# Bacton Energy Hub

Business Opportunity Report prepared by the Bacton Energy Hub Special Interest Groups

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The findings and analysis contained within this Business Opportunity Report have been developed by industry as part of the extensive work undertaken as part of the Bacton Energy Hub Special Interest Groups; the NSTA supports the work to progress the Bacton Energy Hub.

The document can be found on the NSTAs website.



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# Executive Summary

**Bacton is a strategic gas processing hub in the UK and is ideally positioned to become a significant Hydrogen production site to support meaningful decarbonisation of London, the South East and beyond by 2030, whilst enabling long term viability for the terminal and associated infrastructure**

There is an opportunity for a Bacton Hydrogen production hub to be quickly established providing significant contribution to UK Government targets for both Hydrogen production and $CO_2$ capture by 2030. Bacton provides:

- Access to a large gas demand in London and the South East with very little demand side build out required.
- Access to upstream feedstock, with no new upstream development required in the short term.
- Opportunity to abate meaningful amounts of $CO_2$ in the early 2030s. It is recognised that speed of action is critical to achieve Paris aligned carbon reduction pathways.

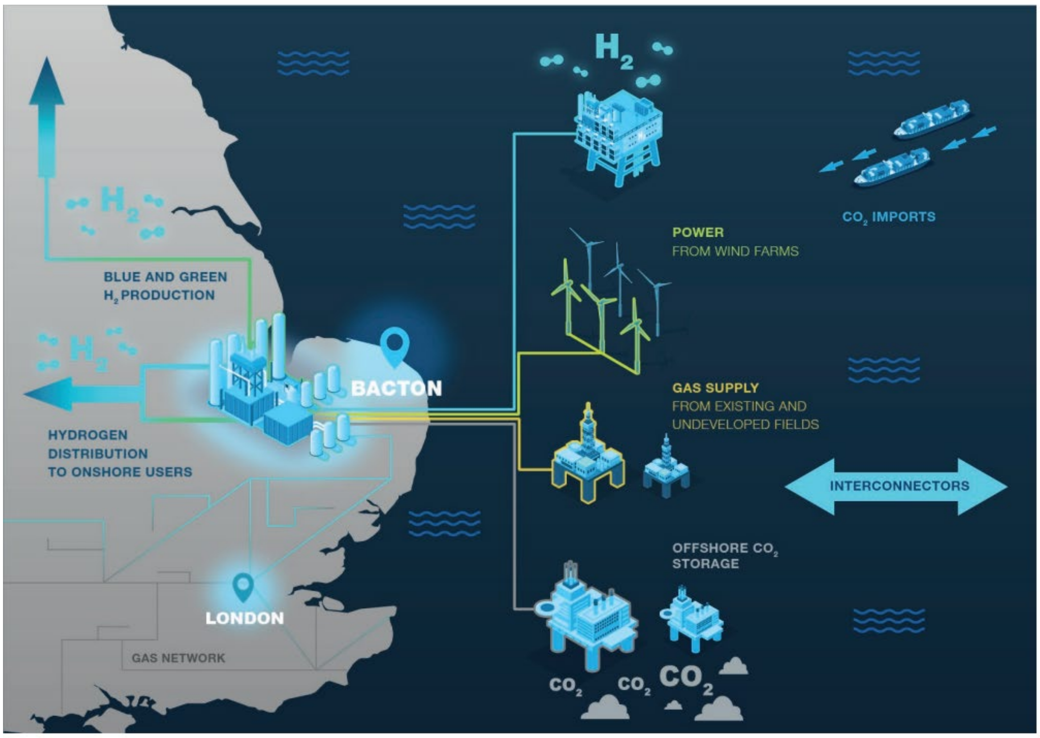


**Figure 1: Bacton Energy Hub (BEH) Overview**

In 2020 the North Sea Transition Authority (NSTA formerly the Oil and Gas Authority 'OGA') recognised that Bacton has the potential to establish itself as a low carbon Hydrogen hub. This would ensure Bacton remains a key regional energy hub, leveraging existing infrastructure and resource in the region. It was recognised that Bacton has several critical advantages:

- Existing gas connections to London, the South East of England and beyond to supply Hydrogen to potential future key demand centres
- Excellent basis for Hydrogen production for both Carbon Capture and Storage (CCS) enabled Hydrogen and electrolytic Hydrogen as well as access to offshore storage
    - CCS Enabled Hydrogen:
        - Access to indigenous and, later, imported natural gas for CCS enabled Hydrogen production,
        - Existing gas processing plants that can be repurposed
        - Availability of offshore structures and pipelines for $CO_2$ sequestration

- Electrolytic Hydrogen
    - Access to offshore wind farm output for electrolytic Hydrogen production
    - Potential availability of offshore storage for Hydrogen at scale
- Local engineering skills and cluster of companies servicing the oil and gas industry that can be transitioned to the Hydrogen economy

The NSTA launched the BEH area plan in June 2021. The NSTA then established five Special Interest Groups (SIGs) to undertake scoping level studies to assess the opportunity to establish a foundation on which a credible project could emerge. This stage of the project aimed to demonstrate a value-add opportunity that can be taken forward by a consortium to deliver a Hydrogen production site and CCS value chain. This represents an opportunity for private entities across the energy sector to invest in a strategic Hydrogen production hub including oil and gas owners, infrastructure investors, offshore wind developers, CCS project developers and the associated supply chain.

This document summarises the key findings from the five SIGs (Demand, Supply, Infrastructure, Regulatory, and Supply Chain and Technology) and outlines the business opportunity that exists for a consortium to take forward the BEH vision. The SIGs were industry led, across the energy sector and included energy companies, supply chain, consultancies and legal firms.

Two scenarios illustrate the opportunity:

- A "Core Project" considering a plant capacity of 355 MW to deliver 3TWh of CCS Enabled Hydrogen production annually by 2030
- A larger "Build Out" project which considers a combination of expansion of the CCS enabled Hydrogen and electrolytic Hydrogen production. The build out project could deliver a plant capacity of up to 9.5 GW Hydrogen production facility by 2050.

These scenarios illustrate the upper and lower bounds of the BEH opportunity and to frame the value proposition. They are not considered to be optimised in terms of size or development pathway. To put these two projects in context, the "Core Project" represents 4% of the UK Government's Hydrogen production target in 2030 of 10 GW.

## Business Opportunity

**The overarching goal for the Bacton Energy Hub is to harness the potential of repurposing infrastructure to lower the cost of Hydrogen transition and establish sustainable Hydrogen systems to ensure Bacton remains a key regional Energy Hub with a low carbon future.**

**Demand – significant potential Hydrogen demand exists that BEH can readily supply through existing pipeline infrastructure**

There is potential for significant Hydrogen demand that the BEH could supply as soon as 2030. It is likely a blend of Hydrogen 20%$_{vol}$ (c. 6.5%$_{energy}$) can be accepted by power stations, industry, and domestic / commercial heating by 2030 increasing to 100% Hydrogen gas feedstock available for all National Transmission System (NTS) connected users by 2040.

Demand will be dominated by domestic heating users from London and the South East. Emerging projects from gas distribution infrastructure owners National Grid and Cadent could provide Hydrogen offtake routes to market to both industry and domestic demand. Project Union, Capital Hydrogen and Hydrogen Valley projects have identified Bacton as a key supplier of Hydrogen.

Annual Hydrogen demand that falls within the appropriate catchment area for Bacton could be as much as 8TWh in 2030 increasing more than tenfold by 2050 to circa 86 TWh. By 2030 a "Core Project" 355 MW CCS enabled Hydrogen project could supply 40% of the 8 TWh projected Hydrogen demand.

With a blended gas grid led demand, demand is not the limiting factor on the BEH production capacity and therefore there is the opportunity for a larger "build out" project to be developed at pace.

Nearly 20% of the UK population lives in London and the South East in the area that could be supplied by Hydrogen produced at Bacton. An energy hub at Bacton has the potential to abate 1.6Mtpa of $CO_2$ emissions in 2030 increasing tenfold to 17MTpa by 2050 by shifting emissions from burning natural gas to a CCS enabled Hydrogen plant. Conversely, waiting for a 100% Hydrogen distribution network or a non-CCS enabled Hydrogen solution has the potential to delay this abatement by as much as 10 years. This would result in circa 16MT $CO_2$ being emitted to atmosphere, equivalent to circa 75% of the 10-Point plan lower objective to remove 20MT by 2030.

**Supply – indigenous UK natural gas can provide base supply for the Core Project. Transition to electrolytic Hydrogen can be realised through connection to offshore wind farms in East of England.**

There are material volumes of undeveloped discoveries within the Bacton Catchment Area (BCA) with total reserves of up to 2Tcf. Analysis has shown reserves growth of producing fields and undeveloped hydrocarbons has the potential to sustain production through Bacton to extend the life of the facility and provide feedstock for CCS enabled Hydrogen production. A CCS enabled Hydrogen plant can potentially facilitate the development of previously undeveloped off-spec natural gas, increasing the accessible gas reserves to produce Hydrogen in the UK to meet energy security needs. Together with the recently launched 33rd licensing round, this opens a new opportunity for development of this type of resource in a manner aligned with net-zero objectives.

The East of England has an abundance of offshore wind potential and by 2030 will have c. 15 GW of capacity, providing almost a third of the UK's offshore wind target. The BEH could provide an alternative route to market for offshore wind developers by adopting a Power to X approach. It is likely that connections to existing offshore substations will be required, given onshore grid constraints surrounding Bacton. Further engagement with offshore wind developers and the Crown Estate is required to establish whether electrolytic Hydrogen production at Bacton could be accelerated.

Water is required for build out of electrolytic Hydrogen. The BEH and Anglian Water are jointly exploring opportunities on how to deliver a supply of potable water for existing domestic demand as well as future electrolytic Hydrogen production.

The combination of natural gas and renewable energy as potential feedstock provides flexibility for the BEH to ramp-up Hydrogen production to satisfy demand.

**Existing infrastructure can be repurposed for a new Hydrogen hub at Bacton**

There is adequate space within the existing BEH complex to accommodate the Core 355MW Plant. Later build out projects would require optimisation of available footprints, which require further investigation, but it is believed this could be achieved.

Existing NTS connections enable Bacton to deliver Hydrogen into the NTS grid network with limited modifications.

Subject to the plans of existing infrastructure owners, there are several offshore pipelines accessible from Bacton that could be re-used for $CO_2$ transportation to $CO_2$ stores, and possible Hydrogen storage that would assist the intermittency of electrolytic Hydrogen from offshore wind farms. The NSTA's CCS licensing round includes a number of areas that are currently connected to Bacton.

