Annex A14.02

Bacton Terminal Redevelopment Engineering Justification Paper

December 2019

As a part of the NGGT Business Plan Submission

nationalgrid

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Executive Summary

The purpose of this investment is to identify the best solution at Bacton Terminal, to ensure safe, reliable and compliant operation meeting current and future stakeholder needs. Bacton was commissioned in 1968 and much of the equipment is of first generation or is over original design life. The severity of a significant failure at Bacton is high, and increasing as the assets age, which our proposed long-term strategy will mitigate. Since it was commissioned, Bacton terminal has never has a full site outage, and operates 24/7/365.

Bacton brings gas into the UK from the Southern North Sea and Europe via interconnectors. It provides gas to the South East of the UK, a key demand area including London. It is the only terminal on the network that regularly switches from being net supply, to net demand, due to reversal of interconnectors. Over the last two years we have seen winter days where the terminal delivered up to 39% of GB gas supplies and other days where export through Bacton represented up to 30% of GB gas demand. Each year, £4billion worth of gas flows through the terminal.

Bacton is a key site for the transmission network, and one of two top tier COMAH[1] sites. To operate safely and reliably until post 2040, the best solution is to redevelop the terminal. This would cost an estimated £144.3m in RIIO-2 and RIIO-3[2]. This cost has been developed with the help of Petrofac, a leading international service provider to the oil and gas industry, who have developed a preliminary design, construction strategy and timeline for delivery.

A counterfactual option of maintaining the current terminal long term has been considered and is the minimum cost option for RIIO-2. However, it does not represent long term value to consumers or stakeholders, due to a high continuing level of asset health spend.

The condition of assets on site is a growing concern, with 121 of 333 mainline valves passing gas i.e. not maintaining a good seal. In addition, several critical systems require major refurbishment or replacement such as site electrical systems, cathodic protection systems and fire protection systems. The buildings are generally non-compliant to the occupied buildings risk assessment. These concerns are in line with issues seen by our customers on the terminal complex, with a similar age of plant.

Stakeholder engagement has shown a strong preference towards a redeveloped terminal, over continued investment over many years. The short timeline, minimising risks to UK supplies, and delivering the future site capability is important to our stakeholders' strategies. It is recognised that National Grid's Bacton Terminal will play a key role in their business strategies. One of our customers has recently invested over £350m into their terminal assets[3]. These assets are of a similar age and condition and have required significant investment. It is also an indication of their intention to continue flowing gas through Bacton.

The design of the terminal will consider options to ensure that Bacton is resilient to hydrogen, or hydrogen blends. We will also look to make the redeveloped terminal build a carbon neutral project. These two features will ensure the maximum cost and societal benefits for the consumer now and into the future.

The significant volume of asset health interventions required in RIIO-2, mean that deferral of this decision to redevelop the terminal is not an economically viable option.

North Norfolk District council, East of England Energy Group and several offshore operators have issued statements of support of our plans at Bacton Terminal. These are available in appendix D.

[1] Control of Major Accidents and Hazards

[2] There is an additional £9m of "least regrets" asset health, accounted for as part of the NARMs methodology, required to maintain and operate the terminal in the interim period.

[3] https://www.shell.co.uk/energy-and-innovation/meeting-todays-demands/processing-oil-and-gas/about-processing-oil-and-gas.html

1. Summary Table

Name of Project	*Bacton Terminal Redevelopment*		
Scheme Reference	*PAC 3721*		
Primary Investment Driver	*Asset Health*		
Project Initiation Year	*2018*		
Project Close Out Year	*2027*		
Total Installed Cost Estimate (£)	*£144.3m (18/19 price base)* *£[redacted]m (Baseline, FEED and tender event)* *£[redacted]m (Baseline Variant, Brownfield Terminal[4])*		
Cost Estimate Accuracy (%)	*P50*		
Project Spend to date (£)	*-*		
Current Project Stage Gate	*Stage 4.1 – Establish Scope and Options*		
Reporting Table Ref	*Table 3.01 – Project Listings*		
Outputs included in RIIO-T1 Business Plan	*No*		
Spend apportionment	**RIIO-T1**	**RIIO-T2**	**RIIO-T3**
	-	*£139.3m*	*£5.1m*

2. Project Status and Request Summary

2.1. National Grid are requesting funding to redevelop Bacton Gas Terminal. The most cost-effective and lowest risk option is to rebuild the site. This would cost £139.3m in RIIO-2 and £5.1m in RIIO-3. This value consists of:

- £[redacted]m baseline funding for Front End Engineering and Design (FEED) study and tender event
- £[redacted]m baseline variant for brownfield terminal design and build
- £[redacted]m baseline asset health funding, accounted for in the relevant asset health themes, for least regrets work in RIIO-2. Not requested in this paper.

2.2. The £[redacted]m requested as baseline funding will be used to conduct an in-depth FEED study and tender event. We propose a PCD to measure our delivery of FEED in RIIO-2.

2.3. We are requesting baseline funding to redevelop Bacton terminal in our RIIO-2 plan. We are proposing to use a re-opener uncertainty mechanism post-FEED to adjust these baseline costs and to define a new PCD for delivery of the solution identified. This will allow greater certainty over the total cost of the project.

2.4. The project is currently at stage 4.1 – Develop Options and will progress to 4.2 – Select Option in September 2020. See figure 1. The brownfield terminal build would be commissioned in 2026 and project completed in 2027. Decommissioning of the

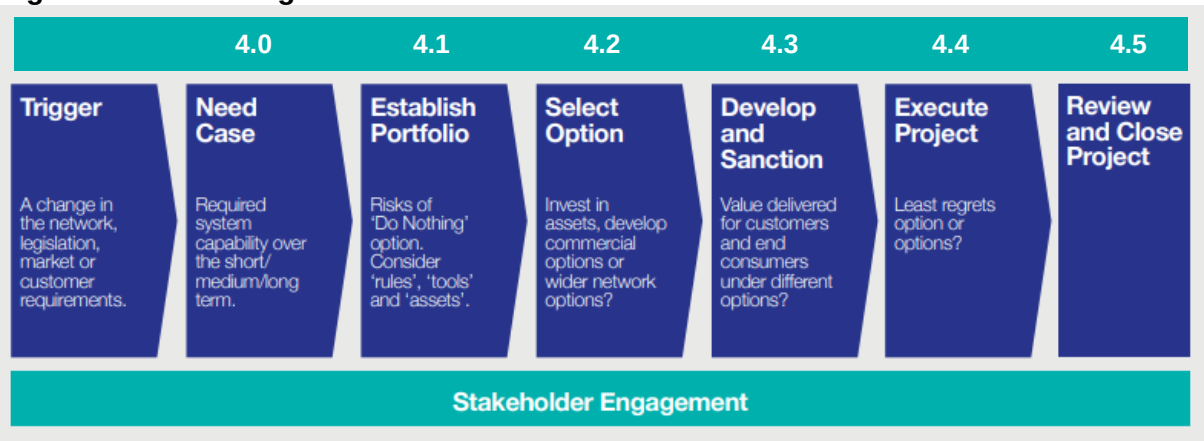
[4] Brownfield site is defined as being built within the current operational site boundaries

existing terminal would commence afterward and is forecast for RIIO-3 in our redundant assets engineering justification paper.

2.5. To date, a needs case for a long-term future at Bacton has been established, a number of options have been ruled out, and the final options have been costed. These options have been through a cost-benefit analysis.

2.6. Extensive stakeholder engagement has been carried out to understand what internal and external stakeholders need from the Bacton gas terminal.

Figure 1: ND500 Stage Gates



3. Problem/Opportunity Statement

3.1. Bacton brings gas onto the system from the Southern North Sea, and connects to Europe. It delivers gas to the South East of the UK, a key demand area including London. It is the only terminal on the NTS that regularly switches from being net supply, to net demand.

3.2. As the single highest entry and exit point in the UK, it is key to security of supply and UK/EU market position. Over the last two years we have seen winter days where the terminal delivered up to 39% of GB gas supplies and other days where export through Bacton represented up to 30% of GB gas demand. It supplies the majority of gas required in London, home to over 8 million people.

3.3. Bacton was commissioned in 1968 and much of the equipment is of first generation or is over original design life. Future Energy Scenarios 2018 (FES) indicates Bacton will still play a significant role beyond 2040, and our stakeholders who use the terminal require it to support their business strategies in accordance with this. This would mean a life of over 70 years for some of the assets if no intervention is taken.

3.4. Assets that have been replaced since the site was commissioned i.e. control systems, are also approaching, or over their design life. These typically have a shorter design life.

3.5. Bacton was designed at a time of increasing UKCS gas quantities coming into the UK and was designed with the flexibility to accommodate future flows. When commissioned only UKCS imports were being received and over its life the terminal has been developed to accommodate new connections. This “layering” of Bacton over 50 years has increased the complexity of site, as new connections connected to current infrastructure. The result of this, is a complex and integrated terminal making outage requirements challenging. Bacton has not achieved a full site outage since commission, operating non-stop since 1968.

3.6. National Grid have reviewed the future requirements of Bacton Terminal. With the assets at the end of life, the energy industry in a period of rapid change, and the needs and requirements of our customers changing, we have taken a step back to explore with our stakeholders what the best enduring solution is. Our work at Bacton must be able to support a range of different future scenarios.

3.7. There is no practical option to “do nothing”. The condition of the assets and expected deterioration, combined with the constraint costs, and loss of supply impact at Bacton is too severe. We need to decide on a long-term option for Bacton in our RIIO-2 plan. As our most strategically important node on the network, millions of consumers and thousands of businesses would be affected by a loss of supply.

3.8. Asset condition is a concern on site. There are 121 out of 333 main valves on site considered to be “passing” i.e. not sealing. These valves are block valves, whose main function is to block gas. Further asset concerns are detailed in section 5.24.

3.9. Those valves that are passing a small amount can operate providing gas is vented to atmosphere. This has environmental implications. See section 5 for more details.

3.10. The site is one of two upper tier COMAH sites on the network, as it contains enough inventory of hazardous material, and as such represents a major accident hazard which must be managed. Failure to do so represents a major process safety risk.

3.11. In addition to the asset issues, another significant consideration is the requirement to limit disruption to shippers during any construction work, or due to asset failure if we do nothing. In case of a major asset failure, we would conduct an emergency shut down. This would close incoming and outgoing valves at Bacton, constraining shippers and preventing gas flow to offtakes. The local gas distribution offtake onsite is a single feed offtake; therefore, this poses a risk to consumers as well as customers. In a high forecast scenario, constraint management actions of £[redacted]m per day are forecast. There would also be security of supply risks to the South East, including London and Great Yarmouth power station. This scenario would also cause significant cost and disruption to consumers in the South East.

3.12. The construction of a brownfield terminal would take place between 2021 and 2026, with project closure in 2027. Work to decommission redundant assets is planned for RIIO-3.

3.13. We will achieve carbon neural construction by 2026, by following an external framework to reduce our capital carbon from construction as much as possible, then offset the remaining emissions.

3.14. As interconnectors are predicted to flow until 2050, and it is likely that Bacton will still be required in future zero carbon energy scenarios. UKCS flows into the terminal, which are forecast to continue to decline, are not a factor in the investment decision.

3.15. During Front End Engineering Design, we will evaluate options and cost to make National Grid’s Bacton terminal a net zero emissions site, in line with the government ambition. We will work with on site stakeholders, considering aspects such as;

- How can we reduce venting through design?
- What sustainable modes of transport and energy can we implement?
- Can we use waste heat from compression on site?

