Gas System Operator

Gas Operational Forum

National Grid House
13th June 2019

nationalgrid

Health & Safety

No Fire Alarm testing is planned for today

In case of an alarm, -please follow the fire escape signs to the evacuation point

There are no tests planned for today in the event of a continuous alarm, you will need to leave via the fire exit n E3 (Turn left out of this room end walk to the end)

NG House Fire Exits

Fire Exit Maps are shown on the back of the doors

General Rules:

- **Keep your visitors pass with you at all times whilst onsite, and ensure it is visible by wearing around your neck.**
- **Please hold the handrails when using the stairs.**
- **All bags will need to be removed from the room during lunchtime, whilst the layout is re-arranged for the afternoon**

Health & Safety

Control Room Overview

- You must be escorted by National Grid Staff at all times (Including to and from the toilets).
- Large bags should not be left unattended or taken into the incident room.
- Photography of the control room and detailed NTS maps is strictly prohibited for security reasons and protection of sensitive data.
- NTS simplification maps are available to take away today.
- If an NTS incident occurs, visitors will be asked to leave the incident room immediately.

Feedback & Questions

For any questions during the forum you can:

- Ask during the presentations
- Speak to an NG representative during the break
- Utilise the Query Surgery time at the end of the Forum

Agenda for today

01	Previous Operational Forum Actions and Feedback since Last Forum	10:00
02	Operational Overview	10:10
03	Bio Methane/Biogas projects	10:15
04	Hydrogen Projects	10:45
05	Gas Markets Plan	11:50
06	Gas Prices	12:05
07	Constraint Management	12:20
08	Winter Consultation and Review	12:50
09	**Signposting of information, followed by:** **Lunch, query surgery, hydrogen go-see, and GNCC overview**	13:00

Breaks:

Morning Break
11:30 – 11:50

Lunch Break & Query Surgery
13:00 onwards

Previous Actions

Item	Action	Detail
Gas Quality	Trial of Gas Quality Data	We have heard concerns about confidentiality of data if providing this, but received very little feedback about use for data. Without any further feedback, we are currently minded not to include Gas Quality data in the enhancements project, or to publish our trial data.
Hydrogen	Further insight about in-fight projects requested following agenda item at May forum	Included as part of the agenda- project presentations as well as go-see opportunity during forum morning break and lunch

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02

Operational Overview

June 2019

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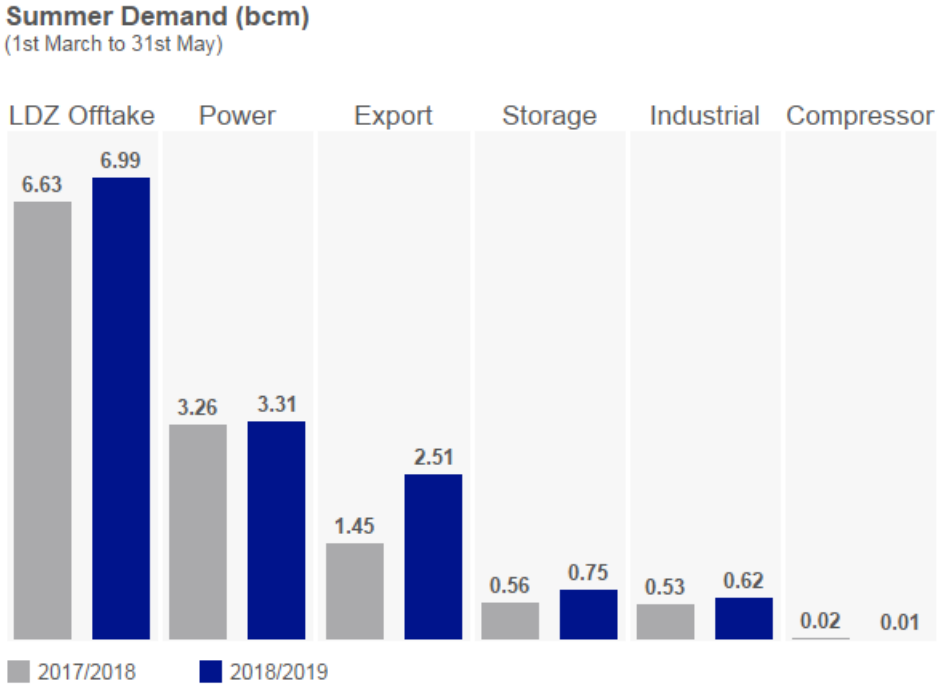
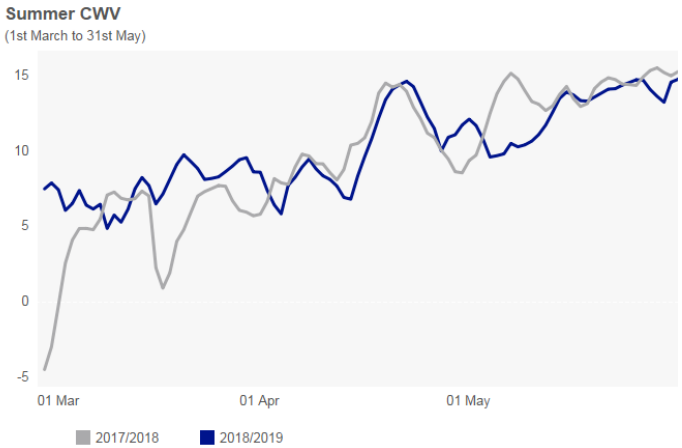
Demand - Components

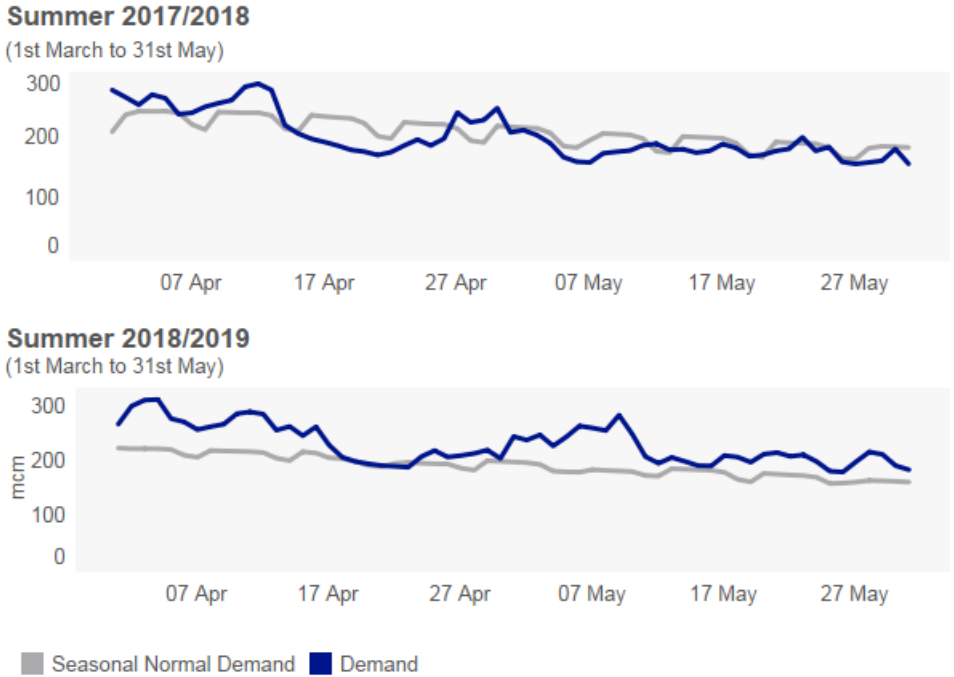
- This summer so far there has been a slight increase in LDZ/Domestic demand
- There have been higher exports to Belgium
- Gas fired electricity generation has been consistent with last year



Demand – Comparison to seasonal norm

- Demand this summer has consistently been above seasonal norm
- Particularly high demand due to colder weather in early May





Supply - Components

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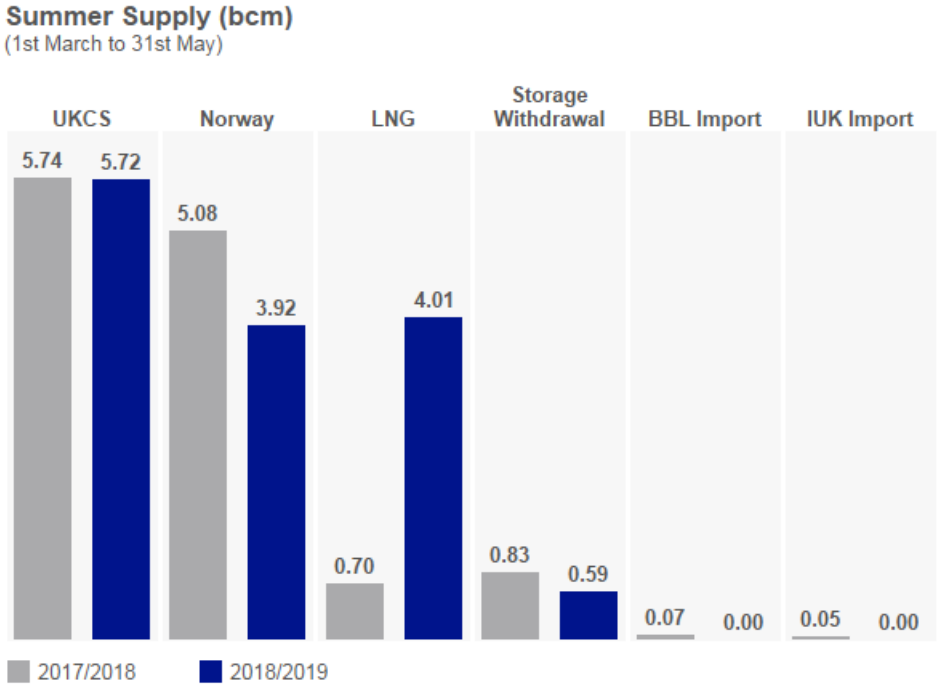
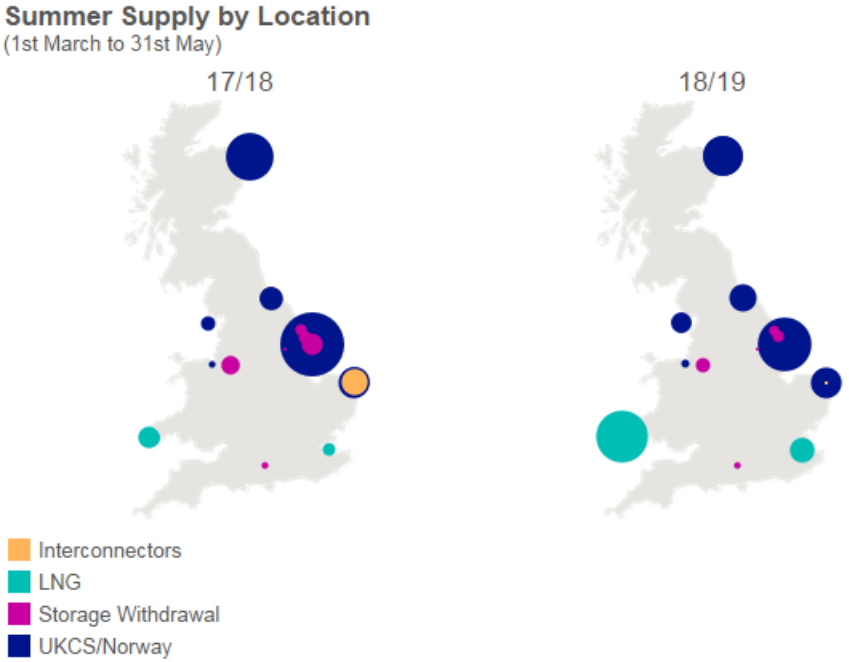
- This year has seen a much greater proportion of supply coming from LNG
- There has been a significant reduction in the amount of gas supplied from Norway



Supply - Location

- The biggest increase in LNG supply has been from Milford Haven
- National Grid has modified maintenance plans to ensure an effective operating strategy for a different supply pattern to that of recent years



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03

Biomethane/ Biogas

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Biomethane Briefing
Top Ten Interesting Biomethane Things

14th June 2019

John Baldwin
Managing Director
CNG Services Ltd

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www.cngservices.co.uk
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cng services ltd

CNG Services Ltd

- Supports projects to inject biomethane into the gas grid
  - Around 98 existing projects
  - Estimated 20 new ones until end Jan 2020
- Supports back-up gas generation projects
  - Connection of a 50 MW gas engine plant to 2 bar grid in 2017 (12,500 scmh)
- Part owner of CNG Fuels Ltd, a company set up to build national network of Bio-CNG stations on the high pressure grid
  - Leyland CNG Station, others in build
  - 84% saving in GHG compared to diesel
- Developer of highlands virtual pipeline projects taking gas out of NTS to supply 4 off grid distilleries
  - Largest CNG station in EU
  - Islay next year

THE QUEEN'S AWARDS FOR ENTERPRISE: INNOVATION 2016

Innovation in Natural Gas

cng services ltd

The Top Ten

1. What is biomethane?
2. How is it made and what is the feedstock?
3. How much is produced and what is the potential?
4. What about the CO2 separated?
5. How is it financed and level of subsidy?
6. Bio-CNG as truck fuel?
7. CNG Virtual Pipeline to Supply Distilleries?
8. The capacity issue?
9. Competition in high pressure connections?
10. And what about net zero by 2050?

If you want more info, UK Biomethane Day every year since 2012 all slides from all years here:
http://www.cngservices.co.uk/index.php/news/cng-events

1. What is Biomethane

1. Biogas is 55% CH_4, 40% CO_2, 0.1% O_2, 0.5% N_2. 100 – 1000 ppm H_2S, saturated wet
2. Also can have traces of siloxanes (shower gel) and other VOCs
3. Biomethane has all contaminants and H_2 Removed and is typically:
   - 97% CH_4
   - 2% CO_2
   - 0.2% O_2
   - 0.8 % N_2
   - Gross CV around 37 MJ/M3
4. For injection into NTS (eg Project CLoCC at Somerset farm), that's fine
5. For LDZ needs propane to meet Flow Weighted Average CV (typically 39 MJ/M3) and odorant
6. Note – biomethane industry does not want a change in higher wobbe as if no N_2 injected from LNG, CV will rise and more propane required

98 projects injecting biomethane

2. How is it made and what is the feedstock?

1. Anaerobic digester, made by bacteria
2. Adding small amount of O2 causes the H2S to become elemental S
3. Typically 40 deg C and 3 weeks retention time
4. Most ADs are wet – so if you look in through a sight glass it's a big tank of black liquid that is continually stirred
5. If 50,000 tonnes of feedstock then may have 45,000 tonnes of digestate (spread to land, valuable fertilizer) and 5,000 tonnes of gas
6. Note CO2 has Molecular Weight of 44, CH4 is 16 – so most mass is from CO2
7. Typical capex if feedstock is maize would be £8 million, if food waste can be £12 million because of de-packaging
8. Can have pre-treatment to break down structure (eg thermal hydrolysis uses high pressure steam)
9. Feedstocks – maize, sewage, food waste, distillery waste (draff), manure

Govt now only gives subsidy for projects with >50% of biogas made from waste

3. How much is produced and potential

1. A typical new project is 40 million kWh/annum, around 500 scmh
2. Total biomethane injected in 2019 will be around 5 TWh
3. Biggest LDZ for biomethane is Scotland – around 5% of domestic customer demand (more like 40% in July and August)
4. UK gas demand around 800 – 850 TWh
5. Realistic production of 20 TWh by 2030
   - Lots of biogas produced in sewage works, gets ROCS, from 2027 these run out and this gas will probably become biomethane and be injected
   - Not a good idea to burn biogas for electricity in post 2025 period!

