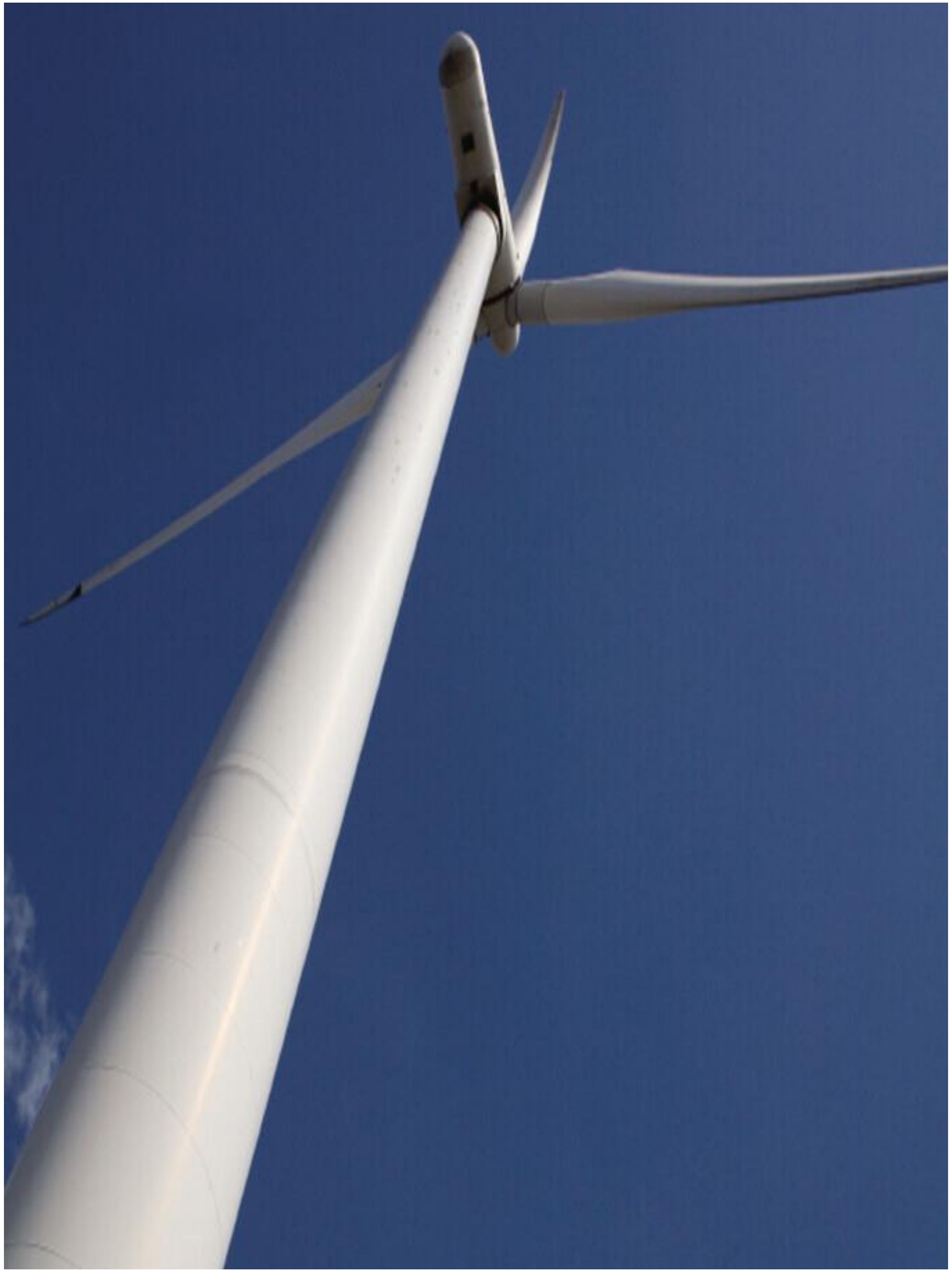

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Milford Haven Heat Network: Phase 2

Final report

March 2022

Document Verification

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		Signature			

Disclaimer

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Executive summary

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Overview

PROJECT PURPOSE

Phase 2 of the Milford Haven Heat Network study aims to further understand the 'no regrets options' identified in the Phase 1 work. Arup has been commissioned to support the Port of Milford Haven (PoMH or also referred to as the Port in this report) to define:

1. The optimal expansion strategy for renewable generation at Liddeston Ridge (no extension, extension of ground PV, or extension via an onshore wind turbine)
2. The optimal (commercial) use of renewable energy for the Port (export to the grid, virtual PPA or physical private wire to the Port assets)
3. The impact of grid curtailment on the optimised system
4. Any critical cost tipping points for battery or electrolysis energy storage at Liddeston Ridge.

KEY FINDINGS

What are the best opportunities for expanding Liddeston Ridge comparing no expansion, solar expansion and onshore wind?

A 2.5MW wind turbine would be the preferred option based on lower annualised costs (CAPEX and OPEX) and associated carbon emissions compared to all other scenarios. However, any renewable option is shown to be more favourable than doing nothing.

What is the best approach for dispatch of electricity from Liddeston Ridge (i.e. physical PPA, virtual PPA to the Port owned properties, virtual PPA agreement or sale to grid)?

Based on our modelling assumptions, a physical private wire connection to the waterfront achieves the lowest cost and carbon emissions. The system prioritises local consumption of electricity before export and electrolysis.

What is the impact of grid curtailment on the optimised system?

Grid curtailment does not have an impact on the preferred system selection.

