June 2025

LookNorthH2 Alpha

Show and Tell

nationalgrid

Guidehouse
Outwit Complexity

CIP
Copenhagen Infrastructure Partners

national gas

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Asheya Patten
Project Oversight

Mark Copley
Project Director

Jon Hunte
Innovation Engineer

Alex Goodey
Senior Manager – Market Analytics

Stefan Borozan
Senior Analyst

Zain ul-Abadin
Energy Analyst

Alex Jakeman
Associate Director

Milo Boirot
Project Manager

Lauren Emmens
Project Consultant

Mark Livingstone
Partner | Communities, Energy and Infrastructure

Copenhagen Infrastructure Partners

Marina Mourão Starling
Energy Islands Manager

Hessel De Jong
Chief Operating Officer

Rhys Jones
Vice President | Government Affairs and Communications

Alistair Carvell
H_2 Innovation Manager

Kris Jacob
Market Change Development Analyst

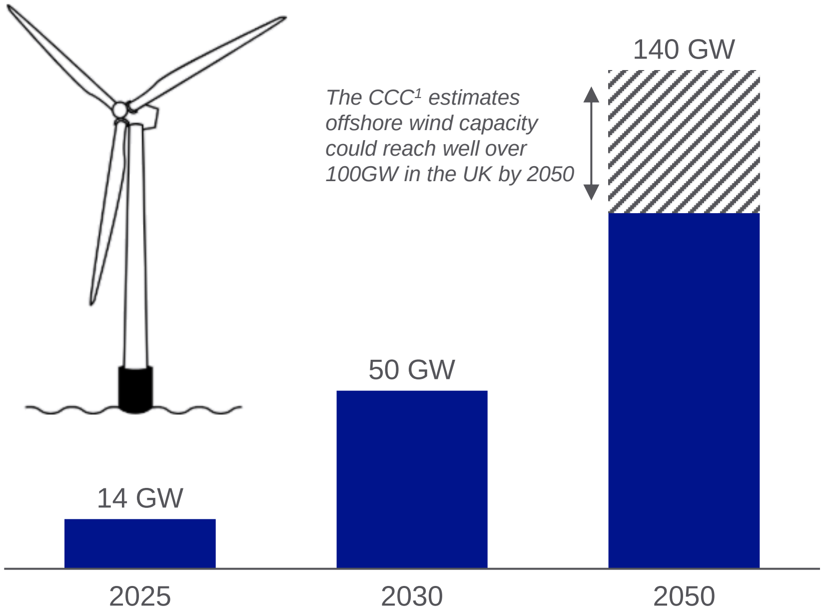
...with many other valuable contributors from each partner!

Project Overview

Motivation, Overview and Opportunities Identified

The UK has a huge wind and hydrogen potential, harnessing it to achieve net zero targets and beyond will require new solutions

Installed UK offshore wind capacity is set to triple by 2030 and reach well over 100 GW by 2050



Which will require an increase in the scale, pace, and complexity of both hydrogen and electricity assets by 2050

The existing electricity and gas network:

- Largely planned and built separately
- Not a significant amount of large-scale investments in the last 30 years

The future electricity and hydrogen network:

- Needs to take more power from windfarms off the coast and connect it to the same population centres
- More is required to connect the coast to central regions

We estimate that **£85bn[3] of investments in UK offshore electricity transmission infrastructure alone are needed by 2050, in addition to the transformation of the gas networks to hydrogen**

Sources: [1]CCC Six Carbon Budget, [2]National Grid – The Great Grid Upgrade, [3]Estimated based on ONDP figures scaled to the UK

Project Overview

OBJECTIVE

The primary objective of LookNortH2 Alpha is to progress understanding of offshore energy hubs and their potential benefits.

KEY OUTPUTS

1. A whole system modelling skeleton that, when full developed in Beta, can help underpin the business case for offshore energy hubs.
2. Greater awareness and understanding of energy hub commercial market options in the UK.

FUNDING MECHANISM	PROJECT BUDGET
Ofgem Strategic Innovation Fund, Round 3 Alpha	**~£447K**

PARTNER	DESCRIPTION
National Grid Electricity Transmission Plc (Lead Partner)	The owner of the high voltage electricity transmission infrastructure in England and Wales.
Guidehouse Europe Limited	A next-generation advisory, technology, and managed services firm dedicated to shaping the future of the energy system.
Copenhagen Energy Islands ApS	Copenhagen Energy Islands (CEI) is a company carved out from CIP and dedicated to early-stage development of energy island projects globally.
National Gas Transmission	The owner of gas and hydrogen transmission infrastructure across Great Britain.

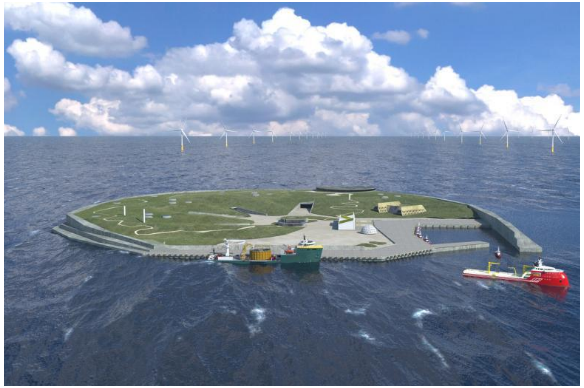
Hub Concept - Definition

What is an offshore energy hub and what benefit could it provide?

