Enter

Innovation Annual Summary

2021/22

Gas Transmission and Metering

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Welcome to our Annual Summary

For 2021/22

The future of our gas network depends on finding a 'greener' alternative to natural gas that will continue to provide heat and power to homes, businesses and industry reliably and safely.

Hydrogen has been identified as a potential low-carbon replacement for natural gas. Converting our network to carry hydrogen would be a lower-cost, less disruptive option for customers and consumers than replacing our entire network.

2021/22 was the first year of RIIO-2. Throughout the year, the team increased our focus on hydrogen-related projects to help us reach our target of net zero by 2050. As part of this, we undertook 17 projects with £2.17m in funding from the Network Innovation Allowance (NIA). Another eight projects are sanctioned and due to begin imminently.

In RIIO-1, we carried out several projects looking into the capability of the National Transmission System (NTS) to transport hydrogen.

To increase our efficiency, we changed our team structure this year – creating a Hydrogen Innovation team and a Business-As-Usual (BAU) Innovation team.

The BAU team has focused on further developing innovations identified within RIIO-1 and ways of implementing them within the business.

Meanwhile, the Hydrogen Innovation team has continued building on the hydrogen-focused work from previous years, undertaking a wide range of projects that explore the opportunities surrounding hydrogen as an alternative to natural gas.

This includes looking at the possibilities of transporting blends of natural gas and hydrogen, identifying the available hydrogen deblending technology options, and exploring the likelihood that our existing compressor units could successfully operate with hydrogen.

In addition, the team also looked at ways in which our asset data will need to improve, and the digital technologies available to support us with this improvement.

Alongside all of these activities, we continued to progress the FutureGrid Phase One project, which is building an offline test facility at DNV's research and testing site at Spadeadam in Cumbria.

Construction of the facility is well underway, with testing due to begin in early 2023 of concentrations of hydrogen at 2%, 20%, and 100%.

This year, the process for the new Strategic Innovation Fund (SIF) began. Alongside our NIA projects, we submitted applications for 11 SIF Discovery phase projects and were delighted to be awarded funding for 10 of them.

These projects lasted for two months, concluding in April 2022, and focused on better understanding some of the challenges associated with converting our network to carry hydrogen.

Decarbonising our network remains a significant yet exciting challenge for our business. Our innovation projects are vital in helping us achieve this.

Over the next year, we'll continue to focus our efforts on hydrogen research, to better understand what we need to do to convert our network and reach net zero by 2050.

Tony Green
Hydrogen Director,
Gas Transmission & Metering

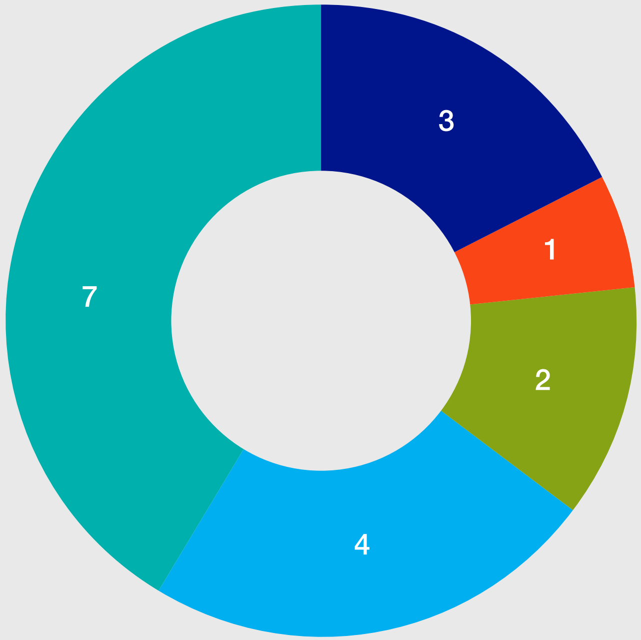
"Decarbonising our network remains a significant yet exciting challenge for our business. Our innovation projects are vital in helping us achieve this."

Network Innovation Allowance (NIA) projects

Next
Strategic Innovation Fund (SIF) projects

Number of NIA projects per portfolio theme:

- Asset development for risk mitigation
- Automation and measurement
- Digital systems and simulation
- Materials and processing
- Business development



17
NIA projects run this year

£2.17m
spent on NIA projects this year

8
additional projects sanctioned and due to start soon

10
collaborative projects

27
third parties involved

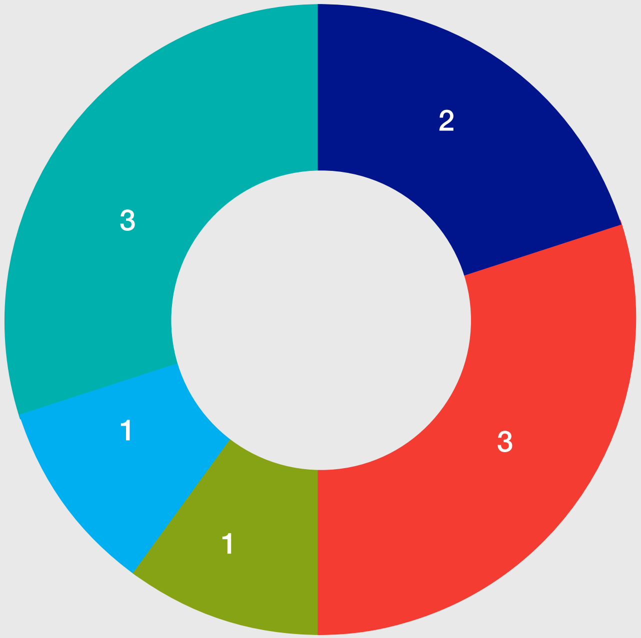
40+
business experts involved

Strategic Innovation Fund (SIF) projects

Back
Network Innovation Allowance (NIA) projects

Number of SIF Discovery projects per portfolio theme:

- Asset development for risk mitigation
- Automation and measurement
- Digital systems and simulation
- Materials and processing
- Business development



10
Led on 10 SIF Discovery projects

£1.1m
funding awarded for SIF Discovery projects

8
Supported 8 additional SIF projects

15
collaborative projects

21
third parties involved

25+
internal experts involved

Our RIIO-2 strategy

We published our RIIO-2 innovation strategy in December 2019, which consisted of three strategic themes; ‘Fit for the Future’, ‘Ready for Decarbonisation’ and ‘Decarbonised Energy System’.

These themes continued to remain relevant for 2021/22, reinforcing our focus on activities that will help us prepare for a net zero future. ‘Fit for the Future’ focuses on extending the lifetime of our network, to enable its use in a decarbonised future. ‘Ready for Decarbonisation’ looks at the assets and technologies we’ll need to transport a blend of ‘green’ gases within the NTS; and ‘Decarbonised Energy System’ is about developing the systems and processes needed to run a net zero gas network.

To support these themes, we also established five Innovation Technology Portfolios that set the direction for the innovation projects we’ll deliver throughout RIIO-2.

These portfolios are:

Click to select 1 2 3 4 5

Asset development for risk mitigation
which focuses on developing hydrogen-ready resilient assets, with optimised maintenance systems.

Our overall innovation portfolio for RIIO-2 looks at increasing the efficiency of our day-to-day maintenance and operational activities across Gas Transmission & Metering, as well as focusing on projects that will help us reach the target of net zero by 2050.

Innovation is about taking calculated risks that can drive change and deliver value to our customers. The innovation funding mechanisms available allow us to take greater risks, with potentially higher payback. Our strategy for RIIO-2 considers the various funding mechanisms, and which of these will provide the best route to ensure greater benefits are realised for our end consumers.

In RIIO-2, we are not only focused on regulatory innovation, but also on reinforcing the innovation culture within our business. We hope to drive innovation and efficiency into every investment activity undertaken across Gas Transmission & Metering. Although some of these innovations may not provide the same scale of benefits, they help to develop the business culture needed to help us achieve our innovation strategy vision.

As a business, Gas Transmission & Metering is the owner and operator of the National Transmission System (NTS), which puts us in a unique position to take a leading role on whole energy system thinking. In the future, we need to ensure we work closely with not only the other gas networks, but also the electricity networks, to drive the most efficient and cost-effective solution for the energy transition. This is a challenge that can only be met if supported by innovation.

RIIO-2 funding

RIIO-2 funding

In RIIO-2, there are two funding mechanisms available to support the gas industry with the delivery of innovation projects. These are the Network Innovation Allowance (NIA) and the Strategic Innovation Fund (SIF).

Network Innovation Allowance (NIA)

The NIA provides an allowance to fund smaller-scale projects and is accessible throughout the year. Key drivers for the NIA are:

- **Research and development:** encouraging operational and technological innovation
- **Collaboration and dissemination:** working with external partners to solve problems and share new learning
- **Customers and strategy:** focusing on solutions that deliver direct financial value to our customers.

Strategic Innovation Fund (SIF)

The SIF is the replacement for the previous Network Innovation Competition (NIC). It is intended to support innovation activities that contribute to the achievement of net zero and deliver real benefits to both network companies and consumers.

Where SIF funding is concerned, Ofgem will set the strategic direction using innovation challenges. Following this, network companies will be invited to apply for funding by submitting project suggestions that address these challenges.

SIF projects are split into three phases: Discovery, Alpha and Beta.

The SIF phases:

Click to select 1 2 3

The Discovery phase focuses on enhancing the understanding of the problem that needs to be solved and will typically take between six and eight weeks to complete.

Switching from NIC to SIF funding means the focus shifts from funding project ideas submitted by the network companies, to funding the best solutions to specific problems. This means a stronger focus on the energy system transition, and a more responsive process that addresses the issues faced across the energy landscape.

Asset development for risk mitigation

Asset development for risk mitigation involves developing our understanding of the capability of our current assets with net zero gases. This includes developing solutions for compression, capture and storage of hydrogen.

This innovation technology portfolio aims to make sure our standards, policies and procedures are suitable for the energy transition and encompasses projects that will ensure our assets operate efficiently during the transition.

Case studies

- **Hydrogen fuel gas for NTS Compressors**
- **Ch4rge emissions reduction**
- **HyNTS compression**

Other projects

- **Variable hydrogen blend compression**

Lynsey Stevenson
Technology Lead –
Asset development

"Innovation is key to developing the transmission system for transportation of hydrogen. The use of innovative techniques and technologies will allow us to repurpose our assets where possible, ensure new assets are fit for purpose, and enable safe operation and maintenance of our future hydrogen transmission system."

CASE STUDY

Hydrogen fuel gas for NTS Compressors

Gas is moved through the National Transmission System (NTS) by a complex compression system that includes 24 compressor stations and 70 individual compressor units, located at various points on the network. These compressor units are powered by gas turbines to move the gas where it needs to go, depending on use and demand.

We're looking to transition our network to carry hydrogen, helping us meet the Government target of net zero by 2050. In the period between now and then, it's likely that blends of hydrogen and natural gas will be needed to meet varying customer requirements.

This project is a feasibility study, using an example NTS compressor station, looking at the safety, environmental, technical, operational, and economic impacts that blended hydrogen and natural gas mixes could have on our existing gas turbines.

Alongside this, the project is seeking how to establish an innovative green hydrogen production, storage, and supply facility to fuel gas turbines on varying hydrogen and natural gas blends.