What is the tipping point where hydrogen import and onsite production becomes cost comparable with the optimised solution for the site?

Sensitivity testing showed that at a green hydrogen import price greater than £6/kg, electrolysis became an increasingly viable use of excess electricity after local electrical demands are met.

What is the cost tipping point where battery storage becomes a viable option for the site if not part of the optimised solution?

Battery storage is part of the solution in all scenarios at different scales.

RECOMMENDATIONS AND NEXT STEPS

The Port should undertake a feasibility study for an onshore wind turbine up to 2.5MW with a private wire solution, the feasibility should include technical studies, costs, planning, regulations and other key risk areas. The scheme has the potential to reduce the annualised cost by more than 50% compared to the current system and will provide energy resilience.

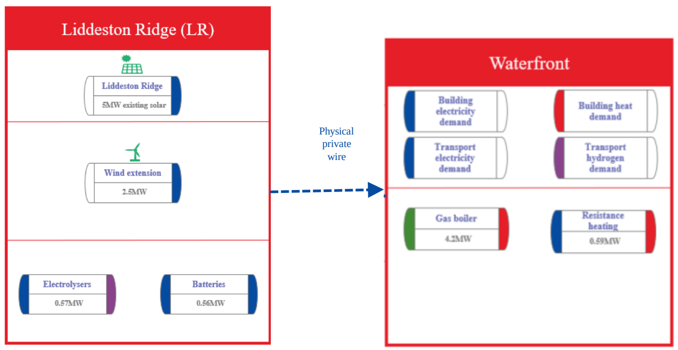

Figure 1: Representation of the preferred system. See page 16 -17 for more details.

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Glossary

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Summary of acronyms used throughout report

Table 1 gives an overview of the acronyms used throughout this report.

Acronym	Meaning
BAU	Business as usual
BEIS	Department for Business, Energy and Industrial Strategy
ESCo	Energy Services Company
GWh	Gigawatt hours
IDNO	Independent Distribution Network Operator
ICP	Independent Connection Provider
JV	Joint Venture
kg	Kilogram
kW	Kilowatt
kWh	Kilowatt hour
MH:EK	Milford Haven Energy Kingdom
MW	Megawatt
PoMH	Port of Milford Haven
PPA	Power Purchase Agreement
PV	Photovoltaic
SLES	Smart local energy system
WPD	Western Power Distribution

Table 1: Report acronyms

1. Introduction

ARUP

Overview

PROJECT PURPOSE

Phase 2 of the Milford Haven Heat Network study aims to further understand the ‘no regrets options’ identified in the previous work. Arup has been commissioned to support the Port to define:

1. The optimal expansion strategy for renewable generation at Liddeston Ridge (no extension, extension of ground solar photovoltaic (PV) panels, or extension via a wind turbine)
2. The optimal (commercial) use of renewable energy for the Port (export to the grid, virtual Power Purchase Agreement (PPA) or physical private wire to Port assets)
3. The impact of grid curtailment on the optimised system
4. Any critical cost tipping points for battery or electrolysis energy storage at Liddeston Ridge.

The boundary considered in this project is shown in Figure 2.

RECAP OF PHASE 1

The Phase 1 commission followed an initial heat network feasibility study prepared by Arup for the Port. The objectives of the Phase 1 study were twofold:

1. To determine whether a heat network was an economically and financially viable option for the Port
2. If so, to determine the optimal combination of technologies to provide heat to the heat network
3. To explore renewable energy opportunities around the Port

Phase 1 of the work identified that a heat network at the Milford Haven Marina could be a viable proposition, but would depend on the incentives for building users to connect to the network, and the timings of heating system changeovers. The impact of the Covid-19 pandemic created significant uncertainty over the former, and it was deemed that a heat network would not be an attractive investment option at this time. However, Phase 1 identified the potential of other potential no-regret options, which included onshore wind, an extension to ground PV at Liddeston Ridge, and rooftop PV.

REPORT PURPOSE

This report includes:

- Outline of the modelling methodology used for this phase of work, including the sensitivities tested.
- Modelling results
- Output from the sensitivities tested
- Outcome of a commercial workshop held with the Port of Milford Haven, and key stakeholders.
- Recommendations and next steps, along with a mini business case.

1. Introduction

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Site boundary

Figure 2: Project boundary

2. Project methodology

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Summary of approach

PROJECT APPROACH

To identify low regrets investment options for the Port of Milford Haven, we used a combination of quantitative and qualitative approaches as shown in Figure 3.

1. Quantitative – linear optimisation modelling

We used linear optimisation software to model and identify the theoretical optimal solution for the Port in terms of both cost and carbon. This is explained in further detail in Section 3 - Modelling methodology.

2. Qualitative – commercial workshop

Any recommended energy system solution requires support and input from a range of stakeholders to drive the project forwards. Therefore, in parallel to our modelling, we designed and delivered a commercial workshop to better understand the appetite of local stakeholders for different system configurations for a PoMH smart local energy system (SLES). The workshop also aimed to understand the different roles and responsibilities that stakeholders would be interested in playing to identify preferred delivery models for the optimised system.