Bacton could position itself as both a Hydrogen hub as well as $CO_2$ import terminal, benefiting from connections to Europe via two interconnectors.

**BEH project economics are competitive, and a project could be delivered by 2030**

The Core Project capital requirement is envisaged to be c. £0.5 billion, representing an opportunity for investment in the region whilst transitioning skills to deliver a large-scale Hydrogen enabled project.

The Core Project, which is exclusively CCS enabled Hydrogen production, has an anticipatory Base Case Levelised Cost of Hydrogen (LCoH) of £65/MWh. This is comparable with BEIS Hydrogen Production cost modelling and demonstrates the competitiveness of the BEH as a potential Hydrogen hub. The LCoH is primarily influenced by feed gas price and capital cost.

In a Base Case scenario, the Core Project could be delivered by 2030. This requires a consortium to be formed in H1 2023 with the project reaching FID by Q3 2025. This would require certainty on the ability to blend Hydrogen into the gas network, which is currently scheduled for review in 2026, or an alternative offtaker being secured.

The Build Out project economics will depend on the level of investment and for learning curves to be realised in electrolysers. This could deliver further competitively priced Hydrogen, with potential private wire connections to existing and future dedicated offshore wind farms.

**An initial bankability assessment indicated that no red flags were identified, and the BEH has the potential to raise project finance in the future, depending on the final commercial structure, and the technical and other features of the project.**

Societe Generale, a leading energy project finance bank, undertook an initial bankability assessment for the BEH. Based on the information reviewed and recognising the early stage of development of the project[1], the initial conclusion of this work was that the project has the potential to raise project finance in the future depending on the final commercial structure, technical and other features of the project. The assessment did identify a number of material risks, including leakage of CO2 and the potential for assets financed to become stranded at some point (i.e., the failure of one part of the project that prevents them performing as a whole), but these types of risks are common to other similar CCS projects. At this stage no red flags were identified that Societe Generale believed could not be resolved during detailed design, development and the financing process but a more detailed and ongoing assessment of bankability would be required as the project matures. Indeed, some of the material risks identified could be resolved during the ongoing discussions between government and the industry around the CCS and Hydrogen Business Models, and BEH would benefit from the results of these discussions. From a commercial perspective, BEH would need to operate under both the CCS and Hydrogen business models, which are still being negotiated with no certainty on outcome or whether they will be fully applicable to the BEH.

Other bankability risks identified include areas like technology, contracting/supply chain challenges, cross chain risks, impact of outages, third party access, insurability and the rights and obligations associated with the interaction between the assets and the wider Bacton operations. BEH is a highly integrated energy project, so an early and continuous engagement with the finance community on these and other risks will be key to ensure that bankability considerations are reflected in the commercial and technical arrangements being negotiated with all stakeholders, including contractors and government. This early engagement will also be critical to ensure the banks are informed on the project and are clear on the risk allocation and commercial terms to facilitate a financing process when this is launched.

**Regulatory regime requires updates to accommodate Hydrogen, but this is common to all UK Hydrogen projects**

Hydrogen cannot currently be blended into the national gas transmission network. Amendments to the GS(M)R are required to allow blends of Hydrogen, or 100% Hydrogen, to be transported. The current timeline for a decision on Hydrogen blending is expected in 2026, which provides ample time before BEH’s target production date of 2030.

The storage and transport of Hydrogen is currently not covered in any regulatory regime. A common definition of the word ‘’gas’’ in legislation for offshore activity and industrial processes is required.

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[1] *The views of Societe Generale at this stage are preliminary and do not constitute a commitment or recommendation to provide financing for the transaction.*

The current funding landscape for low carbon Hydrogen production presents an opportunity for a more joined up approach. The UK requires a predictable, long term competitive funding framework that will enable Hydrogen to be developed at scale and pace. This has successfully been achieved in the offshore wind sector through the Contracts for Difference (CfD) scheme.

## There are potential supply chain constraints at a UK level, but there is an opportunity for the BEH to support jobs and skills in East Anglia.

The supply chain is critical to BEH and will be needed throughout the life cycle of the repurposed and new assets.

A high level of UK content can be achieved by using existing skills, competency and capability which are transferable from other sectors including oil, gas, chemical and power - that said, resource availability and skills are a major constraint for the energy sector and must be addressed going forward.

Early and appropriately timed supply chain engagement is critical to ensuring optimum market response to support the development, construction, and operation of Bacton.

Technological maturity already exists in terms of the equipment, plant and services that will be needed. The CCUS and Hydrogen technologies which are being developed and deployed globally however will require close attention during the concept development phase to ensure technology developments including readiness are factored into the project's schedule.

Bacton and the wider CCUS and Hydrogen projects represent an opportunity to deliver a paradigm shift in the use of digital and automation, this will be critical to cost effective delivery of major engineering construction projects going forward.

## Next Steps: Momentum is key to realising the potential of the BEH

Maintaining momentum and the timely formation of a consortium is critical to ensuring Bacton maximises the value proposition that has been identified. The NSTA has launched the 33rd offshore oil and gas licensing round within which priority clusters within the SNS have been identified to encourage production as quickly as possible. Recognising the drive to reach net zero greenhouse gas emissions by 2050 alongside the drive for energy security, the BEH presents a strong proposition and viable route for hydrocarbons to become a low carbon fuel. This proposition is further strengthened given the recent NSTA carbon storage licence round which will see the future of carbon storage in the region moving ahead.

The BEH also represents an opportunity for offshore wind developers to supply a future electrolytic Hydrogen plant at Bacton, providing an alternative route to market. Early and continued engagement could facilitate acceleration of electrolytic Hydrogen production at Bacton.

# Abbreviations

| Abbreviation | Description |
|---|---|
| BCA | Bacton Catchment Area |
| BEIS | Business for Energy and Industrial Strategy |
| BEH | Bacton Energy Hub |
| CAPEX | Capital Expenditure |
| CCS | Carbon Capture and Storage |
| CfD | Contracts for Difference |
| CNS | Central North Sea |
| $CO_2$ | Carbon Dioxide |
| CoP | Cessation of Production |
| FEED | Front End Engineering Design |
| FID | Final Investment Decision |
| Ha | Hectare |
| GSMR | Gas Safety Management Regulations |
| GW | Gigawatt |
| GWh | Gigawatt hour |
| LCoH | Levelised Cost of Hydrogen |
| LNG | Liquefied Natural Gas |
| Mmscfd | Million standard cubic feet |
| Mtpa | Million Tonnes per annum |
| MW | Mega Watt |
| NSTA | North Sea Transition Authority |
| NTS | National Transmission System |
| OGA | Oil and Gas Authority |
| OPEX | Operational Expenditure |
| SIG | Special Interest Group |
| SNS | Southern North Sea |

| | |
|---|---|
| TWh | TerraWatt hours |
| UK | United Kingdom |

Links to all sources, data and analysis can be found in the Appendices sections on page 34 at the end of this Report.

# Background

The BEH area plan and related studies consider the area, which is referred to as the BCA, defined as the geographic area covering the Southern North Sea (SNS) specifically the fields whose pipelines make landfall at Bacton or which could use pipelines making landfall at Bacton, and the adjacent onshore areas where Hydrogen from Bacton might be used or stored.

Bacton receives natural gas from the SNS, Central North Sea (CNS) and interconnectors from the Netherlands and Belgium. The Bacton site comprises three gas processing plants, owned and operated by Shell, Perenco and National Grid. The existing Eni terminal has been decommissioned and gas is routed through the Perenco terminal. The total gas processing capacity at the Bacton terminals is 1,650 mmscfd.

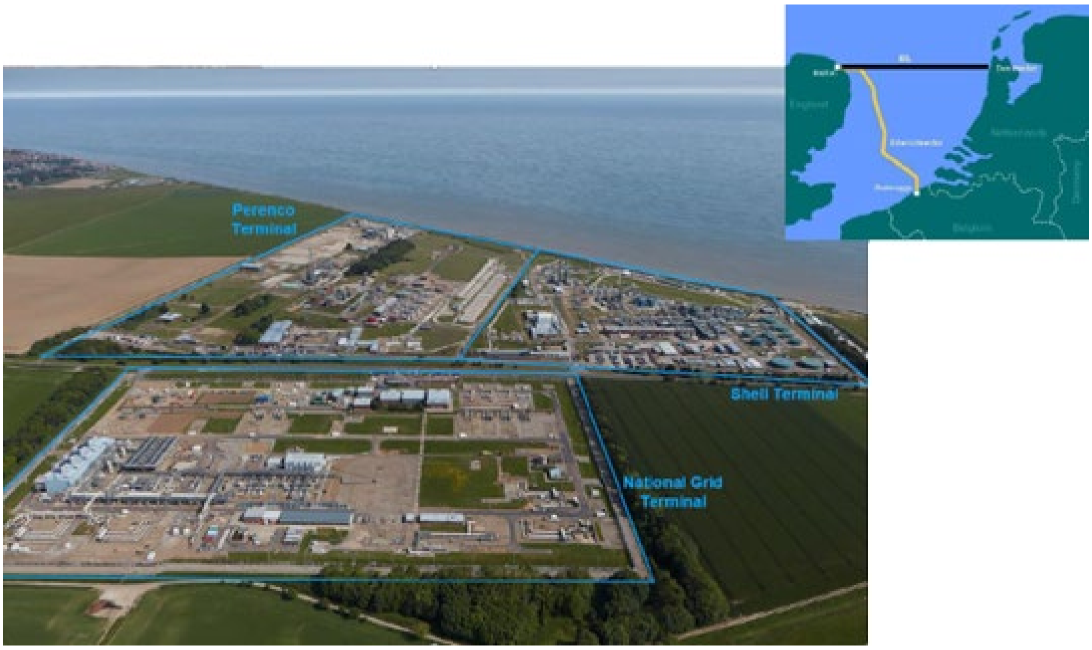



**Figure 2: Bacton Terminal Overview**

The objective of this phase of the project was to work towards **building a foundation on which a credible project can emerge**. Five SIGs executed key work scopes to frame the value proposition to develop a business opportunity articulating the potential that the BEH could unlock.

The project has focused on the following five key areas for which a dedicated SIG made up of industry participants was established.