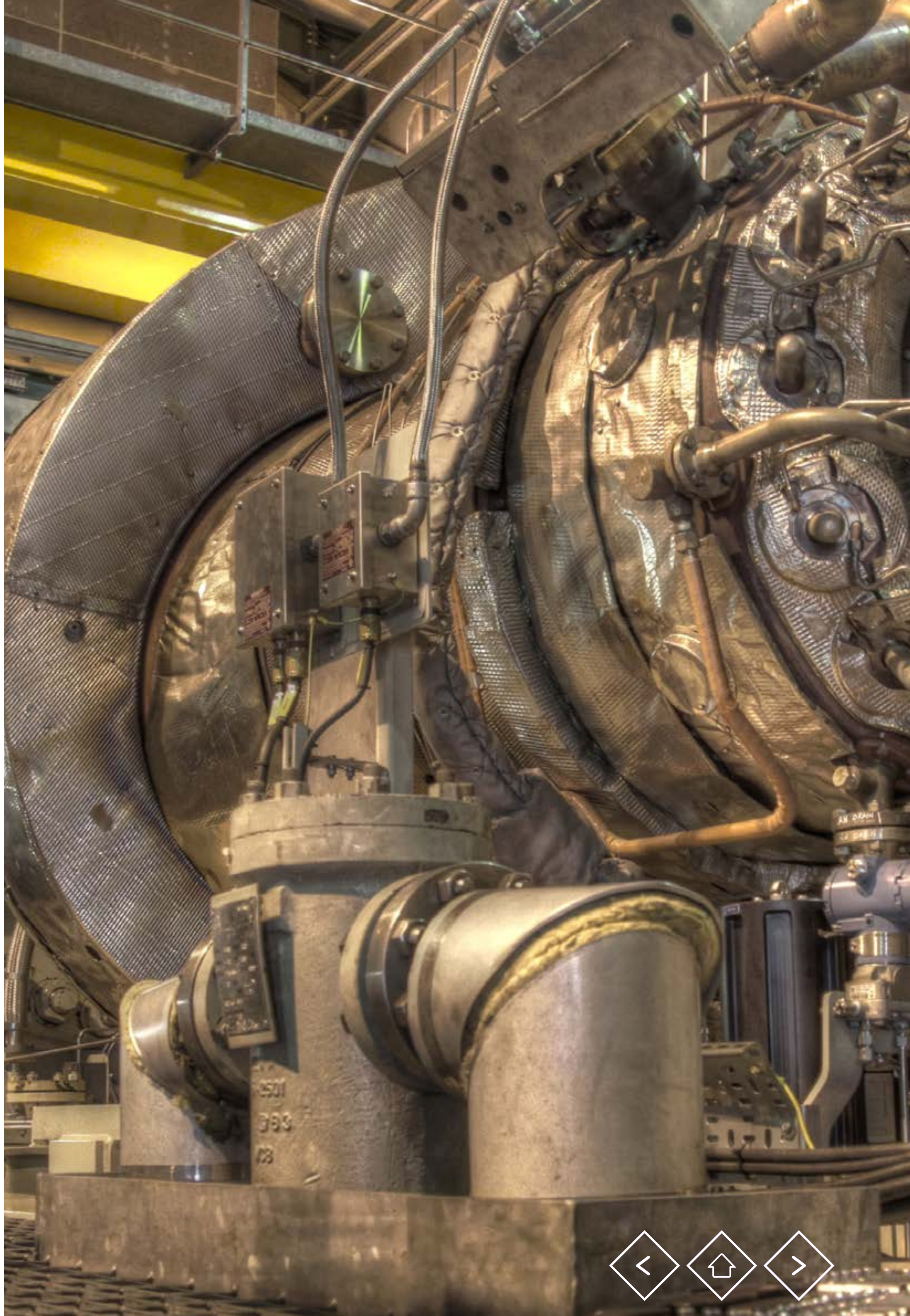
Asset development for risk mitigation

Work is currently under way and comprises five work packages:

- Gas turbine capability
- Operational considerations
- Business case
- Project management and reporting

Working with SBLC Ltd, Siemens Energy, Mott MacDonald, Imperial College and Cardiff University, the project will examine how hydrogen can be produced locally and be supplied to power the gas turbines at the example compressor station. It will also consider how new technologies, processes and commercial arrangements could facilitate these activities, enabling a transition to hydrogen on our network.

The work will be completed in July 2022, followed by a report outlining the findings from the study. If the concept proves feasible, we'll use the outcomes to develop future project phases, through to final implementation.



CASE STUDY

Ch4rge emissions reduction

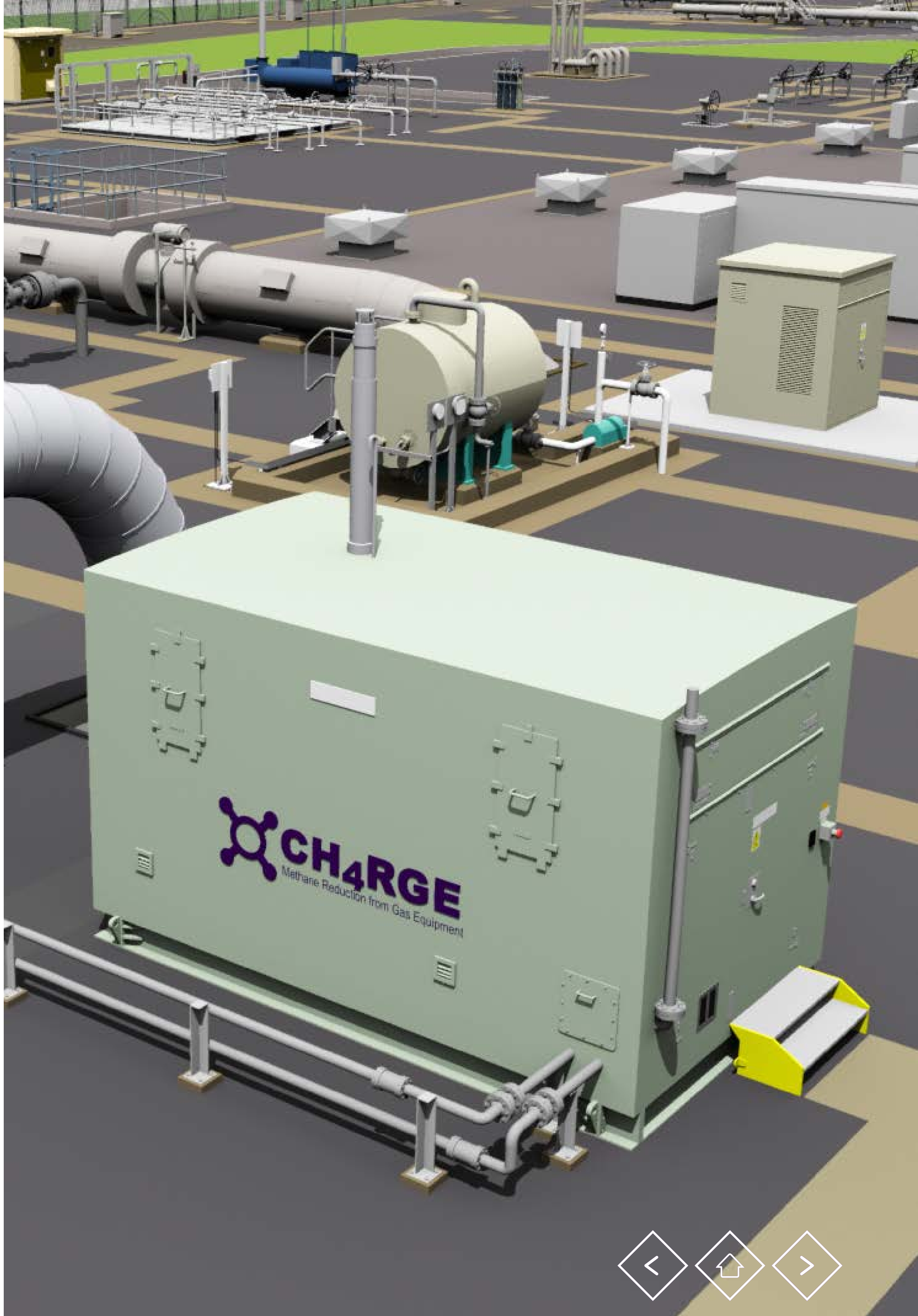
Across the National Transmission System (NTS), gas losses occur for various reasons, including planned and emergency venting or through unforeseen emissions. These losses are classed as fugitive or venting emissions. This Strategic Innovation Fund (SIF) Discovery project explored the feasibility of different emissions reduction technologies to minimise unplanned gas losses and reduce overall emissions.

Working with Project Environmental Solutions Limited (PESL) and Mott MacDonald, the team evaluated solutions from three original equipment manufacturers, focusing on both technical and environmental factors. The project has allowed us to gain a greater understanding of the different technology options, and how they could be applied to the NTS.

Initially we thought the outcomes of the Discovery project would enable us to choose a solution to take forward to detailed design and potentially a site pilot. However, the varied options and innovative nature of the technologies has meant this isn't possible at this stage.

Following discussions with Ofgem, future phases of Ch4rge will move from innovation funding to the Methane Uncertainty Mechanism Pre-construction and Small Net Zero Projects Re-opener. This funding mechanism will allow us to progress the work further, through a conceptual design phase, into detailed design, construction and commissioning, finally leading to a proof-of-concept trial installation on a live NTS site.

Asset development for risk mitigation



CASE STUDY

HyNTS compression

We are looking into the feasibility of converting the NTS to carry hydrogen, and this project investigates the key challenges associated with the compression of hydrogen and hydrogen blends.

The project has focused on the requirements needed to demonstrate hydrogen compression. It has also considered the technical feasibility of repurposing our existing compression assets and of using the FutureGrid testing facility to demonstrate hydrogen compression.

We carried out net zero modelling, looking at the NTS and the potential compression requirements for a future, repurposed network. The model worked on the assumption that hydrogen demand in the future will be less than the demand for natural gas today due to the electrification of some sectors. The model also used current NTS physical attributes such as operating pressures.

The project also included a high-level assessment of the effect of hydrogen on two compressor units and their drive system, as well as a feasibility assessment for carrying out a hydrogen compression demonstration at the FutureGrid facility.

We had previously assumed that compressor stations would require replacement. However, the project has shown there is potential to repurpose a gas turbine with 100% hydrogen and a compressor for hydrogen blends up to 50%.

We've now applied for the next phase of the SIF process – the Alpha phase – to continue our research into hydrogen compression. If our application is successful, we'll consider future hydrogen demand scenarios and the associated requirement for compression, as well as hydrogen production options and the required interactions between the gas and electricity networks.

Asset development for risk mitigation

Automation and measurement

Automation and measurement focuses on all sensing systems within the gas network, as well as assessment methodologies, such as the use of pipeline inspection gauges and robotic assessments.

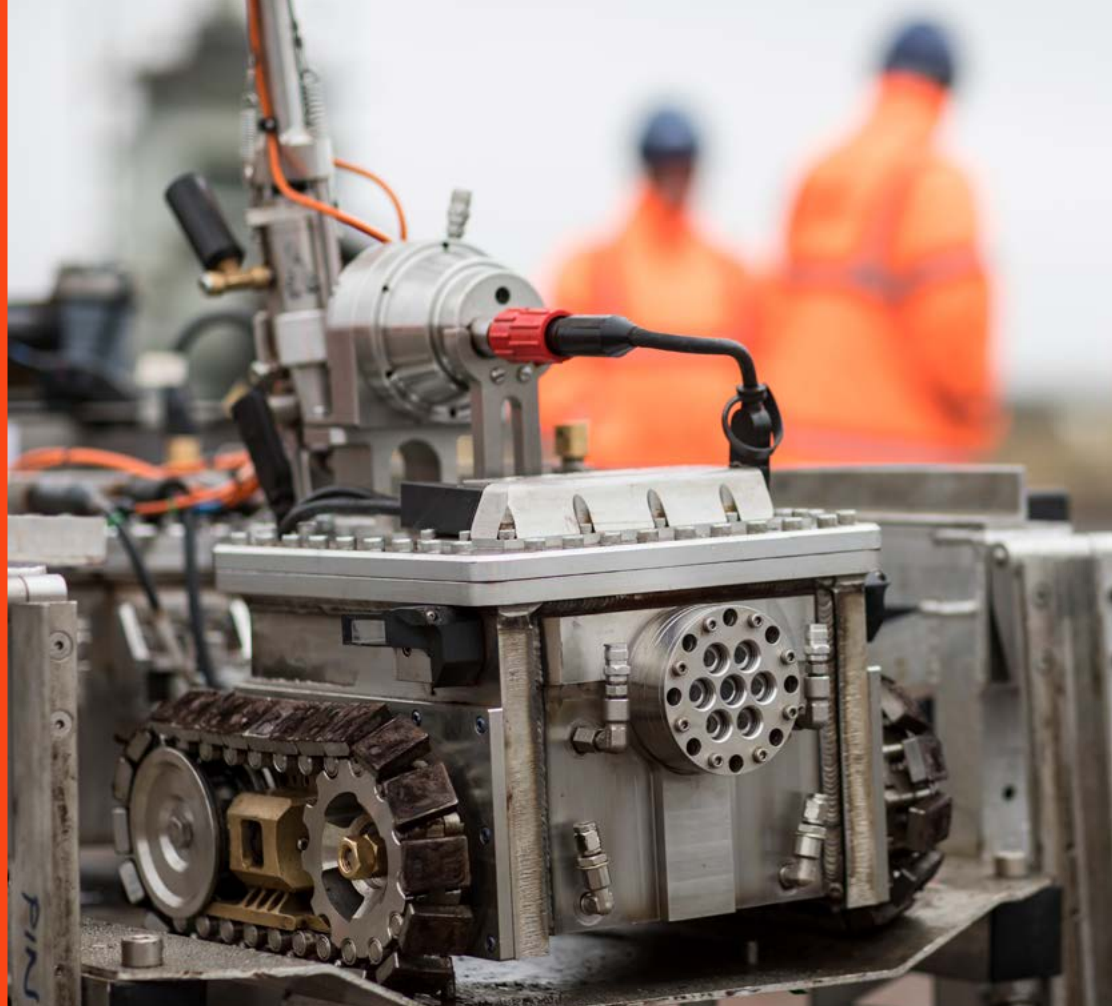
This innovation portfolio supports the roll-out and use of the GRAID (gas robotic agile inspection device) system developed in RIIO-1, looking to further develop this capability with improved autonomy and sensing.