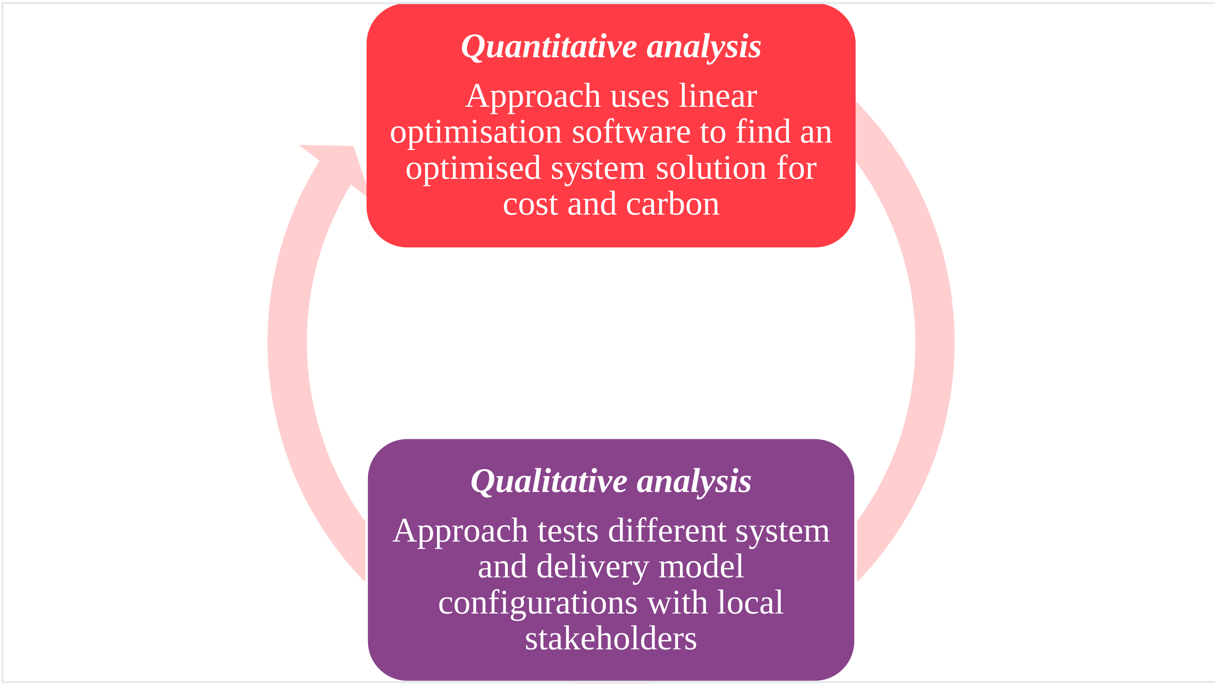

Figure 3: Visual overview of project methodology

3. Modelling methodology

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Modelling background

MODELLING OBJECTIVES

The key objective of our optimisation modelling was to understand the low regrets investment decisions that the PoMH could make now, that would make sense in the future regardless of how the local, regional and national energy system transitions. We compiled and agreed a list of key questions with the PoMH during the project inception meeting.

Questions included:

1. What are the best opportunities for expanding Liddeston Ridge comparing no expansion, solar expansion and onshore wind?
2. What is the best approach for dispatch of electricity from Liddeston Ridge (i.e. physical PPAs, virtual PPA to the Port owned properties, virtual PPA agreement or sale to grid)?
3. What is the impact of grid curtailment on the optimised system?
4. What is the tipping point where hydrogen import and onsite production becomes cost comparable with the optimised solution for the site?
5. What is the tipping point where battery storage becomes a viable option for the site if not part of the optimised solution?

MODELLING TOOLS

We used an Arup suite of modelling tools to compare a range of scenarios and sensitivities for the site. Data on technology parameters, location co-ordinates and existing infrastructure was fed into a database and reviewed as per Arup's quality assurance procedures. The database was used to create input files for our Python based optimisation tool which optimises the system for each scenario and sensitivity tested. The output files were analysed using PowerBI to highlight the cost and carbon emissions associated with each optimised system output so that the overall best approach for PoMH could be identified from across the scenarios tested.

3. Modelling methodology

ARUP

Our approach to energy system modelling

MODELLING STEPS

Our modelling approach followed three key steps as summarised in Figure 4.

Step 1

Our first step was to compare the various options for Liddeston Ridge. The modelled options were:

1. Existing solar only (5MW)
2. Existing solar (5MW) + solar expansion (3.5MW)
3. Existing solar (5MW) + wind (2.5MW)

The expansion capacities shown were calculated in Phase 1 of this project using the available area of land around Liddeston Ridge.

Step 2

We considered the export arrangement for renewable energy from Liddeston Ridge. The Port currently exports to the grid at an agreed price and therefore this was used as the business as usual (BAU) option. This option was costed at 10p/kWh as this is the price that the Port has agreed from May 2022 onwards for their 5MW capacity. This price is high and not guaranteed from Spring 2023, however sensitivities are to be undertaken on export price if exporting to the grid is favourable.

We compared options for a physical private wire between the PoMH building assets / energy centre and Liddeston Ridge (costs based on a 2018 report by Hoare Lea including some WPD network reinforcement costs) and options for a virtual PPA to Port owned properties using the existing Western Power Distribution (WPD) grid (costed at 5p/kWh).

Renewable electricity could also be exported to the grid, however the payment received is unlikely to be more than the current purchase cost. Therefore this option has not been modelled under the assumption that it would not be cost comparable.

We tested the impacts of curtailment of exported electricity, and discovered that the impact of curtailment was not significant enough to sway the modelling results between scenarios.

The grid configurations were tested across different renewable combinations from Step 1. This was to test whether the renewable energy recommendations were still relevant under different grid configurations and to enable us to answer all of the underpinning questions set out in the Modelling Objectives. Table 2 shows all of the renewables and grid arrangements tested along with the resulting scenario name.