- Demand
- Supply
- Infrastructure
- Regulatory
- Supply chain and technology

### Study Basis

This phase of the project focused on developing potential credible scenarios that could result in Hydrogen production at Bacton. It is recognised that other potential concepts exist, and further work is required to establish a technically feasible and bankable project for the BEH. The purpose of this phase was to propose a development concept supported by scoping level design outline to help frame the potential opportunity for a future consortium to take forward through concept to execution.

The decision was taken to focus on two key grounding scenarios:

- **Core Project**: which aims to represent the minimum potential / minimum value proposition of a Hydrogen hub at Bacton.
- **Build Out:** which aims to represent how a potential build out scenario from the minimum potential to a hub which delivers what we believe is a base analogous with a P50 development case.

A summary of the scenario basis is shown below.

| | | Core Project "355 MW CCS Enabled Hydrogen" | Build-out "Combination of CCS Enabled / Electrolytic Hydrogen" |
|---|---|---|---|
| Demand | **Demand Base Assumption** | Supply Driven<br><br>Domestic Only | Balanced supply / demand scenario<br><br>Domestic Only |
| Demand | **Maximum Demand (TWh)** | 8.1 TWh (2030), 55.1 TWh (2040), 85.9 TWh (2050) | 8.1 TWh (2030), 55.1 TWh (2040), 85.9 TWh (2050) |
| Demand | **Maximum Blend %** | Assumed 20% blend in 2030 increasing to 100% Hydrogen in some parts of region in 2040, all 100% Hydrogen in 2050 | Assumed 20% blend in 2030 increasing to 100% Hydrogen in some parts of region in 2040, all 100% Hydrogen in 2050 |
| Supply | **Supply Base Assumption** | CCS Enabled Hydrogen | CCS Enabled Hydrogen + Electrolytic Hydrogen |
| Supply | **Phasing Description** | 1 x 355 MW CCS Enabled Hydrogen Facility by 2030 | Up to 3.6 GW CCS Enabled Hydrogen by 2050<br><br>Up to 6 GW Electrolytic Hydrogen by 2050 |
| Supply | **CCS Enabled Hydrogen Feedstock Assumptions** | Indigenous UK gas from CNS/SNS. | Indigenous UK gas + likely import from 2040 |

| | | | |
|---|---|---|---|
| | | Core project requires c. 30 mmscfd of natural gas. | |
| Supply | **Electrolytic Hydrogen Feedstock Assumptions** | Potential for early production facility to decarbonise local demand | Redeployment of constrained wind power + connection to (green) grid (2040), Dedicated wind/solar plus connection to (green) grid (2050) |
| Infrastructure | **Land requirement** | Within existing plant boundary | Requires optimisation of existing site |
| Infrastructure | **CCS enabled Hydrogen Base Assumptions** | Existing upstream gas pipelines available to supply natural gas to terminal over life of project.<br>Electricity supplied from the grid for H2 generation + CO2 capture plant<br>Depending on technology steam / oxygen generation<br>Desalination plant | Existing upstream gas pipelines available to supply natural gas to terminal over life of project. May require import of natural gas from Europe.<br>Electricity supplied from the grid for H2 generation + CO2 capture plant<br>Depending on technology steam / oxygen generation<br>Desalination plant |
| Infrastructure | **Electrolytic Hydrogen Base Assumptions** | N/A, unless local supply | Electricity supplied from green source (offshore wind).<br>New desalination plant required. |
| Infrastructure | **CO2 Transport and Storage Assumptions** | Re-use of existing pipelines with connection to $CO_2$ storage site.<br>Capacity of 1 MTPA required. | New storage site and pipeline required with required injection capacity of up to 10 MTPA |
| Infrastructure | **Hydrogen Storage Base Assumption** | Linepack | New Hydrogen storage site, either depleted gas field or saline aquifer |

**Table 1: Scenario Overview**

# Demand

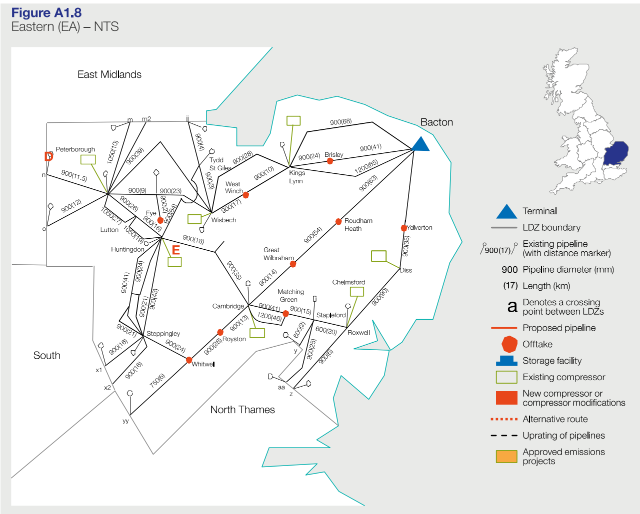
The Demand SIG aim was to determine an aggregated forecast for Hydrogen demand that could be reasonably supplied by the BEH.

The demand assessment was based on public domain information to deliver an estimate of future potential Hydrogen demand for the following sectors:

- Power
- Industry
- Domestic / Commercial
- Transport (excluding marine and aviation)

The demand forecast basis assumed that a blend of up to Hydrogen 20%vol (c. 6.5%energy) can be accepted by power stations, industry and domestic / commercial heating by 2030 increasing to 100% Hydrogen gas feedstock available for all NTS connected users by 2040. The conversion to 100% Hydrogen gas feedstock is premised on National Grid's overarching strategy to transition the national gas network to Hydrogen through Project Union.

The identified key demand centres that BEH could supply Hydrogen to comprise of the National Grid NTS areas of East Anglia and North Thames. It was assumed that there is limited communication between the gas networks in the North and South of London, and that any Hydrogen demand for South London would be supplied from other Hydrogen projects such as from the Isle of Grain, and therefore South London demand has been excluded.



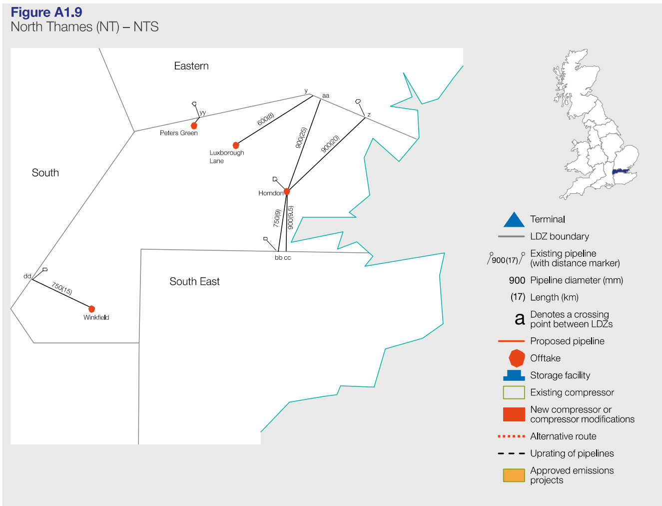




**Figure 3 Areas Bacton Hydrogen Could supply via the NTS**

Hydrogen demand estimates have been developed at time stamps of 2030, 2040 and 2050. The demand estimates are based on the potential theoretical demand, and do not consider constraints regarding supply or infrastructure.

| Sector | Hydrogen Demand (TWh) 2030 | Hydrogen Demand (TWh) 2040 | Hydrogen Demand (TWh) 2050 |
|---|---|---|---|
| Power | 1.6 | 20.0 | 12.0 |
| Industry | 0.6 | 4.8 | 6.5 |

| | | | |
|---|---|---|---|
| Domestic / Commercial | 5.7 | 28.4 | 61.8 |
| Transport (Excluding Marine and Aviation) | 0.2 | 1.9 | 5.6 |
| **Total** | **8.1** | **55.1** | **85.9** |

**Table 2: Hydrogen Demand Scenarios**

## Key findings

**Hydrogen demand potential that could be supplied by Bacton is not considered to be the limiting factor.**

- Hydrogen demand to be served by Hydrogen produced in Bacton will most likely be dominated by domestic demand from London and the South East.
- Local industrial demand is relatively limited and dispersed across the region. This alone could not support a fully commercial scale size Hydrogen plant but could support an early production electrolytic Hydrogen facility.
- The Core Project of a 355 MW facility could deliver 3 TWh of Hydrogen, which represents less than 40% of the projected Hydrogen demand in 2030.
- In the longer term, Hydrogen demand continues to be dominated by domestic supply, but with potential for an increase in demand from power and industrial sectors. The Build Out scenario can be developed to match evolving Hydrogen demand up to 85.9 TWh by 2050.
- Power demand may also offer an opportunity for earlier Hydrogen offtakes as the hub builds up to its full potential.
- The realisation of the full potential demand will be determined by the ability of the NTS and local gas transmission and distribution systems to accommodate a blend of Hydrogen in natural gas, and later to convert to 100% Hydrogen. Pilot studies are ongoing to demonstrate the impact of blended Hydrogen for domestic use.
- Blending and CCS enabled Hydrogen are key enablers to facilitate rapid carbon reduction in support of net zero targets. If Hydrogen blending was deferred by 10 years in the BCA waiting for other Hydrogen demand markets to develop, this would be a missed opportunity to capture circa 16MT $CO_2$ (1.6 MT/yr.), equivalent to circa 75% of the 10-Point plan lower objective to remove 20MT $CO_2$ by 2030.

| Year | $CO_2$ Abatement (Mt/ yr.) | |
|---|---|---|
| 2030 | 1.6 | Opportunity to abate 16 MT between 2030 and 2040 through blending |
| 2040 | 11 | |
| 2050 | 17 | |

**Table 3: $CO_2$ Abatement potential through blending**

Upside opportunities

- Subject to technological development and implementation, both marine and aviation sectors could evolve into significant demand sectors for Hydrogen, or Hydrogen carriers, but this has not been included in the core demand estimates above.
- The Interconnectors to Belgium and the Netherlands which land at Bacton may offer scope for import of feedstock gas for CCS enabled Hydrogen production, import of European $CO_2$ for permanent geological storage in the UK sector or export of Hydrogen and integration with a European Hydrogen Backbone.
- Further opportunities exist to supply Hydrogen to other demand centres from Bacton, including the West Midlands via projects such as Hydrogen Valley.

# Supply

The Supply SIG aim was to determine the required feedstock of Hydrogen, technology, power requirements and cost for the Core Project and Build Out Scenarios.

Analysis considered the following factors: Hydrogen production phasing, Hydrogen production technologies, blending, feedstock, power, water, Hydrogen storage and indicative cost and economics. Both CCS enabled and electrolytic Hydrogen have been considered for the development of the BEH.

