. The outcomes of the project can help inform the general topic of communication, collaboration and cooperation discussed here and how this can be evolved over the coming years as the likely need to do so becomes more apparent to realise the UK's ambitions for its future energy system.

1 https://es.catapult.org.uk/impact/specialisms/energy-data-taskforce/

Balancing concepts – Communication, coordination and cooperation (continued)

Identify and improve data provision and sharing between system operators and energy participants (Step 2)

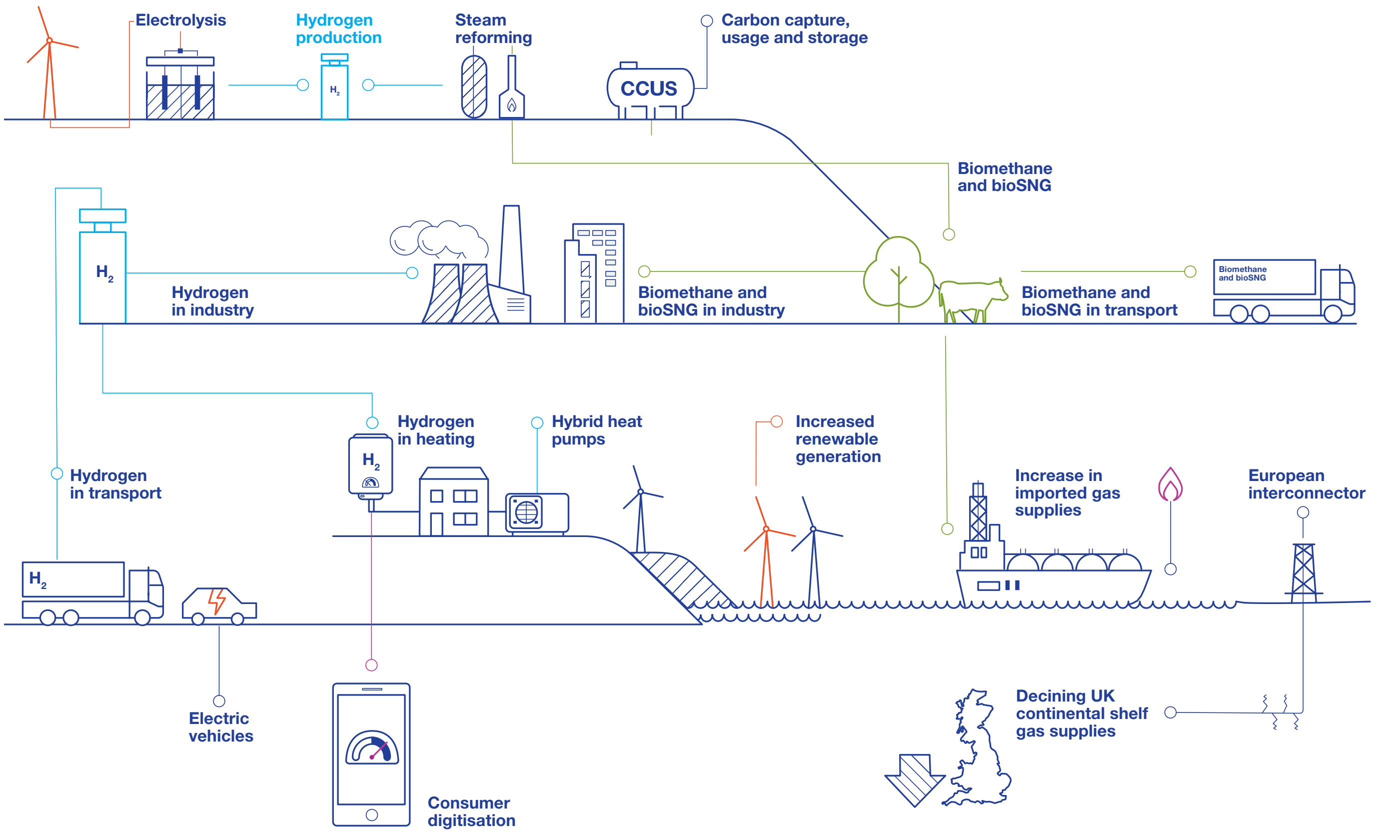
Against a backdrop of an increasingly complex energy system, the potential for systems to diverge into more discrete networks, the likely introduction of new system operators to manage these new networks and the development of new or more complex interactions between different energy vectors arising, the identification, and subsequent communication, of relevant data between system operators and energy participants as well as the provision of more data relating to the use of energy systems would seem a logical step to take.

An example of some of the potential future relationships between energy vectors, new technologies and the increasing complexity of the energy system can be seen below.

By allowing the system operators and other energy industry participants to share relevant information which has a material impact upon the physical networks and assets they manage, we can potentially move towards the operation of the networks in close to real time, as well as improving whole system operability. This could also highlight, in the fullness of time, ways of improving whole system forecasting, network planning, as well moving towards whole system thinking and operation.

In respect of balancing, the current market structure relies upon the customers of the networks to inform the system operators of intended balancing actions, primarily seen in the balancing mechanism[2] market where thermal generation is responding to requests from the Electricity System Operator.

This process takes time and, in the case of this example, results in a delay between the action being taken and the Gas System Operator being aware of the action and its implications. By allowing and improving data provision this process could be optimised allowing for greater lead time and subsequent control of the gas system's balance.



2 https://www.elexon.co.uk/knowledgebase/what-is-the-balancing-mechanism/

Balancing concepts – Communication, coordination and cooperation (continued)

Work has already been completed in respect of the example given above through Wales & West Utilities' 'Flexible Generation Forecasting' project[3]. This project aimed to identify the key drivers and datasets that would enable and improve whole system forecasting and network planning/operation in close to real time and highlighted the value of data-sharing between energy vectors.

This is necessary due to the significant changes in the ways in which gas is used for electricity generation, as gas generation moves from base load to a more flexible, responsive mode of operation as it is used to balance the intermittency of renewable generation supplies. This has required specific derogations from the UK regulator, Ofgem, to take forward due to the aforementioned issues around market competition and is limited to the scope of the Flexible Generation Forecasting project only.

However, in United State of America, with the intervention of the Federal Energy Regulatory Commission[4] (FERC), amendments to regulation contained within Order No. 787[5] enabled relaxation of communication constraints on a continuing basis for the wider industry.

Whilst not a direct comparison to this concept, this order amended regulations to: "provide explicit authority to interstate natural gas pipelines and public utilities that own, operate, or control facilities used for the transmission of electric energy in interstate commerce to share non-public, operational information with each other for the purpose of promoting reliable service or operational planning on either the public utility's or pipeline's system. As a protection against the disclosure of non-public, operational information not covered by FERC's Standards of Conduct, Order No. 787 also adopted a 'no-conduit rule' that prohibits subsequent disclosure of information received under the rule to a third party or the transmission operator's marketing function employees."

This provides a good example of how another market has acted to improve communication and data provision between system parties where legal barriers previously prevented them from doing so. As was required in this case and the above noted project from Wales & West Utilities, intervention was required from the regulator to allow this communication to occur. It is likely that intervention from both Ofgem and BEIS would be required to advance this concept further to ensure market competition concerns are addressed.

The role of system operators in a future energy system (Step 3)

As we move towards net zero, there are several pathways that are currently being explored by various parties to establish the technologies best placed to achieve this ambition. Which technologies will be used, and their prevalence in a net zero world, is still a matter for much debate and analysis, however there is a clear indication that energy will be provided from a number of different and new sources compared to those we see today.

There will be new interdependencies and interactions between energy vectors that are yet to be established and understood, and the very nature of centralised energy provision could be completely turned upon its head with movement already well underway to a more decentralised energy system. This can already be seen with the burgeoning of local energy partnerships, community energy projects, and the introduction of time-of-use tariffs in the retail space.

This all points towards a much more complex and integrated energy system future. Inevitably, as this complexity arises and further integration occurs, questions regarding the role of system operators will likely arise, including whether a significantly different system operator role to that which is employed today should be developed. It should be noted however, that if routes to increased communication and data sharing between system parties can be achieved, as set out in the previous concepts, the requirement for significant changes to system operator functions could be precluded.

A consultation on system operation governance arrangements and the exploration of the roles and functions of a Future System Operator was launched by BEIS and Ofgem in July 2021[6]. This follows and will build upon Ofgem's initial assessment report[7] on the subject which was published in January 2021.

> There will be new interdependencies and interactions between energy vectors that are yet to be established and understood

3 https://www.smarternetworks.org/project/nia_wwu_068/print
4 https://www.ferc.gov/
5 https://www.ferc.gov/sites/default/files/2020-04/order-787_0.pdf
6 https://www.gov.uk/government/consultations/proposals-for-a-future-system-operator-role
7 https://www.ofgem.gov.uk/publications/review-gb-energy-system-operation

Balancing concepts – Regime evolution

Before moving on to discuss the next three concepts, it is worth emphasising that the previous themes, around communication and improved data sharing between system operators and energy system participants, could preclude the need to move towards a more defined change in current gas balancing arrangements to manage linepack swing at the within-day timeframe.

The understanding of the potential benefits and impacts of enhancements to data provision and communication should be explored by the industry as a first step towards managing the increasing volatility of supply and demand within the gas network, as well as the broader goal of energy sector integration and potential market alignment.