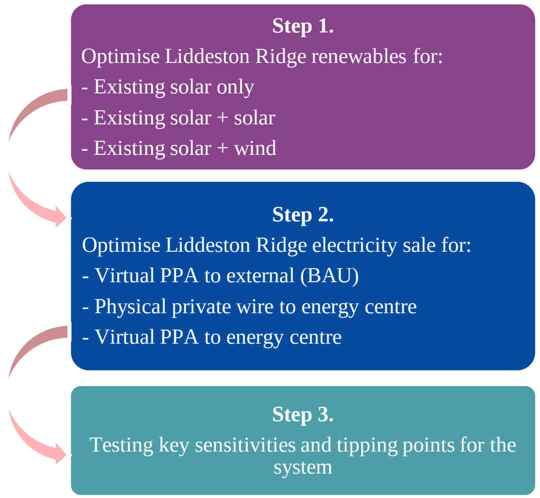

Figure 4: Summary of modelling approach

	Electricity distribution		
Renewable energy generation	Export to grid	PPA	Physical private wire
No expansion at Liddeston Ridge	BAU	Existing + PPA	Existing + PW
3.5MW solar expansion		Max solar + PPA	Max solar + PW
2.5MW wind expansion		Wind + PPA	Max solar + PW

Table 2: Scenario naming conventions

3. Modelling methodology

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Sensitivity analysis

MODELLING STEPS CONTINUED

Step 3

We investigated how the comparison between systems would change when core modelling assumptions were altered. The sensitivities applied are summarised in Table 3. The sensitivities were applied to each scenario to validate the optimised solution. The results section of this report only shows sensitivity analysis of the optimised solution for clarity.

Ref	Sensitivity	Rationale	Variable parameters
1	Hydrogen prices	In this scenario, hydrogen import costs are altered to test the tipping point at which producing hydrogen via electrolysis becomes beneficial.	There are three iterations of this sensitivity: a) Hydrogen import price is varied from £0.135/kWh (£4.5/kg) - predicted price from local generation (central case) to the higher Ryse cost of £0.18/kWh (£6/kg) b) Hydrogen import price was reduced to the current natural gas cost of £0.023/kWh (equivalent to £0.8/kg) c) Hydrogen import price was varied to a mid point between the current gas price and the predicted price from local generation at £0.079/kWh (£2.6/kg)
2	No natural gas	In this sensitivity, there is no gas allowed into the energy system. This is to understand the mixture of energy technologies the system would select if gas was no longer an available option.	The maximum value of gas boilers allowed within the system was set to zero in this sensitivity.
3	Lower battery prices	In this sensitivity, the cost of batteries is changed to test the conditions that would increase system dependence on batteries.	In this system, battery costs were changed from £480/kWh to £257/kWh (projected 2035 value BEIS (Department for Business, Energy and Industrial Strategy), 2018)
4	Lower electricity price, higher gas price	Import costs for the Port's system are high for electricity (at £0.26/kWh) and low for gas (at £0.022/kWh). Gas shortages and the high carbon emissions associated with gas relative to electricity create a case for better regulation of costs shifting some of the costs of electricity onto the gas cost. This sensitivity tests how the system would change if the gas price were to double and the electricity price were to half.	In this sensitivity, gas costs were doubled from £0.022/kWh to £0.044/kWh and electricity costs were halved from £0.26/kWh to £0.13/kWh.

Table 3: Sensitivity testing

3. Modelling methodology

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System representation

SYSTEM ASSUMPTIONS

Figure 5 shows the energy system as modelled. This is shown in detail in Appendix A. Note this does not show the sensitivities tested.

The energy system is represented as two nodes, one for Liddeston Ridge and one for the Waterfront where the demands are located. The solar and wind expansion and various electricity distribution methods are modelled within different scenarios as outlined in Table 2. The existing solar at Liddeston Ridge and the four energy demands shown (top right, with solid external lines) are forced to be built or met in every model run. All other technologies can be selected or omitted by model runs based on assessment of the optimal solution.

Hydrogen produced from electrolysis can be moved around the system by tanker or via a pipeline for the purposes of our modelling. Further work could explore co-location of an electrolyser alongside demand if the Port decides that they would like to explore electrolysis further.