Related Projects

3.16. Funding for the “least regrets” asset health work during RIIO-2 is being requested via the appropriate asset health sub theme and will be reportable within the NARMs methodology. The total least regrets work requested is £[redacted]m.

3.17. Our wider business plan shows the forecast Bacton redundant asset decommissioning costs (RIIO-3). Separate funding is also being requested for the Bacton physical security solution (RIIO-2). In our business plan submission, we have worked to ensure the existing terminal continues to operate safely and reliably in RIIO-2, at the lowest cost to consumers, by reviewing and minimising investment in asset health, cyber and ISS programmes of work.

3.18. During RIIO-1, several Asset Health programmes have been ongoing at Bacton. These have been “least regrets” works, mainly focussed on critical valve operations. Learning from these projects have been applied into the future strategy, as well as costs. For example, the use of pre-assembled assets where possible to limit outage time.

Project Boundaries

3.19. This project concerns the rebuild of Bacton terminal.

3.20. It includes the FEED study during RIIO-2, which will inform the final solution and cost.

3.21. It does not include any “least regrets” asset health works while the brownfield terminal is built. These are included within the relevant asset health themes.

3.22. The boundary is the Bacton site, within the current fence line.

3.23. Enhance Physical Security investment for fence line of site is not included. See Annex A15.08. The redeveloped site will be built to incorporate cyber compliance.

3.24. Decommissioning is not included. See Annex A16.08. Efficiencies will be sought during the design phase to bundle decommissioning and new build.

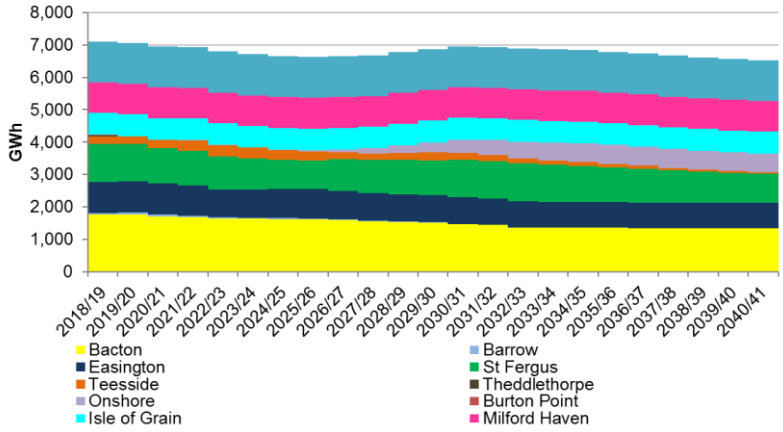
4. Project Definition

Supply and Demand Scenario Discussion and Selection

4.1. FES 2018 shows a clear need for Bacton terminal beyond 2040, Figure 2, with 2040 peak supply at 1341GWh.The other three FES scenarios show a similar peak level of supply. Interconnector flows (import and export) are steady until at least 2040. These forecasts only consider GS(M)R[5] compliant gas accepted onto the transmission network. There is ongoing industry work to review the GS(M)R compliance gas limits with a view to widening them which may extend UKCS forecasts into the 2040s.

[5] Gas Safety (Management) Regulations, 1996

Figure 2: Peak Supply by Terminal, Steady Progression[6]



4.2. Stakeholder engagement with sub terminals (Shell, Perenco and upstream producers) indicate that UKCS supplies into Bacton could continue until at least 2042. Operators are looking to extend field life through reduced operational expenditure (OPEX), high oil prices and improved technology[7][8]. It is likely that a mixture of relaxed GSM(R) limits, increased field recovery and blending developments will lead to UKCS inputs into Bacton well beyond 2035, until at least 2042.

4.3. For example, the Cygnus field operated by Neptune Energy has an estimated field life of 20+ years, excluding future developments and tie ins[9]. This field feeds into Bacton Terminal. There are further wells planned to feed into Bacton, contributing an additional 7mcm/d supply.

4.4. Figure 3 shows the results of National Grid's network capability assessment at Bacton and the impact of the availability of compression at King's Lynn. Although Bacton supplies are dropping towards 2040 (shown by the light blue dots), there is still a long-term requirement for the Bacton terminal to be operational.

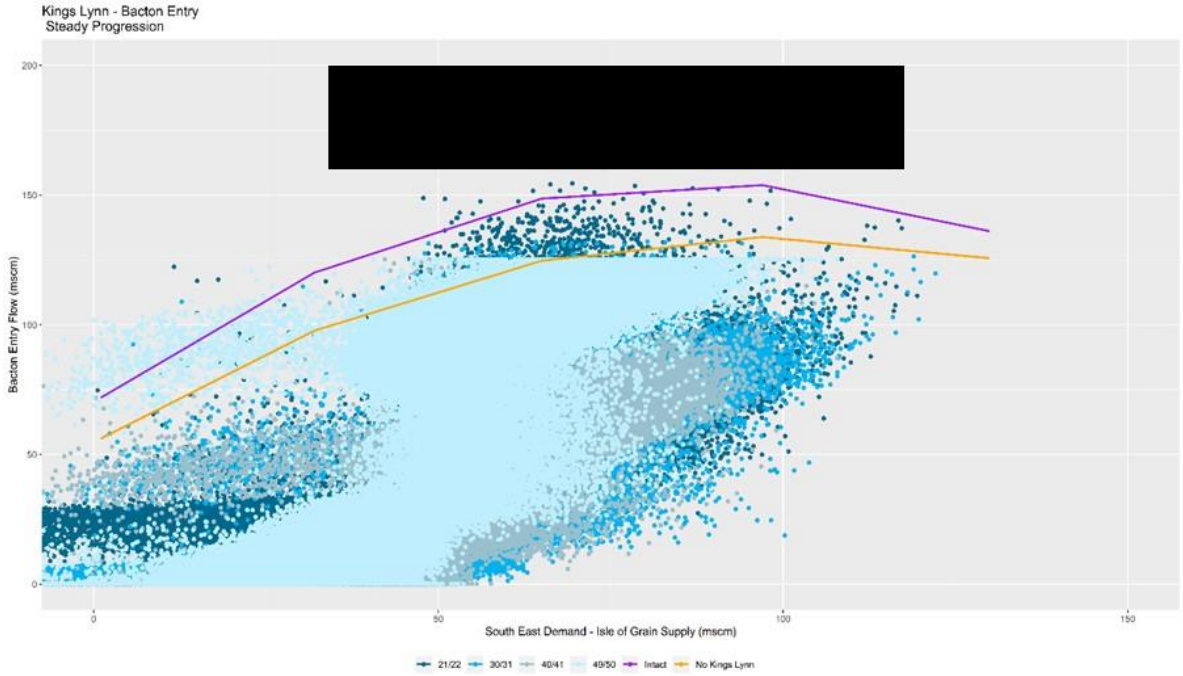
[6] Gas Ten Year Statement 2018 https://www.nationalgridgas.com/insight-and-innovation/gas-ten-year-statement-gtys

[7] https://www.ogauthority.co.uk/media/5122/oga_reserves__resources_report_2018.pdf

[8] https://www.ogauthority.co.uk/media/4521/oga-sns-tight-gas-stimulation-december-2017.pdf

[9] https://www.neptuneenergy.com/en/activities/operated-fields-in-production/cygnus-uk

Figure 3 Bacton Entry - Network Capability



4.5. Demand in the South East is not expected to change significantly until at least 2040, with gas from a mixture of interconnectors and LNG meeting exit obligations. Bacton will continue to act as a key node for managing this demand.

4.6. Beyond 2040, pathways to decarbonise heat suggests that hydrogen could be produced offshore, using existing infrastructure to bring onshore[10]. Another alternative is combined transportation of methane onshore for steam methane reformation, and offshore for carbon capture and storage[11].

4.7. FES also shows an enduring requirement for the exporting of gas into Europe (Figure's 4 and 5). Currently this is achieved through IUK. However, BBL reverse flow has commenced in 2019. Although the overall capacity will be unchanged (60mcm/d), there is an increased likelihood of all of this capacity being used. This is due to the presence of two suppliers in the market (increased availability, competitive market).

4.8. It is clear through stakeholder engagement, that there is a long-term future at Bacton. However, the volatility of the market is reducing the amount of long-term capacity bookings in favour of short-term. The long-term capacity bookings do not reflect the true future need, and we should not be basing future strategies on capacity booking data.

[10] https://www.worldenergy.org/wp-content/uploads/2018/01/WEC-brochure_Online.pdf
[11] https://policyexchange.org.uk/can-hydrogen-and-ccs-save-one-another/

Figure 4: Bacton Export Forecast

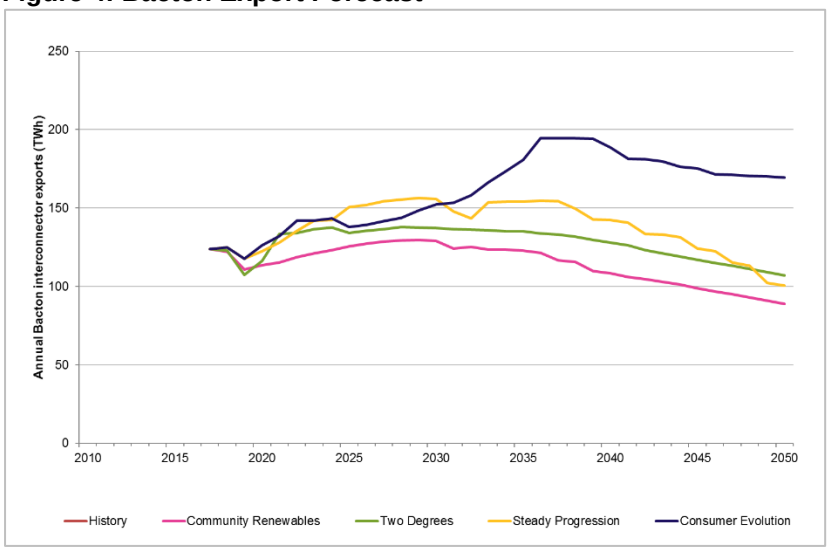
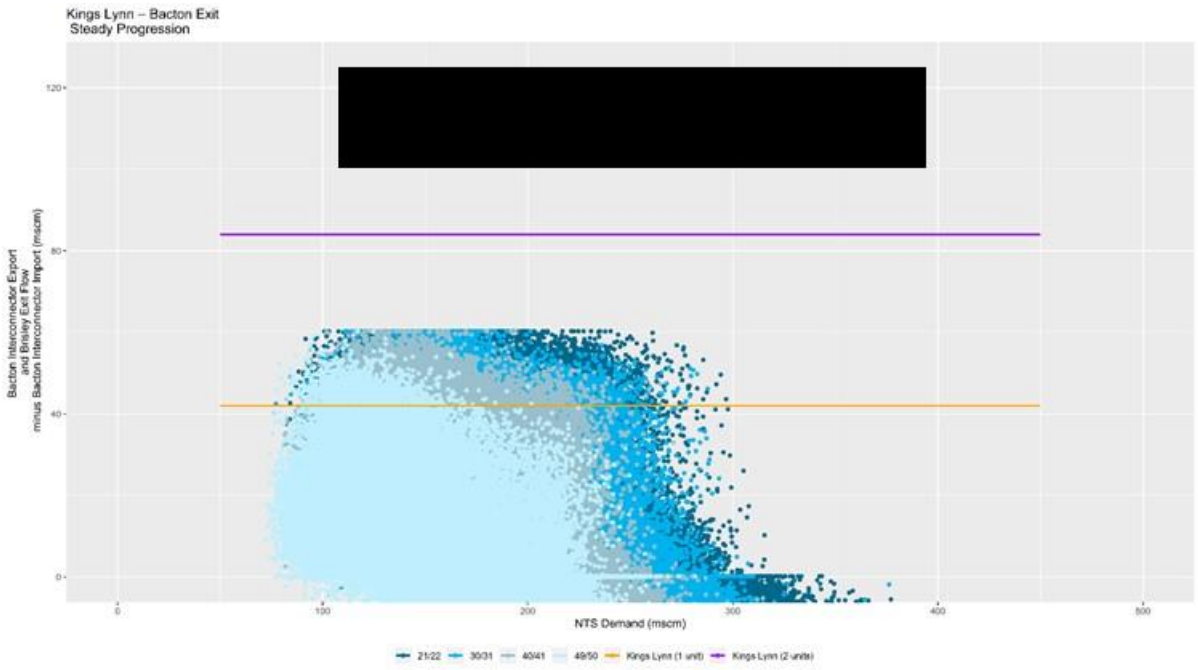


Figure 5: Bacton Exit Forecast – Network Capability



Project Scope Summary

4.9. The supply and demand base scenario used is “steady progression”, this is in line with our other investments. Other scenarios are considered in the sensitivity analysis.