Bio-SNG in theory could produce a lot more – eg DRAX

4. What about the CO2 produced?

1. Around 12 projects capture CO2 from waste gas and liquefy it
2. Sold as food grade CO2, eg making beer and fizzy drinks
3. Unfortunately, the need for 50% means a lot of CO2 has no market (coca cola from sewage biogas…)
4. If we have SMR to make CH4 into H2 with CCS then th CCS will give an option for CO2 from biomethane

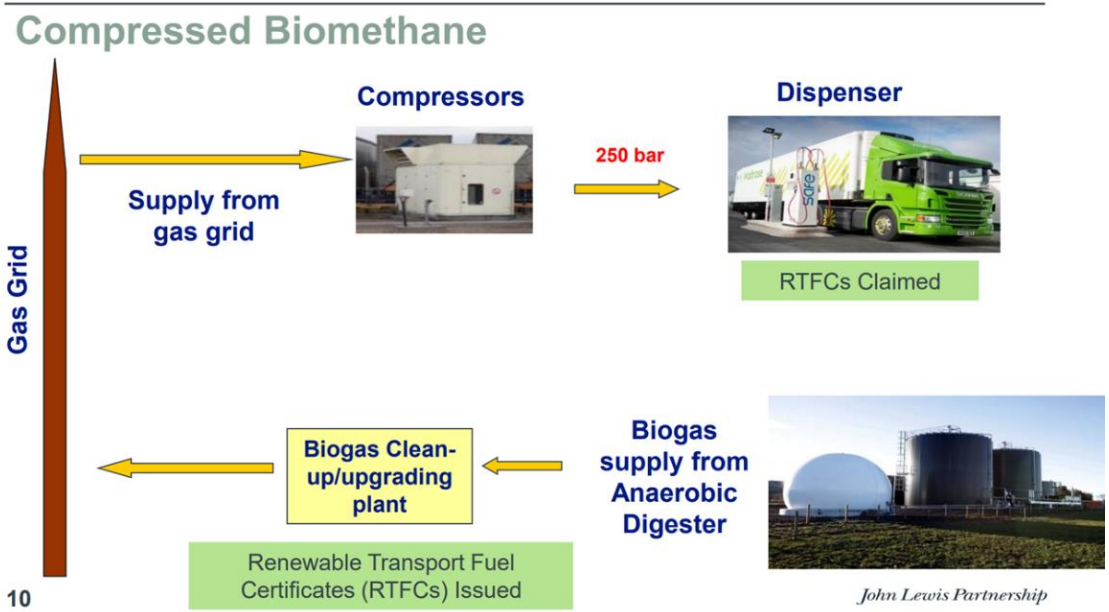
Liquid CO2 from ‘clean’ biomethane is great for food industry eg growing tomatoes

5. How is it financed and level of subsidy

1. Renewable Heat Incentive – for most projects this year tariff of 5.8 p/kWh on top of the gas commodity price
2. For 20 years , escalated with RPI each year
3. Tier 1 = 40 million kWh
4. So typical annual subsidy around £2.2 million
5. Green Gas Cert has a value – if waste around 0.4 - 0.5 p/kWh
6. Financed from general taxation
7. 5 TWh in a year will cost around £350 million as subsidy higher for older projects

RHI ends 31 March 2021 – post RHI funding one option may be gas supplier obligation

6.1 Bio-CNG as truck fuel



Inject into grid but do not claim RHI, can earn RTFC when trucks filled with CNG

6.2 John Lewis

Outcomes

- 83% reduction in WTW CO_2
- 35% reduction in fuel cost (payback at 360,000 km)
- 50% (approx.) reduction in noise
- Good driver reaction

53 dedicated gas trucks

Its not chicken and egg – its all about the truck

6.3 Leyland CNG Station

- Connection to 38 bar LTS for CNG station
- LTS CNG gives 17 - 25% saving on GHG ("Well to Motion")
- 85% GHG saving using Bio-CNG
  - Biomethane that has not claimed RHI Subsidy

cng services ltd

6.4 National Network

CNG Fuels Bio-CNG Station Rollout

- 7 new large public access Bio-CNG stations estimated to be open by Q2 2020
  - Further 6-8 Bio-CNG stations to follow in 2H 2020
    - Combined refuelling capacity of 9,000 high mileage HGVs
- £20 million currently being deployed, with another £30+ million to be deployed in 2020
- All stations are grid-connected and capable of dispensing 400-600 GWh/year of renewable and sustainable Bio-CNG

Warrington station in build - huge

7.1 CNG Virtual Pipeline to Distilleries

1. NTS connected Air Liquide owned CNG station at Fordoun NTS Block valve 30 miles South of Aberdeen
2. First NTS self-lay project
3. Measure energy, add odorant, compress to 250 bar
4. Deliver by Type 4 CNG trailer to 4 distilleries (10 tonnes)
5. Reduce pressure to boiler pressure
6. 30% GHG saving, 85% with biomethane

Fordoun will be highest throughput CNG station in EU – having 60 bar inlet pressure makes a huge difference

7.2 Fordoun Mother Station

Fordoun will be highest throughput CNG station in EU – having 60 bar inlet pressure makes a huge difference

7.3 Dalwhinnie and Glenmorangie

Also, Clynelish in Brora – 70 miles from gas grid…next year we are laying a gas grid on Islay to supply distilleries there

8. The capacity issue

1. Most biomethane is injected into 2 bar or 7 bar grids
2. In summer, often not enough demand on these networks to allow injection of biomethane
3. Best option to compress gas within the grid from the 7 bar IP to 38 bar LTS
4. A number of pilot projects are underway
5. By 2030 needs at least 30 such compressor stations
6. Gas Unie aiming for 50 in NL

Sooner or later will also need to export from LTS to NTS

9.1 Competition in Connections to LTS-NTS

- Cadent allow competition in LTS connections and CNG Services have completed 9 such biomethane LTS Connections
- We do all design and build including hot tap –
- National Grid are allowing NTS self-lay at Fordoun as a trial

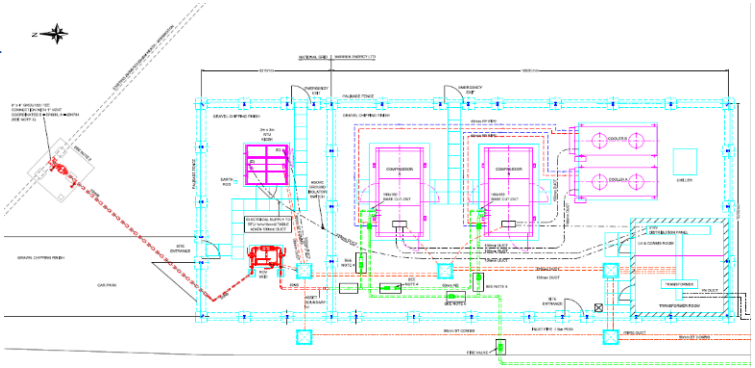
1. Holkham Biomethane Project (19 bar)
2. Euston Biomethane Project (38 bar)
3. Raynham Biomethane Project (19 bar)
4. Methwold Biomethane Project (42 bar)
5. Brinklow Biomethane Project (19 bar)
6. Fairfields Biomethane Project (19 bar)
7. Hampton Bishop Biomethane Project (70 bar)
8. Bay Farm (Bury St Edmonds) Biomethane Project (19 bar)
9. Bonby Biomethane Project (38 bar)

These projects are integrated with the entire project with significant savings in cost and time and reduced hand offs

9.2. Methwold Biomethane Project – 42 bar

- **Summary –** A minimum entry connection to the Roudham Heath – Wissington Local Transmission System (LTS) pipeline, at Methwold, Norfolk, to facilitate the injection of a maximum flowrate of 600 scmh of biomethane into the grid. The connection arrangement includes a remote operable valve (ROV) arrangement and an associated telemetry kiosk within a secured compound. This arrangement is to ensure that only gas fully compliant with the minimum requirement of the Gas Safety (Management) Regulations is allowed into the network.
- The connection onto the LTS pipeline, operating at a maximum pressure of 42 barg, was achieved by installing a grouted tee fitting, as the pipeline could not be taken out of commission.

- **Type of Project** – Biomethane
- **Entry/Exit** – Entry
- **Pipeline Length, Material and Diameter**
- 3.5km PE pipeline to compressor station for injection into 42 bar LTS including final 10M of adopted steel LTS connection pipeline



- **Maximum Operating Pressure (MOP) –** 42 bar LTS
- **Compressor Type** – SAFE reciprocating compressors
- **Local or Remote Anaerobic Digester –** Remote
- **Client –** Warren Energy
- **Grid Company –** Cadent Gas
- **Completion Date** – Oct 2015

10. Net Zero By 2050 (from Green Gas Day 2019)

1. Massive incentive to produce as much Biomethane as possible in all scenarios
2. Biomethane is the only Biofuel that 'theCCCuk like
3. H2/CCS offers potential for CCS at all AD plants with no 'food grade CO2' issue
4. HGVs should all be Bio-CNG by 2040 and can then move towards H2 to 2050 and beyond
5. No burning of raw biogas at all, anywhere, anytime
   - Sewage derived biogas to biomethane in 2025 – 2030 period
   - New super AD plants at ports close to LTS-NTS using organic waste from overseas food production

Its a Golden Age for Biomethane under ALL SCENARIOS

Gas Connections Portal

One of the deliverables from Project CLoCC was a Gas Connections Portal which went live at the end of January 2019.

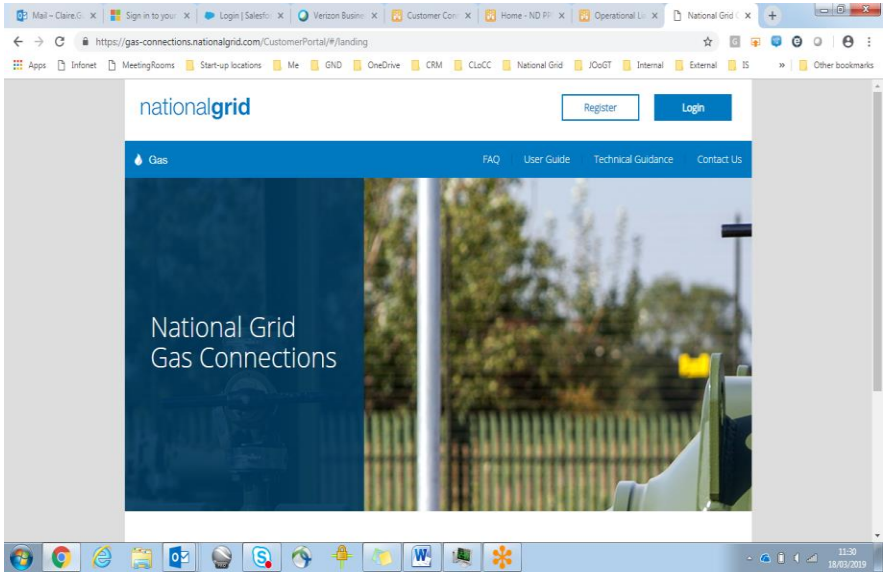
It is now available for customers to register and use for cost estimates, full connection applications and PARCA applications.

If you are interested in registering please use the following link

https://gas-connections.nationalgrid.com/CustomerPortal

For further information on connections please visit our website
https://www.nationalgridgas.com/connections/applying-connection

You can email us at box.UKT.customerlifecycle@nationalgrid.com



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04

Hydrogen Projects

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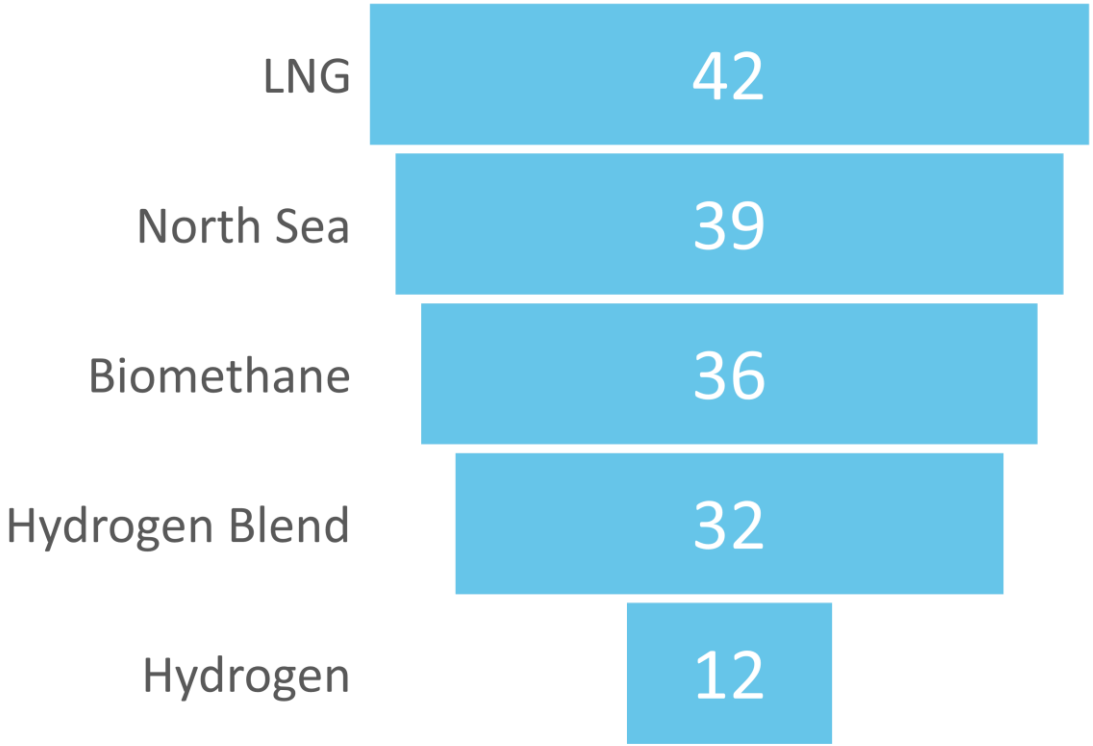
OIL & GAS