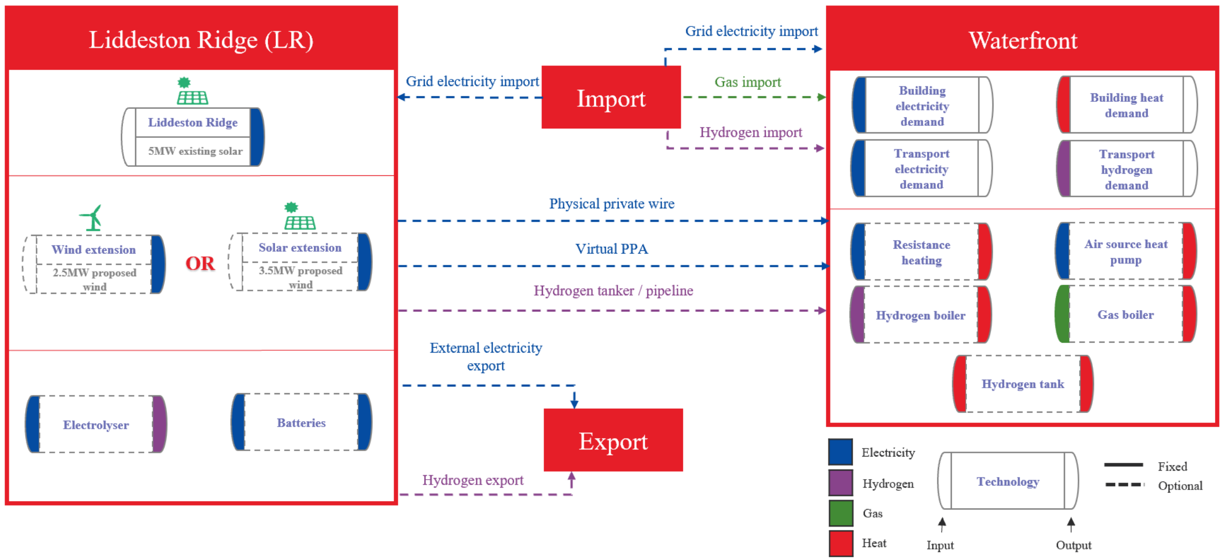

Figure 5: Modelled system (See also Appendix A)

4. Modelling results

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Outcomes from the optimisation model

CENTRAL CASE

The central case refers to scenarios tested without any addition sensitivities. Figure 6 shows the annualised whole life costs and carbon emissions associated with each of the core scenarios outlined in Table 2, this output supports the following conclusions against the study objectives.

Liddeston Ridge expansion

Q. What are the best opportunities for expanding Liddeston Ridge comparing no expansion, solar expansion and wind?

When the model was permitted to extend the solar capacity or build a wind turbine, it chose to do so. Results show that additional electrical generation is beneficial from a cost and carbon emissions perspective.

Of the two expansion technologies, the 2.5MW wind turbine was shown to be preferable to the 3.5MW solar expansion. Despite the wind turbine having a lower capacity, the higher resource availability resulted in higher annual electricity generation. If a wind turbine was installed purely to export electricity and could be added to the existing export agreement of £0.10/kWh, it would be expected to payback in around 4 years with an estimated revenue of £1.2m per year.

However, installing a wind turbine could present planning permission challenges due to visual and ecological constraints. If so, additional solar should be installed as the second preferred option with BAU being the least preferred option.

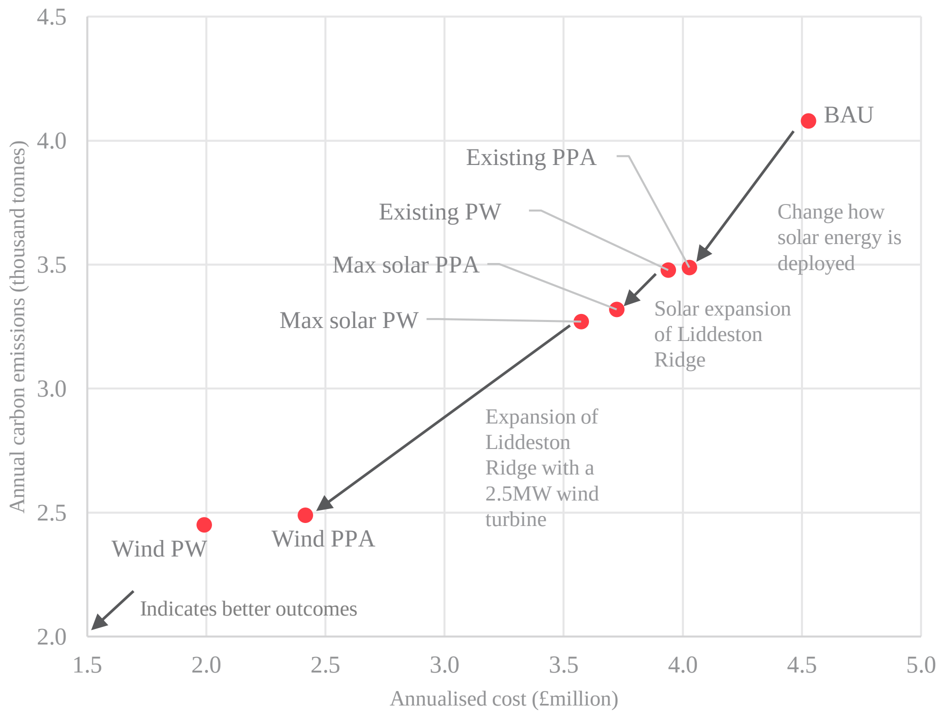

Figure 6: Cost and carbon modelling results for core model

4. Modelling results

ARUP

Outcomes from the optimisation model

CENTRAL CASE

Export arrangement

Q. What is the best approach for dispatch of electricity from Liddeston Ridge (i.e. physical PPA, virtual PPA to the Port owned properties, virtual PPA agreement or sale to grid)?

In all scenarios, local consumption of the electricity produced at Liddeston Ridge was prioritised by the model. Both the virtual PPA and the private wire resulted in lower costs and emissions when compared to only exporting through the Port's current agreement.

The private wire option achieved a lower annualised cost than the virtual PPA. The difference is limited in solar scenarios but greater when the wind turbine is selected.

The annual benefit of the preferred scenario, wind expansion with private wire, against the business-as-usual scenario is estimated to be £2.8m which led to a simple payback of around 3 years. This would require private waterfront tenants to agree to be supplied by the Port's resources (or an ESCo operating on the Port's behalf). To encourage this, the cost of that supply would have to be competitive against existing external utility providers.

Therefore, the estimated £2.8m annual benefit to the system is likely to be split between private tenants and the Port. Assuming a local electricity sale price of £0.18/kWh, annual revenue from this sale and external export would be approximately £1.8m for the Port.