An overview of the system mapping is shown in Figure 4.

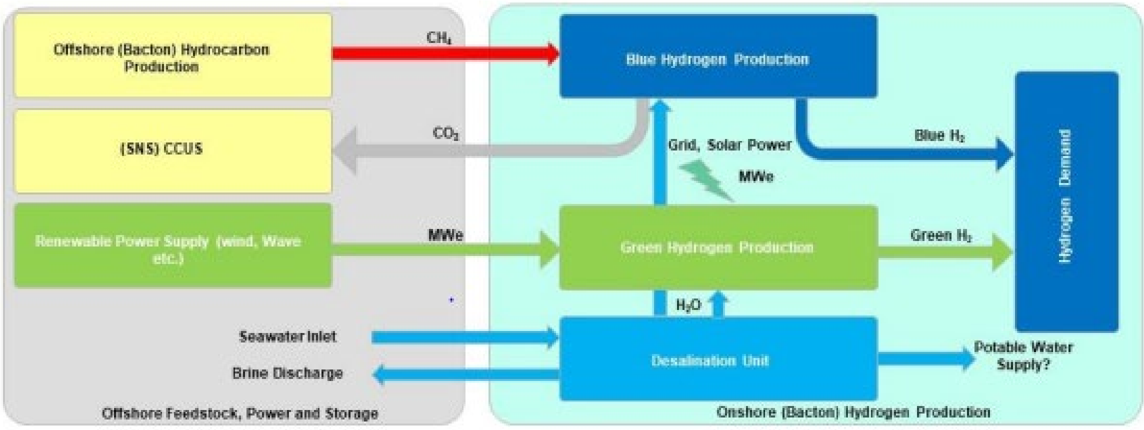



**Figure 4: System Mapping of Hydrogen Production**

Bacton benefits from its proximity to the SNS which can supply natural gas as feedstock for a CCS enabled Hydrogen plant in the Core Project. Future Build Out can be enabled by either expansion of existing CCS-enabled Hydrogen plants or transition to electrolytic Hydrogen, which can utilise East Anglia's offshore wind capacity in the future.

## Key findings

The initial assessment confirms the availability of main feedstock (natural gas, renewable energy and water) and associated storage potential that can deliver the Core Project and enable the Build Out project. Bacton benefits from feedstock (natural gas, electricity) that is likely to be among the most cost competitive in the UK.

### Feedstock

#### *Hydrocarbons*

There are sufficient remaining indigenous hydrocarbons to support the BEH Core Project

Wood Mackenzie were commissioned to assess potential natural gas supply to Bacton to support future CCS enabled Hydrogen production. Three scenarios were considered:

- Low Case: A "minimum" case considering production onstream and under development
- Base Case: The low case with the addition of commercial discoveries
- Incremental Case: The Base Case with addition of reserves growth and yet to find volumes.

The current gas price outlook and the NSTA's 33rd Oil and Gas licencing round, which has highlighted key SNS clusters and aims to encourage quicker production, provide an opportunity for the BEH to provide a low carbon route for hydrocarbon production. CCS enabled Hydrogen production could also unlock high $CO_2$ hydrocarbon developments which have previously been economically challenged. The Incremental Case is considered the most representative for future domestic supply into Bacton. Note that these profiles represent traditional 'blowdown' profiles. Development of a CCS enabled Hydrogen hub may result in a preference for a 'managed feedstock' approach, with a constrained capacity to provide a longer duration plateau of production matched to plant capacity.

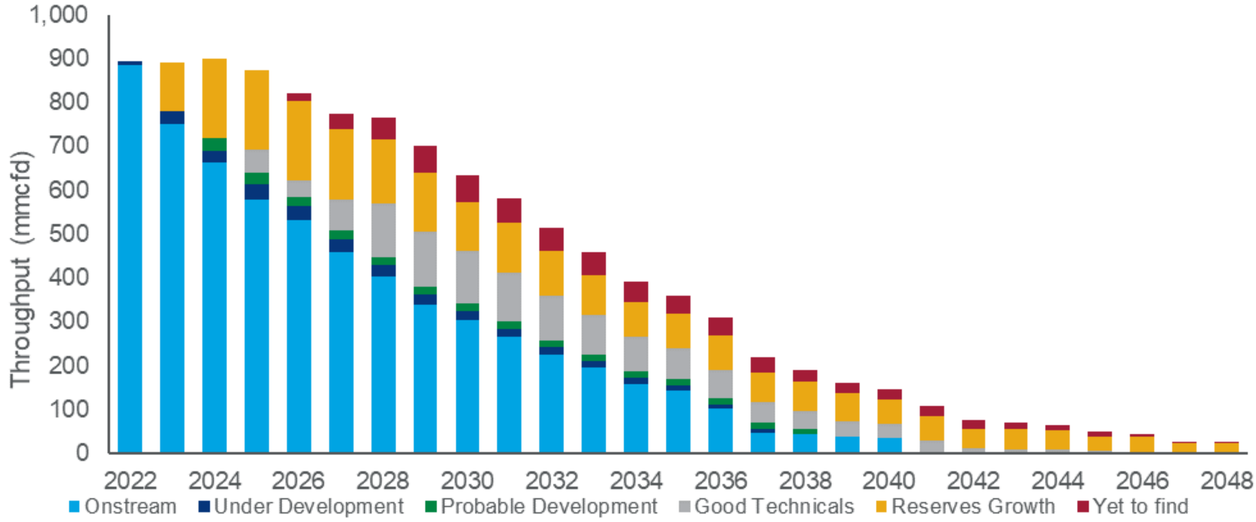



**Figure 5: Potential natural gas feedstock to Bacton (Source: Wood Mackenzie)**

In the Core Project, a hydrocarbon feedstock of 30 mmscfd is required to produce 3TWh of Hydrogen. Based on the projected supply of natural gas to Bacton, there is sufficient hydrocarbon feedstock to supply a CCS enabled Hydrogen production plant through to late 2040s. Build out of CCS enabled Hydrogen production could be supported through domestic supply until 2040 but would require imported gas from either the interconnector(s) or LNG.

***Renewable Energy***

By 2030, the East of England will have c. 15 GW of offshore wind capacity, delivering one third of the UK's target of 50 GW of offshore wind capacity. The BEH represents an opportunity to offshore wind developers with an alternative route to market via a private wire connection.

Any connection would require modifications to the existing offshore substation and would need to ensure that there was no impact on the delivery of electricity to the market. This will require a commercial agreement and may be an opportunity once initial CfD contracts roll off after the initial 15-year period. For upcoming offshore wind farms there may be insufficient CfDs available for the capacity delivered, and as such Private Purchase Agreements (PPAs) and private wire arrangements may become more appealing to offshore wind developers in order to secure project finance. Most recently the Seagreen offshore wind farm successfully secured a PPA for 50% of the capacity, with the remaining capacity contracted through CfD.

***Water***

To support both CCS enabled Hydrogen and electrolytic Hydrogen a source of water is required as feedstock. In the Core Project a water feedstock of 45 $m^3$/hr is required. In the Build Out project, where up to 6 GW of electrolytic Hydrogen has been considered, a water feedstock of up to 380 $m^3$/hr is required. This is equivalent to the water requirement of 26,000 households, or a medium sized town.

Based on discussions with Anglian Water, East Anglia is recognised as water constrained, with relatively limited local potable water available to support electrolytic Hydrogen production. A new desalination plant is likely required to support production of electrolytic Hydrogen at scale.

Anglian Water is exploring the potential for locating a desalination plant to mitigate supply shortages and address local domestic and agricultural uses. An opportunity exists to co-develop a new desalination plant that would satisfy local demand as well as BEH requirements in the Build Out Scenario.

**Power for Electrolytic Hydrogen Production**

Electrolytic Hydrogen would require a dedicated renewable energy source from offshore wind.

For the Build Out project, a direct source of renewable energy is required to provide a power source to the electrolysers. Given the grid is currently not 100% green, this would require connection to an offshore wind farm. Depending on the scale of build-out of electrolytic Hydrogen production this could be up to 6 GW. Further work is required to engage with offshore wind developers to test the feasibility of connection of existing or new wind farm(s) to Bacton. This could be achieved via connection to an existing offshore substation or support the business case for a new offshore windfarm linked directly to Hydrogen production.

There are short- and long-term plans to upgrade and reinforce the national grid network in East Anglia. The current export capacity of the grid in East Anglia is around 3.5GW, and the network operator plans to expand this to between 10-17GW in the coming ten years. This is primarily due to the anticipated increase in power generation that will connect into the grid at this region. The increased generation would come from offshore wind, nuclear and interconnections.

**Storage**

***$CO_2$***

Material $CO_2$ storage capacity exists in the SNS, which is further supported by NSTA's recent CCS licence round

$CO_2$ storage is required as part of CCS enabled Hydrogen technology to enable low carbon Hydrogen to be produced. In the Core Project, an estimated 1 MTpa. of $CO_2$ is captured and requires storage offshore.

The SNS has a potential $CO_2$ storage capacity far exceeding the requirements for the BEH Core Project and Build Out Scenarios.

The BCA benefits from a large number of potential $CO_2$ candidates, with over 20 potential gas storage fields that could be repurposed for $CO_2$ storage within the SNS. This is supported by the NSTA's recent $CO_2$ storage licencing round which closed in September and licences are expected to be awarded in Q1 2023.

There is potential for a number of the $CO_2$ storage licence application winners to work with BEH to provide a full CCS value chain, whilst enabling Hydrogen production at Bacton. Multiple storage sites offer the BEH redundancy in storage which is unique amongst UK CCS enabled Hydrogen production projects.

The potential $CO_2$ storage capacity that is connected to Bacton, coupled with the interconnectors to Europe, presents a future opportunity to develop Bacton into a $CO_2$ import hub. This would provide a cost-efficient means to transport captured $CO_2$ from Western Europe, via existing pipelines, to storage sites located in the SNS.

***Hydrogen***

The Core Project requires relatively limited Hydrogen storage, but a Build Out project will require offshore storage in depleted oil and gas reservoirs or aquifers.

Hydrogen storage is required in both the Core Project and the Build Out project to balance supply and demand.

In the Core Project, the storage requirements for Hydrogen are relatively limited at approximately 5 GWh. This could be accommodated by a combination of either storage facilities at Bacton or line pack of an existing high pressure gas pipeline, either onshore or offshore.