Case studies

- **HyDew – Review of the impact of hydrogen on dew points**
- **Hydrogen metering**
- **HyNTS pipeline dataset**
- **Gas analyser systems for hydrogen blends**

Other projects

- **Precision thermography for pipeline inspection**
- **HyNTS 100% hydrogen metering system**



Peter Martin
Technology Lead – Automation

"The introduction of hydrogen into our network, in its pure form or blended with natural gas, alters the physical characteristics of the gas transported in our pipelines. Traditional technologies in use on the NTS do not have the required capability to measure or sense new hydrogen blends. Therefore, innovation is required in automation and measurement, to allow us to manage a hydrogen network safely and efficiently."

CASE STUDY

HyDew – Review of the impact of hydrogen on dew points

The HyDew project is a desktop study looking at the theoretical impact that different hydrogen blends could have on the hydrocarbon dew point and water dew point within conventional gas mixtures.

Hydrocarbons are the primary constituents of petroleum and natural gas and comprise carbon and hydrogen. The hydrocarbon dew point is the pressure and temperature points where these hydrocarbons condense into liquid form within the natural gas mixture. The water dew point is the pressure and temperature points where water vapour present in the natural gas mixture will condense out of the gas.

We check the hydrocarbon dew point and water dew point when natural gas enters the National Transmission System (NTS). This is because the presence of these liquids can cause damage to our assets, as well as downstream customer equipment. While this can be calculated for natural gas, no such calculation exists for natural gas and hydrogen blends.

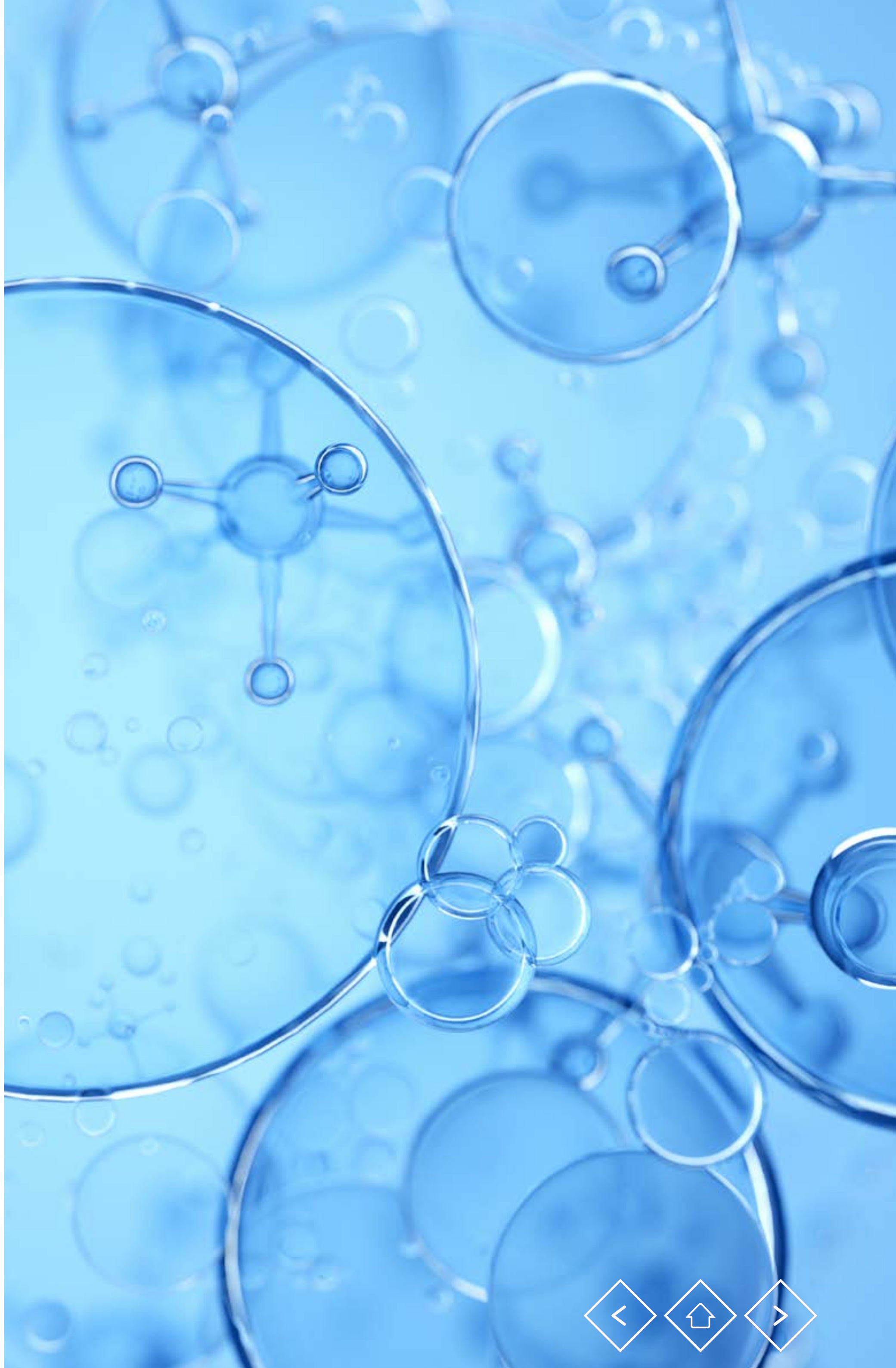
Natural gas is a complex mixture of many chemical species, and the hydrocarbon dew point is highly sensitive to a range of factors within the gas mixture. The addition of hydrogen to the natural gas mix will affect the overall gas composition, changing the dew point.

This study included a comprehensive literature review, which found that there have been limited studies looking at the impact of hydrogen on dew points for natural gas and hydrocarbon mixtures.

The study also investigated the different equations of state – the relation between the pressure, temperature and volume of a gas or liquid – so we could understand the potential error of measurement by introducing hydrogen blends.

The results obtained from the study show that the addition of up to 20% hydrogen and natural gas doesn't significantly affect the hydrocarbon dew point or the water dew point.

Automation and measurement



CASE STUDY

Hydrogen metering

Gas Transmission & Metering is looking for ways to make sure its portfolio of metering installations can be repurposed to measure hydrogen for accurate consumer billing.

This project has examined the feasibility of building metering installations at DNV's Spadeadam Testing and Research facility, to replicate existing metering systems on the gas network – including transmission, distribution and end consumer metering.

We analysed the hydrogen compatibility of over 30 industry standards relating to the design and operation of metering systems, as part of an in-depth review.

Alongside this, the project developed a functional specification and high-level scope for a series of tests to determine what systems could be built at Spadeadam to help identify the most appropriate and cost-effective metering systems for different hydrogen use cases.

The project has identified that there is increased development of hydrogen compatible equipment amongst manufacturers, indicating potential positive coverage of metering equipment that could work on a hydrogen network, but there are gaps in the industry standards for hydrogen compatibility.

During the project, we engaged more than 45 stakeholders from across 23 organisations, including the Department for Business, Energy and Industrial Strategy (BEIS) and Ofgem, as well as energy suppliers, energy transporters, equipment manufacturers, start-ups and energy consultants, to learn more about their position on hydrogen metering.

We found there is strong support for the project, and stakeholders are supportive of ancillary equipment (such as gas analysis assets) being included in future projects. Consumers were also clear that we need improved energy measurements across the network to support consumer bills.

We've now applied for the next phase of the SIF process. This is a joint application that has been combined with another Discovery project looking at gas analysis equipment. Combining these projects allows for a more holistic view of measurement equipment for a hydrogen future.

The project will look at critical data outputs of measurements across the end-to-end gas transportation system This could identify new ways of measuring hydrogen when it is introduced to the network.

Automation and measurement

CASE STUDY

HyNTS pipeline dataset

This project involved examining opportunities to accelerate the pipeline assessments that would be required for a transition to hydrogen, including the use of machine learning (ML) and artificial intelligence (AI). Alongside this, we also considered which datasets we would need to make important decisions about our pipeline assets.

The project included a desktop study to determine the feasibility of carrying out hydrogen pipeline assessments and reviewing all possible methods of gathering the data we'd need.

The datasets for a hydrogen network need to be much more detailed, due to the physical characteristics of hydrogen. The NTS was designed to maintain strength while transporting methane – a relatively inert gas which doesn't undergo chemical reactions when it encounters the pipeline steel. Hydrogen on the other hand is known to permeate steel and other materials much more easily, leading to embrittlement and a potential weakening of the pipeline.

We found that we could gather additional pipeline integrity data by using existing inspection methods, such as in-line inspection (ILI) tools, while using a novel data management system could accelerate pipeline assessments and future proof our asset infrastructure.

Manually assessing our pipelines using records is currently a slow and difficult process, with the data available in a variety of digital and physical sources. As we transition our network, we will need to convert all our data to a digital format, so that it can be used for future pipeline activities.

Following this Discovery phase project, we have applied for the next phase of Strategic Innovation Fund (SIF) funding – the Alpha phase. This follow-up project will determine the detailed design required for the data management system and demonstrate the opportunities to fill the gaps in the current datasets by utilising information gathered with ILI tools.

Automation and measurement

CASE STUDY

Gas analyser systems for hydrogen blends

Gas analysers are used to measure gas quality data. Currently there is limited available technology that can analyse natural gas and hydrogen blends within a fast response time. As we transition our network to carry hydrogen, varying customer requirements mean that blends of hydrogen are likely to be needed. This means there is a requirement for greater flexibility and quicker response times in gas analyser technology.

This project seeks to build on work by Loughborough University and Des19ncor Limited, who developed a fuel cell-based gas sensor (FCS) that may be suitable for analysing various natural gas and hydrogen blends.

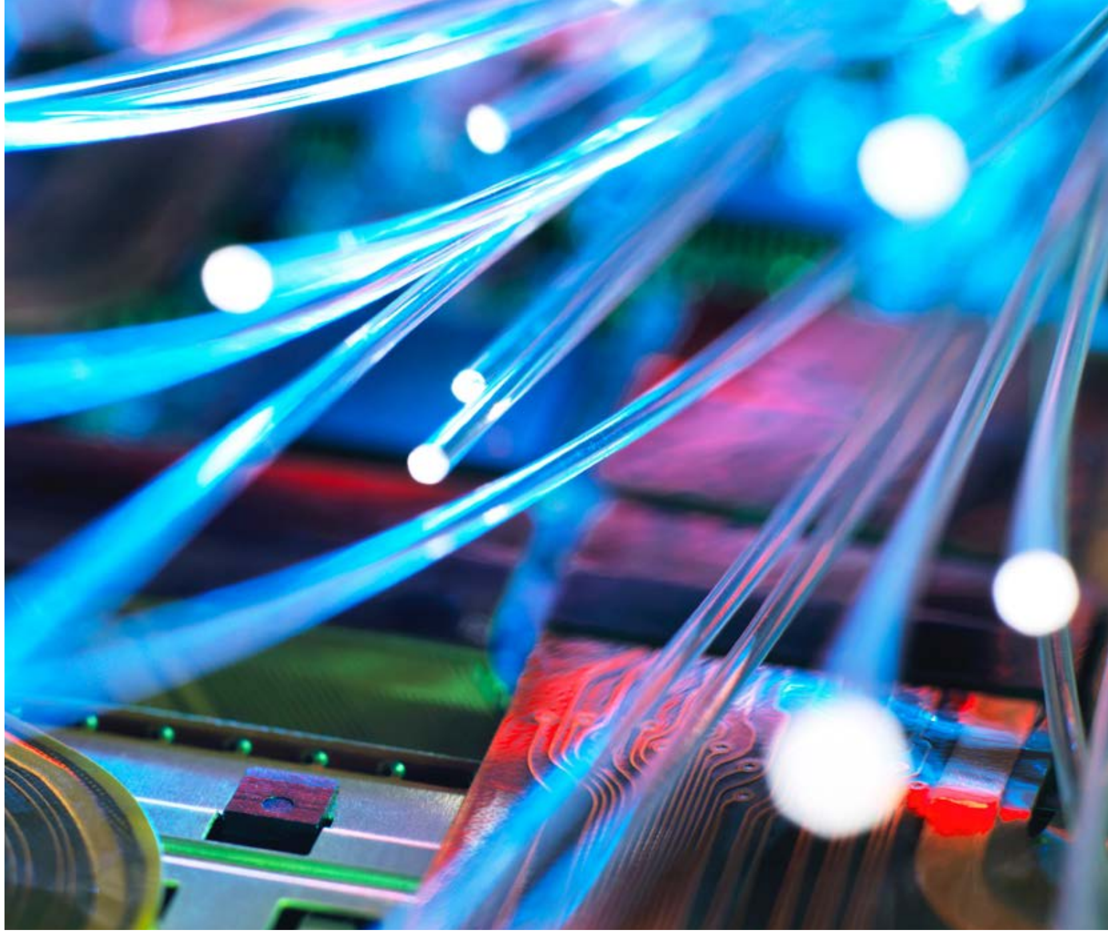
Specifically, we've looked at determining the technology's feasibility and capability when compared to other systems on the market.