Site Requirements

4.10. Bacton terminal is required to import flows of up to 164mcm/d at 69bar, export flows of up to 60 mcm/d at 68 bar, with the ability to both import from UKCS and export to Europe simultaneously, and at short notice. At the same time Bacton must be able

to support South East pressures, local gas distribution, and local power stations, at a range of different flows and pressures up to 67 bar.

4.11. This flexibility makes it unique on the network and is key to our stakeholders current and future business plans. Disruption to operations would have a significant impact on all stakeholders that depend on the site.

4.12. Detailed site requirements are listed below.

System Operator

4.13. The System Operator (SO) has identified several key operational requirements for Bacton Terminal

4.14. Ability to meet National Grid's Entry and Exit commitments. Currently:

- Obligated Entry – 164 mcm/d. FES prediction 107-138 mcm/d.
    - During 2017/2018's "Beast from the East" supplies were in excess of 140mcm/d
- Obligated Exit – 60 mcm/d. FES prediction 40-70 mcm/d.
    - Includes Bacton Offtake (Cadent) and Great Yarmouth Power Station

4.15. Ability to maximise pressures on Feeders 3 and 5. This helps meet National Grid's South-East exit commitments, while reducing the requirement for operation of compression at Diss, Chelmsford, Kings Lynn and Cambridge.

4.16. Ability to manage changing flow patterns and direction changes.

- Includes interconnector reverse flows
- High flows from Isle of Grain Scenario

4.17. Process separation of suppliers

- Processing of each source of gas prior to entering the network or our customers network (filtering, heating etc…)
- To protect our assets, and our customers' assets. Ensuring we can meet GSM(R) regulations and protect against dust and liquids.

Stakeholder Engagement

4.18. Our stakeholder engagement for our work at Bacton has followed a robust process. Representatives from a wide range of groups have been extensively consulted. We realise the importance of Bacton to the wider industry and country and have taken the time to step back and listen.

4.19. During the development of options, National Grid held 1-1's and group workshops with key stakeholders. These included:

- Sub Terminals at Bacton
- Interconnectors
- Producers and Pipeline Operators
- Oil and Gas Authority (OGA)
- Local Offtakes – Cadent and Great Yarmouth Power Station
- Local councils and authorities

Conversations

4.20. At the start of the process, several one-to-ones were had with stakeholders. The primary function of these were:

- Understand how National Grid can improve performance and service, and work more closely with our customers and stakeholders.
- Understand how we can meet stakeholders' current and future needs. How can we align with customers' strategies? What are stakeholders' short and long-term needs for delivering to UK consumers?

Group Engagement

4.21. Following one-to-one engagement, a number of options were developed, as shown in section 5. At a workshop held December 2018, these strategies were presented. This was an opportunity for stakeholders to have their say directly into the options we could propose, "co-create".

Outcome

4.22. The following site requirements were identified:

- Low and consistent pressures when importing onto the National Transmission System (NTS) enabling:
  - Reduced cost of offshore compression
  - Field life extension, and opening more offshore fields
  - Planning for an uncertain future
- High pressures during Export
- Minimal disruption during work
  - Possible to agree/align up to 2 week outages per year
  - More than this has significant financial impact of between £[redacted] to £[redacted] per day[12].

[12] Figures supplied by System Operator

4.23. Our stakeholders also informed us that we need to be able to manage an increase in short term bookings and flow changes

- Market is more volatile, there are less long term interconnector bookings and we need to be able to manage volatile supplies.
- Capacity requirement not reduced

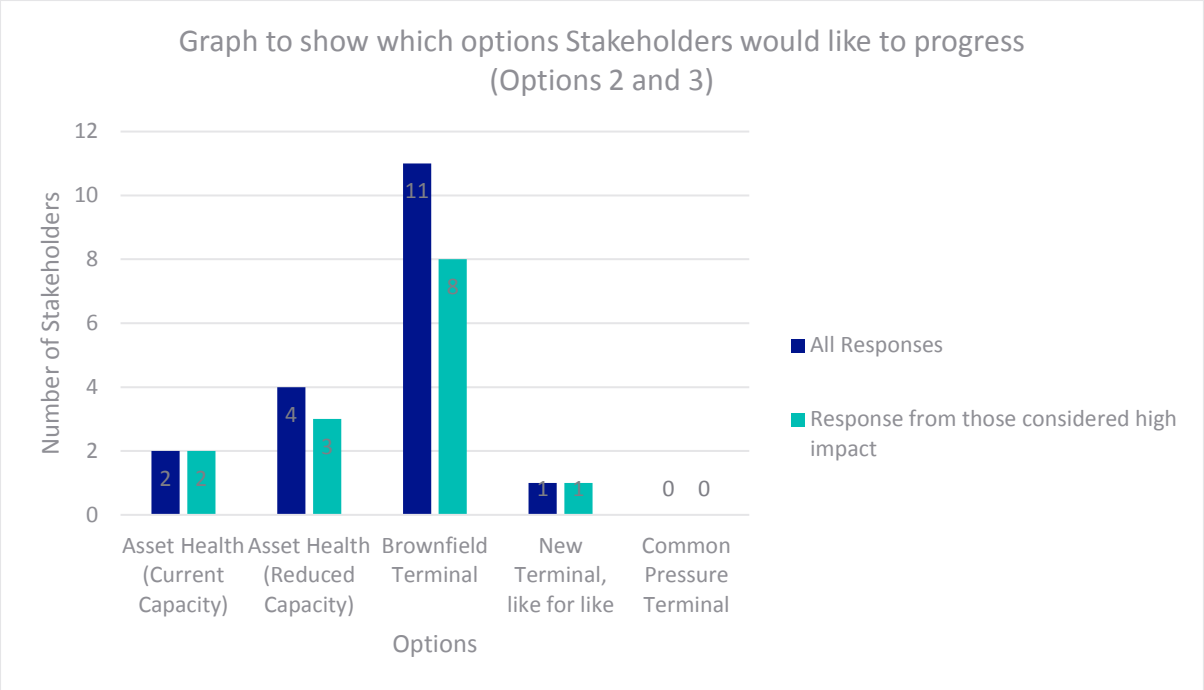
4.24. [redacted] have issued statements of support of our plans at Bacton Terminal. These are available in appendix D.

5. Options Considered

Detailed Options

5.1. The following options were costed and analysed in detail following internal assessment, and stakeholder engagement, see Figure 6.

Figure 6: Preferred Option Poll



*HIGH IMPACT STAKEHOLDERS ARE THOSE WHO HAVE A DIRECT, DAY-TO-DAY INTERACTION WITH SITE I.E. OPERATORS, INTERCONNECTORS AND LOCAL DISTRIBUTION

Stakeholder Discounted Option - Asset Health, (current capacity) – Baseline

5.2. This option retains the site as is, however recognises the need for significant asset health for the site to continue operating safely and reliably. This will be phased according to priority, with significant work required in RIIO-2. Beyond RIIO-2 it is recognised that this option would require asset health work for the remaining life of the terminal. Significant work would be needed each price control to maintain the site operation, as more systems reach end of life.

5.3. This option is considered the counterfactual, or minimum RIIO-2 option to maintain the site and network operating in the same way as currently. It is the default fall back

in the event of the preferred option not being supported and would incur an increase in asset health volumes and costs.

5.4. There is an assumption in this option, that any original valves would need replacing before end of site life (those which have been replaced in the interim are expected to continue to operate effectively). These would be replaced on a priority basis allowing for outage availability i.e. severe non-sealing valves in RIIO-2, partially sealing valves in RIIO-3. It is expected that currently sealing valves will deteriorate. See figure 8 for evidence of increasing failures. They will need future intervention.

5.5. UKCS valves would be replaced in RIIO-2 if they are currently not sealing. There is no allowance made for future failure of these valves in RIIO-3 and beyond, as it is recognised that Southern North Sea (SNS) gas may cease. Signals from the customers with regards to future use may be received which changes this assumption i.e. Hydrogen or gas quality changes. Remediating future failures would be accommodated under future Asset Health allowance requests for the site.

5.6. An option of reconditioning valves rather than replacing was considered. However, since most valves on site are of welded construction and beyond their design life, this is not financially viable. Flow control valves will be assessed for refurbishment but are likely to require intervention if the terminal is operational beyond 2040.

5.7. The following systems have also been identified for replacement, refurbishment or removal.

- Electrical
    - Site Electrical Systems major refurbishment
- Plant and Equipment
    - Filters major refurbishment
    - Preheaters major refurbishment
    - Cathodic Protection Systems major refurbishment
- Gas quality and metering
    - Systems are between 32 and 51 years old
    - Incoming Pipelines and NTS Feeders
- Fire water wing main replacement
- Fire suppression major refurbishment
- Civil
    - Buildings Non-compliant according to HSE Occupied Buildings Assessment. Major refurbishment
    - Pipe supports, pits and ducting major refurbishment
    - Treatment and drainage, tanks and bunds major refurbishment
- ISS Security Fence (Part of ISS request)
    - Non-compliant with specifications
- Control System, Cyber Security and Boundary control systems

Cost Table Asset Health, (current capacity)

Table 1: Cost Table

£m (18/19 price base)	T2	T3	T4+	Total
Asset Health*	[redacted]	[redacted]	[redacted]	[redacted]
Major Construction[13]	[redacted]	[redacted]	[redacted]	[redacted]
Decommissioning**	[redacted]	[redacted]	[redacted]	[redacted]
OPEX***	[redacted]	[redacted]	[redacted]	[redacted]
			Total	395.30

*not included as part of this funding request, however included in CBA. See relevant asset health engineering justification paper.

**not included as part of this funding request, however included in CBA. See Redundant Assets engineering justification paper.

***not included as part of this funding request, however included in CBA.

Stakeholder Discounted Options - Asset Health, (reduced capacity) – Option 1 to 3

5.8. This option is similar to above, however involves the rationalisation of UKCS incoming processing streams. This is due to the reduced capacity that is required since the site was originally built, each sub terminal would require only one pipe to accept all future flow. There are currently six UKCS incoming pipes on site.

5.9. Assumptions regarding the replacement or recondition of valves are the same as paragraphs 5.4, 5.5 and 5.6.

5.10. Three sub options were considered here, decommissioning different combinations of incomers. Reduction in incomers would increase the risk of National Grid constraining customers, in case of outages on site. These options assess the impact of that increased risk vs the benefit.