The issue of within-day linepack swing is not believed to provide any requirement for balancing regime reform over the next ~5 years as forecasts, such as National Grid Gas Transmissions RIIO-2 business plan, show the issue still falls within acceptable operational parameters; this provides industry a window of opportunity to explore low cost, no regret options without the constraint of having to resolve an immediate problem that is impacting upon the gas network and its functioning sufficiently to warrant balancing regime reform.

> ...this provides industry a window of opportunity to explore low cost, no regret options without the constraint of having to resolve an immediate problem

With the above noted, the next three concepts we will explore relate to the observance and evolution of existing balancing arrangements to better manage within-day linepack swing experienced within the UK gas system. Whilst aggregate demand levels for gas in the UK have been reducing over time, the gas system operator is now dealing with more volatile within-day demand profiles.

Balancing concepts – Regime evolution (continued)

Context

Current end-of-day gas balancing arrangements incentivise shippers to match their demand with supply by the end of the gas day, with financial incentives placed upon them to do so. However, these arrangements place no requirement upon the shipper, and the suppliers and end-users they have contracted with for delivery of gas supplies into the network, to match the supply to demand at the within-day timeframe.

This can mean that through the course of the gas day, the differential between supply and demand can widen and narrow significantly, which in turn impacts the levels of linepack within the system and linepack flexibility that the system can provide.

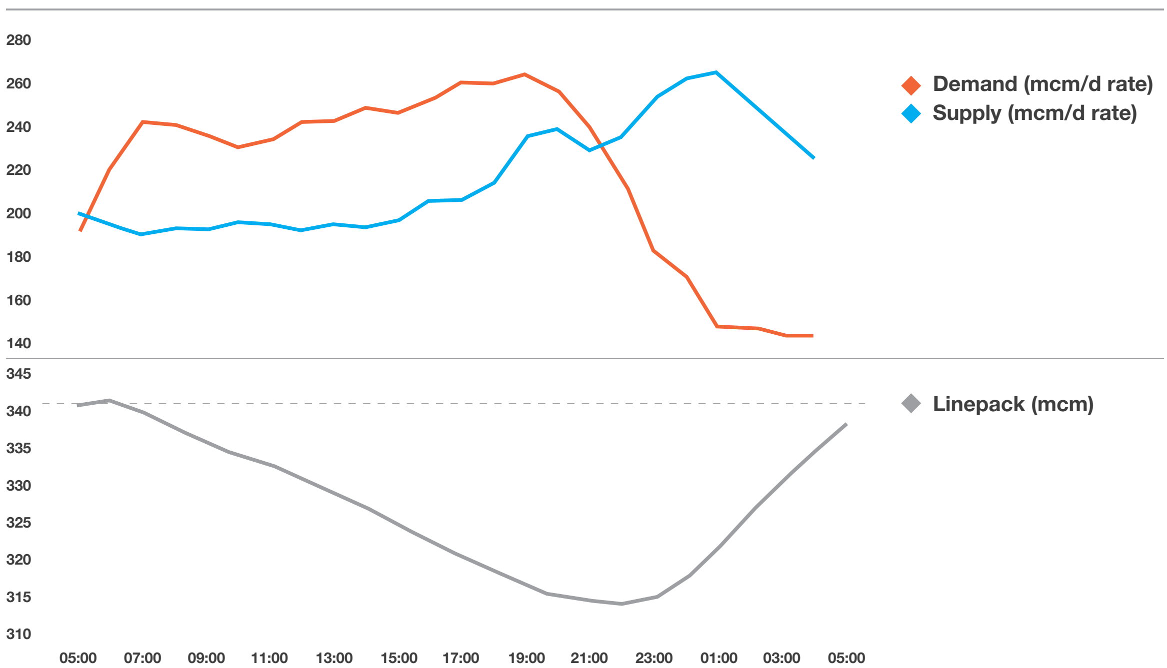
This means that supply and demand are not in a steady state and vary throughout the day. One of the roles of the GNCC is to manage this variation between supply and demand throughout every gas day to ensure system safety and operability for its users. This variation (volatility) affects the volume of gas in the system (linepack) and therefore the pressure within the system itself changes.

If the pressure becomes too high, it could result in the safe operating limits of the physical pipelines being exceeded and result in the risk of rupture. If pressure gets too low, it could fall below the minimum pressures required by the Gas Distribution Networks for them to run their networks safely, resulting in the risk of domestic gas customers being disconnected from the system.

The amount of linepack available to absorb variations between supply and demand is a finite resource. The size of the buffer provided by linepack to absorb this variation is determined by the maximum amount that linepack can fall within-day from its current level without introducing a positive probability of supply failure to the end user; which could manifest as the failure to meet agreed supply pressures with the gas distribution networks with the result as described above of domestic gas customers being disconnected from the system.

With the amount of linepack swing forecasted to increase[1] due to a number of factors, such as the increase in renewable generation and the change in gas supplies to those whose within-day delivery rates are typically less constant (interconnectors and LNG), as well as the potential to introduce hydrogen to the networks and re-purpose existing infrastructure into a separate network, it may become necessary to introduce arrangements where demand and supply are more closely aligned at the within-day timeframe to ensure the continued safe operation of the gas system and ability to meet the requirements of its users.

The below graph shows how supply and demand impacts upon linepack on a typical day within the national transmission system as to help the contextualisation of the following concepts.



1 https://www.nationalgrid.com/uk/gas-transmission/document/126251/download

Balancing concepts – Regime evolution (continued)

Adherence to the implied nomination flow rate rule (1/24)

The implied nomination flow rate rule gives an expectation that the gas will be delivered into the system on a flat basis (i.e. 1/24 of the daily volume per hour, every hour). This rule makes sure that a shipper cannot re-nominate to a level less than would be expected to have already entered the system at the point the re-nomination is made.

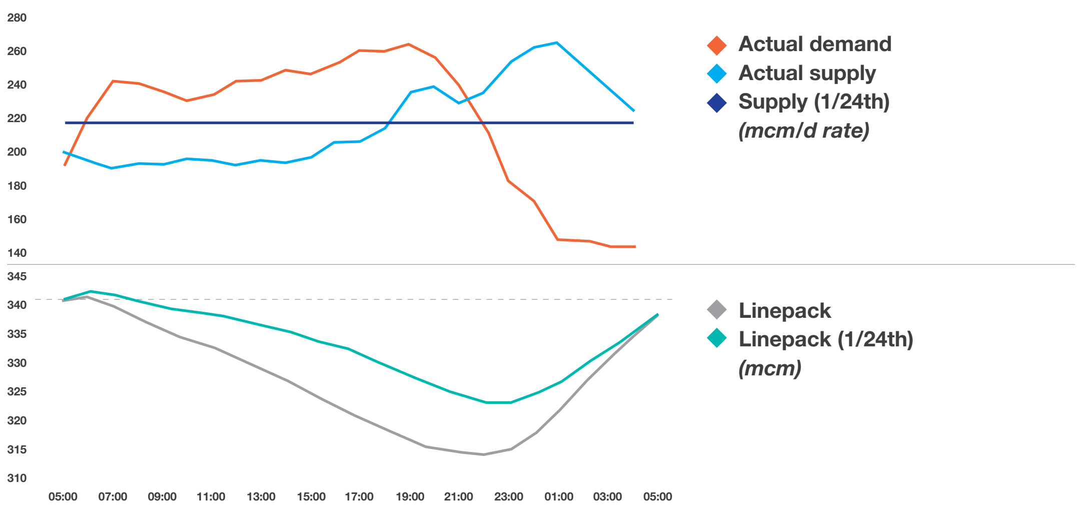
However, due to the inherent flexibility that the national transmission system is able to provide to its users through linepack stock, these rules are not currently enforced upon the parties injecting gas into the system.

If these rules were to be applied, it may have the effect of reducing the observed linepack swing at the within-day timeframe as supply volatility would be mitigated to a certain extent. As detailed in the below graph, this would have the effect of flattening the supply line (top line graph) and raising it above where supply began at the start of the day. This would then in turn have the effect of shallowing the curve observed in the lower graph, narrowing the linepack swing within the gas network over a gas day.

Further analysis would be needed to quantify the benefits that the tighter application of this rule may provide for the management of linepack swing, and if there would be any negative commercial or operational implications due to the rule having not been strictly enforced previously, which out-weigh these potential benefits.

The application of the rule may not be appropriate given the nature of supply and demand seen today, in comparison to when the rule was implemented, and how this dynamic is set to evolve even further as we move through the energy transition.

Also, as a lack of enforcement has become custom and practice for gas system users, users may not be able to respond adequately and efficiently to a tighter enforcement of this rule. As suggested, further analysis would be needed for the basis of new discussions on this topic.



Increase the correlation between gas supply and demand, at the within-day timeframe

As touched upon in the previous section, the nature of supply and demand has changed since the inception of the balancing regime some 25 years ago. This dynamic between supply and demand is only set to change further as we move through the energy transition.

Therefore the introduction of commercial arrangements that look to incentivise shippers to match supply and demand at the within-day timeframe, having the effect of reducing linepack swing, allows for the issue of volatility to be addressed but also allows for inherent flexibility in the nature of the commercial arrangements to adapt to this ever changing dynamic between supply and demand by introducing a correlation mechanism.