In the Build Out Scenario, where electrolytic Hydrogen is produced, a far greater storage requirement of 5 TWh is needed due to the variability of offshore wind and seasonal Hydrogen demand. Storage volumes of this magnitude could be accommodated in geological structures such as salt caverns, depleted gas fields or aquifers. Underground gas storage in salt caverns is a proven, but limited salt caverns exist in the proximity to Bacton.

The potential to store in depleted gas fields should be considered, given the availability of natural gas fields that are connected to Bacton. Further work is required to assess the feasibility of storage of Hydrogen in either depleted gas fields or aquifers.

# Infrastructure

The Infrastructure SIG considered both offshore and onshore infrastructure including the gas terminals at Bacton required to produce and distribute both CCS-enabled and electrolytic Hydrogen. The studies undertaken aimed to assess the key infrastructure required for the production of Hydrogen i.e., feedstock, power supply, transportation and distribution as well as the storage of resultant $CO_2$ from production of Hydrogen. Both re-purposing and greenfield were considered including offshore wind integration.

The BEH terminal facilities comprise of two operating onshore terminals (Shell and Perenco) with reception and processing of natural gas meeting the NTS quality specification. The natural gas produced is routed to the National Grid NTS facility which is located to the south of the Perenco and Shell reception terminals. This supplies natural gas to the UK via five feeder lines. The ENI plot comprises a decommissioned brownfield footprint, with topside equipment removed but foundations and underground facilities remaining in situ.

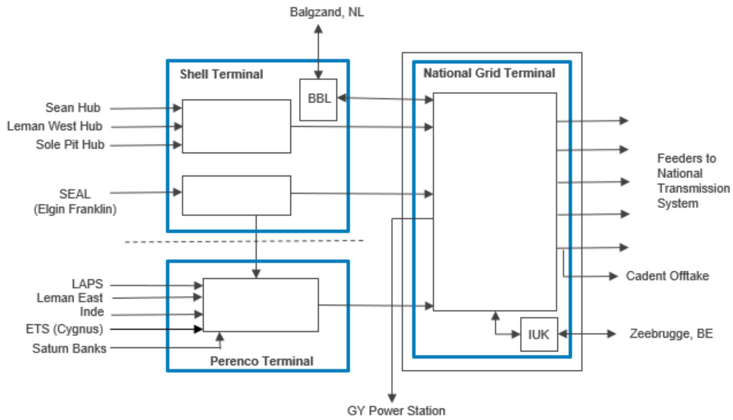




**Figure 6: Bacton Existing Terminal Infrastructure**

A summary of the key information for each terminal is shown below

| | Unit | Bacton – Shell | Bacton Perenco | Bacton – ENI |
|---|---|---|---|---|
| Status | | Online | Online | Decommissioned |
| Gas Processing Capacity | mmscfd | 900 | 750 | - |
| Liquid Processing Capacity | Bbld | 5,000 | - | - |
| Plant footprint | ha | 16.9 | 21.9 | 11.2 |
| Pipelines | | Sean Hub<br>Leman West Hub<br>Sole Pit Hub<br>SEAL<br>Interconnector | LAPS<br>Leman East<br>ETS<br>Saturn Banks | Hewett |

| | | | | |
|---|---|---|---|---|
| CoP | | Post 2030 | Post 2030 | Decommissioned |

**Table 4: Bacton terminal information overview**

## Key findings

### Bacton Terminal Repurposing

**The existing Bacton terminal could be optimised to support the Core Project**

A preliminary assessment of the existing Bacton terminals was carried out to determine whether the terminals could be repurposed for Hydrogen production within the existing plant boundary.

The Core Project (a 1 x 355 MW CCS-Enabled Hydrogen Plant) could be sited within the existing ENI terminal footprint, acknowledging that this would require brownfield remedial works to assess and remove existing services and foundations, and to assess any revisions to operational power / instrumentation and underground pipeline and drainage facilities. A preliminary Core Project site plan was developed based on the proposed plant footprint and is shown below.


**Figure 7: Core Project Potential Site Plan**

Based on the requirement to provide natural gas feedstock to the CCS-enabled plant, and from Operator feedback, it is expected that the Shell and Perenco terminals will be operational during the Build-out phase; accordingly, the Build-out scenarios may require optimisation and additional footprint.

In the event that brownfield solutions are mandated, from initial assessment of footprint, the BEH could be utilised to install electrolytic Hydrogen production facilities following CoP of the existing terminals.

### Offshore Infrastructure Repurposing

**Trunklines to shore represent the best opportunity for repurposing existing infrastructure.**

A high-level assessment of what offshore infrastructure could be repurposed for $CO_2$ and Hydrogen was carried out. A summary of the assessment is shown below

| Item | $CO_2$ | Hydrogen |
|---|---|---|
| Wells | Unlikely to be re-used unless can be proven to be compatible material (13 Cr) and with proven integrity. | Potential for repurposing, but dependent on well integrity and cement quality. |
| Topsides Structure | Could be re-used depending on condition, anticipated future lifetime and required brownfield modifications | Could be re-used depending on condition, anticipated future lifetime and required brownfield modifications |
| Topsides Production Equipment | Highly unlikely to be able to re-use topsides production equipment for $CO_2$ | Highly unlikely to be able to repurpose for 100% Hydrogen processing |
| Jacket | May have potential for re-use depending on proximity to suitable reservoir, anticipated future lifetime and condition | May have potential for re-use depending on proximity to suitable reservoir, anticipated future lifetime and condition |
| In field gathering line | May be re-used for $CO_2$ injection, but will depend on location of injection wells | May be re-used but require extensive assessment on material specification and suitability for 100% Hydrogen transport. |
| Trunkline to shore | Likely to be re-used for $CO_2$ transport, and already being considered in Acorn and Hynet. | May be re-used but require extensive assessment on material specification and suitability for 100% Hydrogen transport. |

**Table 5: Infrastructure repurposing assessment for $CO_2$ and Hydrogen**

Trunklines were identified as key to support CCS-enabled Hydrogen production at the BEH. Currently, 15 pipelines land at Bacton from the SNS and CNS, plus two further interconnectors to Belgium and the Netherlands.

A preliminary assessment of the potential suitability of transporting $CO_2$ was carried out to identify pipeline candidates that could be repurposed. The data was sourced from public domain information and each pipeline was assessed based on the following criteria:

- Availability of pipeline in 2030 in order to meet BEH Hydrogen production target date
- Connection to a store considered within the NSTA CCS licencing round
- Pipeline condition
- Pipeline size
- Design pressure (to consider gaseous and / dense phase)

An overview of the assessment is shown below, depicted using a traffic light system.

| Pipeline | Operator | Key fields | Likelihood of availability in 2030 | Connection to Store | Pipeline Condition | Pipeline size (") | Pipeline Age in 2030 | MAOP (barg) | Potential for re-use |
|---|---|---|---|---|---|---|---|---|---|
| Trent to Bacton | Perenco Oil and Gas | Cygnus | Unlikely CoP to mid 2030s | No | | 24 | 46 | 131 | |
| Leman BT to Bacton A2 | Perenco Oil and Gas | Leman | Currently producing | Maybe | | 30 | 60 | 99.3 | |
| Leman 49/27 AP to Bacton A1 | Perenco Oil and Gas | Leman | Currently producing | Maybe | | 30 | 62 | 93.1 | |
| Lancelot to Bacton | Perenco Oil and Gas | | Currently producing | Maybe | | 20 | 38 | 103.5 | |
| Indefatigable 49/23 AT to 49/27 BT | Perenco Oil and Gas | Inde | Currently producing | Maybe | | 30 | 59 | 110 | |
| THAMES to Bacton (Saturn Banks) | IOG PLC | Elgood | Unlikely CoP to mid 2030s | No | | 24 | 44 | 129 | |
| HEWETT SOUTHERN EXPORT A-LINE TO BACTON | ENI UK LIMITED | Hewett | CoP now | Maybe | 30" external (0.625" wall thi | | 62 | ollowing pipeline failure* | |
| HEWETT NORTHERN EXPORT B-LINE TO BACTON | ENI UK LIMITED | Hewett | CoP now | Maybe | 30" external (0.625" wall thi | | 57 | 26.89** | |
| Clipper PT to Bacton | Shell | Clipper South, Galleon | Currently producing | Maybe | | 24 | 40 | 112 | |
| Bacton to Clipper PT | Shell | Clipper South, Galleon | Currently producing | Maybe | | 3 | 36 | 150 | |
| Leman AP to Bacton | Shell | Leman | Currently producing | Maybe | | 30 | 63 | 99.3 | |
| Bacton to Leman AP | Shell | Leman | Currently producing | Maybe | | 4 | 63 | 45 | |
| LEMAN 49/26-BT TO BACTON | Shell | Leman | Currently producing | Maybe | | 30 | 57 | Mothballed | |
| SHEARWATER TO BACTON (SEAL) | Shell | Elgin Franklin | Unlikely CoP to 2040s | No | | 34 | 31 | 153 | |
| SEAN P TO BACTON TERMINAL TRUNKLINE | ONE-DYAS | Sean | CoP ~ 2025 | Maybe | | 30 | 44 | HOLD | |

**Table 6: Pipeline screening for $CO_2$ transport**

Trunklines landing at Bacton have been screened for suitability for $CO_2$ repurposing.

- The majority of pipelines could transport $CO_2$ in gaseous phase, however if dense phase transportation is preferred from Day 1, or is transitioned to later in operational life, this would reduce the number of potential pipeline candidates that could be suitable for repurposing
- Sean is expected to reach CoP in the mid-2020s and therefore the pipeline represents a potential good candidate for re-use. There is currently no $CO_2$ store identified in the region however the NSTA recently launched a carbon storage licence round with the aim to progress carbon storage and areas to which Bacton could transport $CO_2$ were offered within the acreage.
- The Perenco and Shell operated pipelines to Leman could be potential candidates, but there is uncertainty in CoP timing for the fields.

### Greenfield Offshore Infrastructure

In the event that an existing offshore pipeline could not be repurposed, a new pipeline was also considered.

- From preliminary assessment, for a generic 30km pipeline length, a 16” $CO_2$ pipeline could accommodate 5Mtpa $CO_2$ transport in dense phase, or up to 1Mtpa $CO_2$ in gaseous phase. The Core Project requires just capacity for 1Mtpa. Therefore a 16” pipeline could accommodate an initial gaseous phase transport phase, with transition to dense phase in the future.
- For greenfield offshore $CO_2$ transport and injection facilities injection wells with dry trees located at a normally unmanned wellhead platform would be preferred over a fully subsea solution due to expected lower lifecycle cost. A wellhead injection platform would also enable an ability to workover the wells, which would be simpler than if subsea.