5.11. It is noted that decommissioning more than two incoming pipelines leads to significant forecast constraint costs, outweighing any saving considerably. Therefore, this was ruled out after the first CBA run. The options are:

- **Asset Health, Shell 1** – Decommission Shell 1 incomer
- **Asset Health, Shell 1 and Shell 2** - Decommission Shell 1 and Shell 2 incomers
- **Asset Health, Shell 1 and Perenco 2** - Decommission Shell 1 and Perenco 2 incomers

5.12. Although some saving is seen with this option, the requirement for the majority of site systems needing replacement remains, and significant site OPEX is required. Both interconnectors would remain, as would all five NTS feeders. Savings are predominantly seen due to the reduced number of valves that would need replacing.

5.13. During stakeholder engagement, UKCS customers expressed concern over the amount of rationalisation that could take place and how that might affect flexibility. They accepted the rationale behind the option but would like to make sure there is

[13] See section 5.21

enough flexibility and redundancy still in place to prevent constraint. In the cost benefit analysis, higher constraints are seen in this option.

5.14. Note that in the baseline/ asset health options there is a high volume of decommissioning at the end of life compared to the brownfield redevelopment. This is due to the increased volume of assets that would need to be decommissioned, and the added complexity due to the assets being predominantly underground. In the Brownfield redevelopment, these costs are seen in RIIO-3.

5.15. **Table 2: Cost Table Shell 1**

£m (18/19 price base)	T2	T3	T4+	Total
Asset Health*	[redacted]	[redacted]	[redacted]	[redacted]
Major Construction	[redacted]	[redacted]	[redacted]	[redacted]
Decommissioning**	[redacted]	[redacted]	[redacted]	[redacted]
OPEX***	[redacted]	[redacted]	[redacted]	[redacted]
			Total	347.99

Table 3: Cost Table Shell 1 and 2

£m (18/19 price base)	T2	T3	T4+	Total
Asset Health*	[redacted]	[redacted]	[redacted]	[redacted]
Major Construction	[redacted]	[redacted]	[redacted]	[redacted]
Decommissioning**	[redacted]	[redacted]	[redacted]	[redacted]
OPEX***	[redacted]	[redacted]	[redacted]	[redacted]
			Total	359.65

Table 4: Cost Table Shell 1 and Perenco 2

£m (18/19 price base)	T2	T3	T4+	Total
Asset Health*	[redacted]	[redacted]	[redacted]	[redacted]
Major Construction	[redacted]	[redacted]	[redacted]	[redacted]
Decommissioning**	[redacted]	[redacted]	[redacted]	[redacted]
OPEX***	[redacted]	[redacted]	[redacted]	[redacted]
			Total	343.63

*not included as part of this funding request, however included in CBA. See relevant asset health engineering justification paper.

**not included as part of this funding request, however included in CBA. See Redundant Assets engineering justification paper.

***not included as part of this funding request, however included in CBA.

Stakeholder Preferred Option - Brownfield Terminal – Option 4

5.16. A new design terminal would be designed to satisfy the current capacity needs of site and be made “future proof” to satisfy known and likely future requirements.

5.17. The site would be rationalised, designed to suit what could be reasonably foreseen as future requirements. A suitable level of redundancy would be installed, balancing cost vs risk.

5.18. Due to the unique nature of this option, (National Grid have not designed a brownfield receiving terminal in recent times), an expert external consultant (Petrofac) was engaged. Petrofac were given the current obligations required from site and visited the terminal to understand the current condition and operational requirements. A preliminary design, delivery plan, cost schedule and civils/construction strategy were delivered.

5.19. At this stage, a brownfield only redevelopment has been considered. This would be inside the current operational site. There would be significant planning requirements and timeline constraints to a greenfield development, adding significant cost. It would also reduce the timescales for the benefits to be realised over. Additionally, IUK have a significant number of assets within the National Grid boundary and would be unlikely to move, therefore this option would create two separate sites, which is unlikely to pass planning requirements. However, it is noted that during Front End Engineering and Design (FEED) the greenfield option will be reviewed again.

5.20. The remit to Petrofac was to ensure enduring reliability, minimise site disruption and reduce inventory (and therefore COMAH tier). They were also to ensure consistent, available operation between switch over between old and new assets. The preliminary solution developed includes:

- The use of pre-assembled units (PAUs). These modules are developed offsite, and transported to site, minimising on site build and reducing hook up operations.
- Implementation of a modern Emergency Shut Down (ESD) system.
- The plant could be operated remotely from Warwick Gas Network Control Centre (GNCC). However, this would need developing during Front End Engineering Design (FEED) and detailed design to determine whether viable.
- The capability to blend gas, a stakeholder requirement from the South North Sea gas operators as an option.
- A rationalised, above ground solution. To be confirmed during FEED. Making it easier to maintain and manage.
- The ability to add site capability. Bacton could be used for future storage solutions or other expansions to play a bigger role in maximising the Southern North Sea recovery. At this time, these additions are not included in the design. However, it is prudent to add the ability to undertake future modifications at this stage.

5.21. The design of the terminal will consider options to ensure that Bacton is resilient to hydrogen, or hydrogen blends. We will also look to make the terminal build carbon neutral. These two features will ensure the maximum cost and societal benefits for the consumer into the future.

Table 5: Cost Table Brownfield Terminal

£m (18/19 price base)	T2	T3	T4+	Total
Asset Health*	[redacted]	[redacted]	[redacted]	[redacted]
Major Construction	[redacted]	[redacted]	[redacted]	[redacted]
Decommissioning**	[redacted]	[redacted]	[redacted]	[redacted]
OPEX***	[redacted]	[redacted]	[redacted]	[redacted]
			Total	241.69

*not included as part of this funding request, however included in CBA. See relevant asset health engineering justification paper.

**not included as part of this funding request, however included in CBA. See Redundant Assets engineering justification paper.

***not included as part of this funding request, however included in CBA.

Table 6 Cost Estimate Details

Item	Cost (£m)	% of Total Installed Cost
Engineering Design	[redacted]	[redacted]
Project Management	[redacted]	[redacted]
Materials	[redacted]	[redacted]
Main Works Contractor	[redacted]	[redacted]
Specialist Services	[redacted]	[redacted]
Vendor Package costs	[redacted]	[redacted]
Direct Company Costs	[redacted]	[redacted]
Indirect Company Costs	[redacted]	[redacted]
Contingency	[redacted]	[redacted]
Total Installed Cost	[redacted]	
Cost Estimate Accuracy	[redacted]	

Options Cost Estimate Details

5.22. The source data for costs has come from several locations, a summary of which is contained here and in the Cost Benefit Analysis (CBA).

- Asset Health
    - Any non-valve related asset health that will be required on site. Costed using unit cost information where applicable or based on previous projects in conjunction with current on-site contractor.
        - Note that all least regrets asset health work has been costed using unit costs, in line with the remainder of the asset health portfolio. Some costs, such as a replacement electrical system, fire and gas replacement, or specific occupied building works were built using contractor quotes. This was deemed more suitable due to the specifics of the work.
    - Replacement of valves
        - Underground – Unit cost from recent asset health scheme at Bacton. The use of unit costing information is not applicable in this instance, due to the depth of the valves (up to 10m), and difficulty working around live pipework and assets.
        - Above ground/ in pit – Unit cost, from internal costing team, eHub.
- Major construction costs. These are any major projects not involving like for like replacement. Limited to additional valves for BBL, and brownfield site costs. In the counterfactual and asset health options, the major construction costs are for BBL valves only.
    - BBL – Cost for 2x new valves to be installed on the BBL line, improving the flexibility and reliability. Cost assumed to be the same as an underground valve replacement (as above).
    - Brownfield site – Based on an Engineering Procurement and Construction (EPC) quote obtained from Petrofac, with additional costs for activities outside the quote.
- Decommissioning costs – Costs from decommissioning quote received from onsite contractor
- Site Opex – Taken from historical figures (previous 3 years) and prorated according to number of assets in each site “zone”. Includes any requirement for asset health specific Opex.

5.23. Summary Table

Table 7: Summary table details - all costs including decommissioning.

Option title	*Project start date*	*Project commissioning date*	*Project design life*	*Operating cost*	*Decommissionning*	*Asset Health Cost*	*Major Construction Cost*	*Total installed cost (AH + Construction)*	*Cost estimate accuracy (%)*
Asset Health (Baseline)	*2018*	*Ongoing*	*25 years*	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	*P50*
Asset Health Shell 1 (Option 1)	*2018*	*Ongoing*	*25 years*	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	*P50*
Asset Health Shell 1 and Shell 2 (Option 2)	*2018*	*Ongoing*	*25 years*	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	*P50*
Asset Health Shell 1 and Perenco 2 (Option 3)	*2018*	*Ongoing*	*25 years*	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	*P50*
Brownfield Terminal (Option 4)	*2018*	*2026*	*25 years*	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	*P50*

Options Discounted

5.24. The following options were discounted in the option development process, due to engineering justification or cost. Appendix B shows the full list of options considered.

Discounted Option, Do Nothing

5.25. In this option we would stop all capital investments to the terminal. The terminal needs to continue operating reliably and safely. Much of the hardware is of original installation and there are signs of significant and widespread deterioration. We expect this to accelerate according to the “bathtub curve”, as more assets are subjected to wear out failures. See Figure 7.

Figure 7: Bathtub Curve

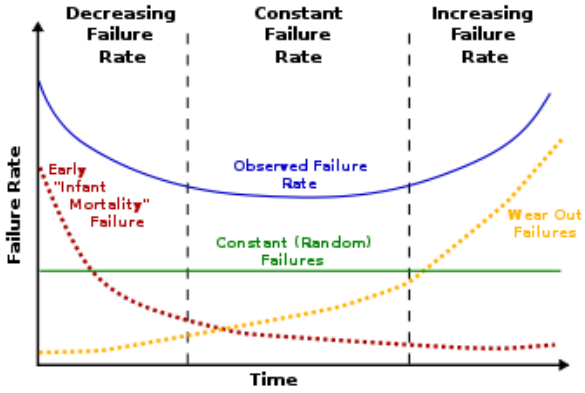
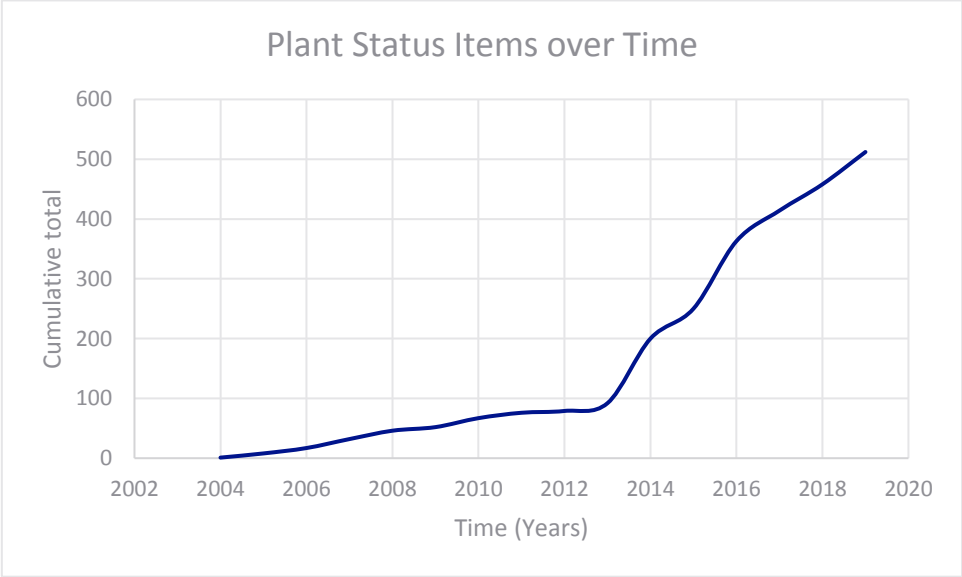


Figure 8: Cumulative Plant Status Items Raised at Bacton



5.26. Figure 8 shows the cumulative amount of plant status items (PSI) since 2004. These are defects/site issues raised for correction by site, which cannot be dealt with locally and need to form part of our investment plan. There has been a much higher rate of failures since 2013, and whilst this may be in part down to reporting accuracy, the sustained level of high PSIs would indicate many assets are approaching “increased failure rate” according to Figure 7. This leaves the site susceptible to increasing amounts of failures, more likely to have high impact.