This mechanism would be different to that of intra-day balancing, which will be covered in the next concept, in that a single end-of-day balancing period would be preserved. The correlation mechanism could potentially feed into the default cash-out mechanism used within the end-of-day regime whereby, if the shipper maintained their position with respect to supply and demand correlation, subject to defined deviations and thresholds, they could attract commercial benefits through the cash-out process.

This could be potentially achieved through adjusted system sell and system buy prices, applied dependent on whether the shipper ended the day either long or short. The premise would be that if the shipper maintained supply and demand correlation throughout the day, subject to defined deviations and thresholds, they could either obtain an increased sell price to that of the standard system price if they were long and a reduced buy price if they were short.

Balancing concepts – Regime evolution (continued)

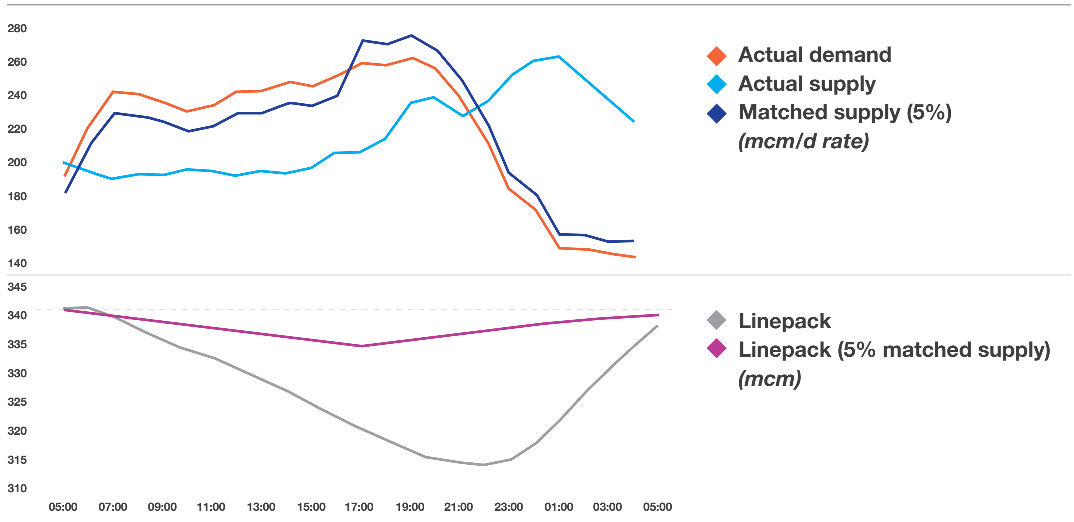
This correlation mechanism could potentially utilise forecasted supply and demand data prior to the gas day as the basis for the incentivisation of shippers to achieve the desired outcome of a closer relationship between supply and demand than which is experienced today. The mechanism would also be adaptable to future changes in supply and demand, as the mechanism would be using actual forecasted data as the basis of ensuring supply is better matched to demand at the within-day timeframe.

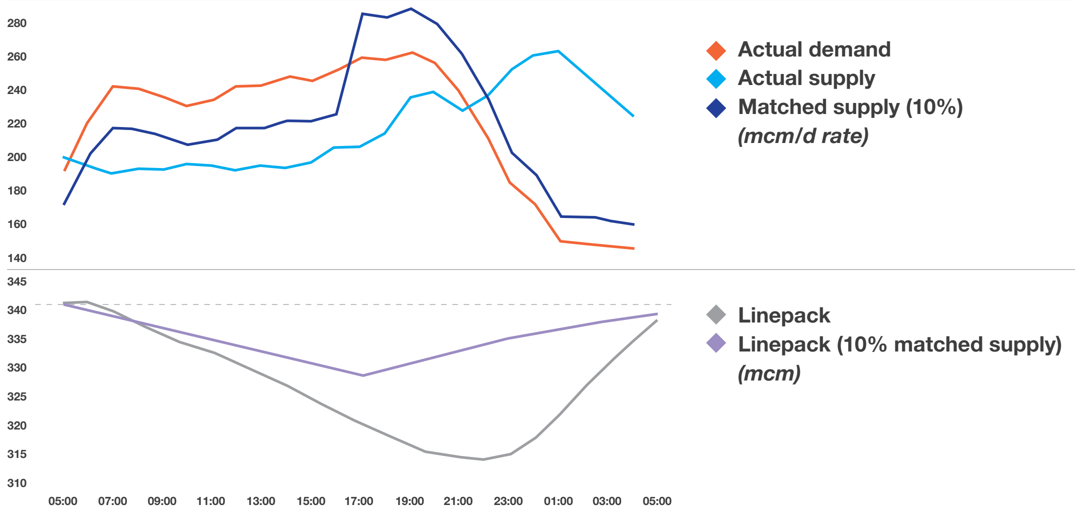
It is accepted that a perfect match between supply and demand would probably be unachievable due to other extraneous variables such as forecasting errors, unplanned asset outages, and other events occurring on the gas day. However, any closer correlation would mitigate some of the linepack swing experienced with the gas network.

Profiling information at hourly level is already supplied by shippers for both entry and exit points on the NTS in the form of Daily Flow Notifications for entry, Offtake Profile Notifications for exit and Storage Flow Notifications that cover both the injection and withdrawal for gas storage sites.

How, or if, this information could be used as the basis for a closer correlation between supply, demand, and the incentivising of shippers to do so, would need to be investigated further and considered carefully to ensure that the implementation of arrangements do not have an adverse effect upon the functioning of the commercial markets and their liquidity.

The below graphs show the effects upon linepack swing if supply were to be correlated within 5% and 10% of demand over the course of the gas day.





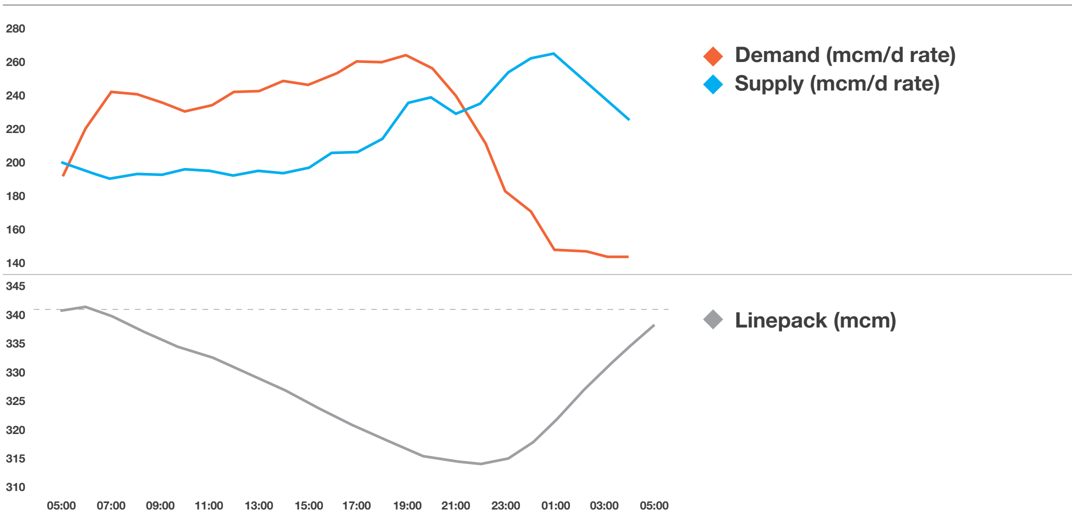
This would be a complex mechanism to introduce due to the multitude of various factors that need to be taken account of within the mechanism itself to ensure incentives placed upon shippers were realistic and achievable, however, if this could be achieved it would provide greater resilience to the gas network to absorb the increasing levels of linepack swing seen at the within-day timeframe.

Balancing concepts – Regime evolution (continued)

Increase the number of balancing periods beyond the current singular end-of-day requirement – intra-day balancing

Current balancing market arrangements place incentives on shippers to match their inputs and outputs for the gas network on a daily basis. Similarly, incentives are placed upon the gas system operator to make sure that the gas network is balanced for each gas day, so that the level of linepack held within the system at the end of the gas day remains close to the level of linepack that the gas network held at the beginning of the gas day.

The below graph shows a typical day experienced by the gas transmission network in respect of supply, demand, and its effect upon linepack held within the system. It shows how linepack decreases from the start of the gas day as demand levels are higher than supplies to the system, with the converse being true as we move through the evening, having the effect of replenishing the linepack level towards its starting position at the beginning of the gas day.