### Onshore Power

Onshore power demand for the Core Project is small and estimated to be 30 MW. This could be supplied from the regional power grid. This would require upgrading of the existing onshore grid and submitting a connection request to UK Power Networks. Based on feedback from National Grid ESO, a connection request of this magnitude could be accommodated.

### Downstream Infrastructure

Bacton benefits from five NTS feeders located at the National Grid terminal, which route gas to London and the Midlands, as well as export / import capability to Europe via two interconnectors. A further pipeline connects Bacton to the RWE operated Great Yarmouth Power Station.

Hydrogen cannot currently be blended into the NTS, and 100% Hydrogen transmission network does not currently exist. However, Project Union has been initiated by National Grid to deliver a blend of Hydrogen across the NTS in parallel to rollout of 100% Hydrogen transmission network. The backbone considers key Hydrogen production sites such as St Fergus and Bacton.

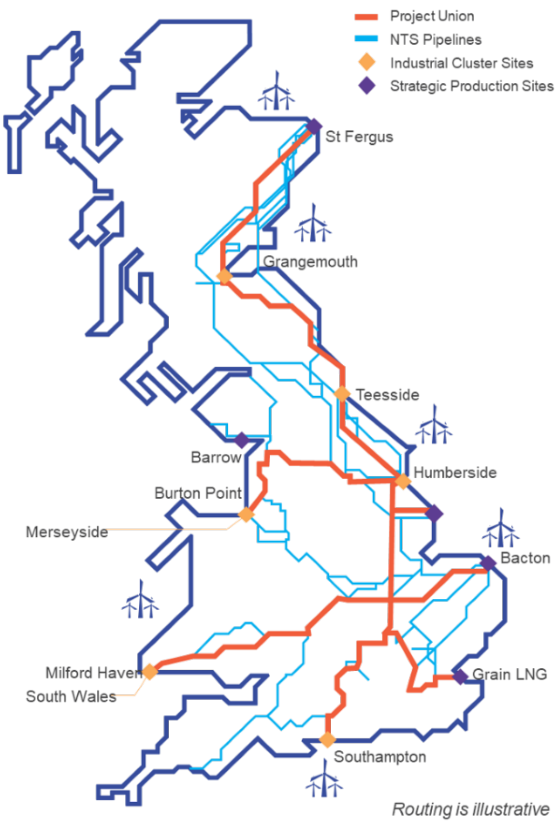



**Figure 8: Project Union Overview**

The current timeline for blending to be accepted under the GS(M)R is in 2026 of up to 20%. This provides time before BEH commences Hydrogen production in 2030.

Other demand led Hydrogen projects have also identified Bacton as a key supplier of Hydrogen. These include:

- Capital Hydrogen – a collaboration between Cadent, National Grid and SGN to transition gas networks in the East of England and South East and London from natural gas to Hydrogen in order to decarbonise London and the South East.
- Hydrogen Valley – a collaboration between Cadent and National Grid to develop a vision for Hydrogen in the West Midlands and East of England Areas.

# Regulatory

The Regulatory SIG reviewed and identified the existing primary legislation, secondary legislation and statutory regulations that might apply to Hydrogen-based development centred on the Bacton gas terminal. The Hydrogen value chain was divided into a series of geographical components four distinct areas were identified for both offshore and five areas for onshore.

Offshore:

- Natural Gas extraction and supply
- Carbon Dioxide Storage (including offshore transportation)
- Hydrogen Underground Storage (including offshore transportation)
- Electrical Supply (from offshore wind farms)

Onshore:

- Plant to be constructed at Bacton
- Plant to be constructed at the Port at Great Yarmouth for export via port
- Pipelines
- Onshore transportation via road and rail
- Electrical Supply (via the National Grid)

## Key findings

Overview

- There are no specific regulatory requirements to enable Bacton; any required changes will be needed by all UK projects.
- The initial Hydrogen demand for Bacton is driven by domestic gas blending or domestic Hydrogen transition. The project will need clarity on the regulatory / commercial framework by early 2025 to allow for FID by end of 2025 and production by 2030

Based on review of the regulatory environment that may apply for the BEH, the following key conclusions were identified. Changes to legislation are not substantive, though it is recognised that securing parliamentary time may be the limiting factor on speed of change.

- The storage and transport of Hydrogen offshore is currently not covered in any regulatory regime. To enable the Hydrogen economy to develop there is a need to ensure that Hydrogen is included in the definition of "gas" in the different pieces of legislation.
- The BEH is predicated on supply of Hydrogen into the NTS, which requires amendment to the existing GS(M)R gas specification to allow a blend of Hydrogen, or 100%, into the gas grid. This is currently planned for review in 2026, which does provide uncertainty prior to sanctioning of any Hydrogen led project that supplies Hydrogen into the gas grid.
- The current funding landscape for low carbon Hydrogen production presents an opportunity for a more joined up approach.
- The UK requires a predictable, long term competitive funding framework that will enable both electrolytic and CCS enabled Hydrogen to be developed at scale and at pace. This has successfully been achieved in the offshore wind sector through the CfD scheme.

A more detailed summary of the assessment of each component is described below using a Red Amber Green approach.

| | | | Comment | Action |
|---|---|---|---|---|
| Offshore | Natural Gas Extraction and Supply | | • Well established, existing regime is satisfactory. | No action |

| | | | | |
|---|---|---|---|---|
| Offshore | Carbon Dioxide Storage | | • Although this is an emerging industry, and there is currently no $CO_2$ injection in UK waters, the regulatory framework is well established, and is managed by the NSTA, the Crown Estate and HSE.<br>• Existing regulatory regime appears satisfactory. | No action |
| Offshore | Hydrogen Transportation and Underground Storage | | • There is currently no Hydrogen injection in UK waters, and there is no specific licencing regime in place to enable offshore Hydrogen pipeline transport and storage.<br>• Hydrogen gas injection and storage is not currently covered by any regulatory regime.<br>• The NSTA have jurisdiction for offshore storage of gas and CO2 but no-one currently regulates Hydrogen offshore storage.<br>• Under the Energy Act 2008 Section 2(4)gas is defined as any combustible substance which is gaseous at a temperature of 15° C and a pressure of 101.325 kPa (1013.25 mb) and which consists wholly or mainly of methane, ethane, propane, or butane (or of a mixture of two or more of those substances). Hydrogen is not covered, however, it is within the Minister's discretion to amend the definition of gas to include Hydrogen.<br>• The Petroleum Act 1998 (Specified Pipelines) Order 2011 applies to what can be transported through pipelines. The definition of "relevant substances" means oil or relative hydrocarbons, natural gas (including such gas as a liquid) or carbon dioxide - Hydrogen not mentioned. It would be appropriate to add Hydrogen to the list of "relevant substances" | Requires revising existing regulations to include Hydrogen |
| Offshore | Electrical Supply | | • Hydrogen production will have a power demand for the processing equipment and the transportation and storage of $CO_2$ and Hydrogen.<br>• Electrolytic Hydrogen will require substantial electricity for the desalination of water and electrolysis which could be in the order of multiple GW. This is unlikely to be able to be provided from a grid connection and may well require a direct connection to a wind farm.<br>• The existing regulatory regime appears satisfactory. | No action |
| Onshore | Plant to be constructed at Bacton | | • Significant process plant will be built at Bacton – whether this is to produce CCS enabled Hydrogen or electrolytic Hydrogen.<br>• This is already well regulated under established regime.<br>• The existing regulatory regime appears satisfactory. | No action |
| Onshore | Plant to be constructed at Port of Great Yarmouth | | • In a build out scenario it is possible that Hydrogen could be exported potentially in the form of high pressure compressed Hydrogen or low temperature liquified Hydrogen or ammonia.<br>• This is already well regulated under established regime.<br>• The existing regulatory regime appears satisfactory. | No action |
| Onshore | Pipelines | | • It is likely that significant Hydrogen will be distributed to markets in the South East of England by pipeline – potentially through National Grid Feeders or through regional gas distribution company pipelines.<br>• This is already well regulated under established regime<br>• Blending is likely key to timely fuel switching to Hydrogen although extensive regulation already exists amendments to GS(M)R are required to permit Hydrogen blending. At present these regulations limit Hydrogen content of gas in the NTS to below 0.1%% (Molar).<br>• The existing regulatory regime appears satisfactory although future frameworks will need to consider measurement and metering for blended Hydrogen. | Blending contingent on amendment to GS(M)R to accept higher levels of blending. |
| Onshore | Onshore Transportation via Rail | | • Hydrogen could potentially be distributed by road and rail.<br>• This is already well regulated under established regime regulated by the Office of Rail and Road.<br>• The existing regulatory regime appears satisfactory. | No action |

| | | | | |
|---|---|---|---|---|
| Onshore | Electricity supply (via National Grid) | | • Hydrogen production will have a power demand for the processing equipment and the transportation and storage of CO2 and Hydrogen.<br>• If this electricity is supplied via the National Grid, then the grid will require reinforcement to enable the electricity to be delivered to Bacton.<br>• The existing regulatory regime appears satisfactory. | No action |
| Onshore | General | | • Onshore salt caverns will be required to be regulated; a natural fit maybe OFGEM who currently regulate the storage of Natural gas in Salt Caverns, but this could also be the NSTA.<br>• The construction of onshore manufacture, storage and transportation of Hydrogen would currently be regulated through the Town and Country Planning Act. It could be appropriate to amend the list of Nationally Significant Infrastructure Projects subject to the Planning Act 2008 (Development Consent Order regime) to include Hydrogen manufacture, storage and transportation facilities (CCS enabled or electrolytic) exceeding 100MW.<br>• A number of health and safety regulations appear not to cover the manufacture and storage of Hydrogen (onshore and offshore). It could be appropriate that the HSE review regulation and internal guidance to address the impact of the increased volumes of Hydrogen and CO2 that might be processed including the impact on on-site inventory. | No action |
| Funding | | | • Other Hydrogen projects are underpinned by existing government co-funding and/ or part of cluster working on decarbonisation through industrial and domestic transition.<br>• The Bacton Hydrogen would require a decision on gas blending or domestic heat transition in the area.<br>• Consequently, whilst, opportunities for government co-funding for current CCS enabled Hydrogen projects are relatively clear, the BEH project without clarity on blending is too commercially immature to easily qualify for many of the schemes currently open and will have to apply for future funding opportunities as and when they become available. Possible opportunities include:<br>• NZHF Strand 1 DEVEX funding (in the anticipated 1H23 application window), but only if the project can demonstrate a credible timetable to complete FEED within the specified window (c. 2 yrs), and a “demonstrated demand” for Hydrogen (the 2023 BEIS decision on blending is critical and GS(M)R in 2026). BEH would also be expected to demonstrate line of sight to a CO2 T&S solution.<br>• Revenue support for the BEH CCS enabled Hydrogen project in operation through the Hydrogen business model would target the proposed levy from c. 2025.<br>• There is no obvious CAPEX funding path currently outlined for CCS enabled Hydrogen projects reaching FID in the period after 2025.<br>• Support for CO2 T&S infrastructure development might be available through the BEIS Track 2 process, but it would be dependent on the timely formation of a consortia and BEIS accepting applications that lie outside the established “industrial clusters”. | |

# Supply Chain and Technology

The Supply Chain and Technology SIG carried out a high-level review of the supply chain and technology requirements to support the BEH, identifying potential constraints within the supply chain and considering the skills and technology that would be required to execute the Bacton Energy Hub vision.