5.27. Figure 9 shows there are 121 valves on site considered to be “passing” i.e. not sealing. These valves are block valves, whose main function is to block gas.

5.28. Those valves that are passing a small amount can operate providing gas is vented to atmosphere. This has environmental implications. For clarity the graph shows a breakdown of valves on site that are passing heavily or have a “heavy blow”. These are not usable for isolation.

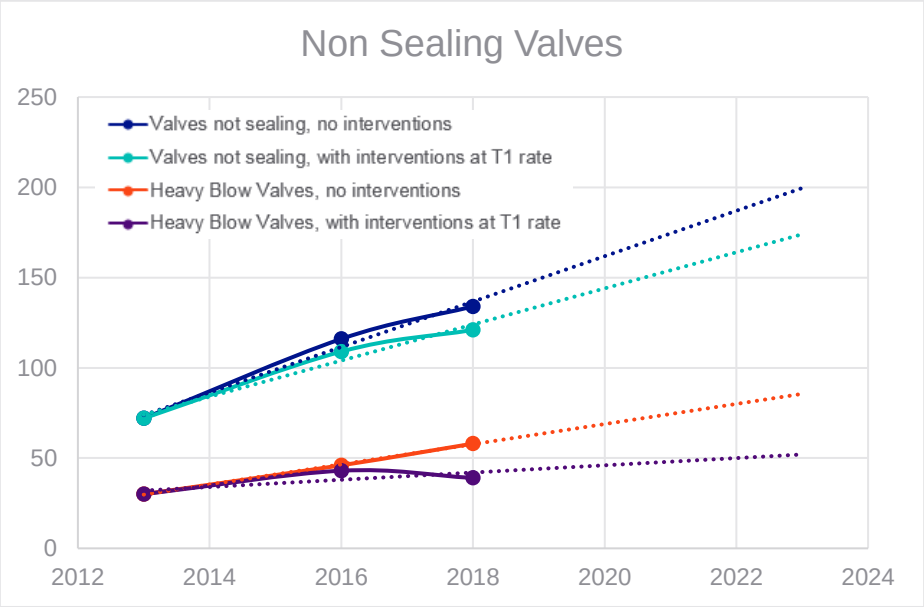
5.29. There are an increasing number of passing valves. Without intervention, the rate of failure is expected to increase. This would limit the site’s ability to manage the required South East flows.

5.30. Bacton is an upper tier COMAH site and as such represents a major hazard which National Grid must manage. Failure to do this represents a major process safety risk, and we cannot continue to operate assets if they pose an unacceptable risk to the safety of site staff or the public. In this instance we would have no option but to isolate and make the asset safe, constraining customers. Bacton is subject to scrutiny from the Health and Safety Executive (HSE) with regular intervention visits by the HSE to Bacton.

5.31. In the event of constraining customers, a significant cost penalty would be incurred, see table 8. This would be in excess of £[redacted] per day in a high forecast scenario (IUK importing), or £[redacted] per day low forecast. These costs are constraint only and does not take into account wider economic and social impacts of constraining significant gas at Bacton.

5.32. In a scenario where flow is constrained or stopped at Bacton, there would be a large effect on the consumers in the area, both to the directly connected consumers via Cadent, and further afield consumers i.e. London. The potential economic and societal impact would be far greater than the constraint management costs above.

Figure 9: Valve Condition



5.33. There is also concern about the longevity of other on site assets, as described in section 5.7.

5.34. If Bacton terminal is unable to meet its obligations, the constraint costs in Table 8 are forecast. This would usually be due to asset failure or unplanned outage. These figures are provided by our Gas System Operator team, in line with constraint cost forecasting processes. A further risk of non-investment is the diverting of gas supplies to Europe due to the unreliability of Bacton terminal. This is a risk to UK energy security of supply.

5.35. The constraint cost below is based on a buyback price of [redacted] p/kWh (£[redacted]/mcm). It is difficult to predict the buyback cost, as it will depend on market conditions at the time. As an example of worst case, 2006 buybacks at Easington and Teesside reached a peak of 9.9998p/kWh (£999,980/mcm).

5.36. This buyback cost at Bacton Perenco would total £[redacted] per day, and whilst unlikely indicates the effect of unplanned outages or significant failure at Bacton terminal.

Table 8: Estimated Constraint Costs

Bacton terminal estimated constraint costs				
Sub Terminal	flow (mcm)		Price (£)/Day (based on £[redacted] per Mcm)	
	Low	High	Low	High
Bacton Perenco	4	8	£[redacted]	£[redacted]
Bacton Shell 1 - 3	5	13	£[redacted]	£[redacted]
Bacton Shell 4	12	22	£[redacted]	£[redacted]
BBL (import)	0	40	£[redacted]	£[redacted]
BBL(export)[14]	Currently interruptible, no export constraint			
Bacton IUK (import)	0	74	£[redacted]	£[redacted]
Bacton IUK (export)	0	58	£[redacted]	£[redacted]

RIIO T1 Least Regrets

5.37. As part of our RIIO-1 submission, we requested funding for Bacton which was not granted. In order to keep the terminal operational "do nothing" was not a viable option. Therefore, a number of least regrets investments were carried out; these investments were either required to keep the terminal safe and operational, or were required to facilitate future outages.

- Valve Replacement: 17 new block valves installed to enable safe isolation of site in the event of an emergency, and during outages. Several smaller valves were also replaced to facilitate this.
    - A number of the valves replaced were leaking to atmosphere, presenting an environmental risk
    - Many of the valves at Bacton site are Borsig ball valves, a construction type which is difficult to maintain. It is generally cheaper and easier to replace these.
- Painting and Corrosion: Several instances of coating failure remedied to avoid corrosion to assets.
- Pipe Supports and Bolting: Replacement of corroded bolts and failing civil assets. Failure of these could lead to significant gas escapes.
- Preheat systems: Resolution of a number of defects on site preheat systems, which could have led to formation of liquid and ice in pipelines and subsequent failure. This was a requirement under PSSR.
- Human Machine Interfaces (HMI): Number of single point failures identified and eliminated. Lack of spares or Original Equipment Manufacturer (OEM) support would lead to site outage.

[14] BBL will start exporting gas in 2019, on an interruptible basis.

Figure 10: Example of valve replacement work

Discounted Option - Minimum Offtake Connection

5.38. For all connections to the terminal, National Grid could offer a minimum offtake connection (MOC). This would form a connection to the network, with a valve, bypass and telemetry. All other requirements would be the responsibility of the customer. For example, gas quality, metering, filtering and flow control. In this instance, all remaining assets on the terminal would be decommissioned.

5.39. In this scenario, there is significantly increased risk of not meeting South East pressure commitments. National Grid would lose the ability to manage pressures using site valves, relying heavily on the south-east cluster of compressors. This is a less efficient and environmentally friendly mode of operation due to increased compressor fuel costs. During interconnector summer export, this problem is exacerbated as Bacton becomes a net demand on the network.

5.40. This would require contracts at Isle of Grain to guarantee gas supplies when required to maintain safe pressures in the South East.

5.41. Under scenarios with high Isle of Grain flows there would be constraints across Bacton and Isle of Grain. A common pressure tier at Bacton eliminates the ability to redirect gas away from Isle of Grain creating an increased potential for constraint at both entry points. In the future the UK is forecast to become more dependent on gas imports. These constraints are likely to impact UK energy supplies.

5.42. Finally, customers and stakeholders are strongly against this option, due to the increased risk to their plant. There would be more onerous requirements on upstream plant (due to greater network pressure swings) and an increased risk of gas contaminants due to reduced filtering. Overall, National Grid would lose significant control of pressure management, and would be reliant on compressors to achieve this (Diss, Chelmsford, Cambridge).

5.43. If adopted, this approach could, under certain scenarios, result in us being unable to meet our existing contractual obligations to parties connected to the network.

Discounted Option - New Terminal, like for like

5.44. A greenfield option to build a new like-for-like terminal was explored. This would retain the existing design principle, but with upgraded equipment. This is considered a very low risk option. It would retain a tried and tested design, and would be built offline, with staggered tie-ins to current infrastructure. This would reduce the risks of working on a live site. The current site would remain operational during construction.

5.45. Preliminary cost estimates show that this option would cost upwards of £600m. In addition, there would be significant planning requirements and it would take longer. When presented to stakeholders, they were concerned by both price and the carryover of existing design issues. This option does not account for the changing future of the Bacton terminals. For the known requirements of Bacton, and future requirements, this option would be significantly over capacity. It is not considered cost beneficial and was therefore ruled out.

Discounted Option - Common Pressure Terminal

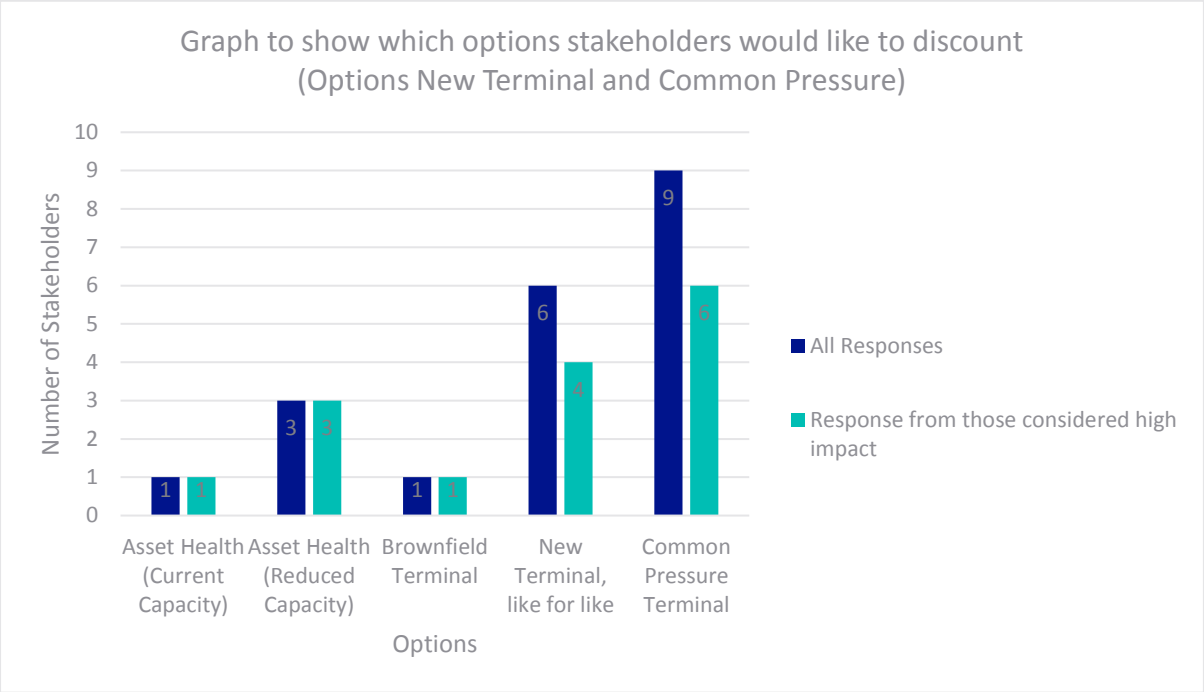
5.46. This complexity (five feeders, UKCS import and interconnector import/export) means a simplified site like Easington or Milford Haven is not feasible.