If the commercial, legal and managerial challenges associated with a private wire would be too great to overcome, the virtual PPA option is shown to be highly preferrable to the business-as-usual operation.

Q. What is the impact of grid curtailment on the optimised system?

We tested the impact of grid curtailment by quantifying the amount of money that the Port would miss out on due to curtailment periods at Liddeston Ridge. We found that the amount was sufficiently small that it would not change which scenario was more financially favourable.

Impacts on heat and hydrogen

The model chose to use the renewable electricity to minimise the electricity imported from the grid for electrical demand. This resulted in negligible electrification of heat and little use of electrolysis to generate green hydrogen. Heat and hydrogen demands are met by natural gas boilers and hydrogen imports respectively. Overall the optimised system changes from a net importer to a net exporter of electricity. Meanwhile, the optimised system continues to meet its heat demand with imported gas.

4. Modelling results

ARUP

Outcomes from the optimisation model

PREFERRED OPTION – WIND EXPANSION WITH PRIVATE WIRE

Figure 7 and Figure 8 overleaf give a visual overview of the optimal energy system based on the modelling assumptions as set out in Appendix B. The majority of electricity comes from the onshore wind turbine at Liddeston Ridge and existing solar PV supplemented by National Grid import at times of high electricity demand. The majority of electricity is transferred to Port owned assets via a private wire, however there is a small amount of electricity export at times of high renewable resource and the Port should endeavour to maintain existing export contracts if possible.

The optimised system also includes some battery and electrolyser capacity. As these technologies only convert a small amount of the energy within the system, they are recommended secondary to the installation of wind and private wire infrastructure.

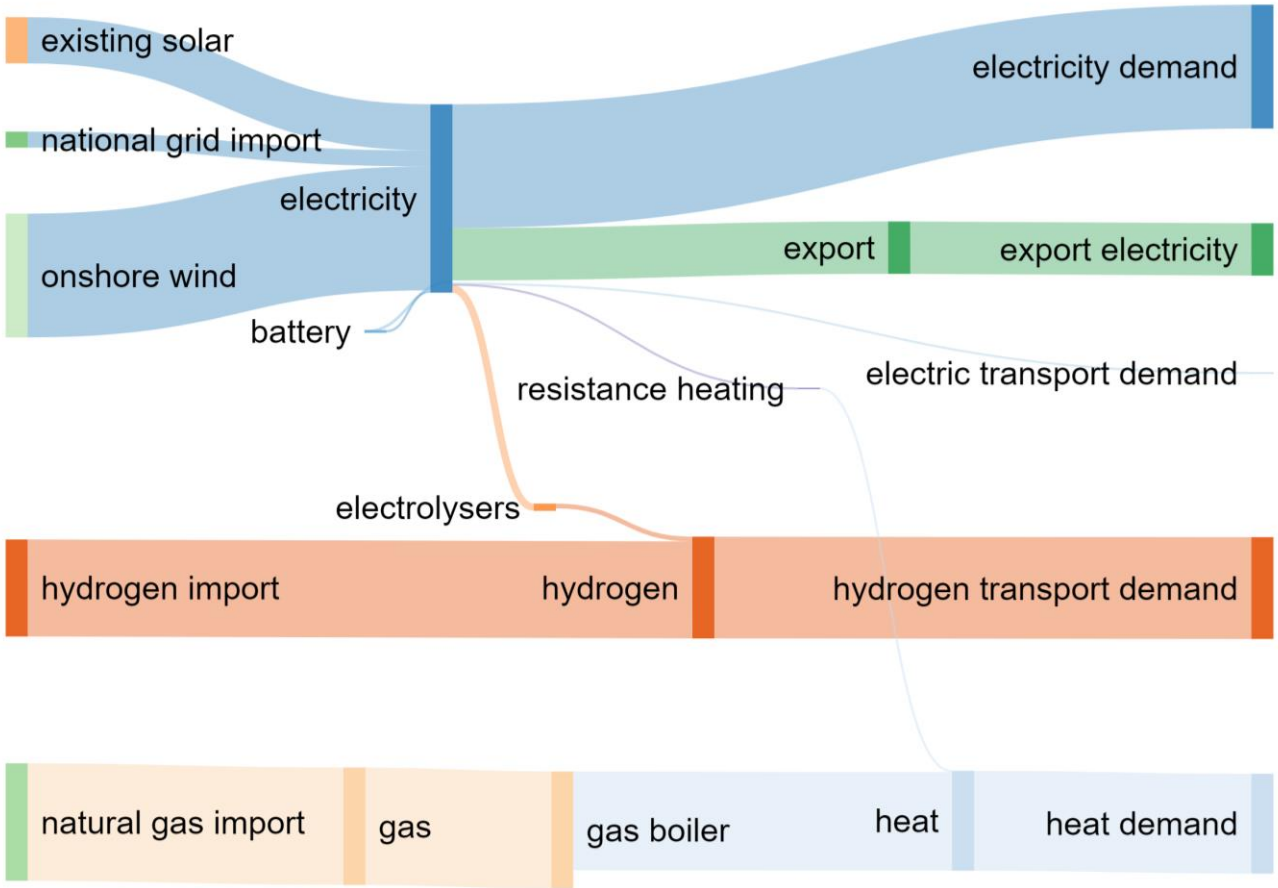

Figure 7: Sankey diagram of optimised system

4. Modelling results

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Outcomes from the optimisation model