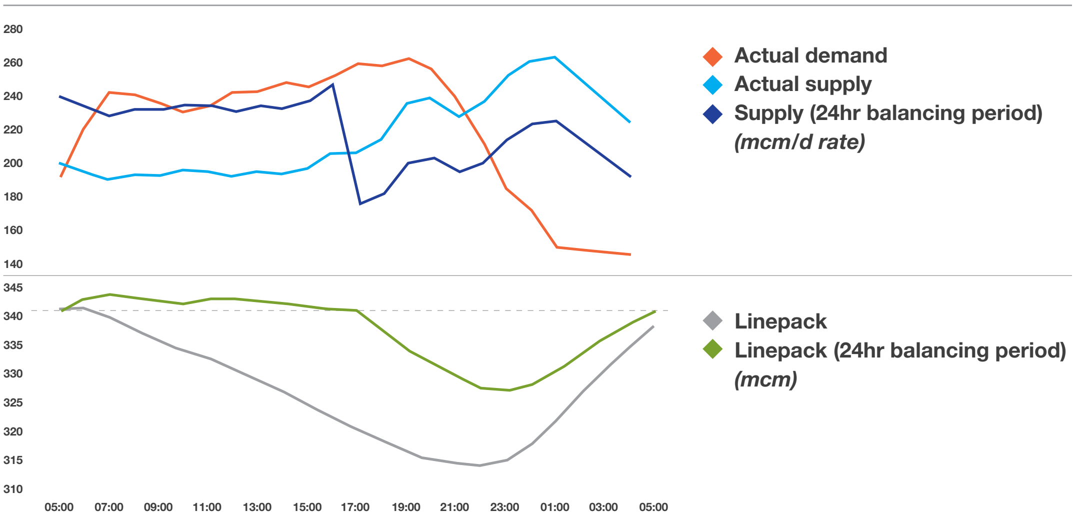
This visualisation also shows the inherent level of flexibility the gas network affords to its users by accommodating this mismatch between supply and demand. Whilst this level of flexibility can currently be accommodated to the system's users, and which is believed to continue to be the case for at least the next ~5 years as confirmed in National Grid Gas RIIO-2 business plan, beyond this point the potential changes required to meet net zero and its ambitious interim targets may impact upon the level of flexibility that can continue to be accommodated.

Should it become the case that the gas network can no longer accommodate the disparity between supply and demand, and its effects upon linepack, a concept that could be deployed to mitigate these effects would be to increase the frequency that the gas network is brought back into balance.

This report makes no recommendations as to the number of balancing periods that an intra-day balancing regime would need to employ in the future. This should be subject to further industry consultation and analysis as to the optimal solution, based around the emergent system dynamics indicating that the established end-of-day regime is no longer sufficient for system operability.

The below graph provides a visualisation of how linepack swing could be impacted by the introduction of a singular additional balancing period. This would in effect mean moving from a 24hr single end-of-day regime to that of two 12hr balancing periods. The data used for this visualisation has respected the original supply profiles, as far as possible, but has adjusted the volumes delivered to ensure that linepack is brought back to where it began for the end of each 12hr period.

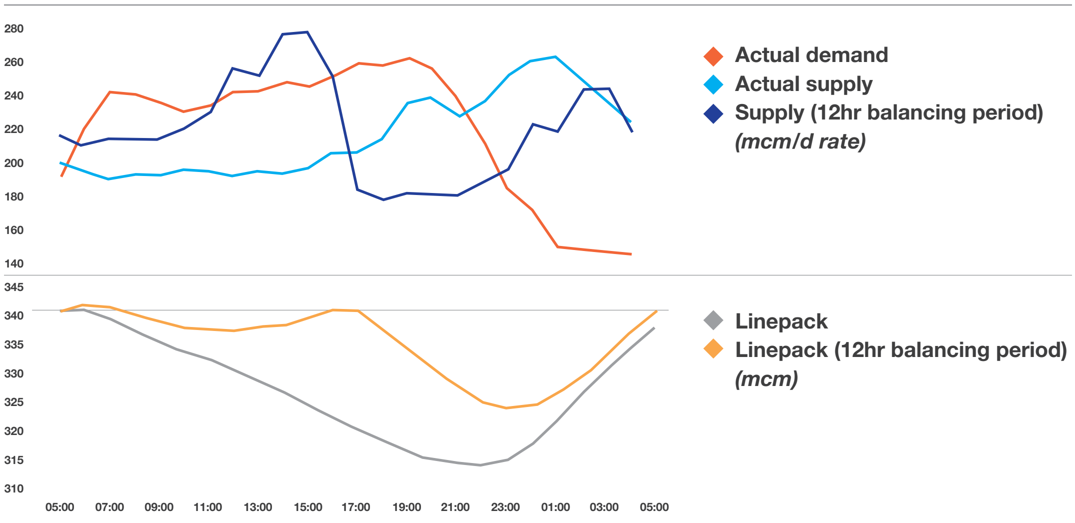
Balancing concepts – Regime evolution (continued)



The second graph below shows the effect of the same 12hr balancing periods on linepack swing, however the data used for this visualisation has observed the traditional shape seen with respect to linepack swing over the course of a gas day but split into two 12hr periods.

The concept of increasing the number of balancing periods is not new and was investigated at length between 2001 and 2003 by Ofgem and industry[1]. It was concluded at that time that this fundamental reform to the gas balancing regime was not required, with Transco[2] providing the view that it could balance the system without the introduction of shorter balancing periods, which has been borne out.

As we are now moving into a situation where forecasted linepack swings are set to increase over the coming years (out to 2025) to greater levels than previously experienced, with potential future changes in the physical infrastructure of the network and the likely changes in the supply and end use of gas compared to today having the potential to increase linepack swing even further, the need to move to an intra-day balancing regime may become evident. It would likely be a preferred option to that of increasing the correlation between supply and demand at the within-day timeframe due to the complexity those arrangements would need to overcome.

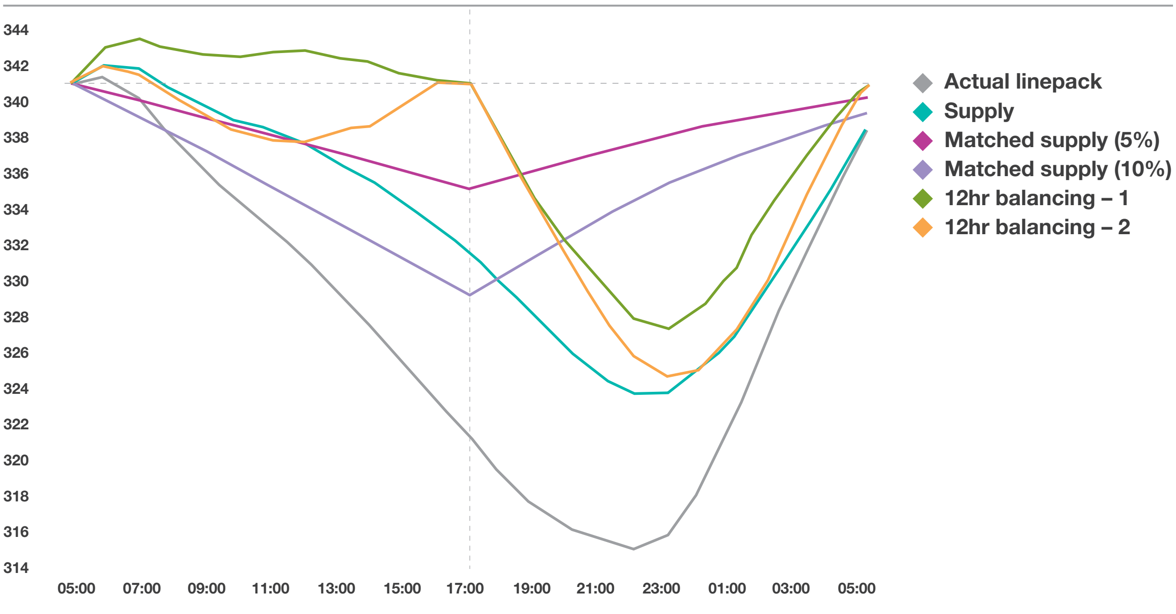


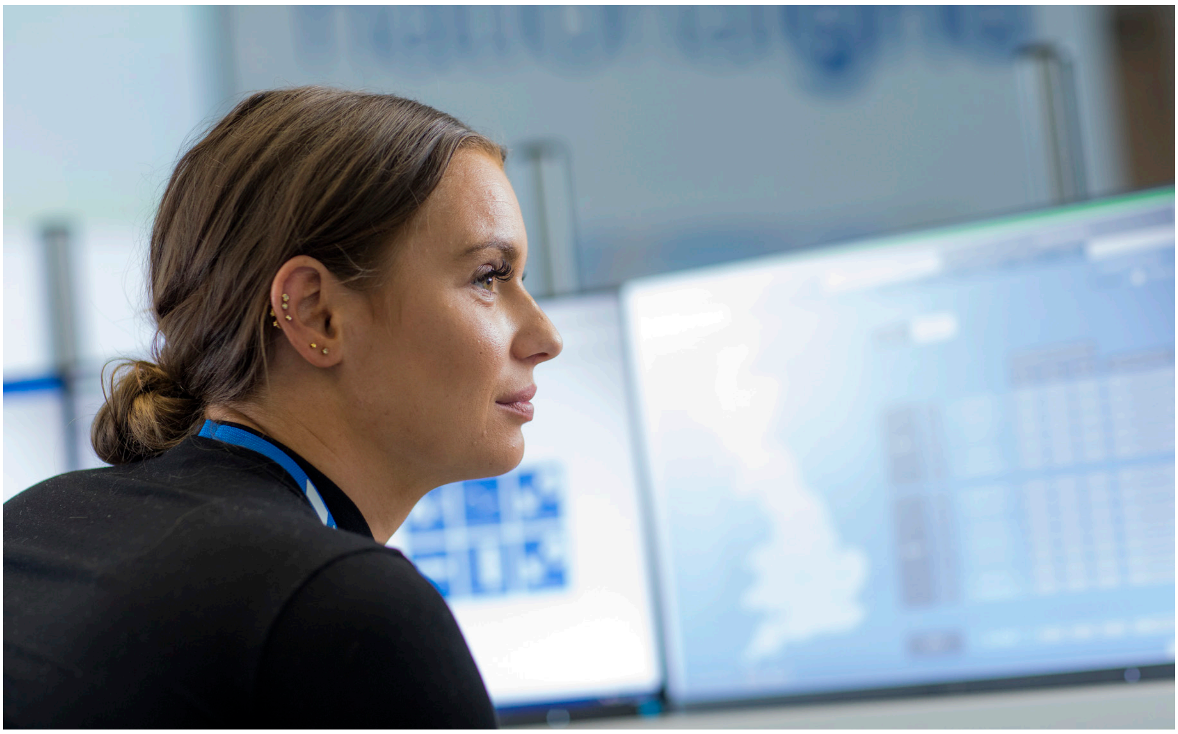
1 https://www.ofgem.gov.uk/sites/default/files/docs/2003/04/2805_2103gasbal_version2.pdf
2 Previous company name for what is now National Grid Gas Transmission