5.47. Converting the terminal to a common pressure, is similar to MOC. However, the majority of pipework and valves would remain, allowing the option of segregating parts of site for outages or operational issues. There would be no flow control, metering, filtering or heating.

5.48. In this scenario, there is significantly increased risk of not meeting South East pressure requirements (45 bar at 06:00 at Tatsfield). This would require contracts at Isle of Grain to guarantee gas supplies when required to maintain pressures in the South East. Under scenarios with high Isle of Grain flows there would be constraints across Bacton and IOG. A common pressure tier at Bacton eliminates the ability to redirect gas away from IOG creating an increased potential for constraint at both entry points.

5.49. Finally, customers and stakeholders are strongly against this option, due to the increased risk to their plant. This is shown in figure 11. There would be more onerous requirements on upstream plant (due to greater network pressure swings) and an increased risk of gas contaminants due to reduced filtering. Overall, National Grid would lose significant control of pressure management, and would be reliant on compressors to achieve this (Diss, Chelmsford, Cambridge).

Figure 11: Discounted Options Poll*



*NOTE THAT OPTION FOR "DO NOTHING" WAS NOT SHARED WITH STAKEHOLDERS DUE TO THE HEALTH AND SAFETY IMPLICATIONS THIS WOULD HAVE.

THE OPTION FOR "MOC" IS SIMILAR IN OPERATION FOR CUSTOMERS TO THE "COMMON PRESSURE TERMINAL", THEREFORE IS NOT SHOWN IN FIGURE 11

*HIGH IMPACT STAKEHOLDERS ARE THOSE WHO HAVE A DIRECT, DAY-TO-DAY INTERACTION WITH SITE I.E. OPERATORS, INTERCONNECTORS AND LOCAL DISTRIBUTION

6. Business Case Outline and Discussion

Key Business Case Drivers Description

6.1. Bacton Terminal, Norfolk, is a key site for the transmission network. It brings gas onto the system from the Southern North Sea, and connects the UK to European Gas markets in Belgium and Netherlands. It delivers gas to the South East of the UK, a key demand area including London. It is the only terminal on the transmission network that regularly switches from being net supply, to net demand. It is one of two top tier COMAH sites on the transmission network.

6.2. Over the last two years we have seen winter days where the terminal delivered up to 39% of GB gas supplies and other days where export through Bacton represented up to 30% of GB gas demand.

6.3. The most cost-effective and lowest risk option for Bacton Terminal is to rebuild the site. This would use modern techniques and processes. The major construction period would be condensed. Construction risk would be reduced by building offline and offsite where possible.

6.4. Construction of a new site (either greenfield or brownfield), allows the terminal to be built for the current and future needs of the network and industry. The main challenge facing our UKCS stakeholders, is maximising the efficiency and economic recovery of gas reserves, contributing to the security of UK energy supplies and benefitting the UK economy. National Grid can play an important role in realising this. This is backed up by dialogue with customers and stakeholders.

6.5. The current site layout is aged and has significant asset health issues. It is also over capacity and does not reflect current or future needs. The cost to rectify the current asset health issues, and then maintain the site is high.

6.6. There is also inherent risk in up to 20 years of continued, significant asset health, if the site were maintained as is:

- People – There is an increased risk exposure to National Grid staff and contractors if we have a prolonged Asset Health programme.
- Cost – Recent costs at St Fergus terminal have highlighted the risk of finding additional items in a poor state and requiring intervention once excavations and inspections start. Current estimates show an overspend of 225% compared with original estimates.
    - Note, it is not expected that this overspend would occur at Bacton as it is not a fully like-for-like comparison. But St Fergus terminal highlights the risk.
    - Some of these risks include, but are not limited to: corrosion, defects and tie-ins of new and old systems and underground equipment which cannot easily be inspected. These risks apply to Bacton.
- Time – As the site deteriorates (per the bathtub curve), there is a risk that increased defects and failures would leave National Grid responding to and managing asset failures, rather than proactively managing the assets.

Table 9 Comparison of costs between brownfield terminal and baseline

	T2/T3 Asset Health (inc. construction) Spend[15]	**T2/T3 TOTEX Spend**	**2042 TOTEX Spend**
Brownfield Redevelopment	£[redacted]m	£[redacted]m	£[redacted]m
Baseline (Asset Health)[16]	£[redacted]m	£[redacted]m	£[redacted]m

6.7. These figures do not consider the decreased risks of constraining customers, reduced cost of operating a lower tier COMAH site (compared to upper tier) or the increased safety. It considers a conservative valve replacement approach. Finally, it does not consider the wider implications to the Southern North Sea, and possibility of longer term gas flows.

6.8. Stakeholder engagement has shown a strong preference towards a new terminal, over significant Asset Health. The short timeline, minimised disruption and future capabilities are important to our stakeholders' strategies. It is recognised that

[15] Not including decommissioning

[16] Including BBL valves

National Grid capability plays a key role in their business strategies. See appendix A.

6.9. A brownfield terminal would secure gas supply in the South East for a significant number of consumers, businesses and customers. It will help maximise economic recovery in the Southern North Sea, which in turn will help deliver savings to the consumer, as continental shelf gas is generally cheaper than LNG alternatives. Looking further ahead, a brownfield redevelopment offers numerous opportunities for expansion and repurpose, as the UK aims to meet its 2050 Net Zero[17] target.

6.10. Finally, if the option of a brownfield design terminal is not taken forward, the default fall back will be asset health. See baseline option. There is no viable do nothing option.

Deliverability

6.11. The Bacton redevelopment proposal has been built up using both internal expertise and external consultants. Although a challenge, the redeveloped terminal minimises site outages by using repeatable pre-assembled units, and by constructing the majority of the terminal offline. By building above ground, costly and time consuming excavations are avoided where possible.

6.12. Recent site experience at Bacton of significant asset health programmes, increases confidence that this programme is deliverable. We have experience of the environmental conditions, constraints, and likely risks as well as good relations with the local authorities.

Supply and Demand Scenario Sensitivities

Constraint Costs

6.13. Assessment of future constraint costs is an important factor in our decision-making process. It enables us to evaluate and recommend investments.

6.14. As Bacton is currently setup, there is a very low likelihood of constraint risk, based on the availability of 6 incoming pipelines (2x Perenco, 4x Shell) and the assumption that **each pipeline stream is 90% available**. This is used to calculate, for the different options, the % of the year that all streams are rendered unavailable at a point when Bacton is flowing. If Bacton is flowing (flows >0) then at least 1 of the incomers needs to be available otherwise constraints will be incurred.

6.15. For this CBA, the constraint management action is an NTS Entry Capacity buybacks (prompts, forwards or options). This action has an assumed cost associated with it and this is reflected in our model. All constraints have been costed as a Section I sub-terminal buyback[18]. The model calculates the volume of gas that we would expect to “constrain” within a yearly period using each specific option, and multiples this by the cost of gas supplied by BEIS.

6.16. Constraint Assumptions include:

- Old asset assumed 90% availability per stream
- New asset assumed 99% availability per stream

[17] https://www.bbc.co.uk/news/science-environment-48596775

[18] See Section I of the Transportation Principal Document http://www.gasgovernance.co.uk/TPD

Figure 12: Total Constraint Cost

6.17. When the site is rationalised, there is decreased availability of the site and therefore the likelihood and quantum of incurring constraints increases.

6.18. Asset Health and Brownfield options show a very low constraint cost over the assessment period. This is due to the reliability of the incomers and forecasted volumes of flows annually. The availabilities show that the likelihood of failure is reduced.

6.19. To test the sensitivity of the Bacton case to different supply and demand scenarios two sensitivities have been applied.

6.20. For the high sensitivity we tested a Stakeholder scenario where we see Bacton UKCS flowing well after 2040.

6.21. The Community Renewable scenario was used as a low case sensitivity. This scenario sees a quicker decline to UKCS and also at a lower volume which reduces the requirements of Bacton terminal into the future.

CBA Assessment

6.22. Note that the calculated NPVs discussed through the rest of this chapter assume a capitalisation rate of 73.5%. This capitalisation rate has now been updated, and therefore there may be a minor mismatch between quoted NPVs between this document and the associated CBA (Annex A14.03). Please note that this does not affect the final proposed option. The impact of the updated capitalisation rate is reflected in the CBA document.

6.23. Based on our central scenario two options have a positive NPV compared to the counterfactual. The options are Shell 1 (disconnect Shell 1) and Brownfield (new terminal).

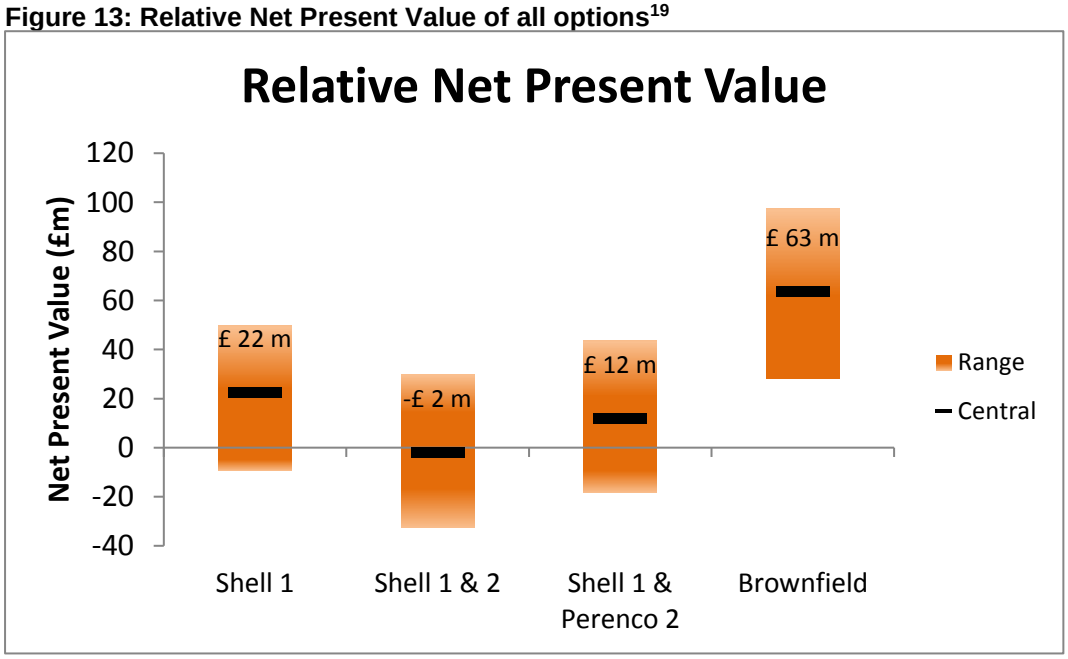
6.24. The lead option is Brownfield, which has a positive NPV of £63m compared to Asset Health as shown in Table 10.

Table 10: CBA Summary

Short Name	Description	NPV £m	Relative NPV £m
Option 0	Phased replacement of aged assets	-£251.4 m	£0.0 m
Shell 1	Disconnect Shell 1.	-£230.3 m	£21.1 m
Shell 1 & 2	Disconnect Shell 1 and Shell 2	-£252.8 m	-£1.4 m
Shell 1 & Perenco 2	Disconnect Shell 1 and Perenco 2	-£239.8 m	£11.7 m
Brownfield	Brownfield Terminal	-£188.4 m	£63.0 m

6.25. Figure 13 displays the NPV of the options relative to the counterfactual (Asset Health). This shows how Brownfield and Shell 1 show are positive NPV compared to the counterfactual.