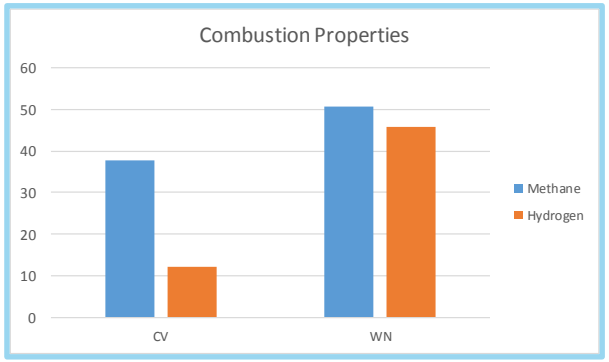
Hydrogen Safety Research at Spadeadam

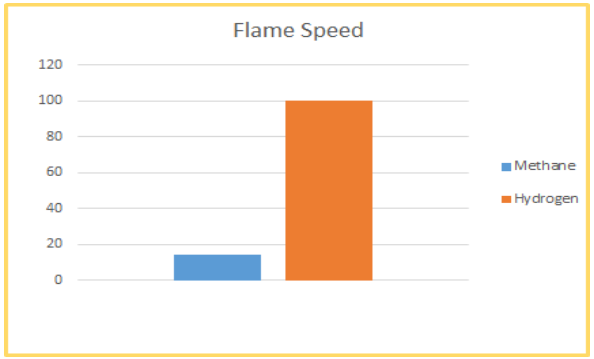
Sarah Kimpton

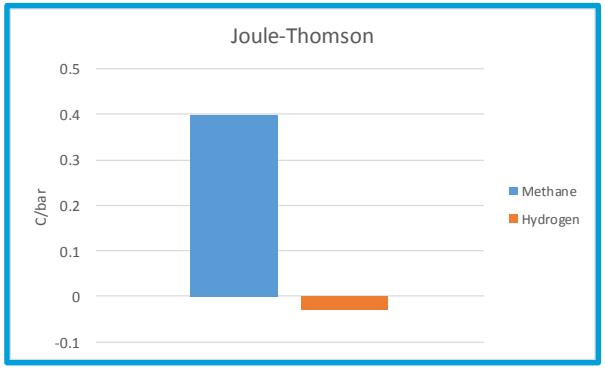
Variation in Energy Content in MJ/sm³

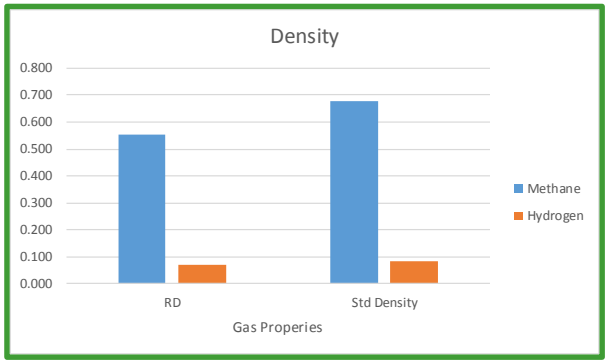


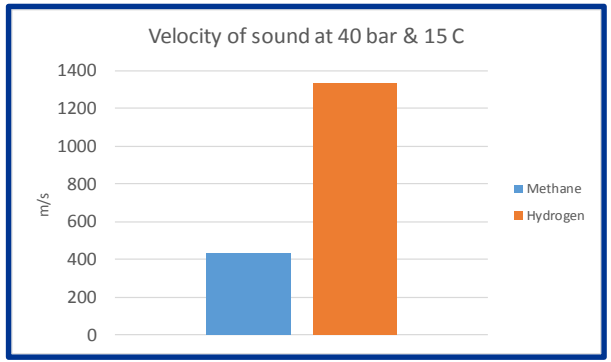
Comparison between Methane and Hydrogen











Hydrogen ≤20 mol% in gas behaves like gas

Hydrogen ≥ 20mol% in gas starts to behave more like hydrogen

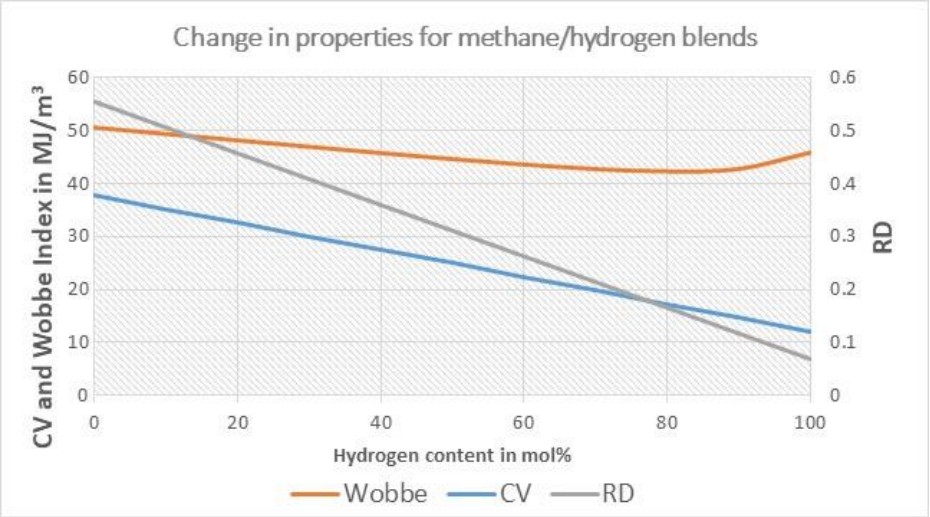
Hy4Heat WP2 - Hydrogen Purity

Production	Clean Up	Transport	Use
• Steam methane reforming • Autothermal reforming • Gasification • Biohydrogen from gasification • Electrolysis	• Pressure swing absorption • Membranes • ATR + methanation • Impurities - carbon dioxide, nitrogen and carbon monoxide • Natural gas slip	• Gas network • Impurities from pipework	• Fuel cells – additional clean-up at point of use • Impact of impurities on fuel properties • Must be cost-effective

Purity recommendations will be on Hy4Heat website shortly

Hy4Heat

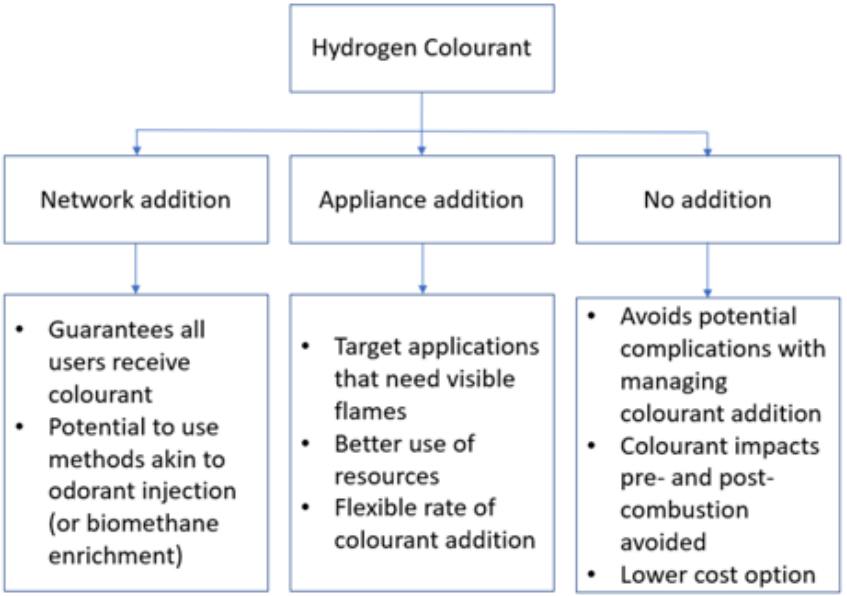
Combustion Properties



Mixture	Wobbe Index/(MJ/m³)	CV/(MJ/m³)
100% H_2	45.9	12.1
98% H_2 + 2% CO_2	37.8	11.9
98% H_2 + 1% CO_2 + 1% N_2	38.9	11.9

Hy4Heat WP2 - Hydrogen Colourant – is it required and where to add it?

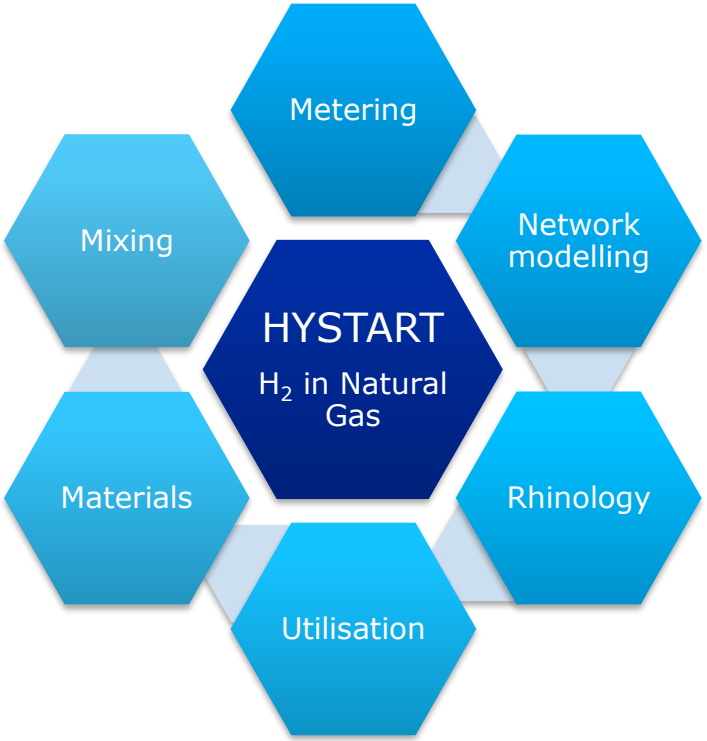
Hy4Heat



DNV·GL

HYSTART – a feasibility study of up to 20 mol% H_2 addition to natural gas

- Extensive, existing desktop study and limited practical tests
  - Documented current status and know-how
  - Included evaluation of work from UK, Europe & international studies
- Key aspects included:
  - Gas entry unit concepts (mixing and metering)
  - Measurement requirements and methods
  - Impact on gas detection
  - Impact on end-users (domestic, commercial and industrial)
  - Impact on rhinology
  - Network modelling to assess zones of influence
- No show stoppers – but some technology/knowledge gaps



Hydrogen Safety Research at Spadeadam

Overview of Spadeadam

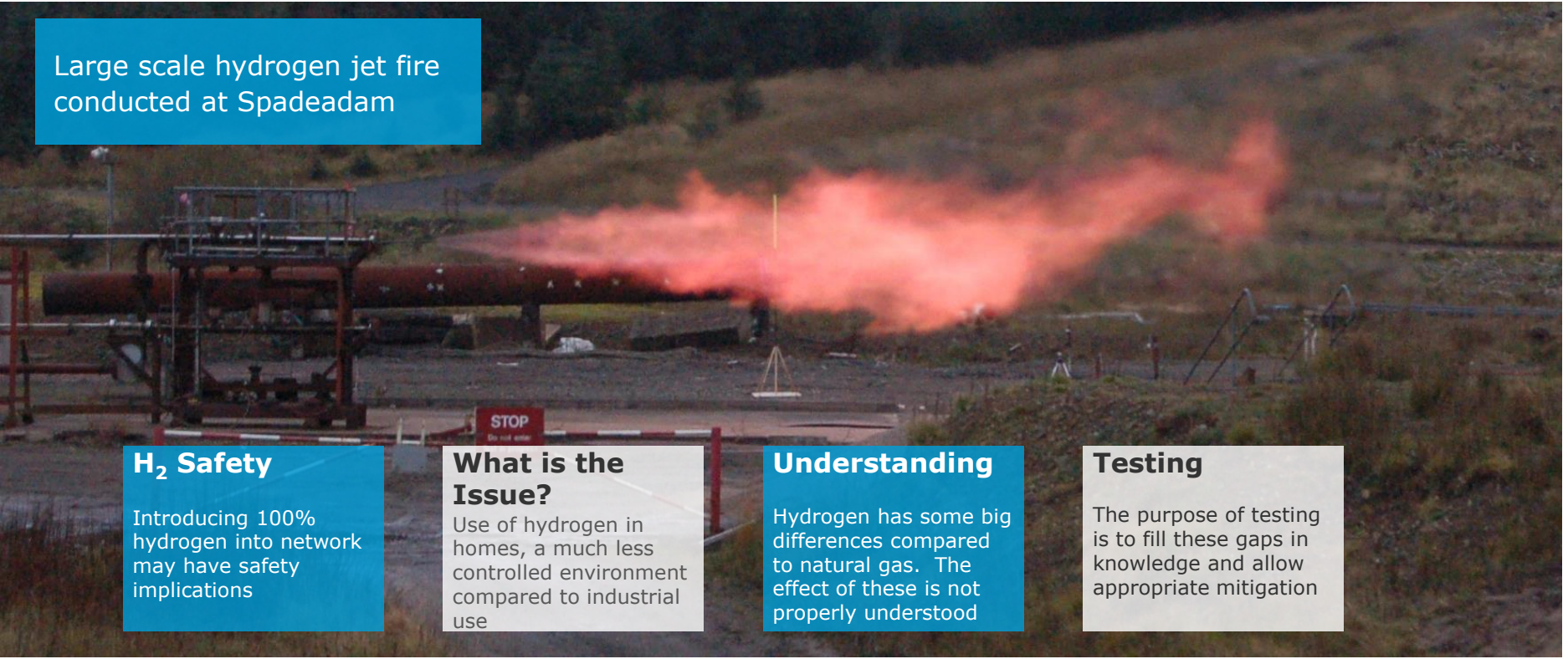
DNV GL Spadeadam Research & Testing

70 hectare facility located within a larger secure MOD site in Cumbria

Has been operational since 1977

Safely conducting hazardous research for over 40 years

Overview of Spadeadam



Need for Research

New developments can prompt the need for research

The need to explain major incidents also is a driver for research

We need to manage hydrogen risks and not be pushed by incidents

Previous Hydrogen Research

- EU Co-funded NaturalHY project
  - Testing to determine the effect of increasing amounts of hydrogen in natural gas on dispersion, fires and explosions.

- Japanese National Project on Hydrogen
  - Testing to understand dispersion, fires and explosion hazards on hydrogen re-fuelling stations

- Hydrogen jet fires
  - Properties of high pressure hydrogen jet fires – conducted under contract to Air Products

- Paris Climate Change Agreement has prompted renewed interest in hydrogen and research

Issues for Use of Hydrogen in Gas Networks

Do the worst case consequences change by introducing hydrogen into the networks?

Do major accidents become more frequent?

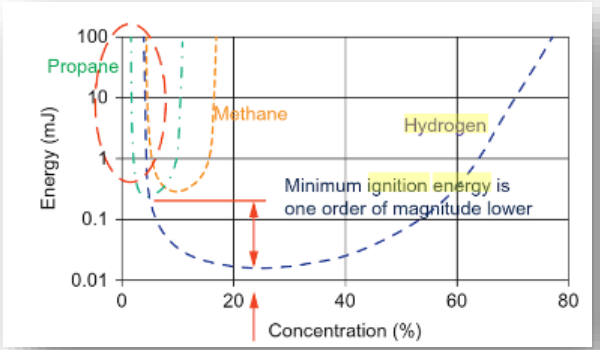
Understanding the Consequences

Gas tracking and dispersion

Build-up in atmosphere

Release

Ignition



Explosion?

Need to understand the effect on each part of this process

Research at DNV GL Spadeadam

- H21 project
  - Hazards from hydrogen releases upstream of the meter
    - Hydrogen tracking through the ground
    - Hydrogen fires
    - Ignition potential
    - Explosion severity

- BEIS Hy4Heat project
  - Hazards from releases downstream of the meter
    - Gas dispersion
    - Ignition potential

Research Facility

DNV GL has constructed a research facility at Spadeadam

Dedicated to understanding the safety issues associated with 100% hydrogen in the gas networks

Includes:

- Underground gas mains and services
- Three properties with different characteristics

Thank You

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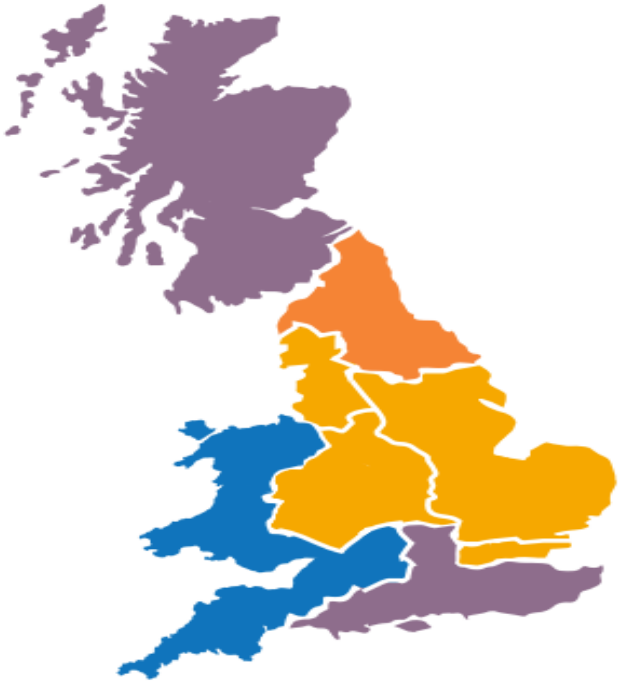
SAFER, SMARTER, GREENER

13/06/19

Andy Lewis – Cadent Gas Ltd

Cadent
Your Gas Network

Cadent - Distributes gas to major centres of population, transport hubs and the heart of the UK economy



GAS DISTRIBUTION NETWORKS

- SGN
- Northern Gas Networks (NGN)
- Cadent Gas
- Wales & West Utilities (WWU)

Cadent Ltd emerged in 2017 from National Grid

HyDeploy

Main objective is to demonstrate for the first time that a blend of hydrogen and natural gas can be distributed and utilised safely & efficiently in the UK distribution network without disruptive changes for consumers.