Throughout the project, we have developed use cases for the technology, which were agreed in workshops that we held with Cadent Gas. We also conducted stakeholder engagement with other sensor manufacturers, such as Bohr Limited, Emersons and H2 Scan, to determine the alignment of the FCS technology with other market systems.

We determined that the gas industry has no single sensing device that is Internet of Things (IOT) networked, and that can economically measure mixed natural gas, biofuels, and hydrogen gases.

We also found that it's feasible for the FCS to measure all these gas types cost effectively and in near real-time, to provide calorific value (CV) data. It can also measure quality control information such as the relative density and interchangeability between the gases.

A key decision early in the product development phase was to make the FCS a modular design, where different gas sensing elements can be added as required. Through this project, we have found that this approach will see significant cost savings for the gas industry.



Following the conclusion of this Discovery project, we've applied for the next phase of the SIF process. It's become clear that blended hydrogen metering will need to link to local gas analysers, so we've submitted a joint application linking this research with the outcomes of the hydrogen metering project. This is looking to develop a hydrogen measurement system that may enable the repurposing of the network to carry hydrogen, and deliver a more cost effective, data led system.

Automation and measurement

Digital systems and simulation

Digital systems and simulation links with automation and measurement to develop Internet of Things (IOT) solutions that provide real insights for our core gas transmission teams. It looks at future options for digital twin solutions and using machine learning (ML) and artificial intelligence (AI).

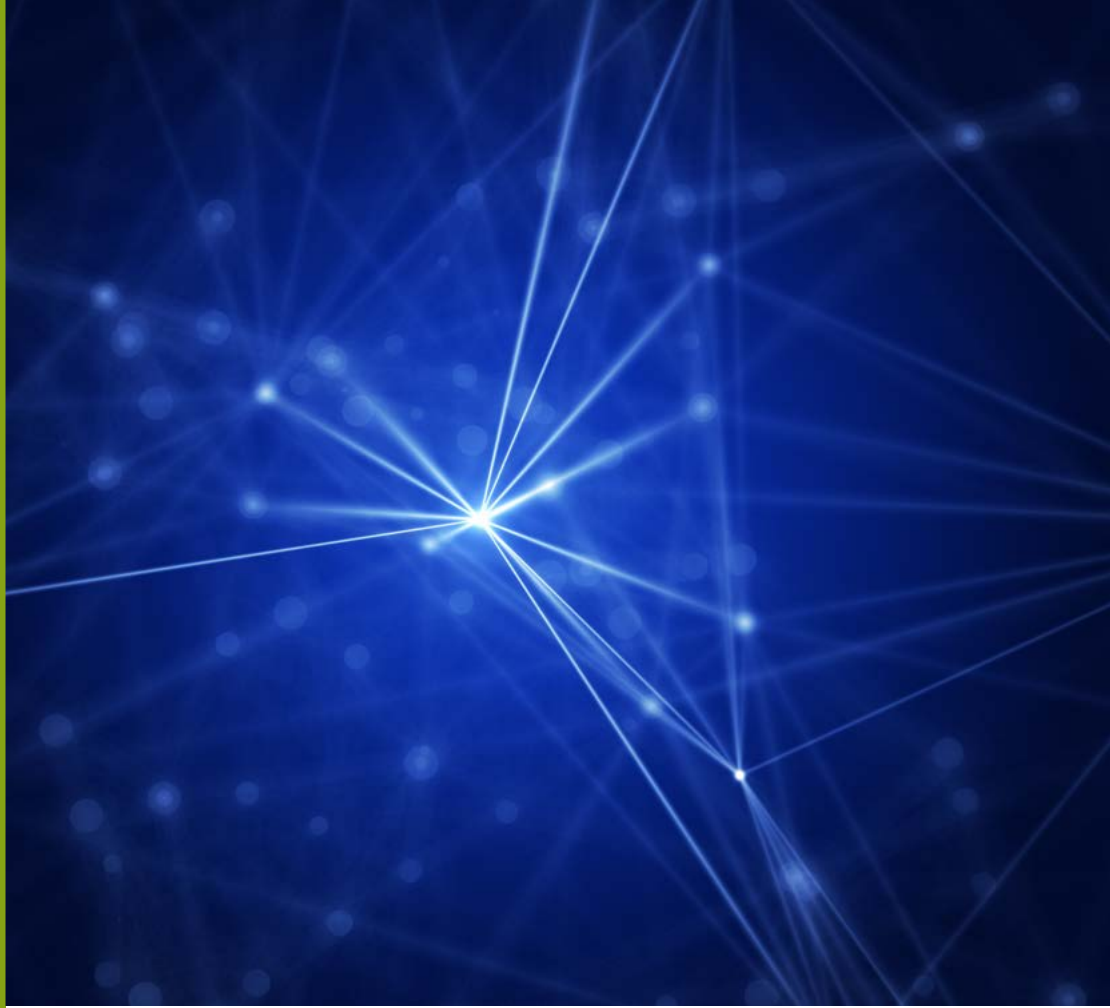
Our innovation technology portfolio lead works closely with our internal data management and IT teams to find innovative solutions to managing and improving our asset data.

Case studies

- **Collaborative visual data twin (CVDT)**
- **Gas network interoperable digital twin**

Other projects

- **New pipeline AI route planning**
- **5G: The art of the possible**



Sabia Sadiya
Technology Lead – Digital

"Digital systems will play a massive part in the energy transition, with complexity of the network increasing with the introduction of net zero gases. It is vital that we ensure we have novel tools to access and manage our data and the gas network. Interoperability with other energy networks and providers will be key to ensuring a robust, reliable network."

CASE STUDY

Collaborative visual data twin (CVDT)

To meet our net zero targets by 2050, we're carrying out several different innovation projects to explore the feasibility of converting the National Transmission System (NTS) to transport hydrogen.

Earlier this year, we started our collaborative visual data twin (CVDT) project, working with DNV, Premtech, Centre for Modelling and Simulation (CFMS) and Durham University. Using Network Innovation Allowance (NIA) funding, this 12-month project looks to develop a robust low-cost solution for combining virtual twins and data twins into one robust digital twin.

A digital twin is a virtual representation of a system that covers its whole lifecycle. It's updated using real-time data and uses simulation and machine learning to help with decision-making.

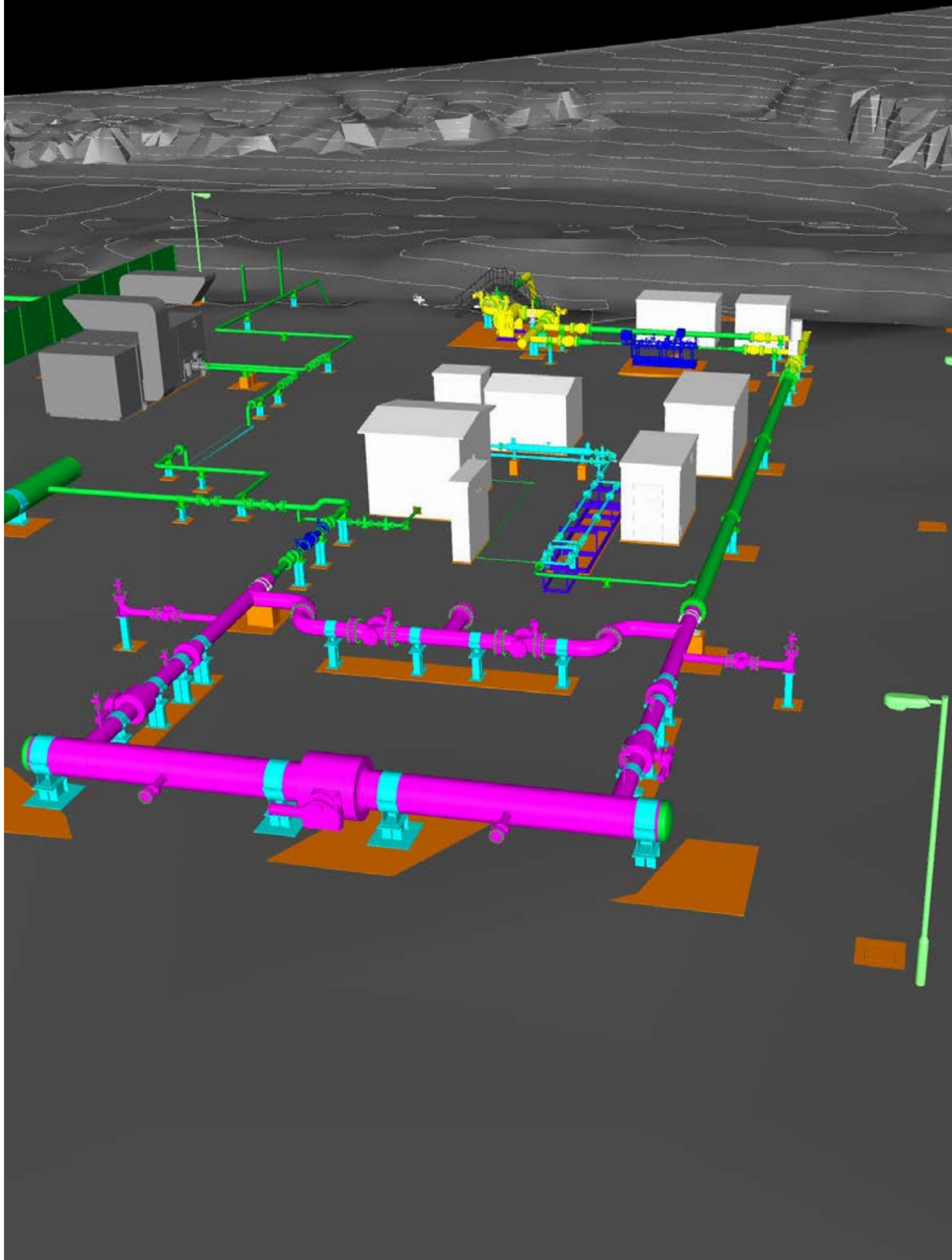
The FutureGrid Phase One project involves the construction of a hydrogen test facility at DNV's research centre in Spadeadam, Cumbria. This will be used to carry out tests across various blends of hydrogen up to 100%, to understand the effects. To fully understand the impact that introducing hydrogen will have on our traditional gas assets, a virtual and data twin will be required.

The FutureGrid programme provides the perfect opportunity to explore how virtual technologies can improve our understanding of the network and how it needs to develop to deliver hydrogen reliably and safely to our customers. Therefore, the FutureGrid facility will be used to develop and test the initial digital twin model.

The virtual twin standards and systems were developed through an earlier project carried out in RIIO-1 (our last price control period) and are in use across our sites today. The data twin is currently in development and will be further advanced throughout the CVDT project, to enable its link to the virtual twin.