Figure 13: Relative Net Present Value of all options[19]



Sensitivities

6.26. The CBA was run under the high and low sensitivities to understand how these could change the results. Brownfield option is the most favoured option with a positive NPV of above £62m in both the high and low sensitivities. The regular flows into Bacton, regardless of when UKCS depletes, results in a requirement to have a safe and reliable terminal and this increases the benefits seen in this option due to the higher reliability and lower cost compared to the asset health options.

[19] Note that this graph is based on NPV over 45 years, as per internal National Grid Cost Benefit Analysis. NPV in tables is project life NPV.

Table 10: CBA Sensitivities

Short Name	Description	Central Case – Steady Progression	Community Renewables (low)	Stakeholder Scenario (high)
Option 0	Phased replacement of aged assets	£0.0 m	£0.0 m	£0.0 m
Shell 1	Disconnect Shell 1.	£22.4 m	£21.2 m	£21.0 m
Shell 1 & 2	Disconnect Shell 1 & Shell 2	-£2.0 m	£0.1 m	-£1.5 m
Shell 1 & Perenco 2	Disconnect Shell 1 & Perenco 2	£11.7 m	£13.7 m	£11.5 m
Brownfield	Brownfield Terminal	£63.3 m	£63.2 m	£62.2 m

6.27. Further sensitivities on OPEX and CAPEX spend are in Appendix C

CBA Summary

6.28. At this stage of the assessment the NPV show the Brownfield is the best option with a consumer saving of £63 million against the default asset health option.

6.29. Shell 1 option (reduction of 1 incomer) also delivers consumer saving. However, due to experience from St Fergus, there is the possibility of a significant increase in asset health cost of working on an old terminal. Therefore, this risk needs to be considered and if the cost of asset health increases, it could reduce the £21million positive position.

Business Case Summary

6.30. The table below shows costs over the project life. The project NPV considers lifetime costs, which includes additional asset health work for all options.

Table 11: Summary of costs

Option title	*Supply and Demand Scenario*	*Project commissioning date*	*Total installed cost*	*Cost estimate accuracy (%)*	*Project operating lifespan*	*Project NPV*
Asset Health	*Steady Progression*	*Ongoing*	*£[redacted]m*	*P50*	*25 years*	*-£251 m*
Asset Health, Shell 1	*Steady Progression*	*Ongoing*	*£[redacted]m*	*P50*	*25 years*	*-£230 m*
Asset Health Shell 1 and Shell 2	*Steady Progression*	*Ongoing*	*£[redacted]m*	*P50*	*25 years*	*-£253 m*
Asset Health Shell 1 and Perenco 2	*Steady Progression*	*Ongoing*	*£[redacted]m*	*P50*	*25 years*	*-£240 m*
Brownfield Terminal	*Steady Progression*	*2026*	*£[redacted]m*	*P50*	*25 years*	*-£188 m*

7. Preferred Option Scope and Project Plan

Preferred Option for this Request

7.1. The most cost-effective and lowest risk option for Bacton Terminal is to rebuild the site. This would cost £139.3m in RIIO-2 and £5.1m in RIIO-3. This value consists of:

- £[redacted]m baseline funding for FEED study and tender event
- £[redacted]m for brownfield terminal design and build
- £[redacted]m baseline asset health funding, accounted for in the relevant asset health themes, for least regrets work in RIIO-2. Not requested in this paper.

7.2. The table below shows Project Spend Profile

Table 12: Spend Profile

£m	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
CAPEX FEED	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
CAPEX UM	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Efficient Cost

7.3. Bacton has been considered using a holistic, site wide approach in order to ensure that the solution is the most efficient. This includes looking at asset health, physical security, decommissioning, and operational expenditure as one, understanding the impact that changes in investment would affect the overall solution. This has allowed the identification of efficiencies within both volume and schedule.

7.4. In calculating the cost for a brownfield site, consideration has been given to several factors to reduce cost and increase efficiency.

- Use of modular build philosophy, to reduce time and movement on site. This will decrease the time required for construction and outages. It will also reduce the effect of site constraints, due to simultaneous operations.
- Simplistic construction strategy, to reduce cranage requirements and stagger delivery of assets, reducing temporary storage
- Schedule developed which allows concurrent working on multiple assets/construction areas
- Repeated fabrication modules, improving quality and reducing cost

7.5. Lessons learned from the current asset health programme have been implemented into costs, and the costs/timescales for RIIO-2 asset health work developed in conjunction with current contractors on site.

7.6. Two external consultants, Petrofac and Atkins, have been used to define and assure our cost for a redeveloped terminal. The use of two independent consultants, in addition with our internal ehub costing team, gives us confidence that we have selected the correct option for Bacton terminal.

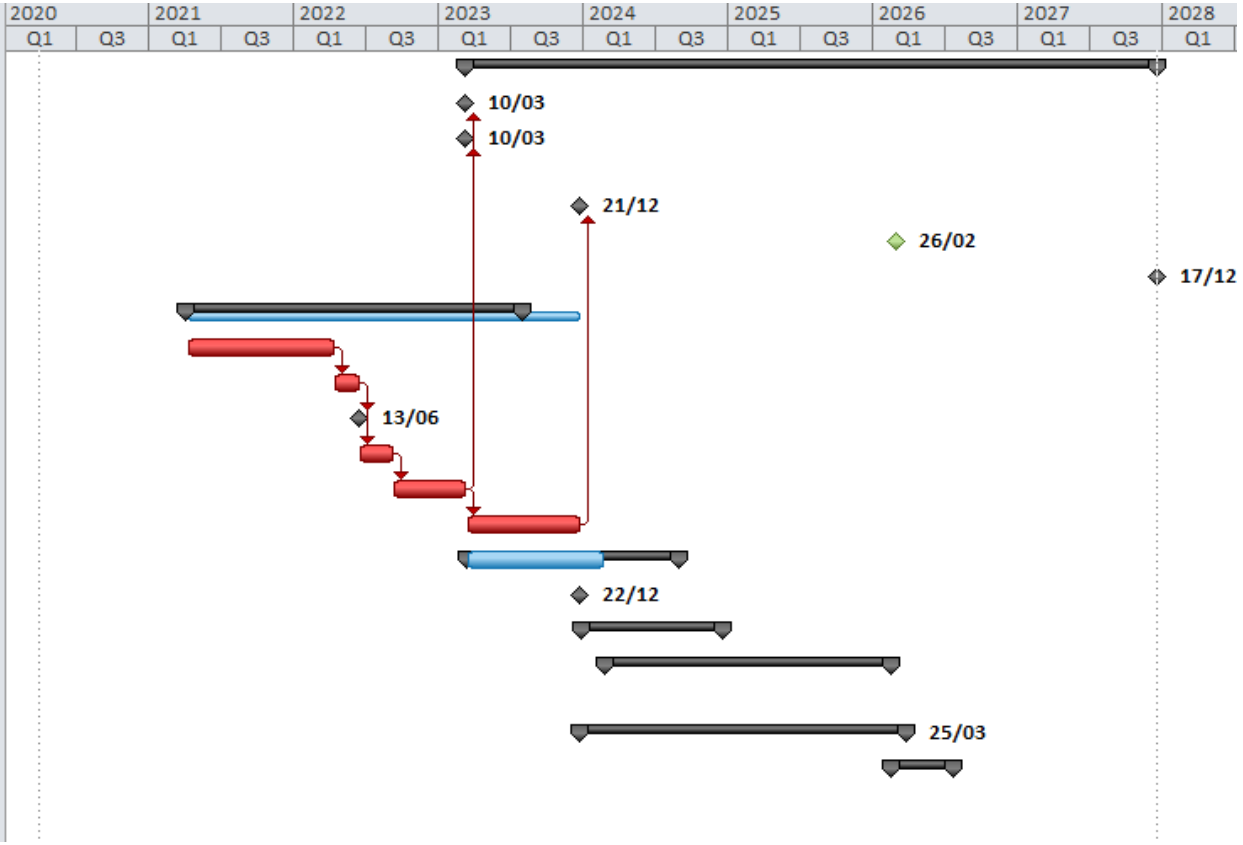
7.7. It is however, understood that these costs carry a degree of uncertainty due to the project stage they are in (Stage 4.1). We propose a PCD to measure our deliver of FEED in RIIO-2. With associated baseline funding to achieve this.

7.8. We are also requesting baseline funding to redevelop Bacton terminal in our RIIO-2 plan. We are proposing to use a re-opener uncertainty mechanism post-FEED to adjust these baseline costs and to define a new PCD for delivery of the solution identified.

8. Project Plan

8.1. Note, this plan is **calendar years** not financial years

	Task Name	Duration	Start	Finish
1	Milestones	1215 days	Fri 10/03/23	Fri 17/12/27
2	FID	0 days	Fri 10/03/23	Fri 10/03/23
3	F3 - Conceptual Design, Long Lead Items	0 days	Fri 10/03/23	Fri 10/03/23
4	F4 - Design and Build	0 days	Thu 21/12/23	Thu 21/12/23
5	T6 - Commission	0 days	Thu 26/02/26	Thu 26/02/26
6	F5 - Project Closure	0 days	Fri 17/12/27	Fri 17/12/27
7	**Design and Engineering**	**590 days**	**Tue 06/04/21**	**Wed 02/08/23**
8	FEED and EIA	260 days	Tue 06/04/21	Tue 12/04/22
9	Compile Reopener	40 days	Wed 13/04/22	Mon 13/06/22
10	Reopener	0 days	Mon 13/06/22	Mon 13/06/22
11	OFGEM deliberation	60 days	Tue 14/06/22	Tue 06/09/22
12	EPC Tender	130 days	Wed 07/09/22	Fri 10/03/23
13	Detail Design	200 days	Mon 13/03/23	Thu 21/12/23
14	**Procurement**	**370 days**	**Tue 14/03/23**	**Wed 28/08/24**
19	**Sub contracts**	**0 days**	**Fri 22/12/23**	**Fri 22/12/23**
23	**Road Extension**	**250 days**	**Wed 27/12/23**	**Wed 18/12/24**
25	**Offsite Modular Fabrication**	**500 days**	**Fri 23/02/24**	**Fri 13/02/26**
32	**Construction**	570 days	Fri 22/12/23	Wed 25/03/26
50	**Main Works**	**108 days**	**Fri 13/02/26**	**Tue 21/07/26**



9. Key Business Risks and Opportunities

9.1. If UK Continental Shelf Gas flows until 2042 and beyond, in line with stakeholder feedback, Brownfield redevelopment becomes even more cost beneficial. See CBA sensitivities.

9.2. All 6 UKCS incoming pipes are assumed to be retained and reducing the number of these would reduce the build cost. However, it would increase constraint risk, therefore it is assumed that they will be retained currently.

9.3. No requirement for significant planning or environmental assessments (Phase 1 only). It is a Brownfield development, with no increase to land acreage, or height and no sensitive sites in the vicinity. If this changes, cost and time would be increased.

9.4. We will seek to minimise the impact of our construction activity on the environment as we progress through the design and build phases of the project.

10. Outputs Included in RIIO-T1 Plans

10.1. There were no outputs or allowances for Bacton included in RIIO-1 plans. All Bacton RIIO-1 asset health work has been completed under our asset health programme.

11. Appendix A – Bacton Stakeholder Engagement

11.1. A robust process of external stakeholder engagement has been undertaken to determine our proposed programme of work on Bacton. Representatives from a wide range of groups including local authorities, local businesses, industry regulators, terminal operators, offshore companies, the gas distribution network (GDN), interconnectors and gas suppliers have been consulted.