Loc: Keele University
Duration: Mar 17 to Mar 2020
Cost: £7.6M

Northern Gas Networks
Cadent
Keele University
Progressive energy
Health & Safety Laboratory
ITM Power Energy Storage | Clean Fuel

Exemption granted: 1 Nov 2018

Materials

Characteristics & Procedures

Lab testing of appliances

Field testing installations

Equipment

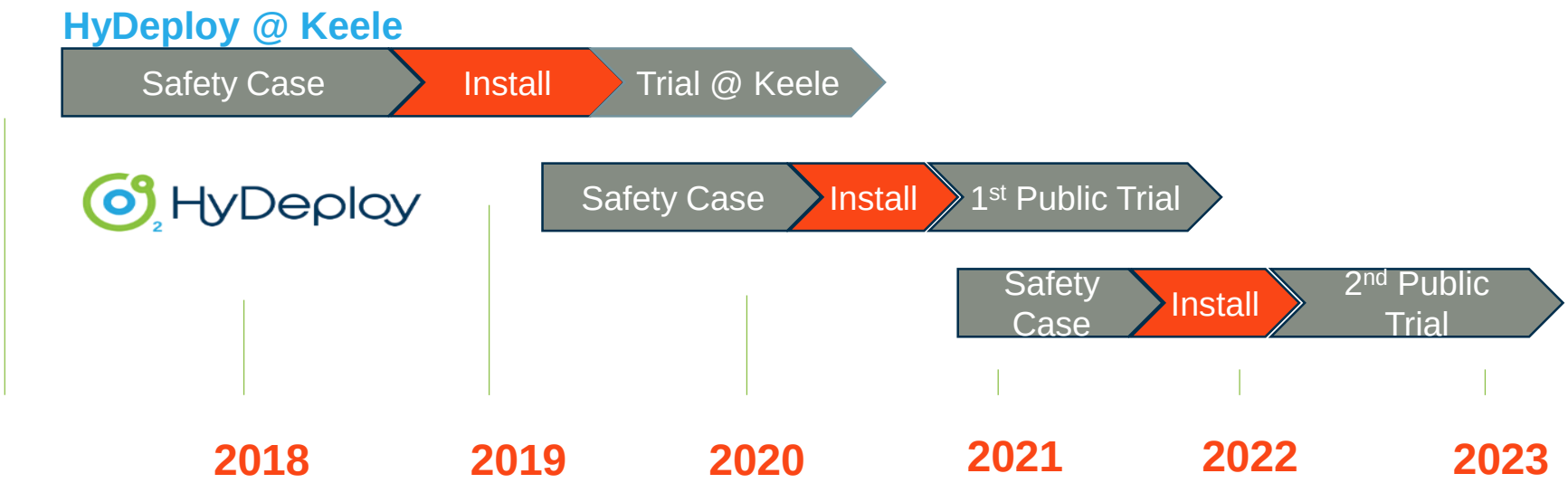
European projects

QRA

HyDeploy

HyDeploy

Overall Timeline

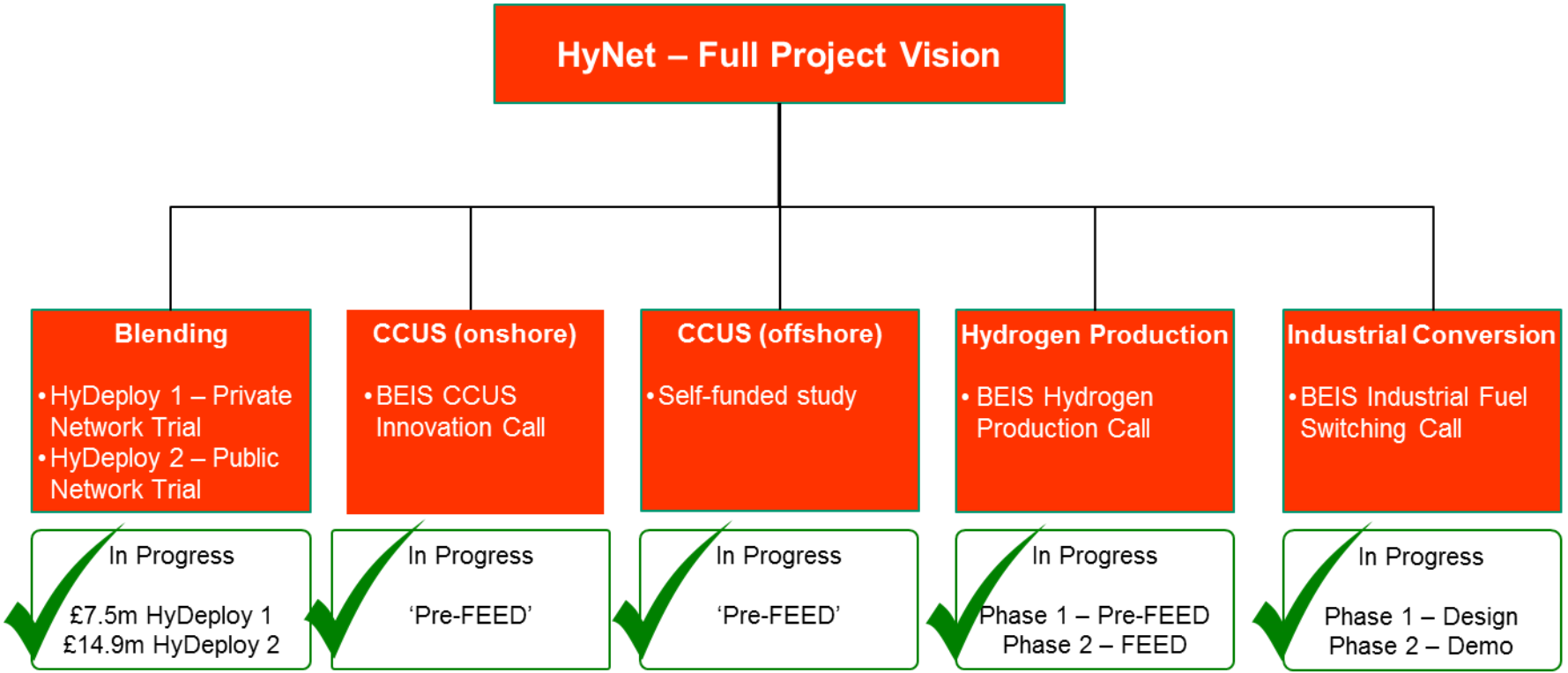


HyNet North West

Progressive energy

Cadent
Your Gas Network


Cadent
Future Hydrogen Sources
Future CO_2 Shipping
CO_2 Storage
H_2 Pipeline
CO_2 Pipeline
Hydrogen Trains
Hydrogen Fuelling
Manchester
Liverpool
Industrial Gas Users
Hydrogen Production
Hydrogen Blend
Future Power Generation
Future Hydrogen Storage
Chester
Jobs and Skills
Inward Investment



Wider Suite of Cadent H_2 Mobility Projects

‘HyMotion

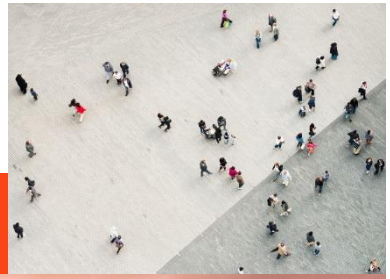
- Demonstrate what hydrogen refuelling network would look like if HyNet pipeline network is built
- Build upon existing evidence base to secure local industry and political support for H_2 mobility
- Work alongside local stakeholders to identify and support nearer-term H_2 demonstration projects

‘Purity’ study (NPL/Imperial/DNV)

- To review the impact of network contamination of hydrogen
- To assess the attractiveness of different purification technologies at varying scales

‘Blend impact’ study (Brighton University)

- To determine the impact of blends of hydrogen upon the operation of CNG vehicles



Thank you

Andy Lewis
andy.lewis@cadentgas.com

Cadent
Your Gas Network

Preparing for a Hydrogen Future

Tom Neal
Lloyd Mitchell

nationalgrid

The role of gas in the UK

22m

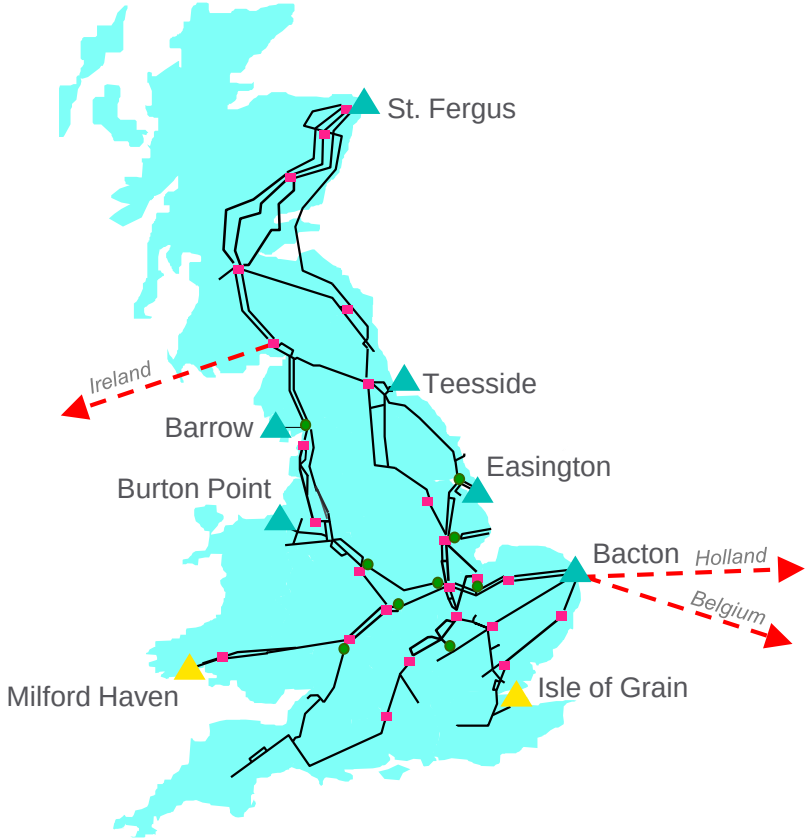
gas customers in the UK

85%

households are using gas for heat

995TWh

of energy is delivered by the NTS



39%

Power Generation

38%

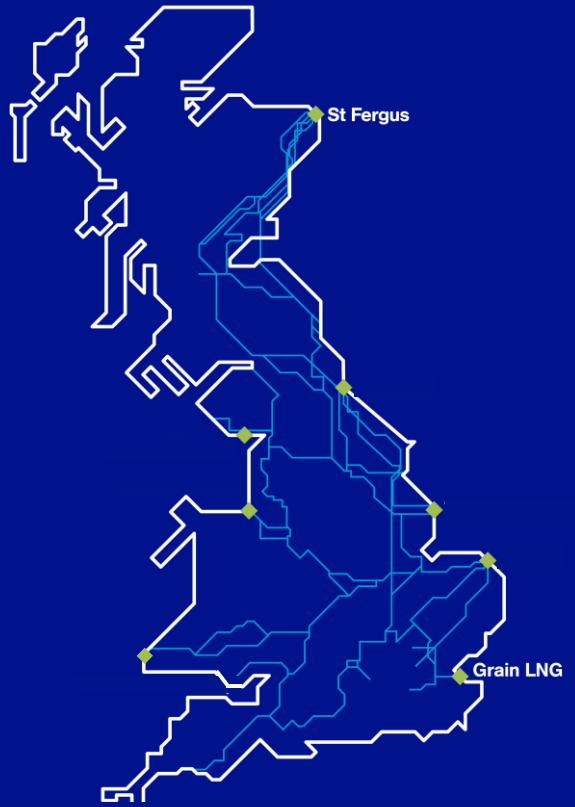
Domestic Use

23%

Industrial & Commercial

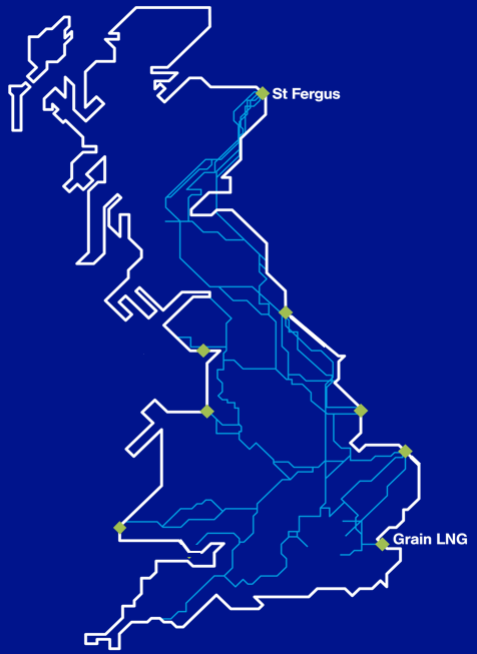
Introducing HyNTS

- Future of heat is complex
- Hydrogen is a challenge to our network
- Opportunities for increased lifespan, other uses
- Maintain flexibility of NTS with a range of options



nationalgrid

HyNTS



HyNTS encompasses all of our work relating to hydrogen across our business and wider industry. Ongoing programmes include:

Feasibility of Hydrogen in the NTS	Project Cavendish	Aberdeen Vision	NEW H2 Flow Loop
A feasibility study with the aim of determining the capability of the NTS to transport hydrogen. Includes a review of relevant assets, pipeline case study and draft scope for offline trials.	A review of the potential of the Isle of Grain region to use existing infrastructure to supply hydrogen to London & the South East including generation, storage, transport and CCS.	A feasibility study for the generation of hydrogen at St Fergus using the NTS (up to 2%) to supply the city of Aberdeen. Includes generation, injection, separation and transport.	Offline test loop to evaluate metallurgy changes on existing NTS steel pipe and new MASIP pipe when exposed to 30% hydrogen, identifying next steps to assess the NTS' suitability to transport hydrogen.

Hydrogen Hub

Established group of technical experts driving our hydrogen ambition across the business and sponsor of the HyNTS programme

Hydrogen Video

HyNTS Feasibility of Hydrogen in the NTS

A feasibility study with the aim of determining the capability of the NTS to transport hydrogen. Includes a review of relevant assets, pipeline case study and draft scope for offline trials.

Start	Nov 2018
End	Apr 2019
Fund	NIA Project

Networks

→ NGGT (Lead)

Deliverables

- Capability assessment: Review of the physical capabilities of the NTS
- Standards review: Evaluation of existing hydrogen within the UK and Europe and gap analysis for NTS
- Live trial optioneering: Evaluation of a range of potential candidates for a Stage 2 offline trial.
- Draft scope for offline trials: Scope cover a wide range of assets to test assumptions of the capability assessment