Digital systems and simulation

Read more



CASE STUDY

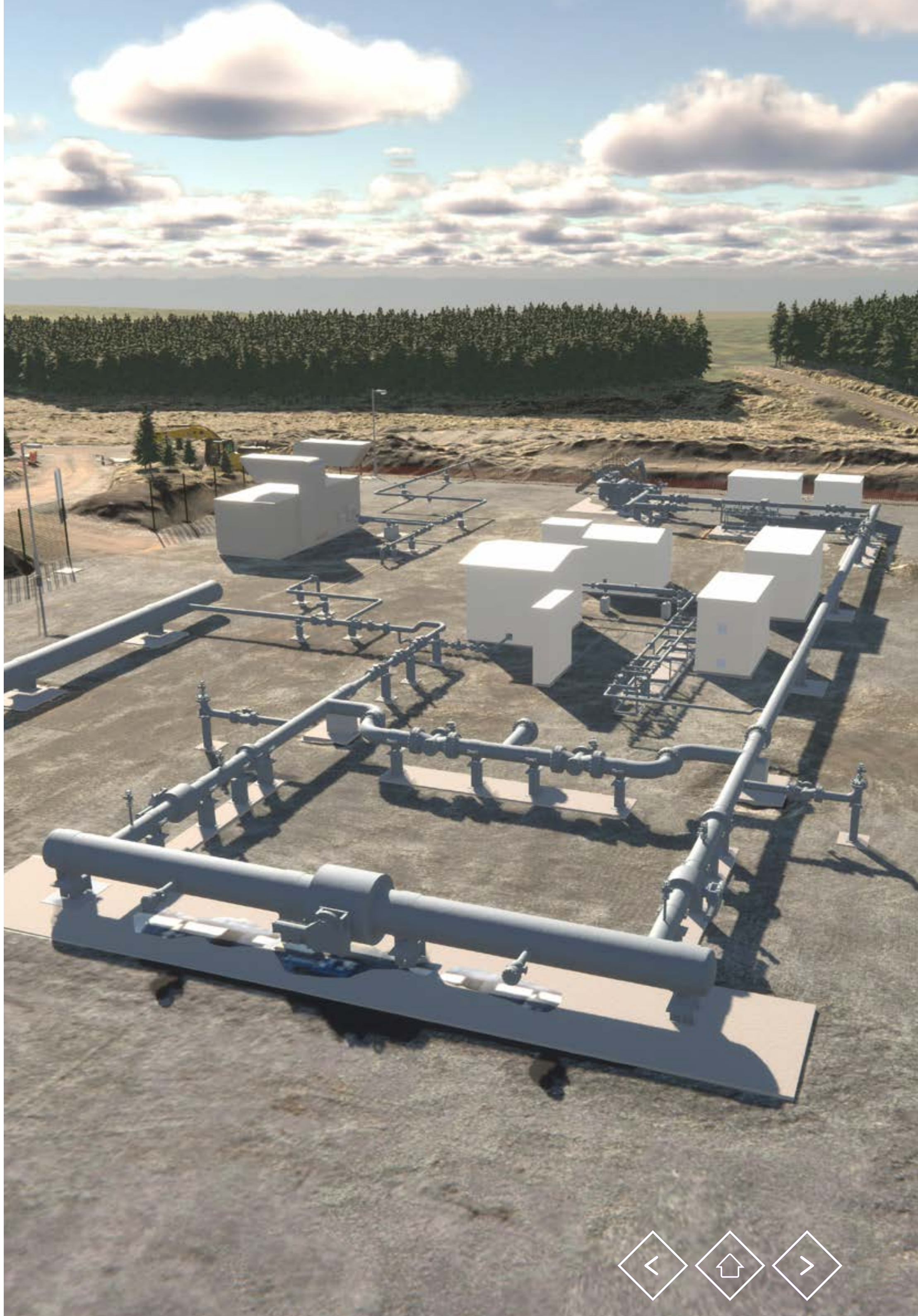
The combination of these two sets of twins (to create one digital twin) will be key to enabling easy access and greater understanding of the large datasets seen in both today's gas network and the network of the future.

The complexity of monitoring and sensoring systems will dramatically increase as we transition to mixed blends of hydrogen and methane – a necessity in the early stages of the transition, as customers will have different requirements around how much hydrogen they can use. This will make managing the NTS more complicated and will mean we are reliant on live, accurate data systems to help us operate the network appropriately.

The CVDT project will help us make more robust asset management decisions. It will also allow us to make predictions on future scenarios and conduct risk analysis using improved analytics, through structured and linked datasets.

The project will provide additional benefits such as a visual 3D representation of the FutureGrid facility and associated activities. This is currently in development, with drone footage and scanning technology being used to survey the FutureGrid facility and create a virtual twin. Alongside this, the project will also provide training and development opportunities on both digital technologies, as well as hydrogen related pipeline management.

"The FutureGrid programme provides the perfect opportunity to explore how virtual technologies can improve our understanding of the network and how it needs to develop to deliver hydrogen reliably and safely to our customers."



CASE STUDY

Gas network interoperable digital twin

As we work towards a net zero energy system, there's a need to better understand how digital technologies can support the transition. One way to enable access to live and historic datasets is by using digital twins – a virtual representation of physical assets, processes, and data exchanges with business systems creating a 'digital knowledge repository'.

This project looked to understand the requirement for interoperability between the gas network digital systems and digital twins currently in development – linked closely with other digital twin projects being led by SGN and the Electricity System Operator (ESO).

We documented key use cases for the gas industry, as well as best practice standards for digital twin interoperability, and technical approaches for future work. We've engaged stakeholders whose input has helped shape the project's scope. We've also examined data and information exchanges between operational systems and processes within GasTransmission, as well as the respective interfaces within two Gas Distribution Networks: SGN and Northern Gas Networks.

The project has identified the need to further explore relevant in-depth processes, so we can increase our understanding of how each system interacts. We expect to consider further use cases involving additional stakeholders.

While the technical report developed as part of this project has already cited case studies from other industries and companies, such as HS2, the NHS and Network Rail, we'll need to carry out further research into digital interoperability.

Currently, the project has been paused while the Energy Networks Association (ENA) considers other options for gas and electricity data interoperability. In the meantime, we'll continue to support the SGN and ESO digital twin projects.

Digital systems and simulation

Materials and processing

Materials and processing focuses on solutions to help improve our materials resistance for current and future scenarios, while developing novel techniques to repair our National Transmission System (NTS) assets more efficiently and help extend their lifetime.

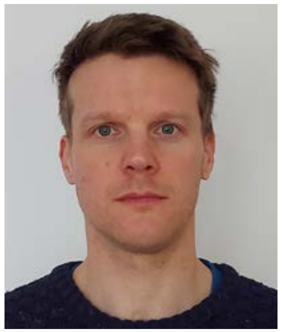
This innovation technology portfolio also explores future materials techniques, such as smart materials, and links with automation and measurement to review automated repair technologies and in-built sensing techniques.

Case studies

- **Multifunctional graphene coatings for pipeline protection**
- **Hydrogen barrier coatings for gas network assets**

Other projects

- **NTS materials testing to enable hydrogen injection in high-pressure pipelines**
- **Inhibition of hydrogen embrittlement effects in steel pipelines**



Rob Best
Technology Lead – Materials

"Innovation is key to understanding the risks associated with re-purposing the existing network for hydrogen and providing mitigation strategies where needed. There are also opportunities to explore the use of new novel materials to improve the operational efficiency of the assets in a hydrogen future."

CASE STUDY

Multifunctional graphene coatings for pipeline protection

Previous research has demonstrated that under certain conditions, exposure to hydrogen can lead to embrittlement in steel and other metals, reducing the life of an asset.

This project, which started in January 2022, is exploring ways to reduce permeation of hydrogen into steel, thereby reducing the risk of embrittlement.

We're doing this because we're looking to re-purpose our gas network, the National Transmission System (NTS), to carry hydrogen – a lower cost, less disruptive way to reach our net zero targets.

The NTS is composed primarily of steel pipes, so we're exploring ways that we could overcome hydrogen embrittlement, making a hydrogen transition possible.

Above-ground installations (AGIs) are susceptible to corrosion due to their exposure to the elements, particularly wet and windy conditions. External coatings and protective paint are used to protect against corrosion. The project is also exploring methods to enhance the protective properties of these paint systems.

Working with Levidian Nanosystems Ltd and Cranfield University, the project comprises three main workstreams:

- Hydrogen embrittlement reduction: exploring whether graphene could be used to coat internal surfaces of the pipe (as a barrier coating) to reduce hydrogen permeation
- Corrosion protection: looking at whether graphene could be added to the protective paint used on the network to minimise corrosion at our AGIs
- Pipeline state sensing: looking at using the conductive properties of graphene to develop "smart" paint systems capable of detecting damaged coatings before corrosion can set in.

We're constructing a rig that will be used to develop and test the application of the graphene barrier coating. We've also been looking into the best formulation of protective paint to specifically enhance the systems already used across the network. Alongside this, we've been considering the coating design needed for the smart paint system.

Next, we'll be seeking to validate the performance of the graphene in all three use cases, as well as exploring methods of application for the coatings. We're also developing the business case to support implementation if the project proves successful.

Using graphene in these ways could help enable us to transition the NTS to carry hydrogen, as well as reducing the risk of corrosion across our network, which would result in more efficient operational maintenance and a greatly improved lifespan for our NTS assets.

Materials and processing

CASE STUDY

Hydrogen barrier coatings for gas network assets

Before we can convert the National Transmission System to hydrogen, we need to understand the impact it will have on our assets. Previous research has shown that hydrogen can lead to embrittlement in certain materials such as steel, reducing the life of the asset.

This project investigated the use of protective barrier coatings to significantly reduce the uptake of hydrogen into the underlying steel, helping maintain material performance. The project also explored alternative pipeline materials, focusing on non-metallics such as polymers or polymer-composites.

For the project, we partnered with Ultima Forma and Warwick Manufacturing Group (WMG).

We determined the barrier coating use cases, considered suitable candidate materials and looked into appropriate deposition methods. We found that:

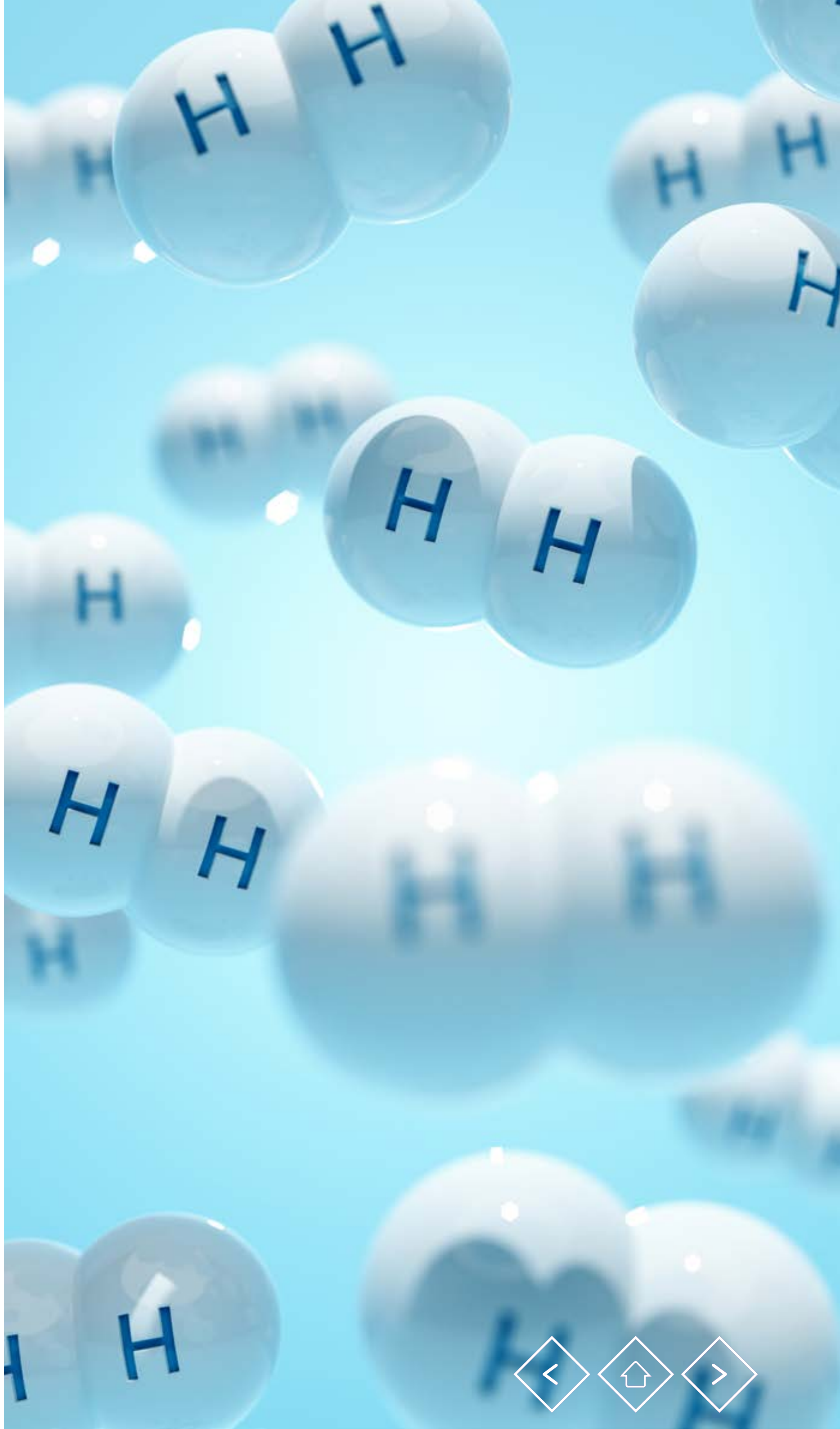
- Filter casings and above and below ground pipework, including the associated girth welds and valves were the highest priority assets and will be the focus of future developments
- The candidate materials zinc, copper, nickel, tin and aluminium, and the deposition technologies electrodeposition and cold spraying were the most promising for hydrogen barrier coatings
- Glass reinforced epoxy pipes and reinforced thermoplastic pipes were the most promising non-metallic pipeline materials.