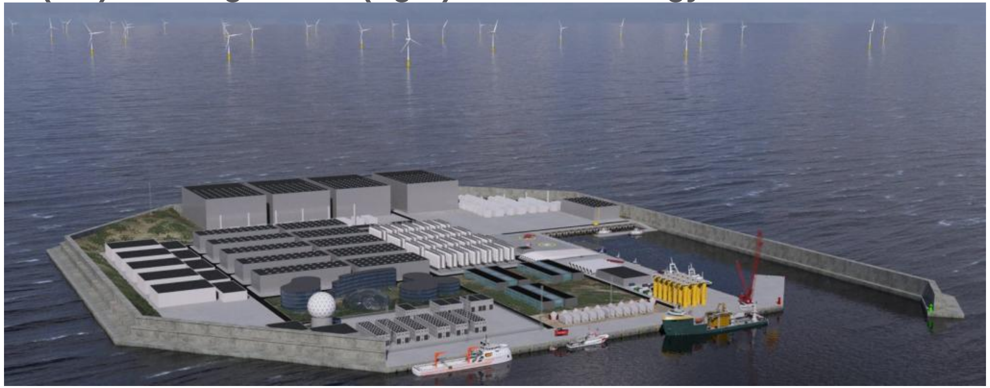
Offshore energy hub project definition

1. Any configuration of offshore wind generation, storage, load, and network assets integrated in a way that can create cost-efficiencies and cross-vector energy system development.
2. This includes offshore platforms, energy islands and approaches which repurpose existing gas infrastructure

Illustration of a small-scale (left) and large-scale (right) offshore energy hub



https://www.straitstimes.com/world/europe/denmark-wants-to-build-the-worlds-first-energy-island



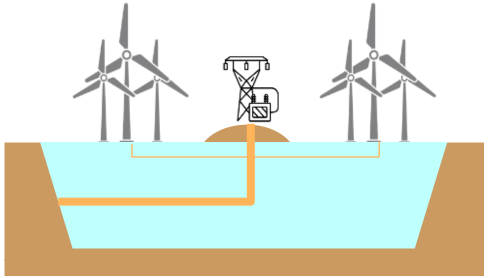
https://renewablesnow.com/news/cip-sets-up-new-company-to-develop-energy-islands-846049/

Offshore energy hubs may evolve in various forms, starting with basic meshed designs and progressing towards fully integrated islands

A "hub" is, by definition, a platform where multiple assets integrate to create efficiencies. In its simplest form, this could include:

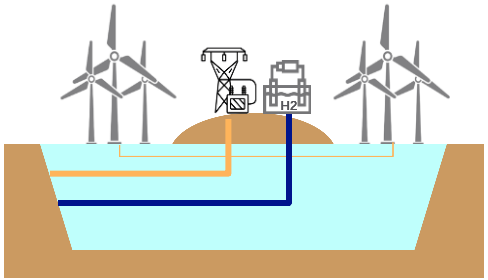
Meshed electrical-only design:

- Offshore wind connected to shore via a meshed system facilitated by an offshore energy island with 525kV (2,000MW) cables
- HVDC equipment is located on the island
- Potentially: could include interconnections to other countries

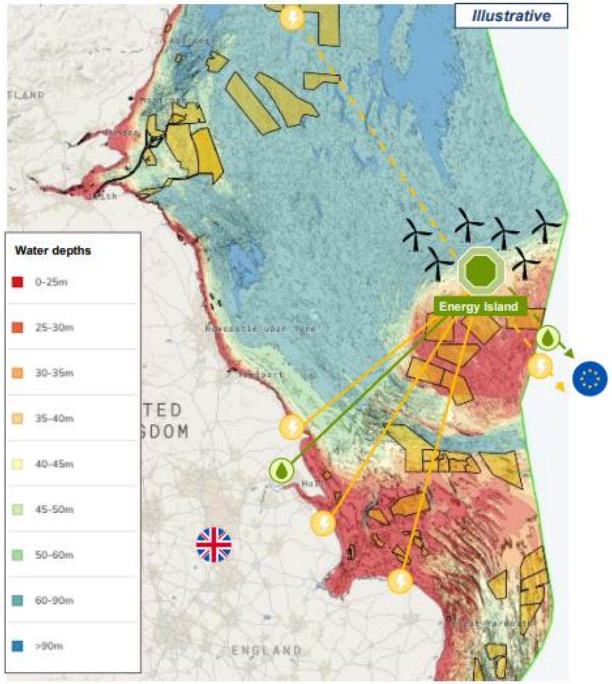


Meshed design with offshore electrolysis:

- Same as above, with integrated electrolysers located on the offshore island
- Electrolysers convert some of the wind power into green hydrogen, which would then be transported to shore via a hydrogen pipeline
- Potentially: could also include additional uses for wind power (e.g., CO2 sequestration)