## Key findings

Overview

- Many of the technologies for CCS enabled Hydrogen and CCUS use mature technology. The UK has an extensive relevant supply chain and engineering skills from in the oil and gas sector that can be transitioned in these segments. CCS enabled Hydrogen production is a form of gas processing.
- Electrolytic Hydrogen is relatively immature and early engagement with vendor and the supply chain would be required to deliver on the proposed timeline and size.

**Supply Chain**

- The UK has an extensive network which can be tapped into from both a supply chain and technology perspective.
- The supply chain can support the BEH development through existing skills, competency and capability which is transferable from other sector including oil, gas, chemical and power sectors.
- A high percentage of the work associated with the BEH can be provided from existing suppliers and consultants.
- It is believed as Hydrogen markets are established a high level of UK content is achievable.
- Although the supply chain has resource availability the skills capacity is a challenge to the broader energy sector over the years to come and currently Bacton is not an area of significant indigenous resource availability.
- The use of modern methods of construction as well as reskilling the local workforce and attracting people from other sectors and locations can support East Anglian to grow both its onshore and offshore workforce.
- Standardisation and use of proven approaches will be an enabler to the supply chain.

**Technology**

A high level of technology maturity exists within CCS enabled Hydrogen production

- A high level of technology maturity exists for the equipment, plant and services that will be needed to deliver the business opportunity.
- There is a growing number of CCS technology solution providers however many of them are not UK based.
- It is believed likely over the next few years the number of organisations providing relevant technologies will grow to meet the UK Government's ambition of sequestering 20 to 30 MT $CO_2$ per annum by 2030 to help meet the UK's 2050 net zero target.
- The CCS enabled Hydrogen solution is an area for specific market analysis, the technology is currently in development and moving to production at the scale.

Electrolytic Hydrogen technology is still relatively immature but is scaling up to a commercial scale. BEH could benefit from an early grid connection to allow supply of electrolytic Hydrogen to a large market.

- Hydrogen electrolyser technology is still developing but is not unique. Over the next decade a number of UK and global projects and clusters will be developing which will provide valuable insight and learnings for the BEH.
- Hydrogen electrolysers and Hydrogen production equipment projects are becoming more of an industry standard.
- A number of organisations are offering complete design or package solutions such as Protium, Lhyfe and ITM.
- A significant number of key electrolyser manufacturers are located in Europe, but the UK should be able to provide most of the plant, goods and services.
- Early engagement in the development phase with technology vendors will be key to ensure it locks in capacity and importantly is aligned with the technology readiness and deployment.

# Project Executability

**Project Economics**

Class 5 CAPEX and OPEX estimates were established for the respective development scenarios. These estimates were used as input to determine LCoH for each scenario.

**Key findings**

BEH project economics are competitive against BEIS Hydrogen production cost estimates

- The Core Project CAPEX is estimated to be in the region of £0.5 billion at current prices
- The Core Project has an anticipated Base Case LCoH of £65/MWh, which is competitive against BEIS Hydrogen Production Cost 2021 equivalent estimates.
- Scaling up the Core Project would achieve economies of scale and realise a reduction in LCoH.
- Key drivers that impact LCoH are feed gas price and capital cost.
- The Build Out project costs could be phased over time as Hydrogen demand increases, with potential reduction in feedstock costs as the project transitions from natural gas to electricity generated by offshore wind farms.
- Future electrolytic Hydrogen LCOH is highly uncertain, not just from the extent of electrolyser cost reductions and efficiencies but also, the cost of renewable power from different sources by 2040 and beyond.

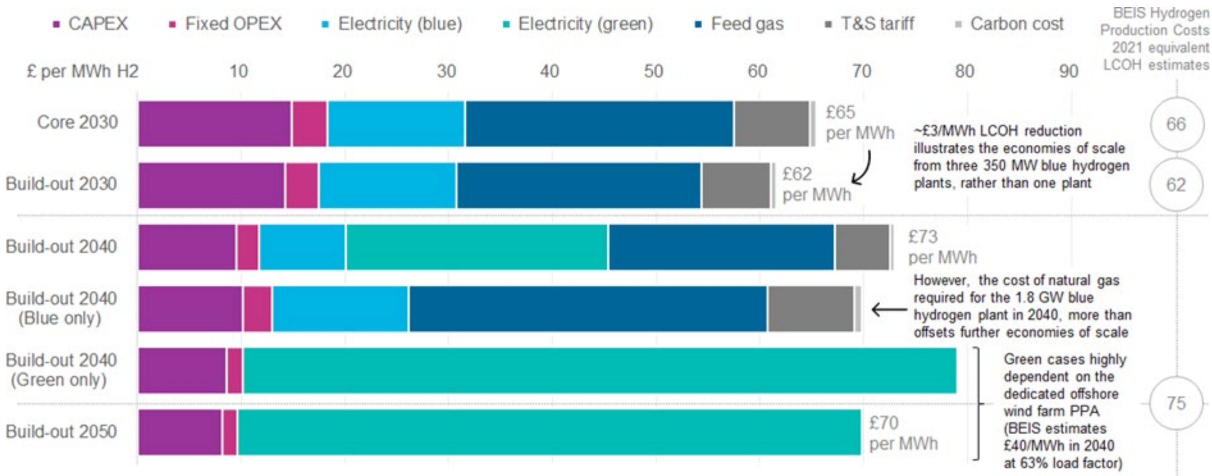



**Figure 9: LCoH Economic Output (Source: io consulting analysis)**

**Bankability**

An initial bankability assessment indicated that no red flags were identified, and the BEH has the potential to raise project finance in the future, depending on the final commercial structure, and the technical and other features of the project.

Societe Generale, a leading energy project finance bank, undertook an initial bankability assessment for the BEH. Based on the information reviewed and recognising the early stage of development of the project[2], the initial conclusion of this work was that the project has the potential to raise project finance in the future depending on the final commercial structure, technical and other features of the project. The assessment did identify a number of material risks, including leakage of CO2 and the potential for assets financed to become stranded at some point

[2] *The views of Societe Generale at this stage are preliminary and do not constitute a commitment or recommendation to provide financing for the transaction.*

(i.e., the failure of one part of the project that prevents them performing as a whole), but these types of risks are common to other similar CCS projects. At this stage no red flags were identified that Societe Generale believed could not be resolved during detailed design, development and the financing process but a more detailed and ongoing assessment of bankability would be required as the project matures. Indeed, some of the material risks identified could be resolved during the ongoing discussions between government and the industry around the CCS and Hydrogen Business Models, and BEH would benefit from the results of these discussions. From a commercial perspective, BEH would need to operate under both the CCS and Hydrogen business models, which are still being negotiated with no certainty on outcome or whether they will be fully applicable to the BEH.

Other bankability risks identified include areas like technology, contracting/supply chain challenges, cross chain risks, impact of outages, third party access, insurability and the rights and obligations associated with the interaction between the assets and the wider Bacton operations. BEH is a highly integrated energy project, so an early and continuous engagement with the finance community on these and other risks will be key to ensure that bankability considerations are reflected in the commercial and technical arrangements being negotiated with all stakeholders, including contractors and government.  This early engagement will also be critical to ensure the banks are informed on the project and are clear on the risk allocation and commercial terms to facilitate a financing process when this is launched.

**Schedule**

In a Base Case scenario, Hydrogen production from BEH could be realised by 2030. This requires a consortium to be formed in first half of 2023 with FID achieved in 2025

- Three scenarios on schedule have been established to address the uncertainty range at this phase of the project.
- Based on typical engineering project timelines, the Base Case could deliver Hydrogen production by 2030. An accelerated scenario could realise Hydrogen production by mid-2028, whereas in a downside scenario Hydrogen production could be delayed to 2033.
- At this stage there is a high level of uncertainty around durations, however based upon typical major engineering projects timelines it would be reasonable at this stage to assume:
    - Initiation, options study and pre-FEED during 2023
    - FEED commencing 2024 into 2025
    - EPC commencing 2025
    - Long lead items could well be 12 to 28 months, there are low number of process critical items however they need to be on-site and into a construction sequence to avoid stacking too many critical activities later in the construction programme
- A key uncertainty that may impact schedule and FID is the decision around the ability to blend Hydrogen into the existing gas network. This is currently planned for 2026. This may result in delays to FID if this cannot be brought forward.