Balancing concepts – Regime evolution (continued)

Regime evolution comparison

The below graph shows how all the regime evolution concepts could impact upon linepack swing when compared to a typical day experienced within the NTS.





Balancing concepts – Linepack valuation and use

The final concept that this report will cover relates to the commercialisation of the flexibility that the gas network provides through linepack, which is one of the tools used by the system operator to manage the differences between supply and demand at the within-day timeframe.

Context

The determination of the value of linepack held within a gas network is a complex question which has been the subject of several reports over the years. This report does not look to answer this question, which would need to be the subject of further research, analysis and industry engagement, however it looks to highlight the reasoning behind why such a step could be of benefit to the overall balancing regime and its associated costs, and to stimulate discussion and debate within industry, based upon research already concluded[1,2].

Linepack valuation and use

As a result of gas transportation system design, a gas network can afford a certain amount of flexibility to its users, in that users do not need to match their inputs and outputs exactly, at the within-day timeframe. This flexibility in the UK is provided through linepack held within the NTS and distribution networks, kept at a level between minimum and maximum operating pressures that the networks are designed to operate under.

This can be viewed as a type of storage (pipeline) where linepack acts as a buffer to the differential between inputs and outputs from the system, with the size of this buffer determined by the maximum amount that linepack can fall within-day from its current level without introducing a positive probability of supply failure to the end user.

The fundamental value of linepack flexibility can be attributed to its ability quickly to manage imbalances at the within-day timescale arising from the temporal imbalance between supply and demand over the same period. Therefore, the economic definition of a gas imbalance depends upon the balancing period, which is the time interval where a shippers supply and demand should match, observed in the UK as a 'gas day' (5:00am – 5:00am).

> The fundamental value of linepack flexibility can be attributed to its ability to quickly manage imbalances at the within-day time scale

Considering that the value of gas demand varies over this period, and the production or import of gas is often less costly when flat, there is value to the matching of gas demand and supply over time. Additionally, the economic value that is created by the flexibility to store gas inside the gas network can be appropriated by different users of the system: the system operator can use this property to minimise pipeline investment, whereas shippers are able to use it for price arbitrage and load management.

In the case for the system operator, as it is responsible for the investment into the gas network it is also responsible for dimensioning. Therefore, a system operator will look to maximise the sale of transport capacity while minimising the capacity it builds. Linepack flexibility aids the system operator to avoid over-investment, meaning the investment in capacity that will not be used during the pipeline depreciation horizon.

In the case for the shipper, who can be any party purchasing or selling gas and who are inherently a profit maximising market participant, they will look to buy their gas as cheaply as possible and sell it for as expensive a price as is possible. Therefore, if an opportunity arises for the shipper to purchase gas cheaply in △t1[3], inject into the gas network and sell the gas at a premium in △t2, the shipper will be interested in using the inherent linepack flexibility afforded by the gas network to arbitrage between prices.

It is also evident that a shipper could also sell gas from the inherent linepack stock in △t1, should the gas have a high purchase price and then inject it back into the system in △t2, when the gas has a lower price as to match their purchase and sales portfolio.

1 Gas Balancing Rules Must Take into account the Trade-off between Offering Pipeline Transport and Pipeline Flexibility in Liberalized Gas Markets
2 Linepack storage valuation under-price uncertainty
3 Fictional time period

Balancing concepts – Linepack valuation and use (continued)

Currently, the linepack used to manage the differences between supply and demand at the within-day timeframe is provided as a socialised cost to users of the system, which is a mechanised process administered through the end-of-day balancing charges[1]. The UK model, which formed the basis for the harmonisation of gas balancing regimes across Europe through the BAL NC, of a singular end-of-day balancing mechanism, with no costs associated beyond the end of day mechanism, with the use of linepack at the within-day timeframe in effect, means giving shippers free short-term storage or free short-term flexibility.

This results in shippers who need more flexibility, especially at the within-day timeframe, pay less than the costs they cause to the network, and conversely, shippers who require less flexibility pay more than the costs associated with their actual use of this flexibility. Consequently, the free linepack flexibility provided may inhibit the development of other less costly sources of short-term flexibility.

Within-day flexibility has become more important over the last decade due to the increasing participation of gas-fired power plants in the electricity market and is expected to continue over the coming decade. The inter-dependence between gas and electricity demand profiles through these gas-fired generators have the effect of increasing the short-term volatility of gas demand.

Therefore, in a daily balancing mechanism as operated within the UK, the flexibility that is required to accommodate the within-day demand variability of gas-fired generation is paid for by all gas shippers and, in turn, all gas consumers. This is a form of cross-subsidisation which has the effect of decreasing overall gas system efficiency.

Linepack flexibility, as discussed, is an important tool in balancing the gas network as it is the main tool used by the system operator to perform physical balancing activities required at the within-day timeframe. Therefore, an imbalance becomes an implicit storage service contract based upon the linepack flexibility between the shipper and system operator.

With the UK balancing regime in mind, the shipper will decide between *ex ante* balancing and *ex post* balancing. *Ex ante* balancing means the contracting of flexibility instruments on the market prior to the imbalance occurring, whereas *ex post* balancing means the shipper relying upon the system operator balancing mechanism. If contracting for flexibility is more expensive for the shipper than paying the balancing charges, the shipper will prefer the implicit storage contract.

The choice between balancing *ex ante* or *ex post* not only implies that linepack flexibility affects the availability of transport capacity, but also affects the market for other flexibility tools. Therefore, cost allocation and cost reflection are both cornerstones for dealing with linepack flexibility. In its 2007 paper,[2] ERGEG[3] stated: "Economically, the costs for balancing the transmission network should be made where balancing can be done the cheapest. In other words, the penalties should reflect the actual and efficient costs of balancing the system."

Economic efficiency can only be achieved if the balancing service is provided by whomever can produce the service at the lowest cost. In a liberalised market, as is operated in the UK, participants' decisions are not centralised, therefore only if the prices/tariffs reflect the real costs will participants make the correct decisions and the least costly balancing tools will be developed.

If cash-out charges and penalties are high enough, in the example of a gas fired generator, they may rely less upon ex post balancing and prefer to contract more ex ante balancing, or purchase more network services that allow for the revision of their nominations, in order to meet their obligations and minimise their exposure to the costs associated with balancing charges.

With the amount of linepack being used to manage the differences between supply and demand increasing, as observed as within-day linepack swing within the gas network, could the commercialisation of this inherent characteristic of gas transportation systems provide a better way to manage its allocation and use within the gas network by the system operator, as well as offering a defined commercial product to parties who value the ability to flex for their own operational and commercial considerations without cross subsidisation from other shippers, and ultimately the end consumer, who value this flexibility less?

> Within-day flexibility has become more important over the last decade due to the increasing participation of gas-fired power plants in the electricity market

1 Scheduling & Maintenance Charges
2 https://www.ceer.eu/documents/104400/-/-/67ba62bd-7b07-843f-8ca1-60c15cca0c97
3 European Regulators Group for Electricity and Gas

Triggers that may indicate the need for change

With the above discussed, what may indicate a need to change or reform the current UK gas balancing regime and potentially introduce one or more of these concepts, or other concepts not discussed in this report, in the future?

As highlighted at the start of this report, stakeholders and the system operator, through engagement and publications, have stated that they believe there is no requirement for changing the current gas balancing regime for at least the next ~5 years taking into consideration the extent of change we are likely to see in the UK's energy networks over the same period.

Added to this, the fact that the UK gas balancing regime has remained largely unchanged over the preceding 25 years, even in the face of the changes that have occurred, would indicate the regimes' resilience and ability to accommodate change, and infers that any future changes to the regime would need to be driven by fundamental shifts in the way the system is operated and utilised by its customers as compared to today.

Below are some examples of the triggers and drivers for potential future change activity.