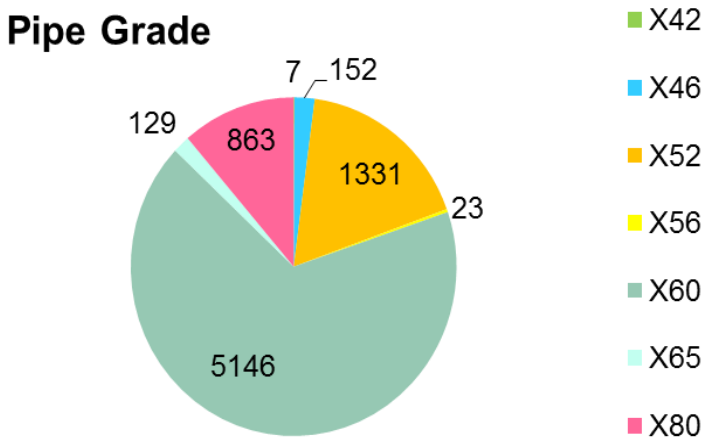
Partners

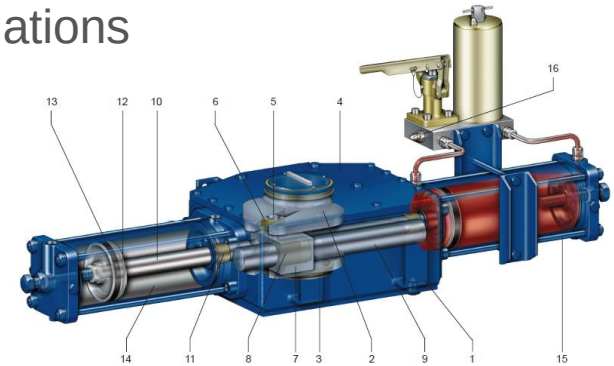
HEALTH & SAFETY LABORATORY

Feasibility & Scoping → Proof of Concept → Offline Trials → Online Trials

The NTS

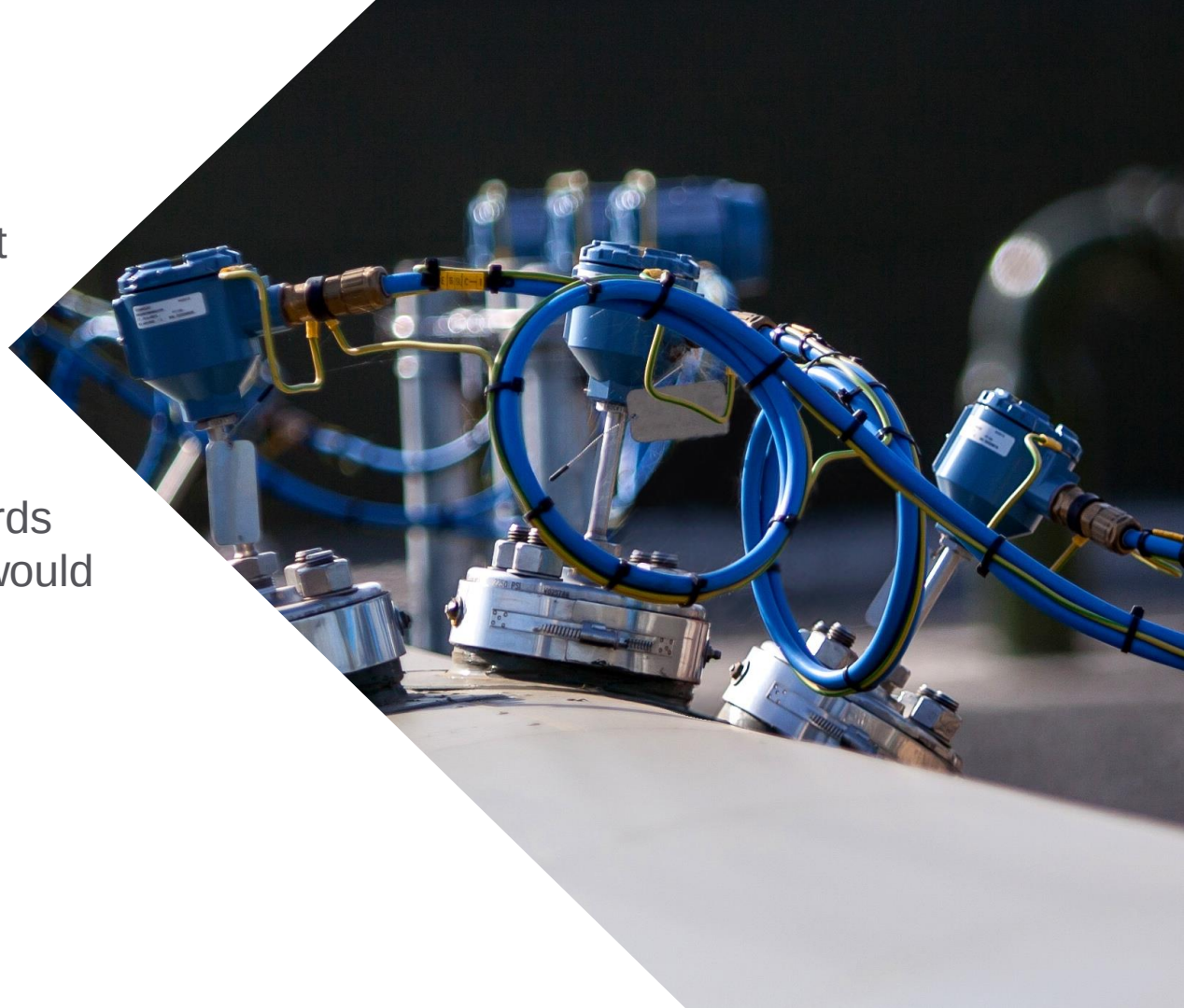
- 7,660km pipeline
- Operating pressure 38 - 94bar
- 24 compressor stations
- Gas National Control Centre (GNCC)
- 600+ Above Ground Installations





Hydrogen Study

- To what extent can the NTS be used to transport hydrogen?
- What is the impact on the operational life?
- What changes to standards and operating methods would be required?
- What are the key risks?



Hydrogen Embrittlement

- A number of mechanisms by which hydrogen impacts material properties

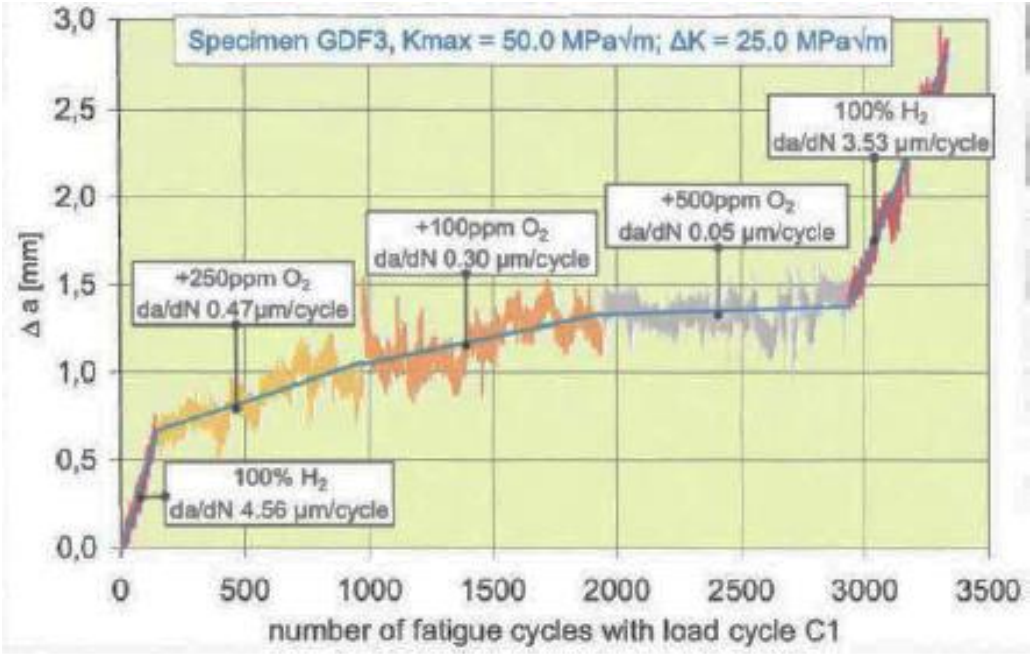
Material effects in pipeline steels at 70-100 bar

Material Property	Impact
Strength	Slight reduction in some areas
Ductility	Significant reduction
Fracture toughness	Slight to significant reduction
Fatigue life	Significant reduction

Is that the end of the story?

- Oxygen introduction can almost eliminate the impact of hydrogen on crack growth rate

X52 Steel at 66 bar



Gasunie Example

- 12km hydrogen transport pipeline, transporting H2 from Dow ethylene cracker to Yara in NL
- 4K tonnes of H2 transported per year
- Re-purposing of an existing line, November 2018 (first in EU)
- Evaluation of materials effects from literature (strength, toughness, fatigue)
- Material analysis demonstrates that material is operating below with acceptable fatigue

DOW YARA ICL gasunie waterstof services

This project has been supported by:

North Sea Port · Provincie Zeeland · Ministerie van Economische Zaken en Klimaat · SDR

www.gasuniewaterstofservices.nl
www.gasunienewenergy.nl

HyNTS Project Cavendish

A review of the potential of the Isle of Grain region to use existing infrastructure to supply hydrogen to London & the South East including generation, storage, transport and CCS.

Start	Feb 2019
End	Feb 2020
Fund	NIA Project

Networks

→ NGGT (Lead)

→ Cadent

→ SGN

Deliverables

- **Discovery:** review of gas network to meet heating demand, technology for separating hydrogen / methane blend, geological review of Isle of Grain, link with TfL
- **Design & Modelling:** technical concepts development, CO2 reduction implications, business model, mapping the end state – future vision of hydrogen in South London
- **Analysis:** refine cost estimates, wider economic benefits, examine commercial / funding options, regulatory arrangements required, road map
- **Completion & Next Steps:** identify next steps and options

Partners

ARUP

Feasibility & Scoping → Proof of Concept → Offline Trials → Online Trials

Project Overview

Objective:

A review of the potential of the Isle of Grain region to use existing infrastructure to supply hydrogen to London & the South East including generation, storage, transport and CCS.

Network(s):

nationalgrid

SGN
Your gas. Our network.

Cadent
Your Gas Network

Engagement

Currently engaged

Planned engagement

HyNTS Aberdeen Vision

A feasibility study for the generation of hydrogen at St Fergus using the NTS (up to 2%) to supply the city of Aberdeen. Includes generation, injection, separation and transport.

Start	Dec 2018
End	Sep 2019
Fund	NIA Project

Networks

→ NGGT

→ SGN (Lead)

Deliverables

- **Hydrogen Production at St Fergus:** outline Steam Methane Reform options at St Fergus and feasibility
- **2% Hydrogen into the NTS at St Fergus:** outline of Hydrogen Injection, evaluation of technical / regulatory / commercial aspects
- **2% Hydrogen Distribution & Use:** identify impact on distribution network and end users
- **Hydrogen Performance Assessment:** outline options, identify hydrogen supply pipeline and phased conversion options

Partners

Pale Blue Dot.

DNV·GL

LONG O DONNELL ASSOCIATES LTD

Feasibility & Scoping → Proof of Concept → Offline Trials → Online Trials

Gas System Operator

05

Gas Markets Plan and Future of Gas Forum:

Developing a Gas Markets Plan together

nationalgrid

The Future of Gas

Is there a role for gas? What might that role be? What might be needed to deliver that future?

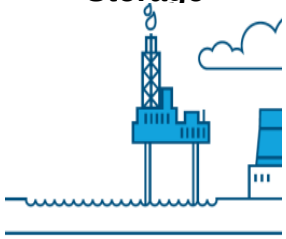
Decarbonisation of Heat

Decarbonisation of Transport

Decarbonisation of Industry

Future Networks & Markets

Carbon Capture Usage & Storage



Whole Energy System

The objectives of the Gas Markets Plan

We committed to work with stakeholders to deliver a long-term market change plan, to support whatever future we find ourselves in

- Stakeholders collectively putting consumers at the heart of decisions about facilitating whatever the future of gas looks like

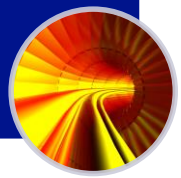
Consumer value

- Facilitating broad stakeholder discussion – educating and debating across industry to gain consensus on the commercial, technical or regulatory changes required

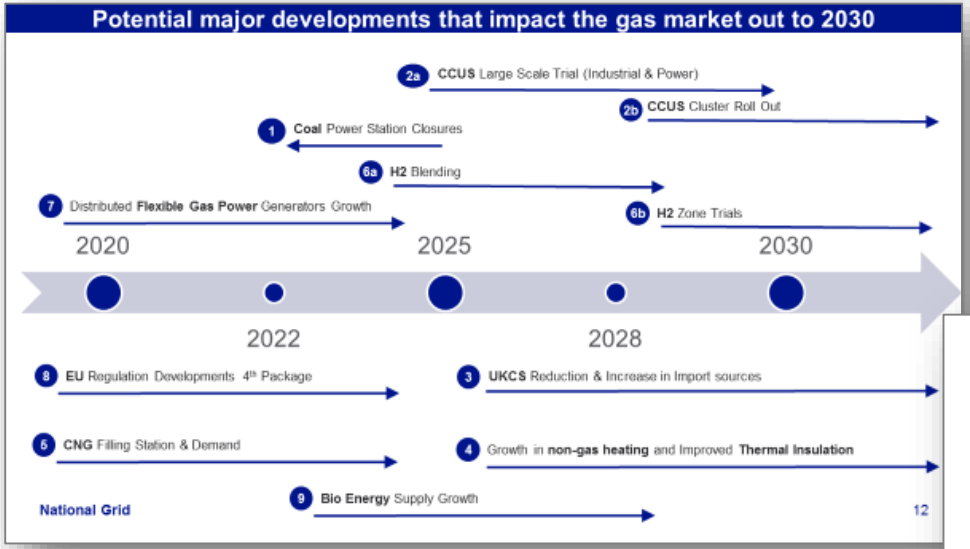
Providing clarity when the future is uncertain

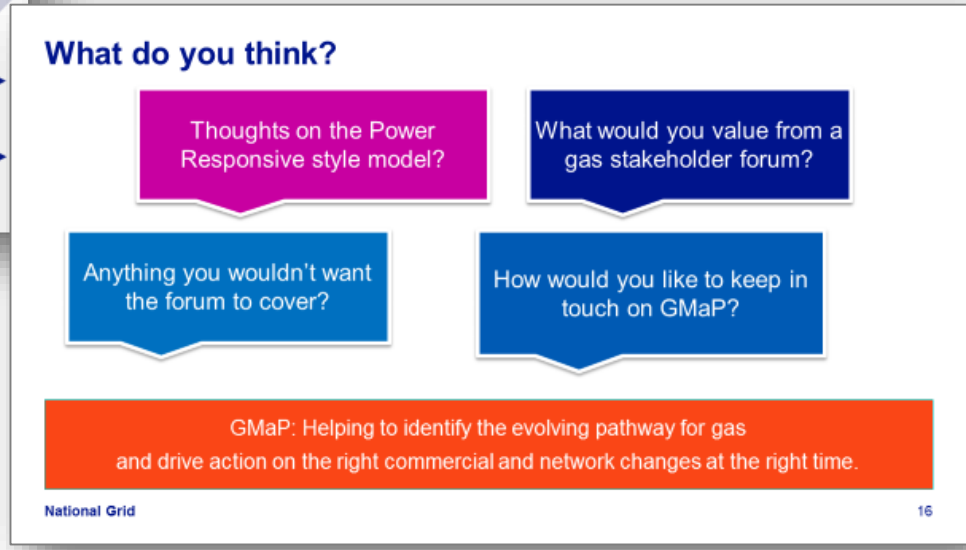
- Sector-wide agreement on the challenges and the right things to do at the right times will allow the SO to facilitate the future market efficiently for consumers

Agile market facilitation



Test the concept Workshop: March 2019





- **~20 stakeholders across industry**
- **Presentations and outputs on futureofgas.uk**

Future of Gas Forum: May 2019

- The Future of Gas Forum was held on 16th May 2019 in London. It was attended by over 30 gas industry stakeholders and facilitated by the Gas System Operator
- The day began with presentations by National Grid SO, giving an introduction to the Gas Markets Plan and an update on our work so far
- Dave Buttery, Deputy Director of Energy Security at BEIS presented A Policy Perspective, highlighting that gas remains important for the future but the industry needs to continue to evolve to meet future challenges.
- Mindful of the importance of European policy activities related to gas, Malcolm Arthur, Business Area Manager – Market, at ENTSOG gave an overview of What is Happening in the EU.

Future of Gas Forum: Breakout Session

- Bringing Together Diverse Perspectives to Prepare for the Future Market
- **The aim of the breakout session was to understand further the impacts of themes of change, which were explored in an initial stakeholder workshop in March 2019.**
- Case studies were created to ‘stress test’ with stakeholders what different themes of change may mean in terms of commercial & regulatory impacts on the market frameworks.

Case Studies to explore themes of change

No	Case Study	Characteristics	Topics Discussed
1	**New gases**	Hydrogen blending from Electrolysis Large scale production from Stream Methane Reforming with Carbon Capture Usage and Storage (CCUS)	• **Policy Direction** • **What is the route for deploying H2** • **New Frameworks, When?**
2	**Growing embedded supply & demand**	Growth of biomethane and bioSNG supply sources Increased uptake of compressed natural gas vehicles	• **Operational Impacts (NTS & DN)** • **Gas Quality Impacts** • **Guarantees of Origin**
3	**Evolving offshore supplies**	UK Continental Shelf (UKCS) supplies decline Proportion of import supplies meeting demand increases	• **Flexible Frameworks & Tools** • **Utilise Existing Infrastructure / Markets** • **Gas Blending**
4	**Changing within-day behaviour**	Increasing flexible use of gas-fired power stations More commercially-driven gas supplies	• **Policy Direction / Market Attractiveness** • **Balancing Regime** • **Value of Flexibility**
5	**Status quo**	Steady progress of gas market without fundamental new technology changes	• **Asset Stranding** • **Flexible Market Solutions**

Future of Gas Forum Steering Group

Senior level cross-industry and stakeholder expert group. National Grid Chair.

Develop and define priorities for GMaP (2-10 years) and associated outputs.

Deliver future market for consumers and support the energy transition through specific, agreed projects

Agreeing triggers to change and impacts on the market frameworks on which the industry should focus in the forthcoming year to maximise consumer value.

Future of Gas Forum Steering Group

Terms of reference

1. Introduction

In November 2016, National Grid launched its Future of Gas (FOG) stakeholder engagement programme to gather evidence, discuss and test the role of gas in the UK's transition to a low carbon economy. The conclusions of that programme were published in March 2018, in The Future of Gas: how gas can support a low carbon future.

Recognising the level of uncertainty and potential change in the gas industry in the coming decades, one commitment was to work with stakeholders to develop a long-term plan for gas industry change in Great Britain (GB).