Example potential project location



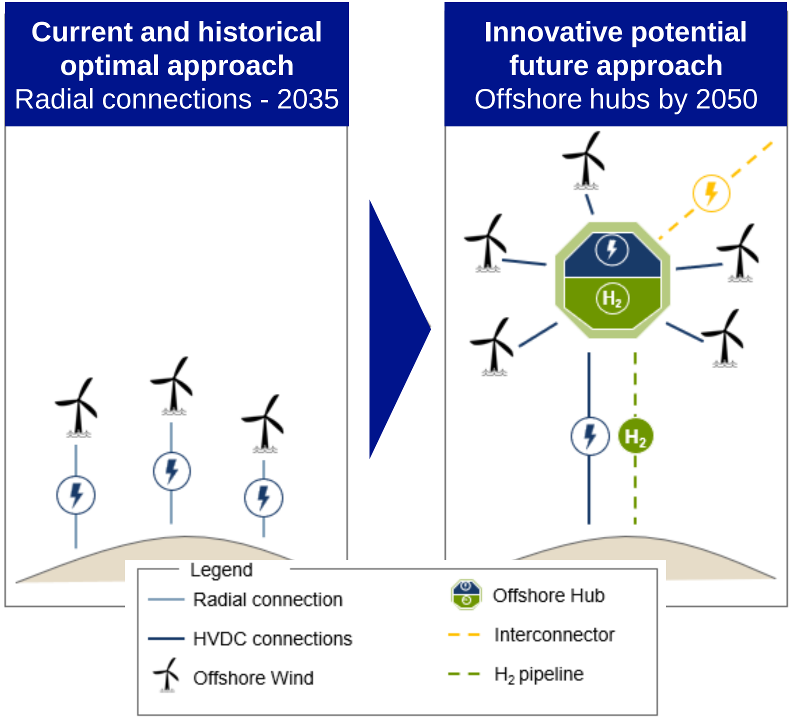
Exploring concepts such as offshore energy islands could help the UK further capitalise on wind and hydrogen

A new, creative approach could support the deployment of offshore wind required to meet the UK's 2050 net zero targets

Beyond 2035, as offshore wind generation expands further away from shore, enhancing asset integration at sea will become ever more important

Potential advantages of an integrated 'offshore hub' approach include:

- ☑ Accelerates offshore wind rollout
- ☑ Potentially limits impact on nature, biodiversity, and communities
- ☑ Increases infrastructure efficiency, with reduced redundancy and costs
- ☑ Potentially facilitates electricity trading and cross-border market integration
- ☑ Enables real-time balancing of variable wind power to enhance flexibility
- ☑ Reduces risk of outages from single points of failure as power can be rerouted through alternative paths in the network
- ☑ Reduces curtailment and grid loss by integrating hydrogen production
- ☑ Unlocks opportunities to repurpose existing oil and gas infrastructure, such as subsea pipelines



Retrospective Review

Project Activities, Benefits, Evolution

Project Activities in Alpha Phase

1. Offshore Infrastructure Market Options/Pathways

Review of hub projects across the globe and market pathways for energy hubs

2. Offshore Hydrogen Planning Considerations

Market enablers for pipeline repurposing, locational impacts, key assumptions

3. Stakeholder Engagement

Key stakeholder engagement plan and integration of stakeholder insights into market modifications

4. Business Case

Whole system configurations, costs and benefit streams, anticipated net benefits

5. Whole System Modelling Architecture

Model objectives, principles, modelling tools, system architecture, next-phase model skeleton

Offshore energy hubs are already being explored by countries with large offshore wind markets across Europe and the globe

Belgium: Princess Elisabeth

Scope: Artificial island with 3.5 GW offshore wind and HVDC connection to Belgium and UK

Status: Construction ongoing, connected by 2030

Brintø: Danish H_2 Island

Scope: Artificial island with 10 GW offshore wind, 6-8 GW electrolyser capacity

Status: Commercially operational by mid-2030s

German Energy Island

Scope: Artificial island with 10 GW offshore wind, 4-8 GW electrolyser capacity

Status: Commercially operational by mid-2030s

Korea project

Scope: Existing island with 6 GW offshore wind with HVDC connection and Power-to-X facility

Status: Commercially operational by mid-2030s

Vindø: Danish Energy Island

Scope: Artificial island with 3-10 GW offshore wind and HVDC connection to Denmark and Belgium

Status: Tender currently on hold

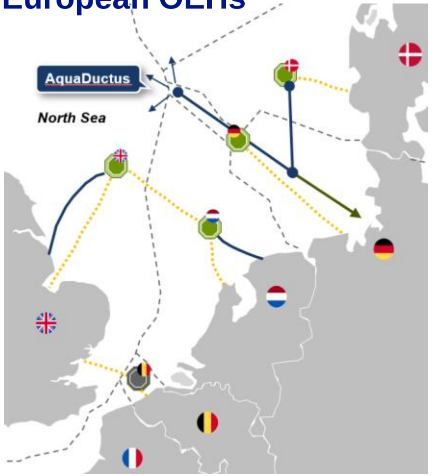
Learnings for UK

- Close collaboration between private developers and TSOs essential
- The commercial model and tender process structure should allow flexibility for private developers
- The supply chain should be involved in the development and tender process
- Hydrogen on-island production and transport via pipelines improves system balancing, flexibility and viability of the business case