...the UK gas balancing regime has remained largely unchanged over the preceding 25 years

Triggers	Drivers
Network capability forecasts indicating within-day linepack swing exceeding operational limits.	– The increasing interdependence between electricity system balancing and gas fired power generation. – The potential repurposing of the National Transmission System to carry blends of hydrogen. – The partitioning of the National Transmission System to create a UK hydrogen backbone.
Changes in the UK's gas supply and demand patterns.	– Increasing import dependence for gas through LNG terminals and interconnectors. – New gas demand arising from the production of blue hydrogen. – The net zero heat decarbonisation agenda.
Central, devolved and local governmental net zero policies and roadmaps.	– Net zero 2050 legislation and interim targets.
Changes in system operational structures.	– The potential for new system operators such as a hydrogen system operator. – The drive towards whole energy system integration.

Case study: Northern Irish and Republic of Ireland's energy systems

The increasing levels of within-day linepack swing and the ability of system operators to manage this characteristic is not an isolated issue.

Indeed, this characteristic is been seen across various markets where there is a significant use of gas for power generation, combined with an increasing prevalence of intermittent renewable power generation in the form of wind and solar.

This is the case for Northern Ireland and the Republic of Ireland which we will now explore to see how this changing characteristic is impacting upon system operation and what steps are being taken by the various energy system participants with the aim to mitigate this issue.

Background to physical gas network

The gas networks on the island of Ireland are a relatively recent development compared to the GB gas network and are much smaller in size comparatively. The discovery of the Kinsale gas field in 1971 effectively transformed the gas infrastructure in Ireland. Prior to this discovery, gas across the island was used in the form of 'Towns Gas' produced from oil however, with the discovery of the Kinsale field this form of gas was rendered obsolete.

Following this discovery, the rollout of a national gas network in the Republic of Ireland began in the 1980s which continued into the 2000s. Interconnectors from Scotland to the Republic of Ireland were constructed in 1993 and 2001 as the Kinsale field depleted. Natural gas arrived in Northern Ireland from GB with the Scotland-Northern Ireland Pipeline (SNIP) branch from Twynholm completed in 1996.

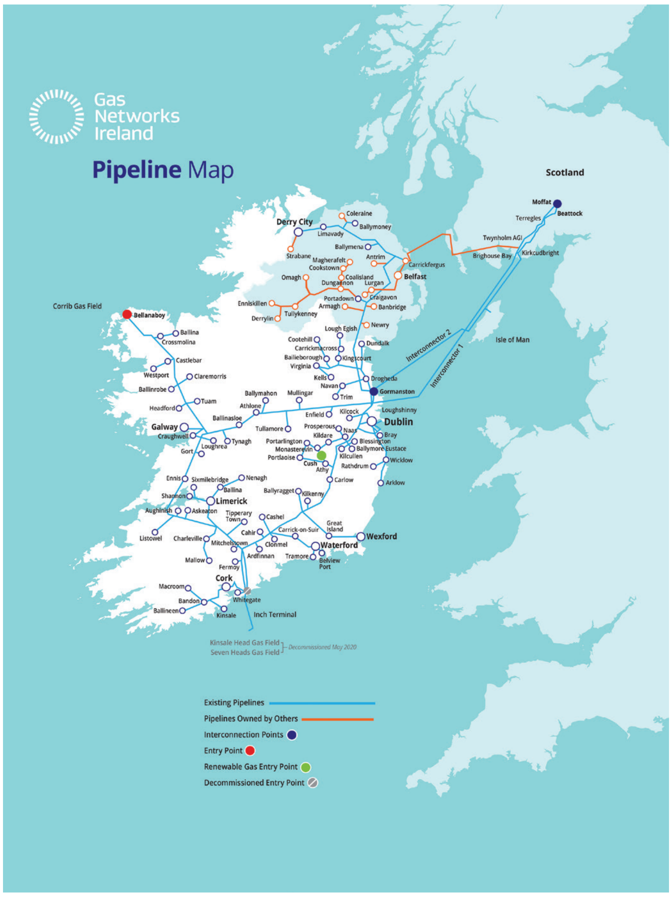
A further offshore discovery was made in 1996 with the Corrib field, located off the west coast of the island, which connected to the gas network in 2015 with the ability to cover over 50% of gas demand. Both the Kinsale and Corrib fields however are relatively short-lived, with Kinsale having ceased all production in 2020 and the Corrib field declining steeply over the coming decade[1].

This will have the effect of the network being wholly reliant upon the importation of gas through GB via the interconnectors for gas fired power generation, domestic heat provision and other end uses unless local LNG import facilities arrive in the form of terminals or floating storage and regasification.

> The gas networks on the island of Ireland are a relatively recent development compared to the GB gas network and are much smaller in size comparatively

The building of an LNG terminal(s) has been a point of contention for several years within Ireland due to various political and environmental concerns, as well as other extraneous factors such as development consent which is split between several different statutory bodies. These issues have surrounded the proposed Shannon LNG Terminal for over a decade where original planning consent was given in 2008.

This is not to say that the development of an LNG terminal will not occur, the latest twists and turns in the Shannon LNG Terminal story is that they plan to submit new planning proposals in 2021, and in May of 2021, New Fortress Energy's (the company which now owns the project) co-founder and chief executive, Wesley Edens, predicted that Shannon LNG would be: "online by the second half of next year"[2] (2022). There are also two other LNG Terminal projects at the planning stage which are been taken forward by NextDecade and Predator Oil & Gas respectively.



1 http://ireland2050.ie/questions/when-will-gas-from-irish-sources-run-out/

2 https://www.msn.com/en-ie/money/news/500m-shannon-lng-project-expected-in-2022/ar-BB1ggES8

Case study: Northern Irish and Republic of Ireland's energy systems (continued)

Market structure – two gas markets with one single electricity market

Gas markets

Northern Ireland and the Republic of Ireland operate as separate gas markets with separate regulators (UREGNI and CRU) with the effect of having different regulatory regimes. This means there are different access tariffs, capacity products, balancing regimes, and balancing charges, however some commonalities exist as both markets comply with EU regulations.

An example of the differences between Northern Ireland and the Republic of Ireland is that Northern Ireland still operates balancing tolerances within its balancing regime as there exists no short-term gas market, or short-term ability to access gas, as there are too few industry participants and the network is comparatively small.

These imbalance tolerances[3] provide a margin for a shippers imbalance position, within which it is not penalised for being out of balance. Imbalance positions within tolerance are 'cleared' each day at the System Average Price (i.e. the GB SAP). Outside of the tolerance level, marginal prices apply, to provide an incentive on the shipper to balance its inputs and outputs to within its tolerance. The marginal prices are calculated using the marginal buy and sell prices from Great Britain.

Gas Networks Ireland (GNI) owns and operates the Republic of Ireland gas network. GNI (UK) shares ownership and operation of the GB interconnector at Moffat with GNI (Ervia).

GMO NI is the gas market operator in Northern Ireland. The gas system consists of five pipelines under different ownership[4]:

- the Scotland to Northern Ireland Pipeline (SNIP), owned by Premier Transmission Limited, part of Mutual Energy Limited.
- the Belfast Gas Transmission Pipeline (BGTP) – owned by Belfast Gas Transmission Limited, part of Mutual Energy Limited
- the North West Pipeline (NWP) – from Carrickfergus to Coolkeeragh, owned by GNI(UK) Limited Ireland
- the South North Pipeline (SNP) – from County Antrim to Gormanstown, County Meath, owned by GNI(UK) Limited
- the West Transmission Pipeline (WTP) – owned by West Transmission Limited, part of Mutual Energy Limited.

With ~60% of total gas demand consumed, both annual and at peak day, within the electricity sector compared to 20-25% within GB, the power sector is essential for the gas system and, by turn, how the power sector operates and changes can have major impacts upon gas system operators.

3 Shippers submit Downstream Load Statements so that the NI TSOs can evaluate the Shippers' applicable tolerance levels. A Shippers' overall portfolio tolerance is a weighted average calculation based on the proportion of the different categories of consumer in their portfolio. Typically, Shippers have individual Imbalance Tolerances of between 3% and around 17%.

4 http://www.mutual-energy.com/introduction-to-our-gas-businesses/

Electricity market

The single electricity market (SEM[5]) was established in 2007, combining the Northern Ireland and Republic of Ireland markets to promote efficiency and cement political developments arising from the Good Friday Agreement which established a spirit of cooperation, cross-border.

The SEM is regulated through the SEM Committee (SEMC[6]) which consists of two Commission for Regulation of Utilities (CRU) and three Utility Regulator (UR) representatives along with an independent and a deputy independent member.

The electricity system operators (EirGrid and SONI) cooperate to run this single system which has a single wholesale market for the entirety of the island and operates under a central dispatch model[7]. This electricity market has a single market operator known as SEMO[8] and is a joint venture between EirGrid and SONI.

The SEM provides for a competitive, sustainable, and reliable wholesale market in electricity aimed to deliver long-term economic and social benefits that are mutually advantageous to Northern Ireland and Ireland.

The Single Electricity Market Operator (SEMO) facilitates the continuous operation and administration of the Single Electricity Market.