1. All output and slides from the Forum are available on the Future of Gas website
2. Steering group Terms of Reference is also published on-line
3. First Steering Group meeting early summer
4. FOG Forum / Steering Group & GMaP timeline developed early summer
5. GMaP engagement mid-summer
6. Ambition to publish first GMaP early autumn

Carrying on the conversation

Subscribe to Future of Gas Website

https://futureofgas.uk/

Meet with us

Neil Rowley | Gas Market Development Manager (Gas) | Neil.Rowley@nationalgrid.com

Bill Goode | Senior Gas Market Development Lead, Future Markets (Gas) | Bill.Goode@nationalgrid.com

Imran Abdulla | Gas Market Development Lead (Gas) | Imran.Abdulla@nationalgrid.com

Dipali Raniga | Frameworks & Policy Development Manager, Future Markets (SO) | Dipali.Ranign@nationalgridso.com

Elaine Baker | Gas Policy Development Lead (Gas) | Elaine.Baker@nationalgrid.com

Gas System Operator

06

Gas Prices

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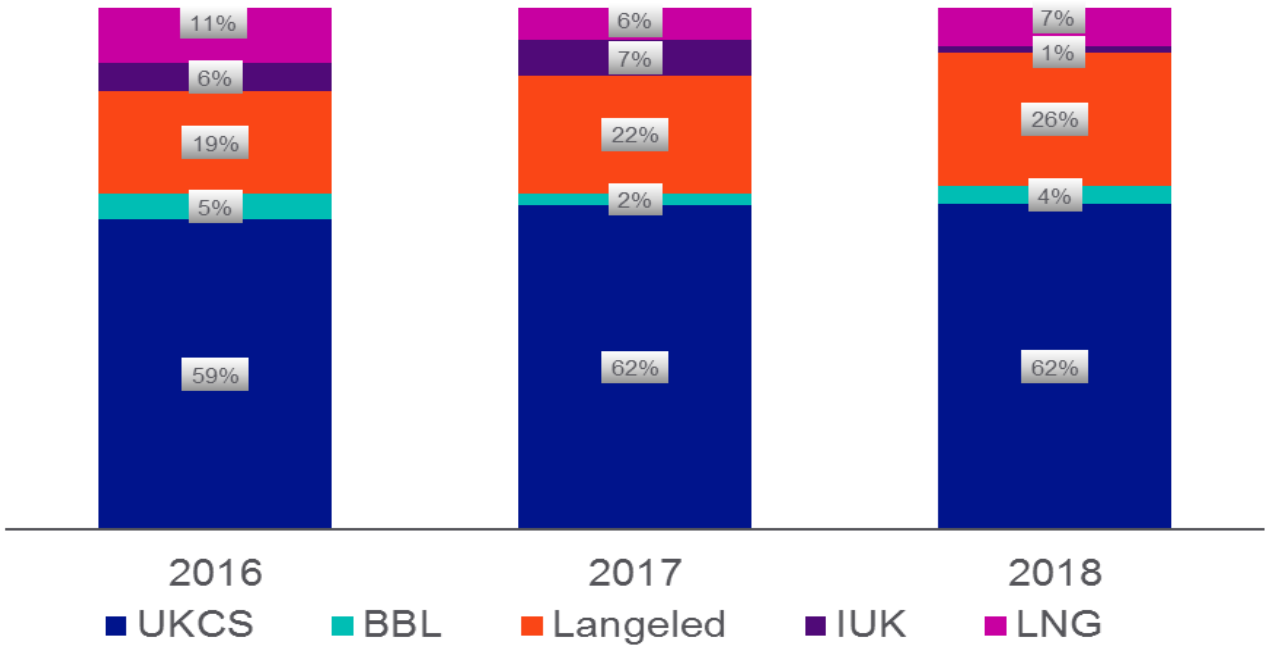
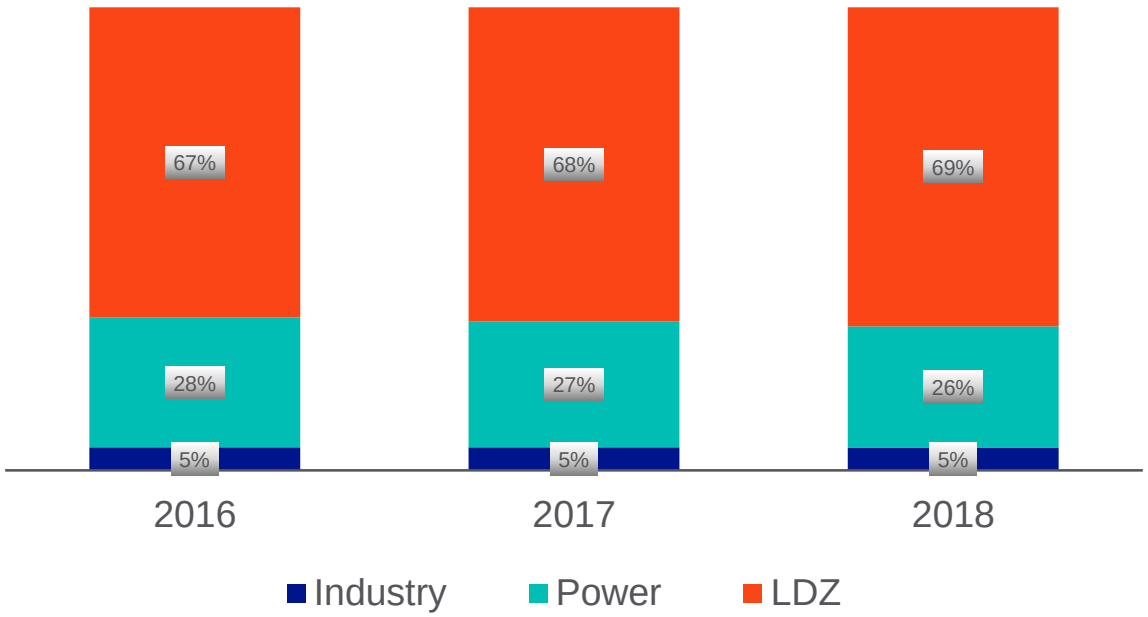
Gas Supply 2016 – 2018



UK Gas Supplies:

- Lower interconnector imports (BBL and IUK)
- Stable UKCS supply patterns
- Higher year-on-year gas supplies from Langeled
- Imports:
  - Langeled (Norway)
  - BBL (Netherlands)
  - IUK (Belgium)
  - Continental Europe and global LNG

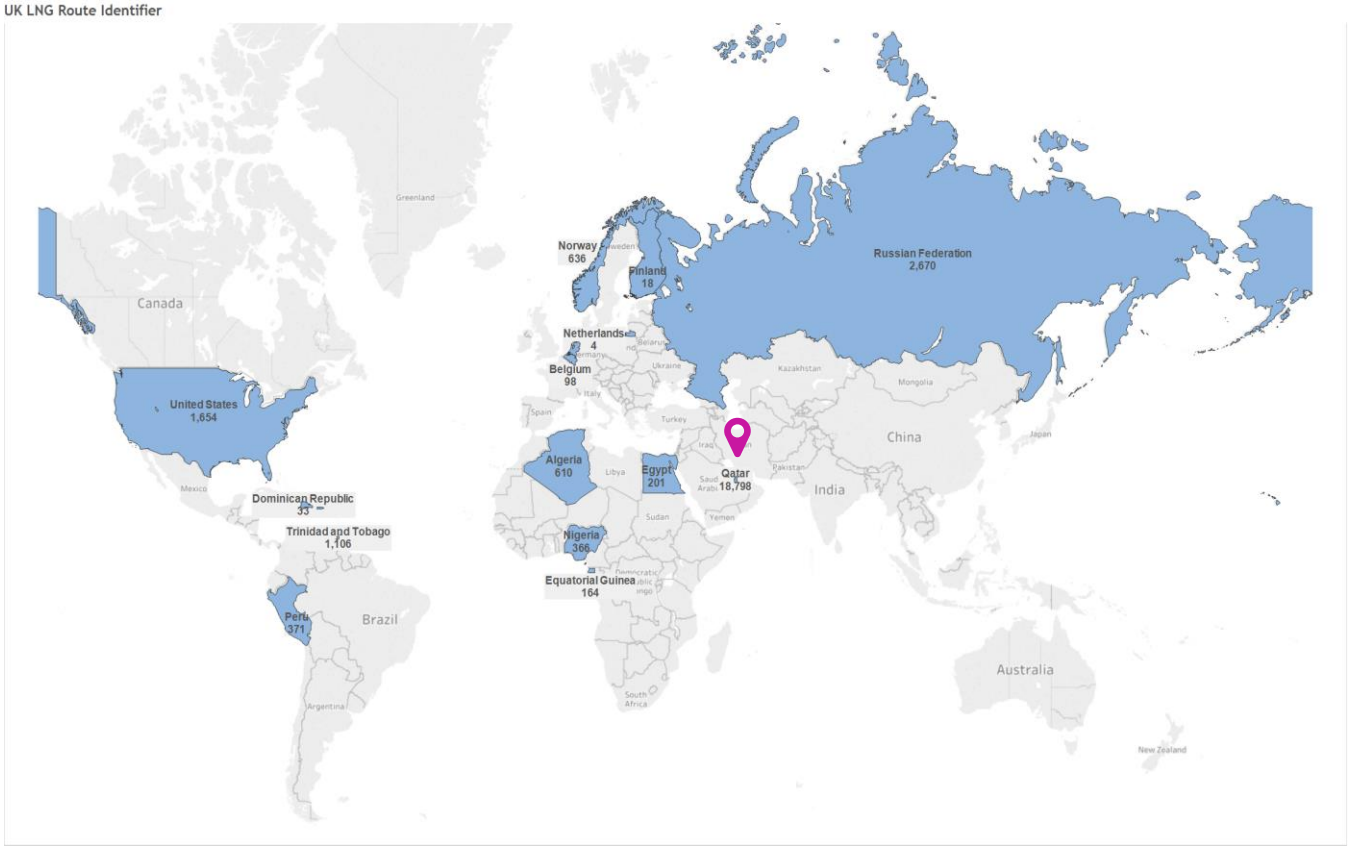
Gas Demand 2016 – 2018



UK Gas Demand:

- Slightly higher year-on-year LDZ demand (driven by temperature)
- Slight decline in gas demand for power generation
- Stable gas demand from the industrial sector

LNG Imports 2016 - 2018



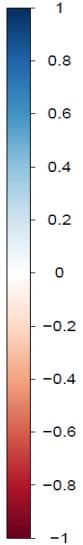
LNG routes to UK:

- Imported 26.9 bcm over last 3 years
- Top 4 LNG importers:
  - Qatar
  - Russia
  - US
  - Trinidad & Tobago
- 24.2 bcm of LNG imports from top 4

What Influences Gas Prices

Correlation Matrix

	Prompt Gas	Prompt Power	Gas Q+1	Power Q+1	UKStorage	EUStorage	Oil	Coal	EUETS	EUR	USD
Prompt Gas	1	0.87	0.67	0.64	0.12	0.23	0.53	0.52	0.44	−0.31	0.14
Prompt Power	0.87	1	0.8	0.8	0.17	0.35	0.59	0.59	0.63	−0.35	0.08
Gas Q+1	0.67	0.8	1	0.99	0.22	0.58	0.64	0.78	0.6	−0.47	−0.03
Power Q+1	0.64	0.8	0.99	1	0.21	0.61	0.64	0.74	0.69	−0.5	−0.04
UKStorage	0.12	0.17	0.22	0.21	1	0.66	−0.24	0.22	−0.15	−0.17	−0.42
EUStorage	0.23	0.35	0.58	0.61	0.66	1	0.04	0.52	0.23	−0.56	−0.22
Oil	0.53	0.59	0.64	0.64	−0.24	0.04	1	0.58	0.63	−0.14	0.45
Coal	0.52	0.59	0.78	0.74	0.22	0.52	0.58	1	0.2	−0.58	0.23
EUETS	0.44	0.63	0.6	0.69	−0.15	0.23	0.63	0.2	1	−0.18	0.08
EUR	−0.31	−0.35	−0.47	−0.5	−0.17	−0.56	−0.14	−0.58	−0.18	1	−0.16
USD	0.14	0.08	−0.03	−0.04	−0.42	−0.22	0.45	0.23	0.08	−0.16	1



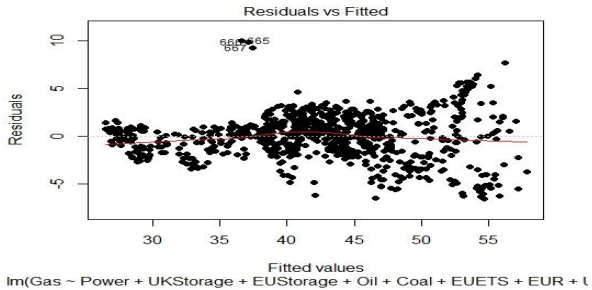
Gas prices move in tandem with:

- Power prices
- Oil prices
- Coal prices
- EU ETS

Gas prices are negatively correlated with:

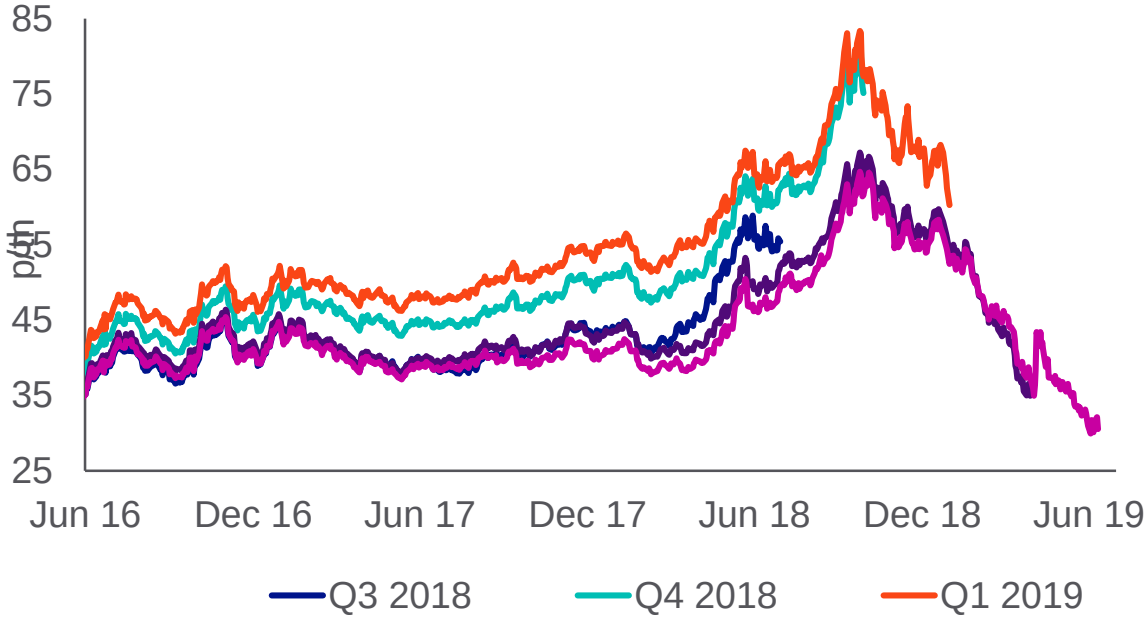
- UK Storage
- FX rates

Residuals of multiple regression:



Gas Quarter Prices Q3-18 – Q3-19

Gas Prices



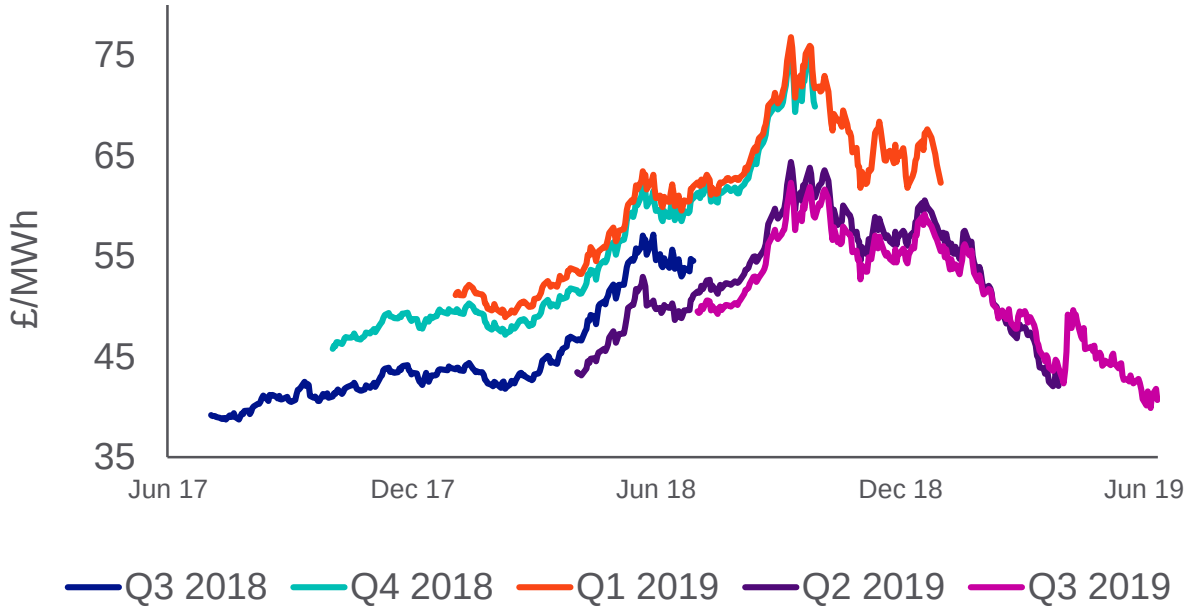
Source: Argus

Gas Forward prices:

- Extreme weather- ‘Beast from the East’ (Feb-18)
- Gas deficit warning (Mar-18)
- Additional supply needed to refill storage

Power Quarter Prices Q3 18 – Q3 19

Power Prices



Source: Argus

Power Forward prices:

- Prices sensitive to gas prices movements
- Carbon Prices (EUETS) key determinant
- Dominant fossil fuel in the UK's fuel mix

Gas Prompt Prices

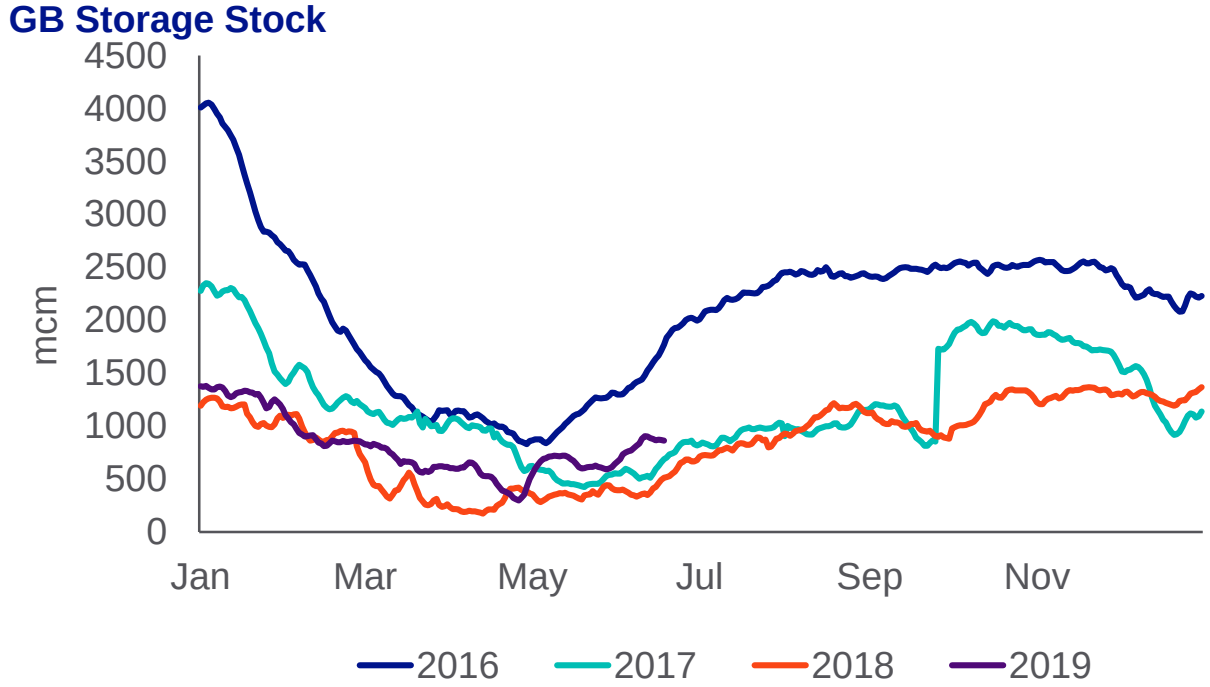
SAP Prices

Source: National Grid

Low SAP prices:

- Mild temperatures
- Strong LNG supply
- High storage
- LNG availability and various supply sources

GB Storage 2016 – 2019

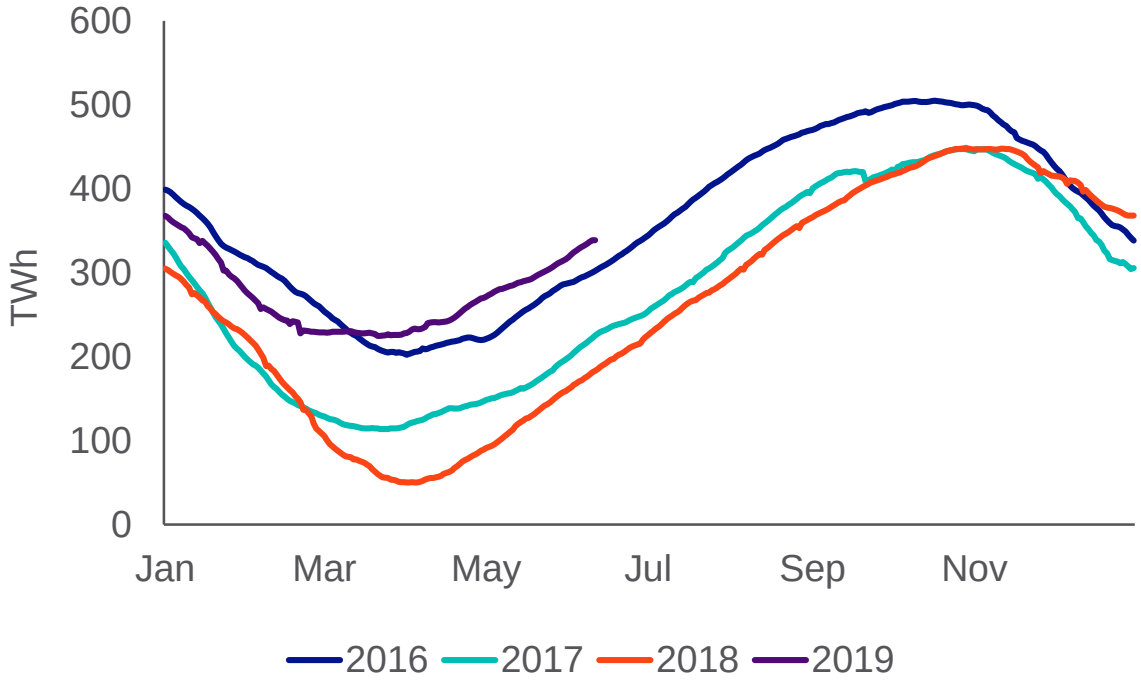


- Effect of “Beast from the East”:
  - Depleted gas storage levels
  - Strong demand for storage to balance demand
  - Lowest levels in 2018

Source: Argus

EU Storage 2016 - 2019

EU Storage Stock



Storage levels driven by:

- Cross-border prices spreads
- “Beast from the East” affected European gas storage
- Lowest gas storage level in 2018

Source: Argus

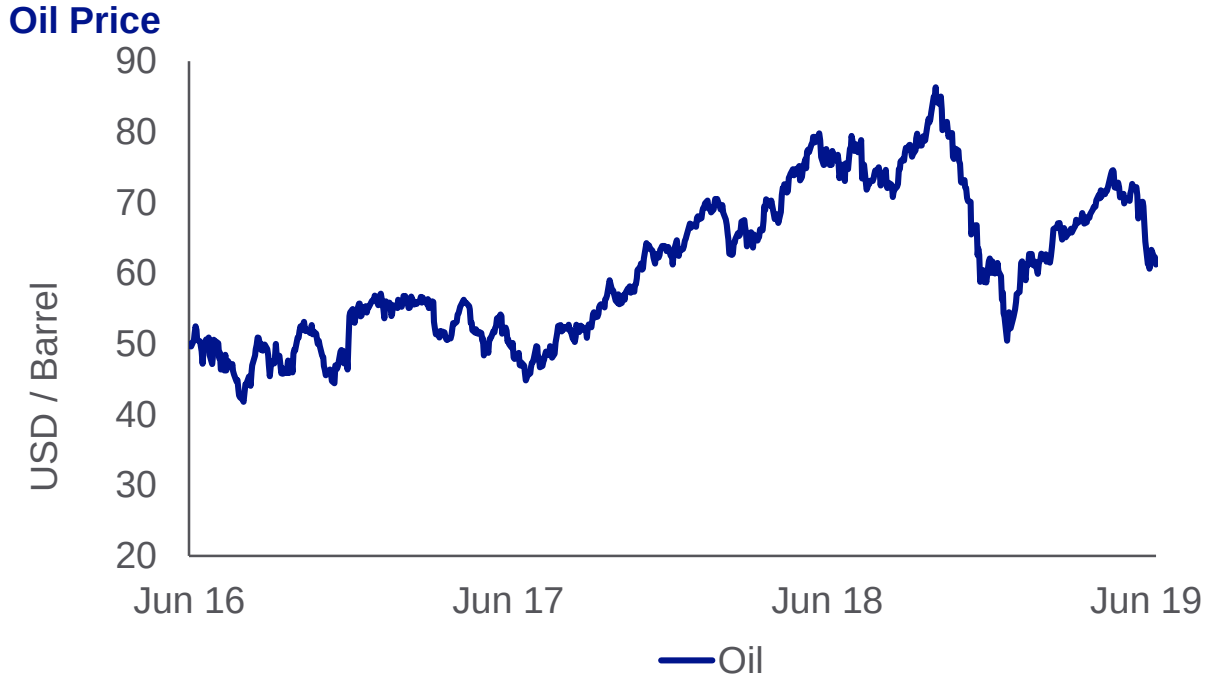
Coal Prices 2016 - 2019

Falling Coal prices:

- In part by lower Asia import demand
- Import restrictions placed by the Chinese government

Source: Thomson Reuters

Oil Prices 2016 - 2019



Source: Thomson Reuters

Volatile Oil prices:

- US sanctions
- Supply cuts by OPEC
- Political unrest in Venezuela

LNG Asia & UK Prices

LNG Asia & UK Prices

Source: Argus

UK & Asia Prices Converge:

- Decreasing demand from Asia
- High forward UK prices after the Gas Deficit Warning

Gas System Operator

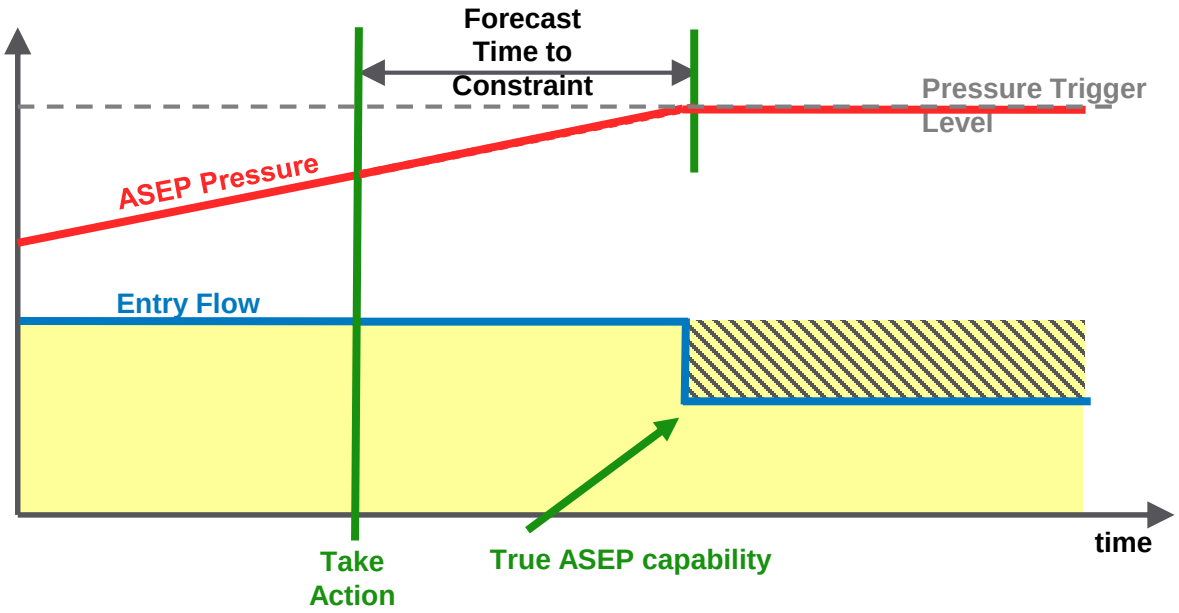
07

Constraint Management

nationalgrid

What constitutes a Constraint?

Entry Example:



In constraint situations, National Grid will communicate with Users via the Active Notification System (ANS). It is therefore important to ensure that your contact details are up to date.

System Operator Actions

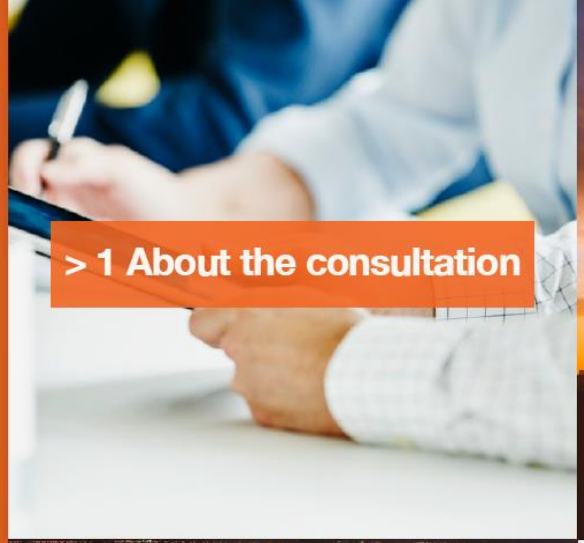
Operational tools (internal)	Operational tools (external)	Commercial tools	Network Integrity
Reconfigure Network Optimise Compressor Fleet Manage Outages	Agree Pressures (Distribution Network Operator (DNO) Only) Flow Swaps (Distribution Network Operator (DNO) Only) Enforce Contractual Offtake Rules Restrict Daily Capacity	Scaleback Capacity (Entry Interruptible & Exit Off peak) Locational Energy Actions Capacity Surrender Offtake Flow Reductions Initiate Constraint Management Agreements	Operating Margins Terminal Flow Advice (TFA) (Entry) Critical Transportation Constraint Gas Deficit Emergency
Information Provision (MIPI *(Market Information Provision Initiative)* / Website / Gemini / ANS *(Active Notification System)*)			

Gas System Operator

08

Winter Consultation and Review

nationalgrid



> 1 About the consultation

> 2 Executive summary

> 3 Whole energy system

> 4 Electricity

> 5 Gas

> 6 Consultation summary

To help you find the information you need quickly and easily we have published the *Winter Review* as an interactive document.

Home/Arrows
Cliccking on the home icon will take you to the contents page. Click on the arrows to move backwards or forwards a page.

'Hover over' content
Words highlighted in purple will reveal a text box when you hover over them with your cursor.

Question marks
These are consultation questions which are spread throughout the document.

Pencil icon
A pencil icon is shown when questions can be answered at the end of each chapter by typing in the editable text box.

Enlarge/Reduce/Info
Hover over the magnifying icon to make chart bigger or smaller. Hover over info icon to reveal text.

> 4 Electricity

'Roll over' content
Contents can be accessed by rolling over the text or clicking to go to that page

www.

Hyperlinks
Hyperlinks are highlighted in **bold** throughout. You can click on them to access further information.

There is a print ready version available if you are having difficulties viewing this interactive pdf on your device.

Winter 2018/19 overview

Executive summary

Winter 2018/19 was the fifth warmest winter in the past 59 years and had high levels of wind. Our operations across the electricity and gas networks responded flexibly throughout the winter period to meet the different challenges presented by variable weather conditions.

1

Winter 2018/19 was the lowest carbon intensity winter on record for electricity generation, and levels of carbon intensity have almost halved in the last five years. High wind and low coal generation contributed to a continued reduction in the average carbon intensity of electricity over the winter, setting a new record of 242.8 grams CO_2 equivalent/kWh, in line with long-term trends.