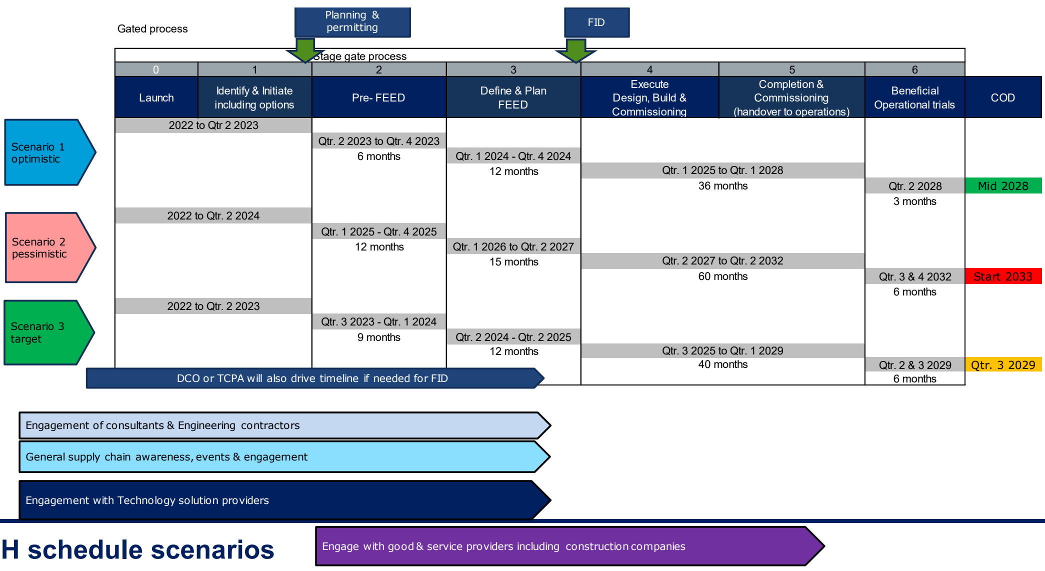



**Figure 10: BEH schedule scenarios**

# Risks and Opportunities

## Risks

- BEH is premised on blending of Hydrogen into the NTS. This requires amendment to the GS(M)R, which is scheduled for review in 2026.
    - **Mitigation:** Pilot studies are ongoing to assess the impact of Hydrogen blending for industrial and domestic use.
    - **Mitigation:** Alternative routes to market for Hydrogen production from Bacton exist, but these require further investigation.
- Hydrogen production economics are heavily reliant on price of feedstock whether it is natural gas or electricity.
    - **Mitigation:** Government support mechanisms will be required to provide price certainty and enable investment in Hydrogen production facilities.
- A CCS enabled Hydrogen production facility is reliant on connection to a $CO_2$ store. This will require close co-ordination between the Hydrogen production facility and Transport and Storage CCS infrastructure owner to ensure timely delivery. Bacton benefits from connections to a number of potential $CO_2$ storage sites, but these will be subject to licence award as part of the NSTA's recent CCS licencing round.
    - **Mitigation:** Including the CCS Transport and Storage infrastructure owner/operator as part of the wider BEH consortium will ensure alignment of schedules and understanding of this risk.
    - **Mitigation:** Clear roadmap for CCS storage license holders on processes from license award to start of sequestration, and alignment/streamlining of requirements from the various regulatory authorities will help reduce timeline and to reduce uncertainty in timelines.
- UK supply chain is constrained, and further investment is required to upskill people to deliver on UK Government's 2030 decarbonisation targets. This challenge is not unique to Bacton and is a broader UK challenge within the energy sector.
    - **Mitigation:** Involvement of skills bodies in the BEH consortium, and involvement of the BEH consortium in UK wide initiatives to reskill / upskill people.
- The storage of Hydrogen in the UK is currently not regulated. This would require amendment to legislation. There is also uncertainty in how large scale (TWh) offshore Hydrogen storage facilities would be developed given none have been developed to date. The UK will require significant Hydrogen storage facilities by 2050 to balance the grid as renewable energy generation increases its share of power supply.
    - **Mitigation**: Programmed development of legislation by government to build the required framework. BEH consortium involvement in activities to support this.
- Re-use of existing infrastructure will require detailed integrity assessments to ensure that the infrastructure is suitable for operation over the project life.
    - **Mitigation**: Early engagement with operators of infrastructure with potential for re-use as part of the BEH to establish the value of early detailed information on the integrity of these assets, in order to allow timely decision making on brownfield/greenfield development.
- Erosion of the cliffs near Bacton potentially poses a long-term risk to the terminals. Activities are ongoing to arrest cliff erosion.
    - **Mitigation:** This is a known issue and being worked on by Norfolk coastal councils to arrest cliff erosion.

## Opportunities

- The Core Project can be developed within the existing Bacton terminal, further optimisation of the project could realise further benefits in terms of scale or integration of electrolytic Hydrogen at an earlier stage.
- Electrolytic Hydrogen early production facilities could be accommodated to decarbonise local industry and transport within East Anglia, developing a Hydrogen economy within the region.
- Continued collaboration with Hydrogen projects such as Capital Hydrogen and Hydrogen Valley will enable the development of a credible Hydrogen value chain that ensures supply and demand are aligned.
- NSTA CCS licencing round could provide multiple $CO_2$ store locations and development of a CCS value chain within the SNS.
- NSTA hydrocarbon licencing round could support additional feedstock to a larger CCS enabled Hydrogen production facility.
- A dedicated pipeline to Great Yarmouth Power station represents a credible alternative Hydrogen route to market for some production if blending of Hydrogen into the NTS cannot be achieved.

- The combination of connections to Europe and material $CO_2$ storage potential in the SNS could position Bacton as a key $CO_2$ import hub for $CO_2$ emitters in Western Europe.
- The development of a strategic energy hub at Bacton can attract investment to the region and ensure continuation of Bacton as a key supplier of energy to the UK whilst meeting net zero commitments.
- Continued co-ordination with Anglian Water could provide a source of water for the development of electrolytic Hydrogen.
- Acceleration of electrolytic Hydrogen could be realised through co-ordination with offshore wind farm developers

# Next Steps

### Maintain Momentum

This project has been delivered by a broad, diverse and engaged group of companies, each of whom is keen to see the project continue. It is now time for a consortium to form that can take the opportunity that has been identified and take forward the project.

### Encourage Stakeholders

The identified key stakeholders that may form, or support, a consortium include hydrocarbon producers, pipeline and terminal infrastructure owners, offshore wind developers, CCS developers, Hydrogen technology suppliers (CCS enabled and electrolytic) and the wider supply chain. A continued engagement with the finance community is also recommended to ensure that the project is considered bankable as the project matures.

### Continue Engagement with Demand Projects

Continued engagement with evolving Demand projects such as Project Union, Capital Hydrogen and Hydrogen Valley.

### Explore Alternative routes to market

Further exploration of alternative routes to market such as power stations, ports, power-to-X and fuel blending will help bolster the business and de-risk the reliance on the NTS blending decision and timing of this.

# Appendices

## Demand

| Title | Link |
|---|---|
| Bacton Energy Hub Hydrogen Demand – SIG report | https://www.nstauthority.co.uk/media/8611/bacton-energy-hub-hydrogen-demand-sig-report.pdf |
| Bacton Energy Hub Hydrogen Storage – SIG supplementary report | https://www.nstauthority.co.uk/media/8612/bacton-energy-hub-hydrogen-storage-sig-supplementary-report.pdf |

## Supply

| Title | Link |
|---|---|
| Bacton Energy Hub Hydrogen Supply SIG – Summary Report | https://www.nstauthority.co.uk/media/8613/bacton-energy-hub-hydrogen-supply-sig-summary-report.pdf |
| Bacton Energy Hub LCOH Analysis | https://www.nstauthority.co.uk/media/8614/bacton-energy-hub-lcoh-analysis.pdf |
| Bacton Energy Hub LCOH Data | https://www.nstauthority.co.uk/media/8615/bacton-energy-hub-lcoh-data.xlsx |
| Bacton Long Term Gas Lookahead | https://www.nstauthority.co.uk/media/8599/bacton-long-term-gas-lookahead.pdf |
| Bacton Long Term Gas Lookahead Data | https://www.nstauthority.co.uk/media/8616/bacton-long-term-gas-lookahead-data.xlsx |
| Bacton SNS CCS Screening | https://www.nstauthority.co.uk/media/8600/bacton-sns-ccs-screening.pdf |
| BEH Supply SIG - Desalination Summary Report | https://www.nstauthority.co.uk/media/8617/beh-supply-sig-desalination-summary-report.pdf |
| Blue Hydrogen Technology Review | https://www.nstauthority.co.uk/media/8605/blue-hydrogen-technology-review.pdf |
| Green Hydrogen Scoping Report | https://www.nstauthority.co.uk/media/8606/green-hydrogen-scoping-report.pdf |
| Green Hydrogen Technology Review | https://www.nstauthority.co.uk/media/8607/green-hydrogen-technology-review.pdf |

| | |
|---|---|
| Project Development Phasing | https://www.nstauthority.co.uk/media/8610/project-development-phasing.pdf |
| Power Supply Technical Note | https://www.nstauthority.co.uk/media/8609/power-supply-technical-note.pdf |

### Infrastructure

| Title | Link |
|---|---|
| Infrastructure SIG Final Report | https://www.nstauthority.co.uk/media/8608/infrastructure-sig-final-report.pdf |

### Regulatory

| Title | Link |
|---|---|
| BEH Regulatory SIG report | https://www.nstauthority.co.uk/media/8618/beh-regulatory-sig-report.pdf |
| BEH Regulatory SIG report - Hydrogen Funding Supplemental Report | https://www.nstauthority.co.uk/media/8601/beh-regulatory-sig-report-hydrogen-funding-supplemental-report.pdf |

### Supply Chain and Technology

| Title | Link |
|---|---|
| BEH Supply Chain and Technology SIG Report | https://www.nstauthority.co.uk/media/8604/beh-supply-chain-and-technology-sig-report.pdf |
| BEH Supply Chain and Technology SIG Report Data | https://www.nstauthority.co.uk/media/8603/beh-supply-chain-and-technology-sig-report-data.xlsx |

# Special Interest Group Core Members

## Demand

- Progressive Energy Limited (Lead)
- NSTA
- Sumitomo Corporation
- Energy Tracks Limited
- Jacobs
- National Grid
- Mace Limited
- Cadent Gas
- EEEGR

## Supply

- Summit Energy Evolution Ltd (Lead)
- NSTA
- Total Energies
- Saipem
- Genesis Energy
- IO Oil and Gas
- Neptune
- Shell
- National Grid
- Johnson Matthey
- ENI
- Fluor
- EEEGR

## Infrastructure

- Xodus (Lead)
- NSTA
- Shell
- Perenco
- National Grid
- McDermott
- Paradigm
- Neptune
- Cadent Gas
- Cavendish Management Consultants
- Fluor
- EEEGR

## Regulatory

- Energy Transition Advisory (Lead)
- NSTA
- Northbrook Energy Advisory Limited
- iGas
- Neptune
- Fluor
- Mace
- Pinsent Masons
- ENI
- Wood Plc
- Shell
- Altwood Energy Advisors
- EEEGR

## Supply Chain and Technology

- Petrofac (Lead)
- Turner & Townsend (Lead)
- NSTA
- Paradigm Group
- Oilfield Production Consultants (OPC)
- Axis Well Technology
- EEEGR

North Sea Transition Authority



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