On 1st October 2018 the SEM became the I-SEM as a result of instruction by the Northern Ireland and Republic of Ireland authorities to develop and implement a new set of electricity trading arrangements that met the requirements of the 'EU Target Model'[9].

With ~50% of the electricity produced for the island coming from gas fired generation, and as was the case for the gas markets, the gas sector is essential for the operation of the electricity network with any changes or impediment to gas system operation potentially having substantial impacts for the electricity system and its customers.

Gas fired generators

The introduction of I-SEM and ambitious targets[10] for renewable generation for the Republic of Ireland is leading to the electricity system operator having to manage system issues due to System Non-Synchronous Penetration[11] (SNSP).

This has led to a change in gas generator operator patterns in that load factors have decreased for gas generators and they are needed to provide more of a flexible service to cover the increasing intermittent renewable generation in the form of wind and solar (the source of the Non-Synchronous Penetration).

5 https://www.semcommittee.com/sem
6 https://www.semcommittee.com/who-we-are
7 https://www.emissions-euets.com/internal-electricity-market-glossary/600-central-dispatch-system
8 https://www.sem-o.com/about/
9 Term referring to the current design of the EU's electricity markets. The EU target model is based on two broad principles: (i) the development of integrated regional wholesale markets, preferably established on a zonal basis, in which prices provide important signals for generators' operational and investment decisions; and (ii) market coupling based on the so-called 'flow-based' capacity calculation, a method that takes into account that electricity can flow via different paths and optimises the representation of available capacities in meshed electricity grids.
10 70% of electricity produced from renewable sources by 2030
11 https://www.eirgridgroup.com/site-files/library/EirGrid/SNSP-Formula-External-Publication.pdf

Case study: Northern Irish and Republic of Ireland's energy systems (continued)

This situation will potentially be exacerbated over time due to the increasing levels of intermittent generation targeted as well as other ambitions, such as to attract data centres to Ireland which in turn would have a significant impact upon electricity demand.

The 1-in-50 peak day forecast for gas demand is expected to grow by 20% before the end of the decade[12] and should Northern Ireland have a coincident demand rise, the gas network may have pressure issues by the end of the 2020s.

What has this meant for the networks?

In Northern Ireland the gas network already needs attention on a day to day basis. The system is small, with two large gas-fired power stations connected to the transmission system. One is located close to the landfall of the SNIP, the other on the other side of the province, at the end of the pipeline system.

High demand from the power sector, especially if unexpected or without timely corresponding gas input to the system, can lead to pressure drops within the network due to the comparatively huge consumption share of the generators and their location. This can also lead to balancing actions being taken by the transmission system operator.

Changes introduced under I-SEM made the operation of gas fired generators less predictable: a new algorithm was introduced, run at intervals throughout the day, in order to provide an outlook for dispatch over the course of the day. The outputs of the calculations can provide widely varying information for expected running, changing indications throughout the day, even close to the time of dispatch.

While the gas industry works in days, electricity works in seconds, and this basic difference between the two can clearly cause issues if the operating patterns of the generators become more volatile and unpredictable.

As a result of this the GMO analysed the instructions coming from the eTSO[13] to predict the actions that would be taken by gas fired generators, as there were concerns that generators were not nominating their flows in accordance with the information resulting from the algorithm. This led the GMO to raise concerns with the gas fired generators as they were not acting as predicted and as a result the GMO began to review the need to introduce stricter, more penal regimes around the nomination process and balancing activities to ensure network efficiency and safety.

Following the raising of these concerns it was agreed to hold discussions between the eTSO, gTSO[14] and power generators with a view to increase the awareness of concerns from all sides.

The power generators raised concerns with the reliability of the information coming from the eTSO, via the algorithm, throughout the day. They were able to explain that they were unlikely to follow the early dispatch outlooks as there was a strong chance that they may not remain valid later due to changes occurring at the within day timeframe.

The eTSO highlighted that its information was incomplete until later in the day when it was able to include information from the electricity interconnectors in its algorithm. Additionally, the impacts of wind generation and the requirement for additional gas fired generation across the SEM and locally are difficult to predict and incorporate into the dispatch outlooks.

There was also discussion around the mismatch between the gas and power day timelines and how the lack of a traded market for short-term gas limits options available to shippers to manage their gas position at the within-day timeframe. This reduces the options for shippers to manage a surplus or deficit of gas, which could encourage caution in actions and information provision early in the gas day.

As a result of the discussions, there was an improved understanding across all parties as to the challenges each faced. This has led to increased communication and transparency between the various parties with additional positive measures agreed.

These positive measures include an increase in data provision between parties, such as within-day profiling of nominations with understanding of the basis and reliability of the information in real time, and the timelier provision of nominations from power generators which has negated the need to introduce fundamental changes in regimes with tighter rules and higher penalties.

There has also been the recognition between all parties that the new role gas is playing in power generation, due to the rise of intermittent generation, is an ongoing and potentially growing concern. With the ambitions to increase renewable power generation sources, the phasing out of coal fired generation and the potential increase in the number of gas peaking plants to provide more flexibility to the power grid in times of low renewable output cited as drivers.

Key takeaways

Although the Northern Ireland and Republic of Ireland gas networks are much smaller in size, with fewer flexibility levers available to the TSOs (such as storage and diversity of supply), the impacts of the changes in gas fired generation operation are felt more keenly for exactly this reason.

As we have explored throughout the document there are several reasons attributed to the increasing nature of linepack swing observed at the within-day timeframe. However, due to the large reliance of gas fired generation for electricity production, and the demand volatility for power that introducing increasing amounts of renewable generation sources bring, this look at the Northern Ireland and Republic of Ireland situation has lent weight to why the project has focused upon this developing characteristic within the GB networks.

It has also provided some real-world examples of the concepts that have been put forwards, namely communication, understanding, collaboration and data provision between different responsible parties.

12 https://www.cru.ie/wp-content/uploads/2021/02/CRU21018-GNI-draft-Ten-year-Network-Development-Plan-2020.pdf
13 Electricity Transmission System Operator
14 Gas Transmission System Operator

Recommendations of the project

With there being no current evidence for the requirement of significant changes to be made to the GB gas balancing regime over the next ~5 years, the recommendations of the project centre around actions that can be taken today to better prepare industry for the challenges of tomorrow.

As stated at the beginning of the exploration of concepts, this report is intended to provoke discussion, debate, and raise awareness of how balancing rules may need to change should within day linepack swing be identified as an issue in the future. With that being said, the project recommends:

1. Improvements to balancing and capacity systems and services

This action is already being taken forward by National Grid Gas with a Periodic Indicative Notice having been provided to market for the provision of future balancing and capacity systems and services. The findings from this report have been shared with relevant leads of the process and the concept of making systems available on a 24/7 basis has been taken forward as a key criterion for future system design.

2. Improved communication and understanding between energy system parties of the challenges faced by the gas and electricity system operators as well as the power generation sector and gas shipping community, with the view to reduce inefficiencies or avoid suboptimal outcomes through adapting market arrangements to fit the changing system/parties' needs. This could be established as a new industry forum or something similar.

Communication and information sharing between parties is difficult due to the legal status of the different businesses that manage the gas and electricity systems in the UK as well as power generators. This is also due to the sensitive commercial information that each party holds, and legalities surrounding what information can and cannot be shared based upon market competition grounds. However, as we move towards an ever more integrated, whole energy system of the future with potentially greater interdependencies and new challenges emerging; ways of collaborating and sharing information cross vector and cross business should be found so mutually beneficial solutions for the whole energy system can be explored with all relevant parties participating. As discussed earlier in this report, Project RIGSSE is well placed to start the review of how communication and data sharing can be developed in both emergency and pre-emergency situations for the future. The outcomes of the project then being able to inform this concept moving forwards.

3. Continued monitoring of system capability to act as an indicator/trigger for future change

. As the issue of linepack swing is defined through the ability of the network to accommodate the swing observed, continual monitoring of the gas network's capabilities as we move through the energy transition should be performed to highlight when/if the issue becomes actionable. National Grid Gas produces several annual reports that can be used for this purpose already such as, the *Gas Ten Year Statement*, *GTYS Network Capability Annex* and the *Annual Network Capability Assessment Report*, which in the case of the *GTYS Network Capability Annex*, National Grid is looking to develop further with illustrative examples of linepack swing and interzonal linepack movement.

4. Continued monitoring of governmental policy relating to net zero to act as an indicator/trigger for future change

. Policy for net zero will potentially have a significant impact upon the role and functioning of the gas industry as we move through the energy transition. An example of this is the potential development of Hydrogen Industrial Clusters that could in time expand to Hydrogen Regions or Zones. This in turn will have impacts on the supply and demand of Natural Gas and potentially the networks capability. As this policy develops and committed projects develop, close attention and review will be needed to ensure the fundamentals of the gas balancing regime still hold true. National Grid Gas and industry already have dedicated resource in the policy arena which will continue to be utilised to monitor, discuss, and debate policy developments as they arise.