(see slide 24 for details)

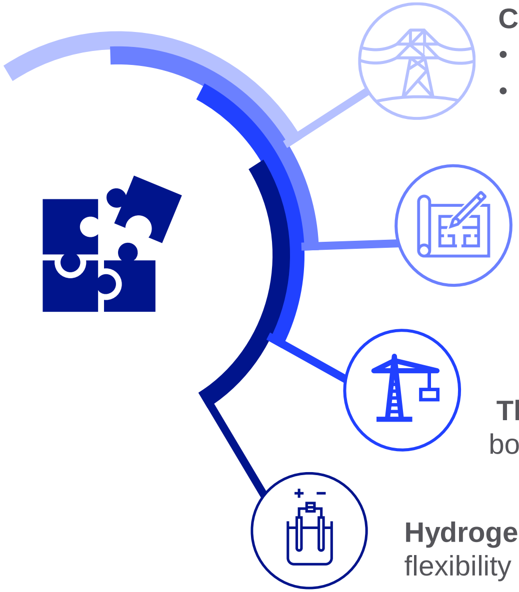
Energy hub planned | Offshore H_2 pipeline | HVDC connection
Energy hub under construction | AquaDuctus

European OEHs



Asian OEH

Whilst still an innovative concept in the UK, lessons can be learned from these international developments



Close collaboration between private developers and TSOs is necessary to ensure

- optimal configuration of the energy hub, and integration of grid systems integration
- optimisation of business cases between regulated and commercial investments and aligning with offtake market needs

In case of a tender process, **flexibility should be enabled for private developers in designing the OEH to allow an investable business case.** This can be done either by allowing design optimisation after award, or by close collaboration before tender to ensure that the specified design is optimised

The supply chain should be involved in the development and tender process to ensure deliverability both technically (technical interfaces to match), financially (balanced risk-reward division), and in time

Hydrogen on-island production and transport via pipelines not only improves system balancing and flexibility but can be crucial for the viability of the business case

The UK has a vast network of legacy offshore oil & gas pipelines; leveraging this infrastructure could be interesting for OEHs

Currently, 19% of all North Sea oil & gas pipelines are ‘not in use’ and are thus potentially available for repurposing. This is expected to increase by 2035.

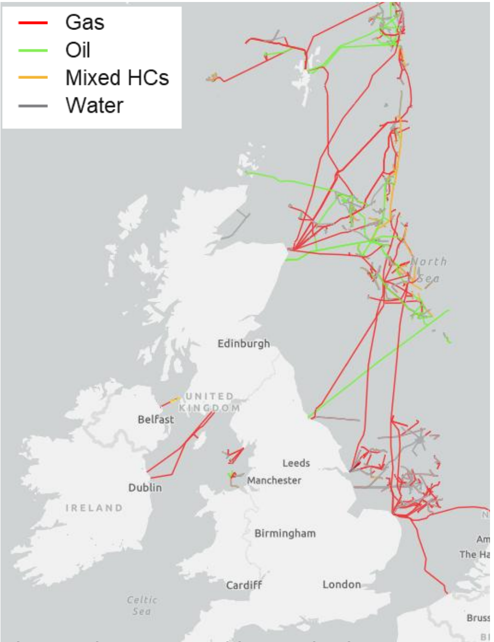
The North Sea Transition Authority (NSTA) mandates that offshore pipeline operators **consider repurposing pipelines** as it expects **~£24bn in decommissioning** costs by 2032.

Lessons learned from discussions with the NSTA and the UK offshore repurposing projects:

- **Economic:** Repurposing could deliver cost savings of up to ~£9.3m/km.
- **Technical:** Offshore pipeline material integrity is well suited for hydrogen repurposing.
- **Timelines:** Repurposing could reduce time to construction by ~50% vs new build.
- **Societal:** The greatest benefit is often reduced community and environmental disruption.
- **Criteria:** Only a subset of offshore pipelines are viable, with repurposing criteria including diameter > 16”, out of use for < 20 yrs, and having previously transported natural gas.

However, **offshore pipeline repurposing is practically impossible under the current regulatory framework.** Elements such as asset disposal/transfer mechanisms, onshore commercial arrangements, and safety standards would need to first be addressed.

Current offshore pipelines



The North Sea Transition Authority

nationalgrid Guidehouse CIP Copenhagen Infrastructure Partners national gas transmission

The stakeholder landscape is highly complex – strong coordination and clarity on roles, responsibilities and objective are key

The offshore infrastructure landscape is heavily fragmented

1 Policymakers

Department for Energy Security & Net Zero

gov.scot

Llywodraeth Cymru Welsh Government

2 Independent advisory

- NIC — National Infrastructure Commission
- NISTA — National Infrastructure & Service Transformation Authority
- National Energy System Operator — NESO

3 Independent regulators

Environmental:

- Marine Management Organisation (MMO)
- Marine Scotland
- Natural Resource Wales

Economic:

- NSTA — North Sea Transition Authority
- OFGEM — ofgem

4 Land managers

- The Crown Estate
- Crown Estate Scotland (Oighreachd a' Chrùin Alba)

5 System planners and/or operators

- National Energy System operator (NESO)
- National Gas Transmission

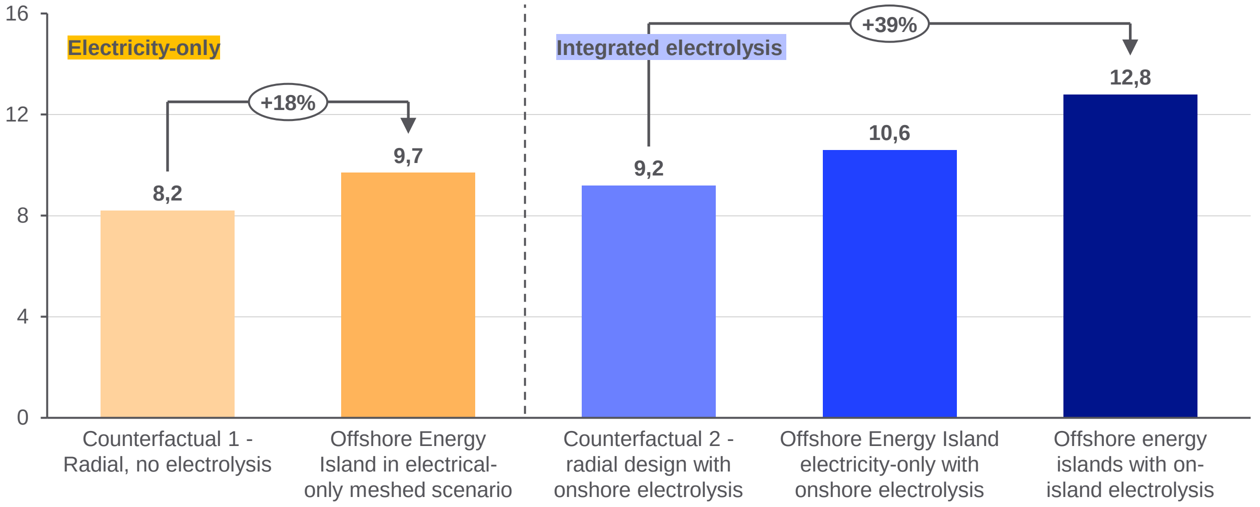
6 Offshore Infrastructure owners

- Regulated electricity TOs
- Regulated gas TO
- OFTOs
- Oil & Gas infrastructure developers
- Gas interconnectors
- Electricity interconnectors
- Offshore wind farm developers

While more detailed exploration is needed, analysis suggests total system cost savings could be realised

Initial modelling shows potential to deliver reductions in total system cost. These savings are dependent on overcoming many barriers and are based on public costs that would benefit from review

Net Present Value of multiple system integration options for 10GW offshore wind capacity, £bn



Most value seems to be driven by infrastructure optimisation and reduced cable outages

- For electricity-only islands, savings are driven by reduced outage costs, jacket removal from offshore platforms, and HVDC equipment placement on the island
- Islands with integrated electrolysis show greater benefits, largely thanks to the further optimisation of HVDC cables to shore
- **While these results show promising potential, they are highly sensitive to changes in costs**

To further test offshore hubs case, we recommend developing an open-source offshore network model adopted by relevant stakeholders

Remaining questions regarding offshore energy hubs

What is the value of a system-wide deployment of offshore hubs beyond 2035?

Where should offshore energy hubs be located to provide the highest system benefits?

What is the most efficient energy hub infrastructure design and sizing?

What are the specific benefits of integrating power-to-X assets in offshore hubs?

What are the benefits for GB consumers in connecting offshore hubs with other North Sea countries?

To address these questions, we plan to develop an innovative model with the following configuration

Cross-vector
- Electricity
- Hydrogen
- Natural gas

Geographic Scope
- Onshore GB: Zonal (main boundaries)
- Offshore: Nodal (>400 nodes)
- Neighbouring markets: European model

Timeframe
- 35 years (2035-2070)
- 8760 hourly profiles

Sensitivities

Large numbers of sensitivities across costs and constraints.

Optimisation speed

Must be ‘reasonable’ to allow for rapid iteration. We define reasonable as being below 24 hours of optimisation time

Look Ahead

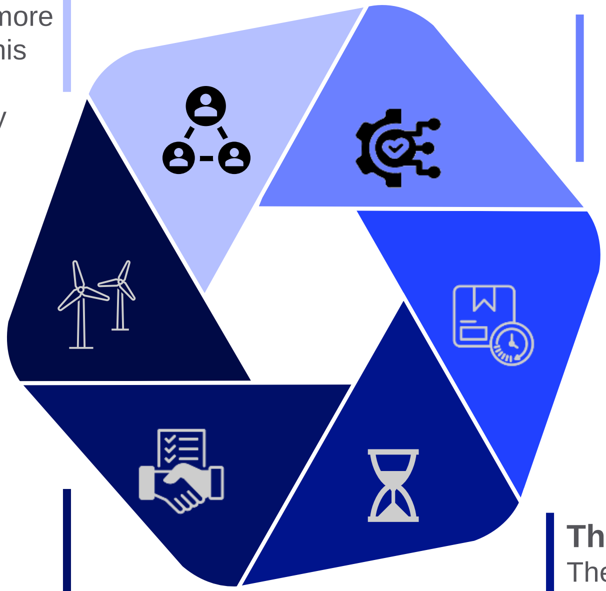
Further Challenges, Lessons Learnt, Look Ahead