2

Whole energy system interactions were prominent as high levels of renewable electricity generation resulted in variable gas demand for power. The preference for gas generation over coal led to the highest day for gas demand for electricity generation on record at 97.2 mcm.

3

Electricity supply margins were in line with expectations and there were no significant difficult days for meeting gas demand. Electricity and gas demand levels were also close to our forecast, although gas demand for electricity generation was higher than expected.

4

Despite the mild weather, there were operational challenges that were overcome in relation to both gas and electricity. On the electricity system, unexpected outages and system conditions contributed to low system inertia and a higher risk of Rate of Change of Frequency (RoCoF) events. The gas system responded to large day-to-day swings in demand and increased supply diversity including higher than expected levels of liquefied natural gas (LNG).

Winter 2018/19 overview

Executive summary

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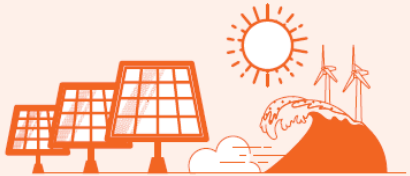
The units 'gCO_2eq/kWh' are grams of carbon dioxide equivalent per kilowatt-hour of electricity generated. Carbon dioxide is the most significant greenhouse gas (GHG).

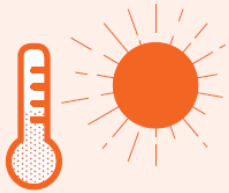
GHGs other than carbon dioxide, such as methane, are quantified as equivalent amounts of carbon dioxide. This is done by calculating their global warming potential relative to carbon dioxide over a specified timescale, usually 100 years.

Winter 2018/19 overview

Executive summary



The lowest carbon intensity winter on record, **almost half the CO_2 equivalent** compared to five years ago

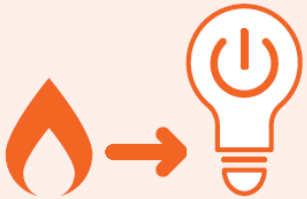


5th warmest winter in nearly 60 years

Gas delivered **over 3 times more energy** than electricity over the winter

Gas and electricity **demand and supply margins close to our forecast**

Flexible system operation was needed to manage the challenges of variable demand



Highest single day gas demand for electricity generation on record at 97.2 mcm

Gas overview winter 2018/19

Executive summary

Headline messages

- There were no significant events during winter 2018/19 that adversely affected gas supply and demand.
- There was an unexpected reduction in gas prices after the time of our forecast. Influencing factors included the mild winter weather, high storage levels and availability of LNG supplies in Europe which led to increased competition in the supply market.
- Overall gas demand in winter 2018/19 was lower than previous years but not as low as our forecast. This was due to a higher demand for gas for electricity generation than anticipated as a result of the low gas prices and hence the relative cost of gas compared to coal.
- Winter 2018/19 included the highest day for gas demand for electricity generation on record at 97.2 mcm.
- The peak gas day demand was 402 mcm as compared to 417.6 mcm in 2017/18 during the severe cold weather.
- A variety of sources met the gas demand including a higher number of LNG deliveries than forecast due to market changes.
- The National Transmission System (NTS) responded flexibly to large day-to-day swings in gas demand, changes in storage and withdrawal patterns and increased diversity of supply.

Gas demand winter 2018/19

	2018/19 Forecast (seasonal normal)	2018/19 Actual (weather corrected)	2018/19 Actual (not weather corrected)
Demand for electricity generation	7 bcm	12.3 bcm	12.3 bcm
Total demand	46.6 bcm	50.9 bcm	49.6 bcm

Case study: whole energy system interaction day-on-day

Figure 3.5
Figure 3.6

Managing sudden and unexpected changes in demand on the National Transmission System (NTS) from one day to the next can be challenging. A drop in demand as renewable generation increases can be just as difficult to manage as a rapid rise and requires more flexible and proactive NTS operations.

A significant day-on-day demand change in winter 2018/19

25 January 2019 was the biggest day-on-day demand change last winter. It was much warmer than the previous day and very windy.

Renewable generation from wind was five times higher than the previous day, resulting in a 35% drop in gas demand for electricity generation. Heating was also switched off leading to a 20% reduction in LDZ demand.

Day-to-day operational management is becoming as important as within-day management. We are ensuring our processes and operating strategies are ready to respond to these changing market requirements.

	24 January	25 January
Demand change	384 mcm	306 mcm
This 78 mcm drop is more than twice the highest linepack swing of the winter and significantly higher than the biggest day-on-day demand change in winter 2017/18 (48 mcm).		
Storage	53 mcm withdrawal	11 mcm injection

Figure 3.5
Absolute day-on-day change in NTS demand (mcm/d)

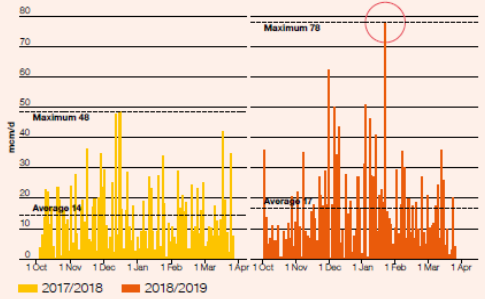
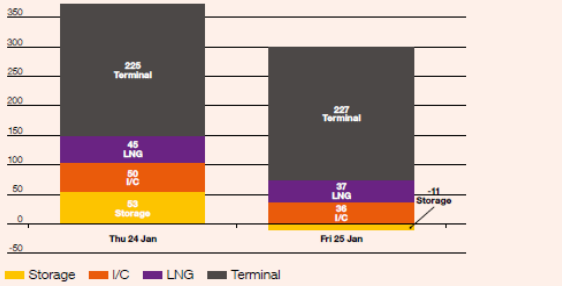


Figure 3.6
Day to day net supply profile on 24 and 25 January 2019 (mcm/d)



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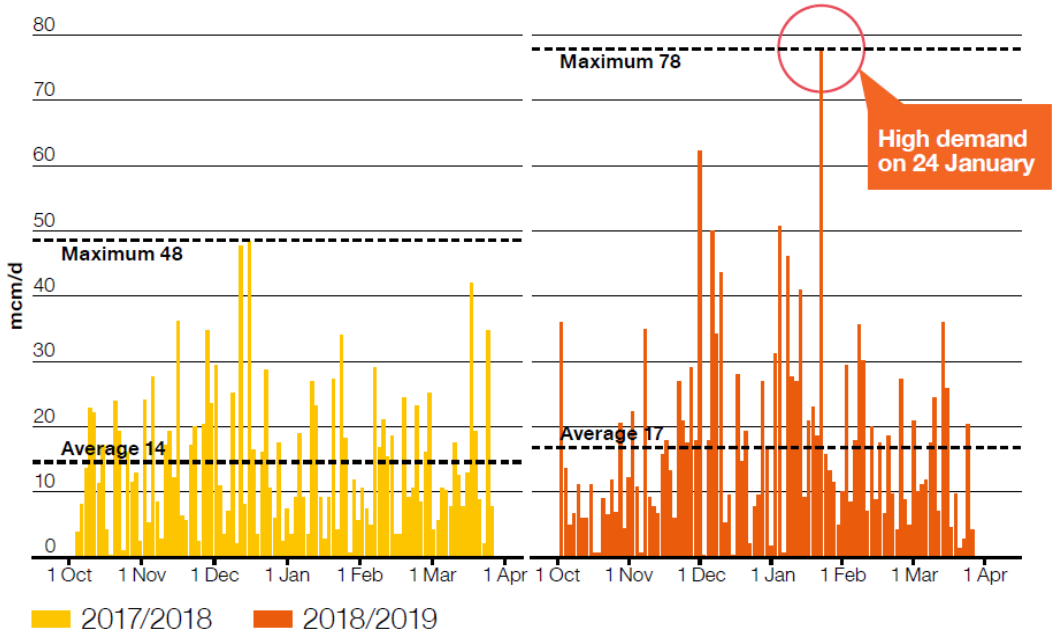


Our publications

Executive summary

Future Energy Scenarios
July
A range of credible pathways for the future of energy from today to 2050. Scenarios are unconstrained by network issues.

The *ETYS*, *GTYS* take the unconstrained scenarios in *FES* to develop requirements for planning and operating the electricity and gas transmission systems over the next 10 years.

Needs case

Electricity Ten Year Statement
November
The likely future transmission requirements on the electricity system.

Gas Ten Year Statement
November
How we will plan and operate the gas network, with a ten-year view.

Options

Network Options Assessment
January
The options available to meet reinforcement requirements on the electricity system.

Ten Year Network Development Plan
Overview of the European gas and electricity infrastructure and its future developments.

The operability publications consider the unconstrained scenarios in *FES* to explore operability risks and associated requirements of the transmission networks and services.

System Operability Framework
How the changing energy landscape will impact the operability of the electricity system.

Gas Future Operability Planning
November/ December
How the changing energy landscape will impact the operability of the gas system.

Ad-hoc, insights -led productions and reports

Operability Strategy report
Highlights the challenges we face in maintaining an operable electricity system, and summarises the work we are undertaking to ensure we meet those challenges.

Future gas supply patterns
How variability in supply pattern seasonally and day-to-day has changed, and could change in the future.

We also produce ad-hoc reports that develop shorter-term plans for more specific elements of operational assets and services, where the need arises.

Capacity report
Capacity Market auctions for delivery in 2019/20 and 2022/23.

System Needs and Product Strategy
Our view of future electricity system needs and potential improvements to balancing services markets.

Product Roadmap for Restoration
Our plan to develop restoration products.

Wider Access to the Balancing Mechanism Roadmap
Our plan to widen access to the balancing mechanism.

Product Roadmap for Reactive Power
Our plan to develop reactive power products.

Transmission Thermal Constraints Management
Our plan for the management of thermal constraints.

Each year we provide short-term forecasts that explore any operational challenges anticipated over the summer and winter periods.

Winter Review and Consultation
June
A review of last winter's forecasts versus actuals and an opportunity to share your views on the winter ahead.

Winter Outlook Report
October
Our view of the gas and electricity systems for the winter ahead.

Summer Outlook Report
April
Our view of the gas and electricity systems for the summer ahead.

Responding to the *Winter Review and Consultation*

The purpose of the consultation is to gather stakeholder insight to inform our analysis for the 2019/20 *Winter Outlook* Report, published in October.

Your views on the market and related issues are important to provide a comprehensive picture of the challenges and opportunities of the forthcoming winter. It also allows us to test how useful the suite of Outlook documents are and to identify potential improvements.

Consultation questions

You will see a ? icon when there is a consultation question specific to that section. In the interactive version when you hover over the icon the question will appear. The questions are also summarised at the end of the section. A full list of consultation questions can be found on pages 44 and 45.

The consultation closes on 19 July 2019.

Response options

You can send your consultation response to us:

As commentary within the report

- Download a copy of the report from the website.
- Complete the questions on the editable pages of the document at the end of each section.
- Email your completed copy to **marketoutlook@nationalgridso.com**

As a separate document

- This can be emailed to **marketoutlook@nationalgridso.com**

Alternatively you can let us know what you think on Twitter, or by joining our LinkedIn **Future of Energy** page.

We look forward to hearing your views.

Gas System Operator

09

Signposting of Information

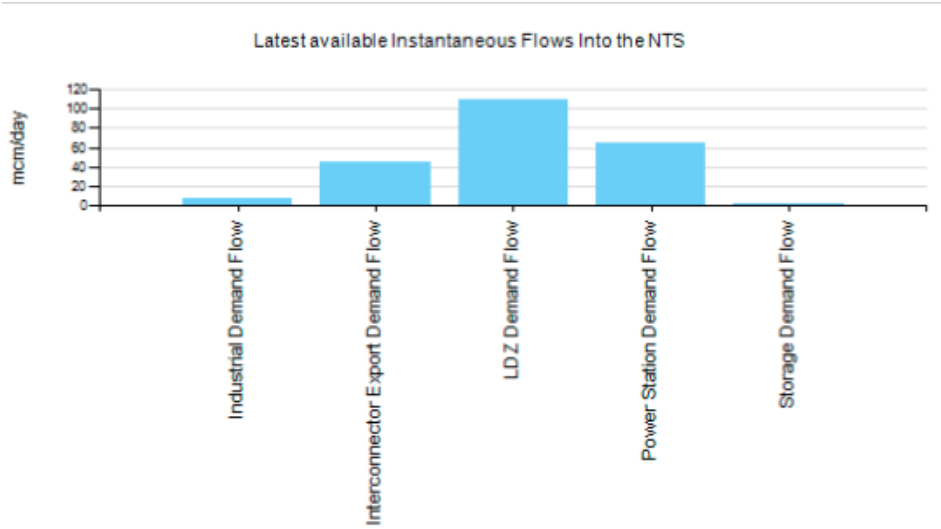
nationalgrid

Instantaneous Demand data

Demand data at the same level of granularity as flows into the NTS is now available.

Temporary link is being used for this data, following which it will be merged with the existing pages

Will also be including a user defined download, as with instantaneous flows into the NTS



More information is available on the community website
https://datacommunity.nationalgridgas.com/

Live Transmission-related UNC Modifications

- **0669R: Review of the Gas Deficit Warning and Margins Notice Arrangements**
  - A change of name from ‘Gas Deficit Warning’ to ‘Gas Balancing Notification’ has been proposed in Mod 0685. June Panel will make a recommendation on implementation prior to Ofgem decision.
  - The review has also considered changes to the calculation of the Margins Notice
    - National Grid will propose a draft modification to the July Workgroup
- **0675S: Enabling changes to the BBL Interconnection Agreement to facilitate physical reverse flow**
  - UNC Panel requested the Workgroup to consider the self-governance status of this Modification and the issues raised in consultation responses about the potential impacts on IUK and other shippers
  - The Workgroup considered the issues and was unable to reach a consensus
  - Panel will re-consider the proposal for decision at its June meeting

Live Transmission-related UNC Modifications

0688: Recovery of Shipper Losses incurred in Supplier of Last Resort events

- Proposal raised by Contract Natural Gas to enable shippers to recover certain costs through Balancing Neutrality during a period between a supplier going into administration/having its licence revoked and the transfer of the customers to a new supplier
- This proposal is currently being developed in the Workgroup

0671: New Capacity Exchange Process at NTS exit points for capacity below baseline

- A proposal raised by WWU to allow Users to coordinate increases in Enduring Annual Exit (Flat) Capacity at offtakes with equal decreases at others within the same NTS Exit Zone and obtain relief from user commitment obligations for the quantity of capacity transferred
- This proposal is currently on hold pending consideration of RIIO-T2 proposals

Query Surgery and Next Forum

The Next Operational Forum will take place on Thursday 19th September

Please send any requested topics to:

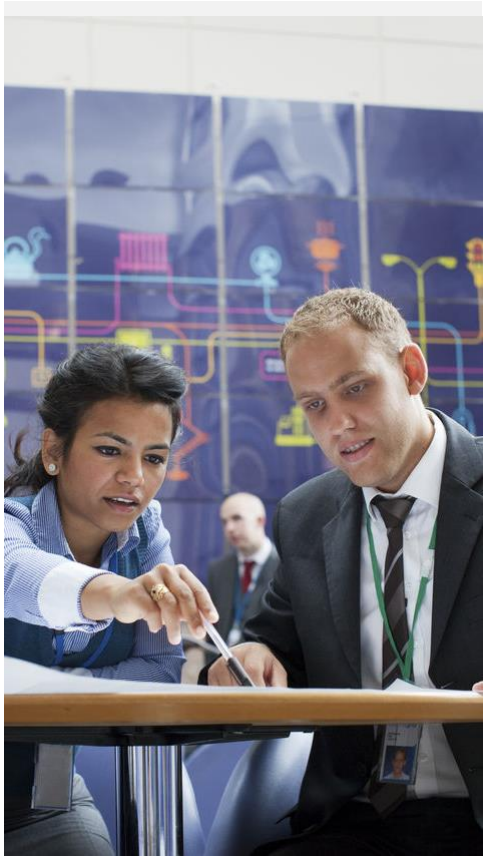
Karen.Thompson@nationalgrid.com

or

.Box.OperationalLiaison@nationalgrid.com

Opportunity now for 121 discussion with NG attendees, Hydrogen go-see, and GNCC overview

Lunch Available



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