11.2. Our engagement on the future for the site came from a business stakeholder event held at Bacton in summer 2018. The purpose of the event was to hear stakeholders' views on the future of the gas transmission system. At this event we heard how important Bacton was to the wider industry, and, in particular, the governments priority to maximise the economic recovery of gas supplies from the North Sea. As a result of the critical nature of Bacton to many of the stakeholders we decided to consult more widely on how we should address the significant asset health issues on site.

Conversations

11.3. At the start of the process, we held individual conversations with 9 stakeholders. The purpose of these conversations was threefold:

- To explain how we are regulated and the need to submit well justified business plans to justify future expenditure. From previous engagement we found that many of our stakeholders did not understand how we were funded and it was a question they asked.
- We wanted to understand their recent experience of working with National Grid so we could identify areas where our performance could be improved, and hence work more closely with stakeholders.
- We wanted to understand how we could help meet stakeholders' current and future needs at the Bacton terminal. Can we align our objectives with their business strategies? What are stakeholders' short and long-term needs from Bacton to enable them to deliver for UK consumers and the local population?

Group Engagement

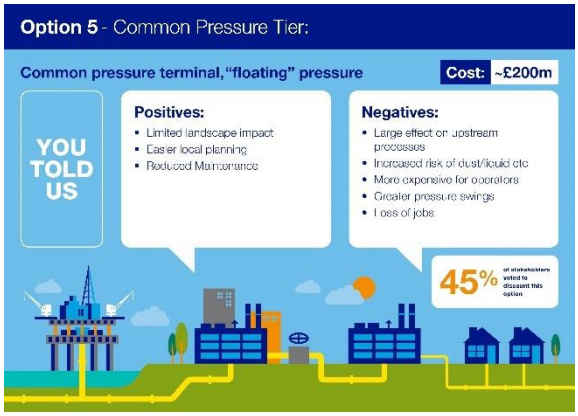
11.4. Following one-to-one engagement, we held a workshop with approximately 20 attendees in Norwich in December 2018. We shared back with stakeholders what they had told us was important for them. Key messages we fed back were:

- Customers want their current contractual requirements honoured.
- Pressures, and the predictability of them, are important to customers. For some it was because it is interdependent with their gas compression capability. Some stakeholders preferred lower pressures and others higher pressures.
- Reliability was critical for all. Our Bacton terminal is the biggest export/import area of the UK for connected parties and any unplanned disruption causes major disruption to their businesses and potentially to UK gas supplies. There are also potential implications for disruption to European gas supplies.
- Obtaining and agreeing outages of more than 2 weeks a year aligned to their plant outages will be very difficult. The gas distribution network connection is a single feed to domestic consumers so no outage is possible.

- Our customers value the flexibility to change flows at short notice.
- Our stakeholders have plans to develop UKCS fields to the 2040s. Interconnector business plans also span this timeframe.
- The terminals at Bacton have recently made significant investments due to the age and condition of their similarly aged assets. This included Shell who published a BBC article stating they had invested £350m in their Bacton terminal.
- Local authorities were keen to understand how the options we developed could impact employment in the area. They also provided insight into land availability should we need to build outside the current terminal footprint.
- UKCS stakeholders were interested in blending services as the composition of some North Sea Gas is falling outside the UK gas specification requirements.

11.5. Five options for mitigating the aging asset issues on the site were developed. These were shared with stakeholders and we asked them in small working groups to provide feedback on each of the options. We asked them for positives and negatives of each of the options, see Figure14 below.

Figure 14: The different options presented to stakeholders and the views given by stakeholders



We then asked Stakeholders which two options they would like us to take forward for further study and if there were any options they would like us to discount.

Figure 15: Responses to the Question: Which Options Would you like us to Progress?

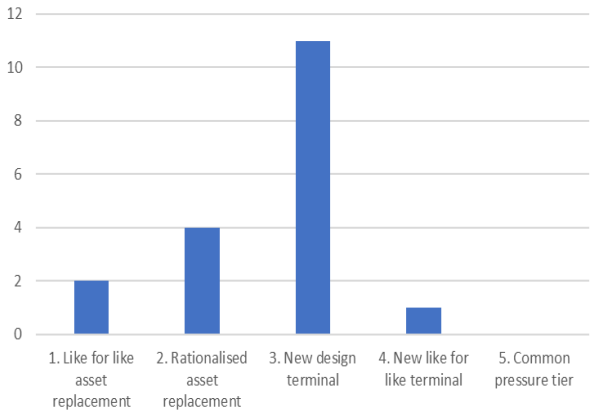
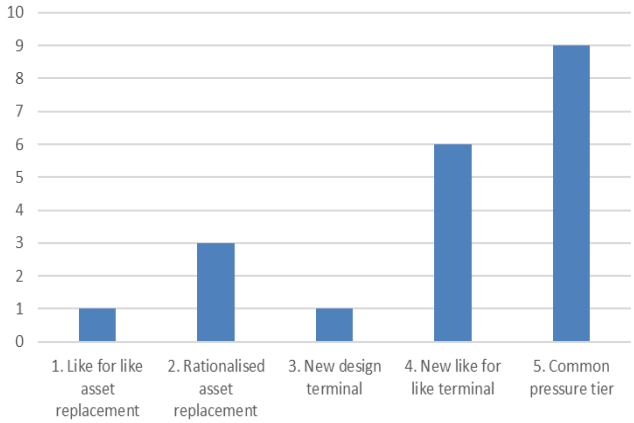


Figure 16: Responses to the Question: Which Options Would you like us to Discount?



Summary

11.6. As a result of the feedback from stakeholders we decided to discount Option 5: Common Pressure Tier and Option 4: New like for like site terminal.

11.7. We will progress Option 3: New Design Terminal and Option 2: Rationalised Asset Replacement for further study.

11.8. In March, we held a webinar with the purpose of:

- Sharing our cost benefit analysis on these options
- Gaining stakeholder views on our proposed option

11.9. During the webinar we asked Do you support our decision to progress with a new terminal?

- Yes - 67%
- Unsure - 33%

12. Appendix B – Full Options Considered

Option No.	Included in this CBA? *(Y/N)*	Corresponding Tab	Description	Comment
1	Y	Baseline	Asset Health, Current Capacity	Site would remain as is, with significant asset investment required in a piecemeal fashion
2	Y	Option 1	Asset Health, Reduced Capacity, S1	Site would remain as is, with significant asset investment required in a piecemeal fashion. Shell 1 incomer would be decommissioned due to reducing UKCS flow.
3	Y	Option 2	Asset Health, Reduced Capacity, S1 + S2	Site would remain as is, with significant asset investment required in a piecemeal fashion. Shell 1 and 2 incomers would be decommissioned due to reducing UKCS flow.
4	Y	Option 3	Asset Health, Reduced Capacity, S1 + P1	Site would remain as is, with significant asset investment required in a piecemeal fashion. Shell 1 and Perenco 2 incomers would be decommissioned due to reducing UKCS flow.
5	Y	Option 4	Brownfield Terminal	Terminal would be redeveloped to suit current and future needs. Complete replacement of most assets.
6	N		Asset Health, Relife of Valves, Current Capacity	The majority of valves at Bacton (circa 70%), are Cameron ball valves. NG have no experience in relifing this valve. In addition the construction of the valves are welded, therefore the costs and risk of deconstructing the valve to perform a relife are likely to be substantial. Therefore this option is discounted.
7	N		Asset Health, Reduced Capacity, S1 +S2 + P1	This option was run in a "first pass" CBA and showed very high constraint risk, therefore was discounted.
8	N		Asset Health, Reduced Capacity, S1 + S2 + S3 + P1	This option was run in a "first pass" CBA and showed very high constraint risk, therefore was discounted.
9	N		Asset Health, Pipe Through Valves	The option of piping through valves rather than replacement has been looked at. This would offer a saving in terms of OPEX. The total cost of piping through valves would in general be similar to that of replacement, as the majority of cost is absorbed in project management and civils. Due to the current site layout, very few of the valves could be piped through due to the requirement for maintenance on filters, heaters etc... there would be insufficient means to conduct a double block and bleed isolation, while maintaining site operation. Therefore this options has been discounted.

10	N		New Greenfield Site	This option has been ruled out during options development as the costs associated with this would be the same build costs as brownfield, + extra land costs, + extra costs to connect incomers and would therefore work out much more expensive. However land costs should be evaluated in greater detail to weigh up PROs and Cons later in the design. It is expected due to planning conditions, this option is not feasible
11	N		New Greenfield Site, Current Layout	This option has been ruled out due to cost, and over design.
12	N		Common Pressure Terminal	This option would significantly reduce flexibility, increasing constraint risk. It would be expensive to implement (similar to Asset Health), due to the fact valves would need piping through. Stakeholders were against this option, as it would mean unpredictable pressure swings.
13	N		Decommission Terminal	This option was ruled out as there is an enduring need for Bacton
14	N		Do Nothing	This option assumes no Capital Investment at Bacton. It is not considered viable due to the age of many of the assets, and HSE intervention.
15	N		Minimum Offtake Connection	This would pass all responsibility for flow, gas quality and metering onto the customer. It would increase the risk to the network. It is also against current contractual agreements and has bee discounted

13. Appendix C – Cost Benefit Sensitivities

13.1. To understand how dependant, the chosen option is to the assumptions, several sensitivities were run in the costs benefit analysis.

- Brownfield terminal, baseline OPEX
- Baseline asset health, +20% CAPEX cost
- Baseline asset health, -20% CAPEX cost
- Baseline asset health, 2-week unplanned outage on Perenco sub terminal
    - Assumes 8mcm/d constraint, 14 days, at £223,800/Mcm
    - Cost smeared over 5 years of RIIO-2
- Brownfield terminal, +30% CAPEX cost on major construction only
- Brownfield terminal, +30% CAPEX cost on major construction only + baseline OPEX

13.2. The summary of costs compared to the baseline asset health, and brownfield terminal are:

Option title	*Supply and Demand Scenario*	*Total installed cost*	*OPEX*	*Constraint Costs*	*Project NPV*
Asset Health	*Steady Progression*	*£[redacted]m*	*£[redacted]m*	*£[redacted]m*	*-£251m*
Brownfield Terminal	*Steady Progression*	*£[redacted]m*	*£[redacted]m*	*£[redacted]m*	*-£188m*
Brownfield Terminal, baseline OPEX	*Steady Progression*	*£[redacted]m*	*£[redacted]m*	*£[redacted]m*	*-£212m*
Asset Health, +20% CAPEX	*Steady Progression*	*£[redacted]m*	*£[redacted]m*	*£[redacted]m*	*-£290m*
Asset Health, -20% CAPEX	*Steady Progression*	*£[redacted]m*	*£[redacted]m*	*£[redacted]m*	*-£213m*
Asset Health, 2-week outage	*Steady Progression*	*£[redacted]m*	*£[redacted]m*	*£[redacted]m*	*-£275m*
Brownfield Terminal, +30% CAPEX	*Steady Progression*	*£[redacted]m*	*£[redacted]m*	*£[redacted]m*	*-£226m*
Brownfield Terminal, +30% CAPEX, Baseline OPEX	*Steady Progression*	*£[redacted]m*	*£[redacted]m*	*£[redacted]m*	*-£254m*

13.3. Even in the worst-case sensitivity, CAPEX costs of brownfield terminal increased by 30%, and current baseline OPEX costs, the brownfield terminal is only £-2m negative NPV compared to the baseline asset health.

14. Appendix D – Letters of Support

[redacted]

[redacted]