PREFERRED OPTION – WIND EXPANSION WITH PRIVATE WIRE

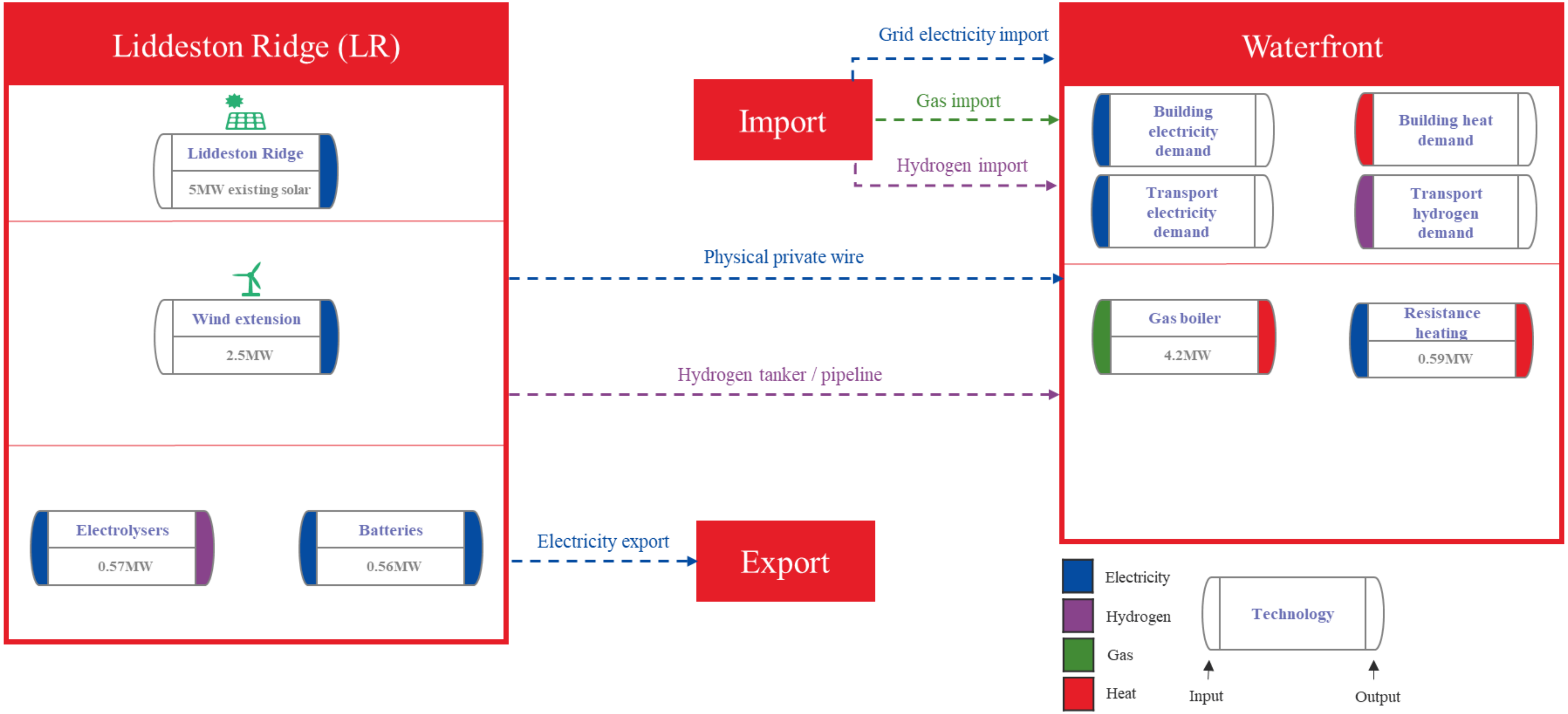

Figure 8: System diagram of optimised solution

4. Modelling results

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Outcomes from the optimisation model

SENSITIVITY TESTING

The impact of hydrogen import prices

Q. What is the tipping point where hydrogen import and onsite production becomes cost comparable with the optimised solution for the site?

Varying hydrogen prices had a significant impact on the makeup of the energy system as shown in Figure 9.

At the lower extreme, with hydrogen the same price as natural gas, gas boilers are almost entirely replaced by hydrogen boilers and hydrogen becomes the primary source of heat. This hydrogen is all imported with no onsite electrolysis.

At the highest hydrogen price of 0.18 £/kWh, the model chose to increase the amount of electrolysis to reduce reliance on hydrogen imports. Furthermore, no hydrogen is used for heat. Electrolysis was highest in the wind scenarios where around 37% of hydrogen is produced locally. Exports of electricity to the national grid are reduced, instead the model chose to produce green hydrogen with that electricity.

When the hydrogen price is at the mid-point between the central case and current gas prices, there was little difference in system operation compared to the central case. No hydrogen boilers were selected and there was only a very small amount of electrolysis in a wind scenario. All imported hydrogen is used to satisfy hydrogen transport demand alone.

This sensitivity suggests current hydrogen prices of 0.135 to 0.18 £/kWh (4.5 to 6 £/kg) are close to a tipping point in making electrolysis viable. If the grid export price decreases slightly, or the hydrogen import price increases slightly, electrolysis is a good use of excess electricity after local electrical demand is met.