There are many challenges that must be addressed to enable offshore energy hub development in the UK

A strong political steer is vital
Energy hubs could help Britain reach net zero more cost-effectively. But only a steer from HMG to this effect will create the confidence needed to encourage investors to make the vision a reality

Network planning must evolve to consider energy hubs
Integrating energy vectors and planning the on/offshore system in an integrated way, through a 2050 lens is vital. We're not there yet but the SSEP is likely to consider hydrogen which is a first step

Managing risks between parties is challenging
Multiple integrated assets create mutual dependence between parties. This requires complex contractual structures or the integration of different elements



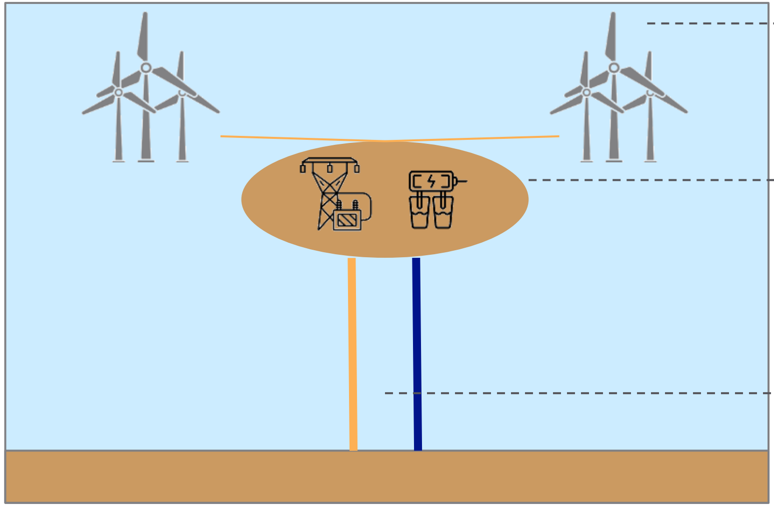
The policy landscape is hugely complex; cooperation is key
The number of parties with responsibilities related to offshore energy is vast and the policy landscape is a complex patchwork. An energy hub could only be unlocked by a level of cooperation between these stakeholders not seen in the UK to date

Regulatory and frameworks will need to evolve
Energy hubs reduce infrastructure needs and infrastructure costs – benefiting customers. Regulatory models would need to ensure an energy hub developer was rewarded for finding those savings

There is a potential role for the state
There are potential roles for the Crown Estate, GB Energy or another party in underwriting early-stage risks and kick-starting the concept

An appropriate regime must distribute risks and rewards appropriately, through choices in asset ownership and de-risking mechanisms

There are three separable elements to an energy island, which could be owned by separate parties



Different ownership models and regulatory framework can be considered for each asset

The generation (offshore wind and electrolytic hydrogen)

1. State-owned
2. Private – CfD regime for offshore wind and HAR for hydrogen

The land

1. State-owned – Crown Estate
2. Private – Merchant or Cap & Floor
3. Private – TO's RAB
4. Private – OFTO model
5. Private – Revenue amortisation

The transmission infrastructure

1. Private - Merchant
2. Private - Cap & Floor
3. Private - OFTO regime
4. Private - RAB
5. Private – BTM wires regime

Too many interfaces would materialise, and thus, too many transaction costs and too much counterparty risk would exist due to the complex nature of the current infrastructure ownership framework

The Alpha phase has demonstrated that hubs could deliver benefits and we think there is a case to further explore how to unlock these

During the Alpha phase…

We have shown that integrating offshore energy infrastructure through **energy islands could provide some economic, environmental and resilience benefits**

Our work also highlighted the **complexity of offshore energy islands,** which create significant governance and planning challenges, and that there is no framework to systematically assess the system value of such assets

That, in our view, suggests that **further work to define the exact role that offshore energy islands could play in the GB landscape would be beneficial**

This work could be progressed in the next phase by:

1. Exploring new leasing, regulatory and incentive models to support the investability of offshore energy hubs
2. Conducting technical and commercial feasibility activities that reduce the current techno-economic uncertainty of offshore energy hub
3. Developing a transparent, cross-vector model that optimises the location and configuration of offshore energy hubs

Thank you for listening!