Alongside these findings, we found that metallic coatings have improved permeation properties over the polymer materials, and the benefits of composite pipes are not as clear cut as we initially thought.

Following the conclusion of the Discovery phase, we have applied for the next phase of the SIF process – the Alpha phase.

If our application is successful, we will validate the coating material deposition methods identified in the Discovery phase and bring in ROSEN as a project partner to conduct a feasibility study on in-situ application methods.

Materials and processing



Business development

Business development focuses on the operation of the National Transmission System (NTS) and builds an understanding of how this may evolve with market changes through the energy transition.

This innovation technology portfolio considers the skills and competencies required for the transition, and how we best support industry and transport in the UK.

Case studies

- **Hydrogen deblending feasibility phase two**
- **HyNTS deblending**
- **Green hydrogen injection into the NTS**
- **Nuclear net zero opportunities**

Other projects

- **Gas and Electricity Transmission infrastructure outlook**
- **Hydrogen Grid R&D programme – assessment methodologies**

Helen Dugdale
Technology Lead –
Business Development

"Innovation creates change by extending the capability of technology and developing new applications. In turn, this technical advancement drives the need for innovation in supporting frameworks, such as the development of an appropriately skilled workforce and creates the opportunity to seek out potential new business relationships."

CASE STUDY

Hydrogen deblending feasibility phase two

This project supports the work we're doing to explore the role hydrogen could play in the future gas network.

One of the challenges faced by the gas industry is how we transport low-cost hydrogen across the UK to help meet customer requirements. One way we propose to do this, is via the existing National Transmission System (NTS).

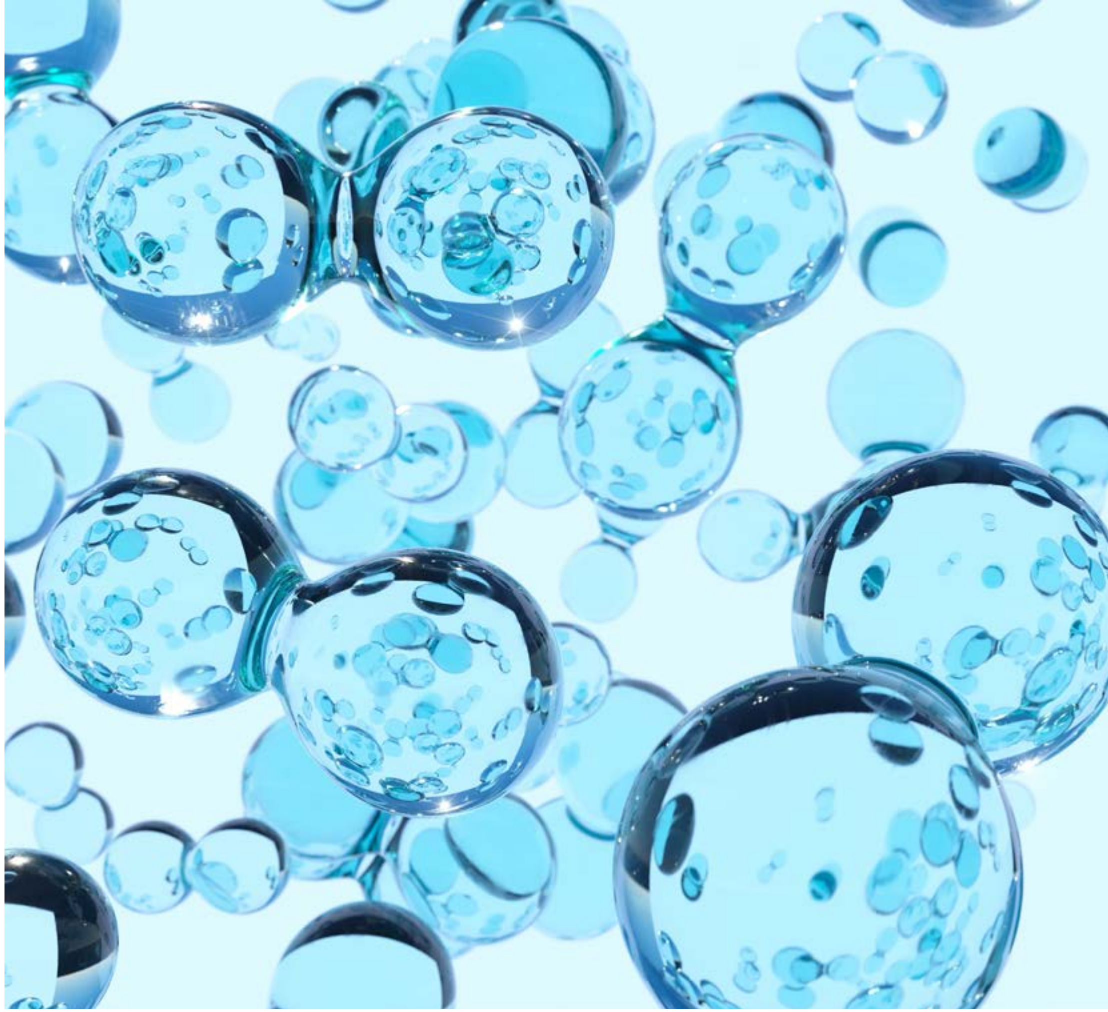
During the transition period between now and 2050, varying customer requirements mean it's likely that different blends of hydrogen and natural gas will be needed. We are looking at the feasibility of transporting mixed hydrogen and methane blends using our network, and then 'deblending' them at scale, on a regional basis.

The project takes our existing understanding of the deblending concept (gathered during previous project phases) and builds on this, focusing on four workstreams; three looking at engineering and one looking at market frameworks.

The engineering workstreams focus on:

- Summarising the most likely locations for deblending technology and understanding the challenges of installing gas separation technology at gas offtakes across the network
- Developing the high-level design of a demonstration scale deblending facility to be constructed at the FutureGrid hydrogen testing facility in Spadeadam, Cumbria. This also involves working with original equipment manufacturers (OEMs) to fully understand the associated costs
- Looking into emerging and future concepts that could disrupt the existing gas separation marketplace.

The market frameworks workstream is considering the key unresolved questions concerning the use of deblending technology on the gas networks, including cost, connections, capacity, balancing, charging, gas quality and system operation.



If deblending is proven to be technically and economically feasible, the concept could provide a credible pathway to achieving the transition from less than 20% hydrogen and methane blends to a fully decarbonised network.

Deblending technology also provides additional options for 'sensitive' customers who will still require 100% methane during the transition phase.

Business development

CASE STUDY

HyNTS deblending

As we transition to a net zero energy system by 2050, varying customer requirements mean it is likely that different blends of natural gas and hydrogen will be needed. This project looked at the feasibility of separating hydrogen and methane gases from within a blended network, to provide customers with gas of a specific composition.

The transport industry will require very pure hydrogen for fuel cell applications, so any impurities and natural gas found in the network will need to be removed before the hydrogen can be supplied to transport customers directly. Following this, the remaining gases could be recompressed and supplied to other users.

This project brought together suppliers from across the end-to-end hydrogen transport refuelling industry, to explore the possibility of creating a mobile deblending facility. This could prove cheaper than the industrial scale gas separation systems that are currently on the market.

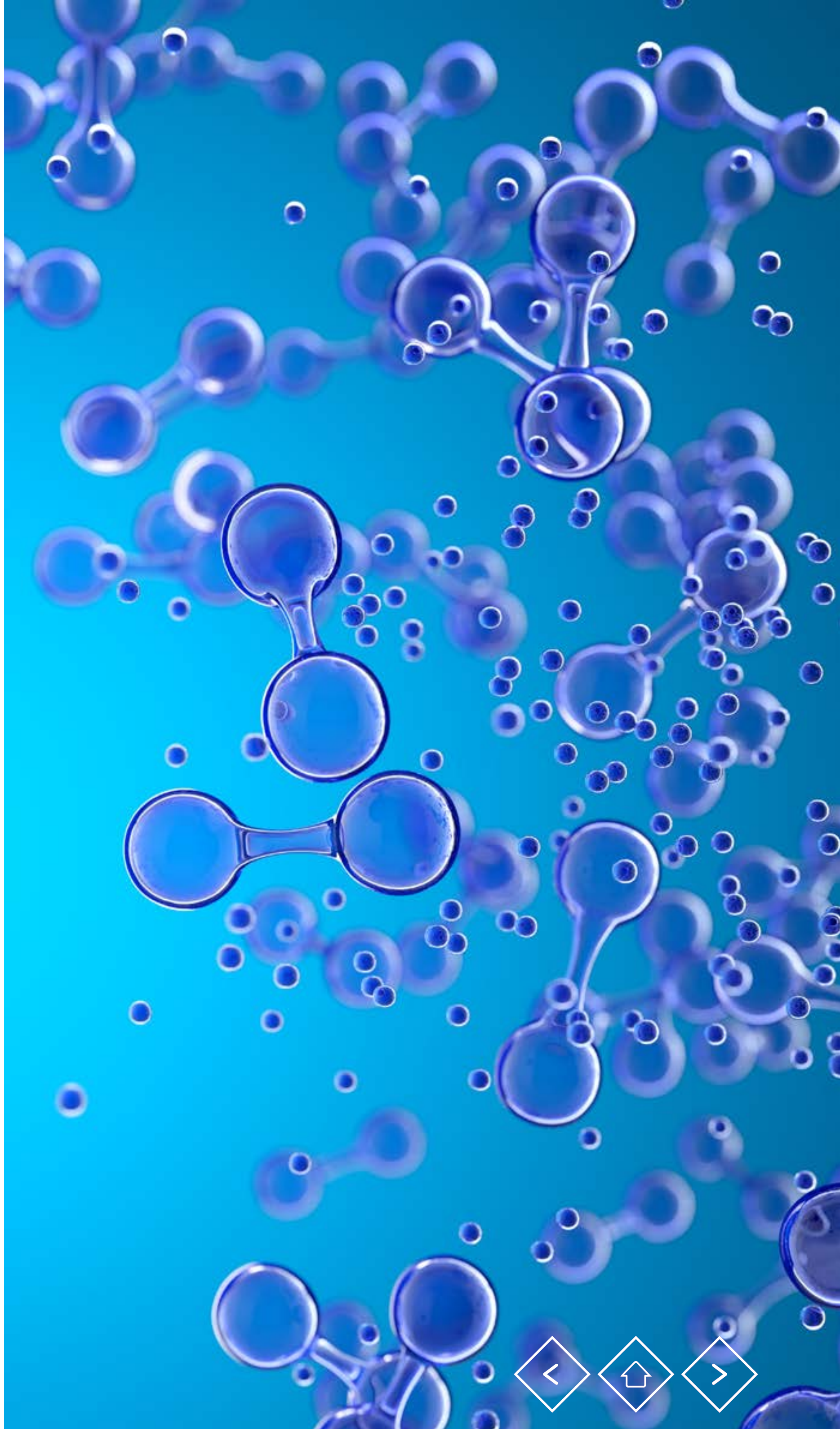
The project findings suggest that hydrogen blending and deblending is a cost-effective method for hydrogen distribution in the transport sector. We also found that polymeric membranes, pressure swing absorption and electrochemical separation technologies could be viable options for a deblending system that meets the necessary technical and functional specifications.