> ...the recommendations of the project centre around actions that can be taken today to better prepare industry for the challenges of tomorrow

Final thoughts and conclusions

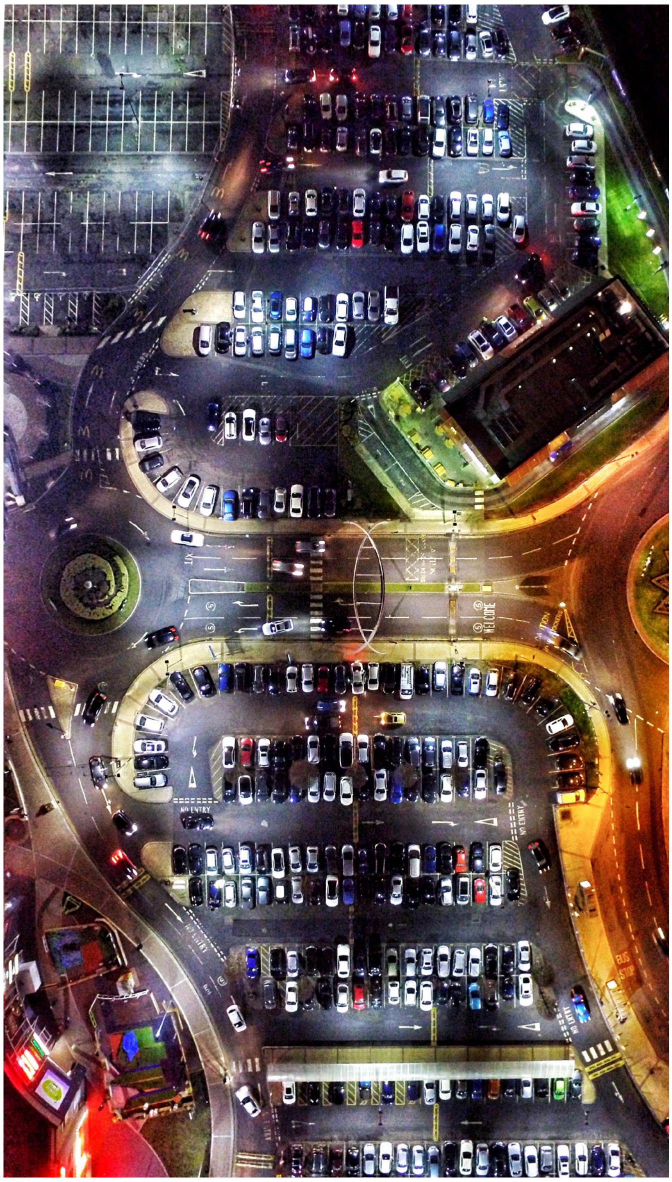
The issue of within-day linepack swing, whilst an increasing trend, has not yet proven the requirement to change how the UK gas balancing regime works today.

The degree to which future gas balancing regime design may need to change is uncertain. This is due to the complex interactions at play and how technology and policy, across the entire energy sector, will develop into the future.

However, the project has proved useful in determining that arrangements are believed to remain appropriate for at least the next ~5 years, that we as an industry understand the future drivers of change in a deeper fashion and that we also understand the potential challenges these changes could bring about.

This allows us, as an industry, to be better prepared for when change is needed and what these potential changes could look like, with enough lead time to be able to discuss, debate and refine concepts in a collaborative manner to ensure solutions, if implemented, have the broad support of all energy participants and are to the advantage of the energy system and its net zero future.

This allows us, as an industry, to be better prepared for when change is needed and what these potential changes could look like



Glossary of terms

Gas system operations The Gas System Operator is responsible for the real-time operation and control of the gas NTS in Great Britain, and for facilitating efficient operation of the GB gas market. It operates the NTS in line with the Primary Gas Transporter Safety Case ensuring that pressure within the NTS is maintained within safe limits and that the quality of the gas that is transported complies with the *Gas Safety Management Regulations* (GSMR)[1].

Gas shipper Gas shippers buy gas from producers, trade gas and sell it onto gas suppliers or deliver to large end-users. Importantly, they need to use the NTS to transport the gas between these two players: this means they have a critical role to play in its overall balance.

Gas balancing Natural gas arrives in GB from many sources, such as offshore gas fields in the North Sea, direct pipelines from countries such as Norway, Belgium and the Netherlands, and large liquefied natural gas (LNG) tankers. Similarly, there are many industries, businesses, and homes that consume this gas. Shippers are incentivised so that every day they put as much gas into the system as their customers take out.

Shipper incentives The UNC sets out the framework to make sure that shippers have commercial incentives to flow gas on and off the NTS in a predictable and reliable way. This is important because it reduces the need for the Gas System Operator to step in as residual balancer. When the Gas System Operator does this, it can have a further financial impact on the market. Shippers face two charges for incorrectly telling the Gas System Operator when they're flowing gas into the NTS which are the costs the Gas System Operator incurs to balance the system:

- imbalance/cash-out charges – encouraging shippers to balance their inputs with their outputs
- scheduling charges – encouraging shippers accurately to nominate the amount of gas that they flow on and off the system.

Imbalance charges – long shippers When shippers over-deliver i.e. put too much gas into the NTS, they will receive a payment for each unit of their excess gas. Shippers have incentives that encourage them to balance because the unit price will be less than the average daily price of gas for that day. This means they're receiving less than if they had sold it for themselves. The price shippers receive for each unit of over-delivered gas is the System Marginal Price Sell (SMPs) price.

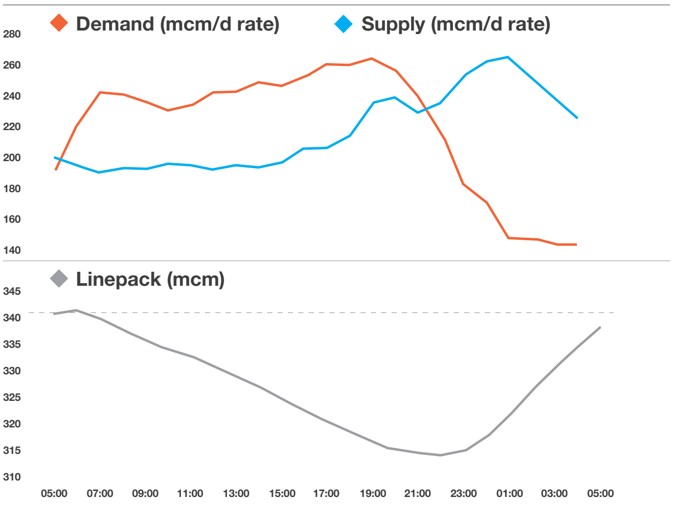
Imbalance charges – short shippers Where shippers under-deliver i.e. put too little gas into the NTS, they will have to pay for each unit of under delivery. Shippers have incentives that encourage them to balance because this unit price will be higher than the average daily price of gas for that day. This means they're paying more than if they had bought it for themselves. The price shippers are charged for each unit of under-delivered gas is the System Marginal Price Buy (SMPb) price.

Scheduling charges In addition to imbalance charges, the UNC sets an additional financial incentive for gas shippers to make sure that they accurately forecast, through their nominations to us, how much gas they will flow on and off the NTS. It is calculated by taking the difference between the nominated values and the actual flows.

Residual balancing In addition to making sure that the system is safe, the Gas System Operator acts as the residual balancer of the GB gas market. In other words, the Gas System Operator monitors and assesses gas supply and gas demands, making sure the NTS remains within efficient operational limits so that it can deliver the level of service that has been agreed with each of its customers. If, on any given day, the Gas System Operator is not confident that shippers will balance the gas market, it may step in and take action to influence them, to make sure linepack levels remain within acceptable limits.

Linepack The amount of gas within the NTS at any time is known as 'linepack'. The acceptable range over which the amount of gas in the network can vary over the course of a year. The ability to further compress and expand this gas is generally referred to as 'linepack flexibility'.

Linepack swing Throughout the gas day, supply and demand are rarely in balance. If demand exceeds supply, levels of linepack within the NTS will decrease along with system pressures. The opposite is true when supply exceeds demand. This can be seen in the below graph which shows linepack level over a typical gas day in relation to supply and demand levels.



Gas day Means a time period of 24hours starting at 5:00am, on any given day, and running to 5:00am the next day. Shippers are incentivised to have balanced their portfolio, that of matching supply and demand quantities, by the end of the gas day for the preceding 24hour period. I.e. if a shipper's customers' aggregated demands were a hundred units over the 24hour period then the shipper would be incentivised to have also supplied 100 units into the system by the end of the same 24hour period. The gas day also establishes the trading window for exchanging day-ahead and daily gas products on relevant trading platforms and is harmonised with the EU energy markets as to promote cross-border trading.

Nominations Is the process by which a shipper must tell the Gas System Operator, through a gas flow nomination, of how much gas it intends to either input or offtake at each separate entry or exit point on the system. A shipper can record its initial gas flow nominations up to 30 days in advance and can also change them at any time up to 3am on the gas day (i.e. two hours before the end of the gas day). In addition to nomination data, the Gas System Operator receives information on expected flows from entry terminals, storage facilities, interconnection points and large end consumers, such as gas-fired power stations. For sites that directly offtake gas from the NTS (NTS offtakes), such as large industrial sites and distribution network offtakes, the Gas System Operator needs an hourly breakdown of the daily gas demand so they can make sure that any changes they make to linepack flexibility deliver customers' requirements and doesn't have an impact on safety.

1 https://www.legislation.gov.uk/uksi/1996/551/contents/made

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