We will now open the floor to Q&A

Appendix

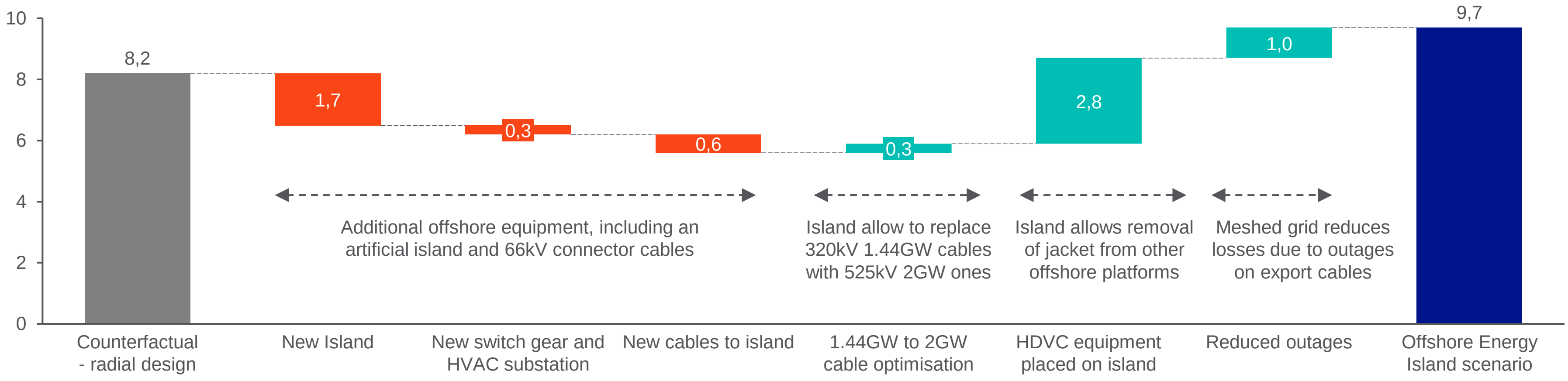
A1. The case for a UK offshore energy hub

Connecting offshore wind to electricity-only offshore islands could deliver some benefits as GB expands its offshore wind market

Integrated offshore electrical assets on an offshore energy island can provide some financial savings…but small changes to CAPEX can significantly impact on the benefits case which needs further analysis

In this offshore island scenario, **10 GW of offshore wind capacity** is connected to the island and then to shore through five 2GW cables instead of radially through seven 1.44GW ones. Beyond potential community benefits, it also shows positive financial results

10GW offshore wind connected to an Offshore Energy Island in electrical-only meshed scenario, Net Present Value, £ billions



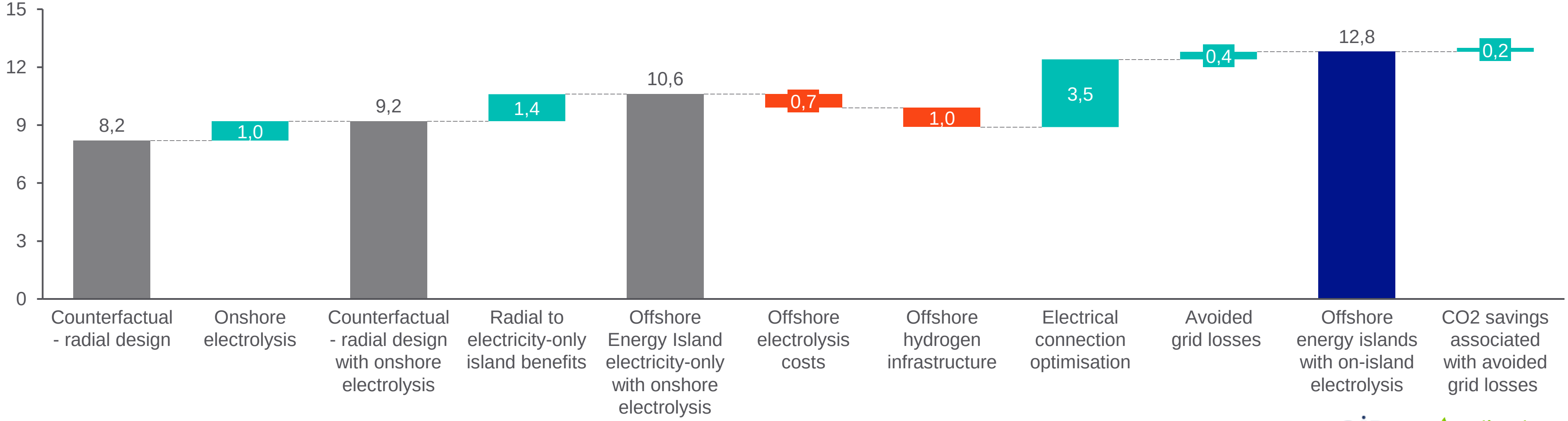
Note: *Cost assumptions are provided in the Appendix. NPV calculated over 40 years, pre-tax, Real-23 at 3.5% Discount Rate*

Integrating electrolysis on the island could provide additional savings, largely through electrical connection optimisation

While developing offshore electrolysis on an island would be costly for the hydrogen developers, savings can be realised by optimising electrical connection to shore

While adding hydrogen infrastructure offshore can be costly, it can further optimise electrical connection to shore. Here again, this would provide some additional financial savings

10GW offshore wind integrated with 4GW of offshore electrolysis on an Offshore Energy Island, Net Present Value, £ billions



In addition, offshore energy islands could potentially create additional, less quantifiable value