A more in-depth study on the proposed electrochemical separation equipment found that it can provide the required hydrogen purities, with flexible variation in input hydrogen blends and gas flow rates. It can also control hydrogen blend rates to supply customers who require very precise blends.

While gas separation and purification are not new concepts, this project proposes an innovative new use case, to provide hydrogen as a fuel for the emerging hydrogen transport sector. Through the project, we've been able to develop an installation concept that can be compared to existing fuelling solutions.

Following the project's conclusion, we've submitted an application for a follow up project, as part of the next stage of the SIF process – the Alpha phase. This project looks to continue the detailed design of the deblending system with a relevant original equipment manufacturer.

Business development



CASE STUDY

Green hydrogen injection into the NTS

Currently, there's no formal process for injecting green hydrogen into the NTS, in large part because up until now it has not been required. This partnership project with CNG Services, Element Energy and Centrica has considered the commercial and technical requirements for such a process, as we'll need a new commercial regime and updates to our current standards and procedures.

CNG Services identified an initial technical regime that would be appropriate for a pilot project. They also engaged with manufacturers and experts within the hydrogen industry including GasUnie, who have completed the only project so far to inject green hydrogen into a transmission grid like the NTS, and HyNet who are working on blending hydrogen within the gas distribution grid.

Element Energy conducted an economics exercise with several potential system configurations, including renewable electricity sources of hydrogen generation (wind, solar, batteries) and grid electricity. The models were used to explore the sizing of system components, such as the electrolysers and hydrogen storage.

Centrica focused on the supply of hydrogen to customers via the NTS. One factor required for the success of hydrogen blending is to have a robust mechanism for verifying the origins of the hydrogen. To provide this, Centrica outlined the mechanisms needed to track and trade hydrogen and provided an overview of the verification process for Hydrogen Certificates and associated Green House Gas (GHG) emissions.

Based on this research, we've determined an optimum low-cost option for injecting green hydrogen into the NTS, based on producing it at NTS pressures, which removes the need for separate compression.

However, there is still a long way to go before we can inject hydrogen into the network. It's never been done before, so it's critical that we understand the correct, safe, and optimal process that will allow this to happen. Consequently, we've applied for funding for a follow-up project, as part of the SIF process. This Alpha phase project will continue with detailed design activities to enable a demonstration of this technology, as well as allowing the relevant standards and procedures to be updated.

Business development

CASE STUDY

Nuclear net zero opportunities

Our Nuclear Net Zero Opportunities project looked at potential ways to help consumers decarbonise their activities, notably in heavy industry, residential and transport.

Through the project, we sought to forecast future hydrogen demand and assess where advanced nuclear technologies (ANTs) could be located for cogeneration of hydrogen and electricity. The project considered the technical, societal, economic, policy and regulatory obstacles of connecting ANTs to the National Transmission System (NTS).

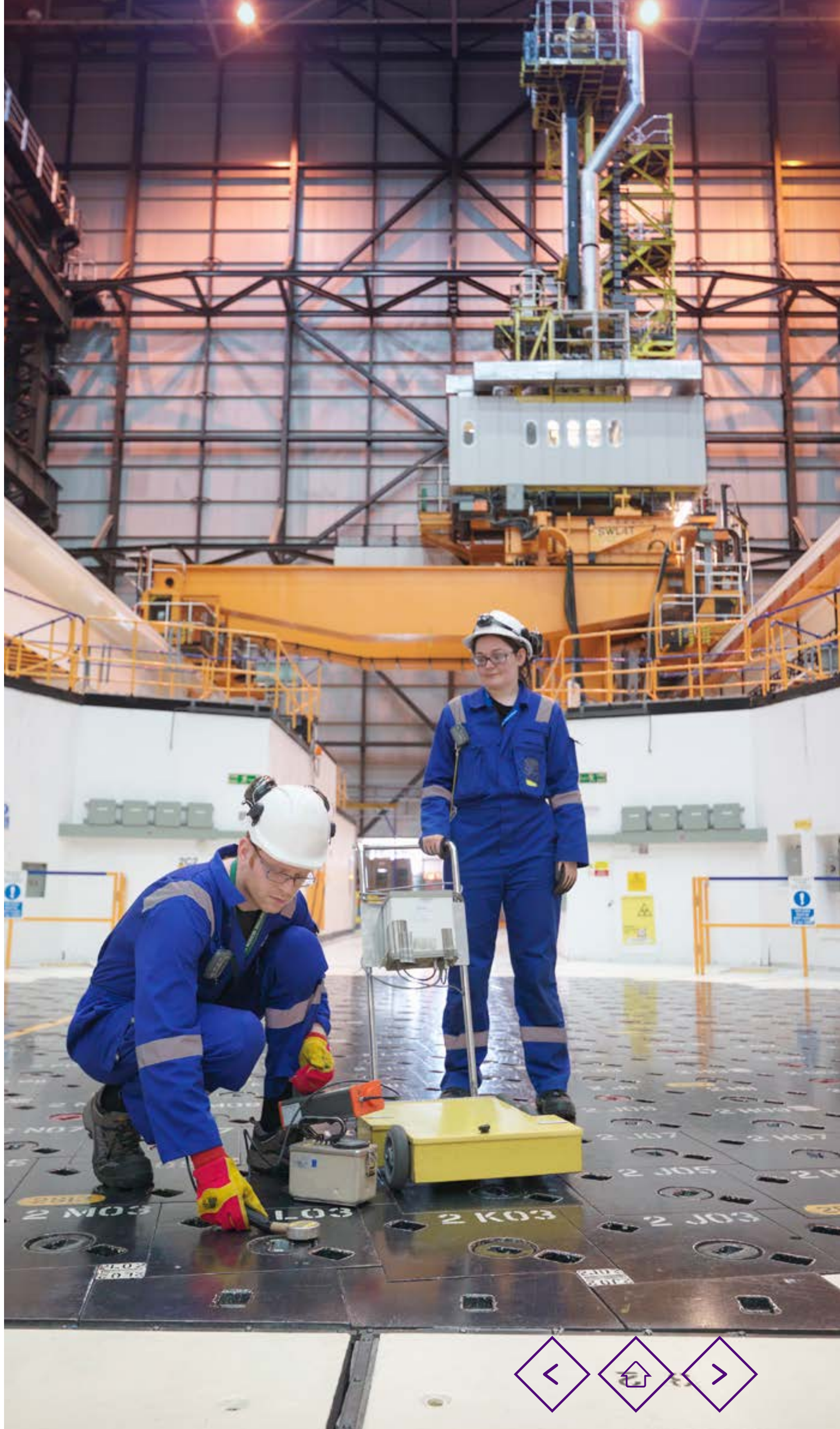
Nuclear power has long been an essential contributor to the UK energy mix. To meet future energy demand, there is the opportunity to design and deploy emerging ANTs to support cogeneration, improving the resilience of both the gas and electricity grids. Outputs from the project can support future policy decisions and help to shape regulatory frameworks. This, in turn, could help with the deployment and integration of ANTs to support the whole energy system.

We undertook stakeholder engagement, a literature survey, and multi-criteria analysis that found:

- Energy intensive industry is suggested to be the first sector to adopt 100% hydrogen. The Teesside, Humberside and Merseyside industrial clusters each have potential ANT sites
- There are no significant siting implications to connecting an ANT to the NTS. The current network has the capability to deal with each of the future demand scenarios
- There are no barriers that completely prohibit nuclear and hydrogen cogeneration sites. We recommended that consultation and collaboration between the relevant regulatory authorities takes place as early as possible, to ensure future amendments are aligned to enable the deployment of these technologies.

Following the conclusion of this project, we've paused work until further research is carried out on modular nuclear reactors. We'll resume work on this project later in the RIIO-2 price control period.

Business development



Click these symbols for more information

FutureGrid: Our NIC project

An ambitious programme building a hydrogen test facility from decommissioned assets at DNV's facility in Cumbria, to demonstrate the National Transmission System (NTS) can transport hydrogen.

Offline Hydrogen Test Facility:
The facility will be commissioned and initially run on 100% natural gas to collect baseline data for the equipment. Blends of hydrogen will then be introduced, starting at a 2% blend of hydrogen to natural gas mix, then moving to 10% and 20%, and finally 100% hydrogen. The facility will have a maximum flow of 1.76 MSm³/day generated by the use of a gas compressor.

ts of rades ioned cility.

2% hydrogen in natural gas

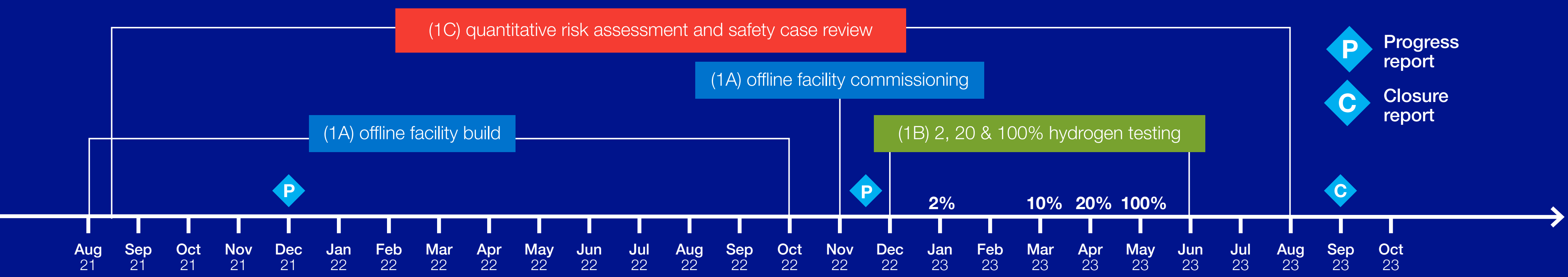
20% hydrogen in natural gas

100% hydrogen

2. Standalone Hydrogen Test Modules

Standalone hydrogen test modules are operating to provide key data required to feed into the main test facility, including:

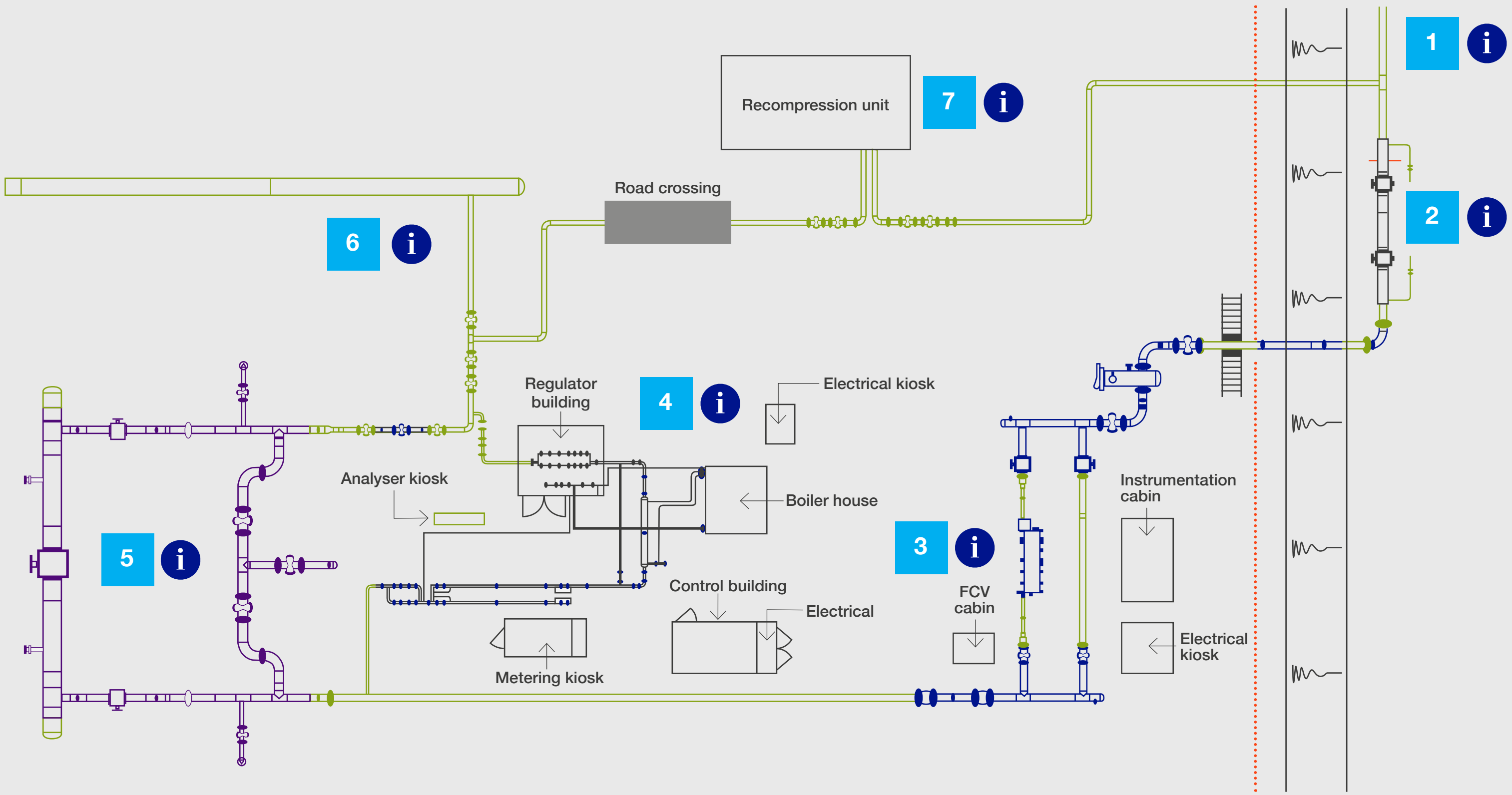
- **Material Permeation Testing**
- **Pipe Coating and CP Testing**
- **Fatigue Testing**
- **Flange Testing**
- **Asset Leak Testing**
- **Rupture Testing**



Our NIC project continued

Click these symbols for more information

FutureGrid: our NIC project



Procedure Review

Hazard Assessment of the NTS (HATS)

Quantitative Risk Assessment (QRA)

Hazardous Area Impact

Overpressure Risk (OR)

NGGT Safety Case: Make recommendations on how the safety case should be updated based on the data generated through FutureGrid.

NGGT Safety Case

DNV HSE Northern Gas Networks fluxys Durham University

Engaging our stakeholders

Communications

We've continued using LinkedIn as the primary channel for our external stakeholders with more regular posts and stories. As a result, we've seen a steady increase in the number of followers over the last year, as well as an increase in engagement scores for most of our posts.

For internal stakeholders, we've increased the frequency at which we publish content to the internal staff newsletter *GT&M News*, as well as attending team conferences and town hall sessions where we've shared information on our team and our role within the Gas Transmission & Metering (GT&M) business. This is something we plan to continue over the next year.

To help keep our stakeholders informed, we decided to revamp the previous *Innovation Insights* newsletter by publishing it as a LinkedIn blog. We've received positive feedback from both internal and external stakeholders about the issues we've published.

One of the main changes to our projects over the past year has been the move from Network Innovation Competition (NIC) funding to Strategic Innovation Fund (SIF) funding for larger-scale projects.

As part of this change, projects are run in phases. The first of these was the 'Discovery' phase, which ended in April 2022.

Engagement for these Discovery projects included a series of project announcements drafted with support from the relevant project suppliers and posted on LinkedIn. Each of these were well-liked by our followers.

Alongside this, our team participated in a series of launch webinars to introduce each of the projects, including what they focused on and what this work would involve. Following the conclusion of these Discovery projects, we also participated in 'show and tell' sessions to share learning and next steps.

FutureGrid Phase One is our remaining NIC project and will conclude in 2023.

The FutureGrid project gives us an opportunity to share information about hydrogen and our journey to net zero. To do so, we have developed four core channels:

- **FutureGrid Explore:** a series of webinars and face-to-face events focused on important topics relating to the FutureGrid project. These interactive sessions allow stakeholders to learn more about the project and participate in relevant discussions
- **FutureGrid InFocus:** a blog series written by those working on the project, providing insights and updates on the progress of the project as it happens
- **FutureGrid Chat:** a podcast series that brings together key experts from around the business and wider industry to talk about some of the big questions in hydrogen and how FutureGrid supports this
- **FutureGrid Feature:** articles that focus on specific topics relating to hydrogen and how our work on FutureGrid plays a vital role.

Events

Events

As with previous years, we attended the Energy Networks Innovation Conference (ENIC) across four days in October 2021. Due to the Covid-19 pandemic, the event was virtual.

It featured online presentations and virtual exhibition stands where we showcased some of our projects and work carried out over the past year.

Our 'agenda presentations' focused on some of our hydrogen research including our Deblending Phase Two project, as well as our work on using hydrogen to power our NTS compressors.

Alongside this, we presented on two of our digital transformation projects; 5G Art of the Possible and i40 Remote Connectivity. We also took the opportunity to discuss our work on Corrosion Modelling and the different phases of our Ch4rge Emissions Reduction project.

We used our exhibition stand to provide people with an overview of Gas Transmission and the National Transmission System (NTS) and to introduce our Innovation Technology Portfolios. We created videos and factsheets on some of our other projects including Mobile Condensate Tank and Removable Composite Transition Pieces (CTP).

The event was very successful, and we received lots of engagement from attendees across the four days. We're now planning the content for this year's event, which has been rebranded as the Energy Innovation Summit. It will be taking place on Wednesday 28 and Thursday 29 September as a face-to-face event in Glasgow.

We also recently held an internal event for members of Gas Transmission & Metering so they could find out more about the hydrogen team, the net-zero challenge and how we plan to respond to this as a business. We also introduced some of our hydrogen innovation projects.

The event included a mix of stalls, presentations and group-working sessions and was well attended, with around 130 people joining us. Feedback from the event was positive. Everyone enjoyed the day and found it beneficial, with people asking us to hold a similar event in future.

As a result, we've decided to hold the event annually and planning for the next one will begin soon.

"Innovation is at the centre of our transition to a hydrogen network and a net zero future. Over the next few years, it's vital that we bring people with us on this journey, and stakeholder engagement is a crucial way of doing this."

Holly Hubbard
Innovation Analyst – Stakeholder

Engaging our stakeholders

Our value tracking

Over the last year, we've begun our RIIO-2 portfolio and further developed our strategy for the remainder of the period.

In closing out RIIO-1 we carried out an assessment of the projects undertaken and have taken on board the learning from both the successful and unsuccessful outcomes.

At the end of the RIIO-1 period, we'd realised £89m of benefits from the projects undertaken. Through the development of our Business-as-Usual (BAU) innovation team, we're continuing to implement and roll out innovations as 'business-as-usual' activities.

The National Transmission System (NTS) has a vital role to play in linking up the whole UK gas energy network and has the potential to transport a variety of decarbonised gases around the country.

We started our journey to a Net Zero NTS in RIIO-1. We're now further developing and demonstrating our capability through the RIIO-2 period.

In RIIO-2, our Network Innovation Allowance (NIA) and Strategic Innovation Fund (SIF) activities are heavily focused on building the case for the NTS to carry hydrogen. The deployment of this is targeted for 2026.

The benefits associated with these innovation projects are unlikely to be seen in the RIIO-2 period but will be tracked robustly through the life of the projects and afterwards into business as usual.

In the period before deployment, we'll collaborate and share our project activities across the UK and wider energy system.

Over the past year, we've continued to embed our Hydrogen NTS innovations within our core business, through subject-matter-expert forums and internal hydrogen conferences.

During this time, we've shared the main technologies we've developed through working groups, conferences and stakeholder sessions. The working groups provide a forum for exchanging knowledge, allow us to seek funding contributions and give us access to a wide range of research and development programmes.

Wherever we can, we aim to provide value across the energy networks by sharing the things we've learnt and collaborating with others.

"Through innovation we can challenge the 'norm' and prepare for a future by identifying different methods. By challenging the existing processes, we can build stronger relationships within our business that will support the net zero target."

Matt Nevin
Innovation Analyst – Governance

Our live projects for 2021/22

For more information on our 2021/22 projects, please use the links below to be taken to the Energy Networks Association (ENA) portal.

Reference	Registered title	ENA Portal Link
NIA_NGGT0179	HGR&D ST assessment methodologies	https://smarter.energynetworks.org/projects/nia_nggt0179/
NIA_NGGT0181	HyDew	https://smarter.energynetworks.org/projects/nia_nggt0181/
NIA_NGGT0170	EPRG (European Pipeline Research Group) 2021 – 2026	https://smarter.energynetworks.org/projects/nia_nggt0170/
NIA_NGGT0172	Risk assessment methodologies for pipelines & AGIs 2021 – 2026	https://smarter.energynetworks.org/projects/nia_nggt0172/
NIA_NGGT0174	Ch4rge – methane reduction from gas equipment phase two	https://smarter.energynetworks.org/projects/nia_nggt0174/
NIA_CAD0073	Common future end states and transition pathways	https://smarter.energynetworks.org/projects/nia_cad0073/
NIA_NGGT0175	5G – The art of the possible	https://smarter.energynetworks.org/projects/nia_nggt0175/
NIA_NGGT0176	Hydrogen fuel gas for NTS compressors	https://smarter.energynetworks.org/projects/nia_nggt0176/
NIA_NGGT0177	Hydrogen deblending feasibility phase two	https://smarter.energynetworks.org/projects/nia_nggt0177/
NIA_NGGT0188	Variable hydrogen blend compression	https://smarter.energynetworks.org/projects/nia_nggt0188/
NIA_CAD0068	Cumbrian Hydrogen vision and pathway – phase 1 feasibility	https://smarter.energynetworks.org/projects/nia_cad0068/
NIA_NGGT0180	NTS materials testing to enable hydrogen injection in high pressure pipelines	https://smarter.energynetworks.org/projects/nia_nggt0180/
NIA_NGGT0182	Multifunctional graphene coatings for pipeline protection	https://smarter.energynetworks.org/projects/nia_nggt0182/
NIA_NGGT0184	Gas and Electricity Transmission infrastructure outlook	https://smarter.energynetworks.org/projects/nia_nggt0184/
NIA_NGGT0183	Inhibition of hydrogen embrittlement effects in pipeline steels	https://smarter.energynetworks.org/projects/nia_nggt0183/
NIA_NGGT0178	Collaborative visual data twin phase one	https://smarter.energynetworks.org/projects/nia_nggt0178/
NIA_NGGT0171	PRCI – Pipeline Research Council International 2021 – 2026	https://smarter.energynetworks.org/projects/nia_nggt0171/

How to get involved

Meet the Hydrogen Innovation Team

Corinna Jones
Head of Hydrogen Innovation

Steve Johnstone
Senior Innovation Specialist

Dave Hardman
Innovation Specialist – Strategy

Matt Nevin
Innovation Analyst (Governance)

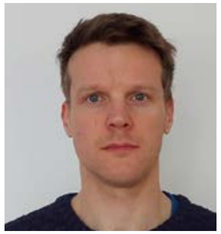
Holly Hubbard
Innovation Analyst (Stakeholder)

Helen Dugdale
Technology Lead – Business Development

Ian Bennett
Innovation Delivery Manager

Lynsey Stevenson
Technology Lead – Asset Development

Sabia Sadiya
Technology Lead – Digital



Robert Best
Technology Lead – Materials

Peter Martin
Technology Lead – Automation

Harriet Guiry
Innovation Graduate

There are a range of funding options available for innovation projects:

Network Innovation Allowance (NIA)
funding is accessible throughout the year to run smaller scale projects. It provides opportunities for innovation programmes to be developed across the gas industry.

The Strategic Innovation Fund (SIF)
is the replacement for the previous Network Innovation Competition (NIC). It's intended to support innovation activities that contribute to the achievement of net zero and deliver real benefits to both network companies and consumers.

We are looking for projects that:

- Accelerate the development of a low carbon energy sector
- Demonstrate customer value
- Directly impact the gas network
- Share learning and intellectual property
- Avoid duplication
- Are innovative – requires a project to demonstrate effectiveness

Get in touch

If you'd like to be added to our mailing list, or have a question or idea you'd like to discuss, just email **box.GT.innovation@nationalgrid.com**

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