Category of Benefit	Description of the Probable Benefit
Avoiding onshore landing points	Reduced community and environmental impact from having fewer transmission lines connected to shore
Consequential benefits for onshore investment	Fewer lines to shore would also reduce or delay the need for onshore reinforcement
Offshore biodiversity	Experience from other countries suggests that islands can provide greater natural benefits (e.g., seal haul-out areas, replica cliffs)
Speed of offshore wind Installation	International experience suggests that an island could be installed in modules and start operation before the full capacity is in place. Once an island is in place, it becomes easier to install other infrastructure
Lower risk for offshore wind development	GB offshore developer today needs to construct their own cable to shore. Having an island located closer to projects could reduce the risk for those developers
Potential for additional uses and services	An island creates significant flexibility and optionality, which could be valuable for future system needs and commercial uses (e.g., fishing, defence, etc…)
Longer expected asset life	Assets on an island may degrade less quickly than offshore assets, leading to longer benefit streams
Coordinated supply chain	The hub concept allows multiple developers to collaborate within similar timeframes, enabling joint supply chain engagement and potentially avoiding interoperability challenges
Benefits to operability	A meshed approach creates additional capability between system boundaries, reducing constraints

A2. Stakeholder Engagement

Stakeholder Engagement - We have collated feedback from key stakeholders to better understand challenges in LookNortH2 (1/2)

A number of stakeholders have had strong interest and input for the project's development, for which we are immensely grateful and have captured the key insights

Stakeholders	Summary of comments and feedback
DESNZ	Considerable interest from teams across DESNZ, discussions identified the potential for a hub to touch on multiple policy goals/objectives and a need to engage with multiple parts of government. Requested to be kept informed
Scottish Government	Interested to learn more and to be kept abreast of the concept. Interested in how an energy hub may facilitate floating wind ambitions
Ofgem	Useful insight into the OTNR process and thoughts on possible regulatory approaches. Also, interesting insights on future interconnection and on the need for clear responsibilities between stakeholders
The Crown Estate	Extremely useful feedback and pointers on particular areas of interest. Including: the spatial characteristics relevant to energy hubs; how the concept would benefit / accelerate overall delivery versus conventional – especially in relation to planning
The NESO	Have been supportive of the project throughout. Particular input from modelling and planning teams on the way in which energy hubs could dovetail with the work undertaken by the NESO as system planning evolves

Stakeholder Engagement - We have collated feedback from key stakeholders to better understand challenges in LookNortH2 (2/2)

A number of stakeholders have had strong interest and input for the project's development, for which we are immensely grateful and have captured the key insights

Stakeholders	Summary of comments and feedback
ENTSO-E	Provided extremely valuable input into the way that the TYNDP modelling, and the modelling for the first Offshore Network Development Plan, was undertaken. With a particular focus on how GB projects are/could be reflected and the specific challenges and opportunities which open-source modelling may encounter
Other European TSOs	Offered interesting insights from energy hub projects around the world. Thanks particularly to Elia and Energinet
OEMs	Offered (confidential) insights into some of the technical challenges they see in developing energy hubs and on the stage of development of those (eg DC breakers, interoperability)
Energy System Catapult	Kindly offered their policy and modelling capabilities

In addition, we have spoken to a range of stakeholders to specifically better understand the repurposing pipeline landscape

Stakeholders	Summary of comments and feedback
North Sea Transition Authority	• Through a screening criteria, have deemed 130 pipelines in the North Sea fit for repurposing for H_2 or CO_2 • Have engaged with all pipeline operators to identify barriers to repurposing against consequence and difficulty to mitigate. As part of this, the NSTA have developed a program to deliver against the barriers for CCS reuse but not for H_2 as they do not see a market maturity or onshore need at present
BUREAU VERITAS	• Offshore pipelines are often built to withstand sour gas, so they are more resistant to the impact of H_2 embrittlement • Assuming a pass in terms of damage and welding quality, it is possible to repurpose carbon-steel pipeline for H_2 or CO_2
bp	• The greatest driver to repurpose legacy oil and gas pipelines is not the cost, but the ability to bring a new vector to market without disruption to local communities and the environment • Viking natural gas pipeline had perfect geopolitical timing, technical feasibility, and business case certainty. It had 3 pigging inspections enabling corrosion rates, maximum operating pressure, and expected CO_2 lifetime to be determined. There was high material integrity due to compensation for sour gas, it connected onshore near large industrial emitters, and there was strong political interest to invest in CCS over natural gas • Repurposing for H_2 is risky due to a lack of market certainty and offtakers
	• Have a 2-tier screening criteria that performs a detailed engineering assessment to consider system asset reuse • Asset transfer would be a long and complex process that could be accelerated by the regulator through subsidies/mandates
PROGRESSIVE ENERGY	• Key considerations for repurposing include material integrity, pressure and flow, safety compliance, and material compatibility. Due to sour gas, “offshore pipelines are more H_2 ready than onshore pipelines from a materials integrity perspective”
STOREGGA	• Location of the pipeline, pressure regime, and ductile fracture risk are the key considerations • Gas pipelines > oil due to locational arrival onshore, less internal corrosion from water, and increased concrete coating • With repurposing, a large cost component will be commercials for transferring ownership and decommissioning liabilities

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