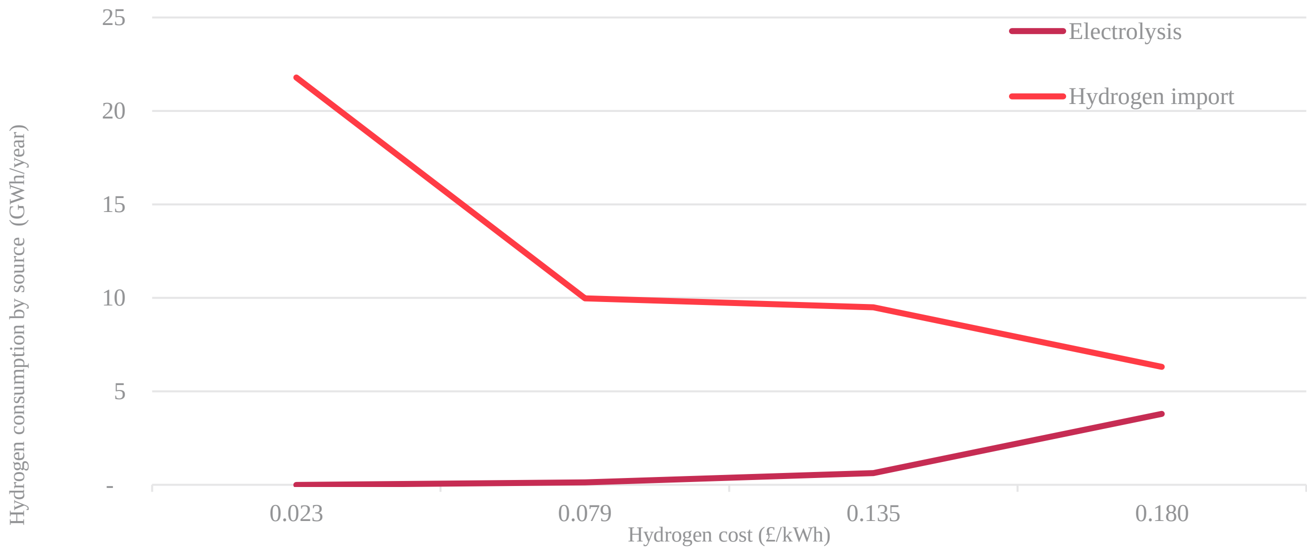

Figure 9: Effect of hydrogen prices on the source of hydrogen (wind scenario)

4. Modelling results

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Outcomes from the optimisation model

SENSITIVITY TESTING

No natural gas

When natural gas imports and gas boilers were banned from the model, heat was largely electrified with air-source heat pumps as the dominant technology. Hydrogen boilers did appear in all scenarios but only met 5-7% of the heat demand. This suggests that electrification of heat is preferable to hydrogen boilers if gas was removed from the system.

Electrolysis and electricity exports are decreased compared to the central case as greater priority is given to using the renewable electricity for heat.

This sensitivity led to very large decreases in carbon emissions, in the range of 45-75% compared to the core scenarios (Table 2) but an inevitable increase in cost (25-32%) compared to the central case where gas boilers had no capital cost. However, for any new buildings, air-source heat pumps are likely to be cost competitive when compared to new gas boilers and therefore should be adopted as the primary heat technologies for new buildings.

Lower battery prices

Q. What is the tipping point where battery storage becomes a viable option for the site if not part of the optimised solution?

With lower battery capital costs, batteries were selected in every scenario. However, capacity varied considerably, with higher installed capacities in private wire scenarios and maximum solar scenarios.

The inclusion of higher capacity batteries resulted in less electricity being imported from and exported to the national grid and instead promoted self-consumption. The heating and hydrogen vectors remained largely unchanged. These changes produced a very marginal decrease in annualised costs and carbon emissions.

Lower electricity price, higher gas price

In this sensitivity, the system started to switch over to electrification of heating via air-source heat pumps. In solar scenarios, the balance was around 50% electric heating and 50% from gas boilers, but this rose to a high of 80% electric heating in the wind + private wire scenario.

This sensitivity resulted in lower national grid exports and higher national grid imports especially in PPA scenarios. This result suggests a prioritisation of meeting the heating demand with the local renewable generation rather than the electrical demand.

Similar to the hydrogen price sensitivities, the optimal solution is shown to be quite sensitive to import fuel costs. The interplay between electricity, hydrogen and natural gas import and export costs is highly influential.

5. Commercial analysis

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Commercial workshop approach and findings

APPROACH

A commercial workshop was held with the PoMH and various stakeholder organisations on 8th September 2021. The objectives for the meeting were to:

1. Share progress to date
2. Understand the aspirations of the Port Authority with respect to the commercial structure for a SLES around the Port
3. Understand the level of interest of stakeholder parties in undertaking the various roles in a Port SLES and which types of SLES they would be most interested to see
4. Map other local stakeholders and understand the roles that they could play
5. Identify any commercial gaps in delivering the SLES

Participating organisations included:

- PoMH
- Pembrokeshire County Council
- Energy Local
- InnovateUK

Within the meeting, we shared five system configurations likely to be recommended from our optimisation modelling. These included:

1. Physical private wire from Liddeston Ridge to the Waterfront
2. Virtual private wire (PPA) from Liddeston Ridge to the Waterfront
3. External sale of renewable electricity
4. Onsite hydrogen generation
5. Hydrogen import and export

Participants were asked to workshop all potential project stakeholders and then to rank stakeholders in a matrix based on level of influence and level of interest. We then discussed 14 roles required to deliver a SLES and asked participants to identify who could play each role across each of the five system types.

FINDINGS

Through the workshop it became clear that the Port would seek the support of other organisations to drive and promote a SLES rather than leading it themselves. This would either result in an Energy Services Company (ESCo) being brought in to co-ordinate and lead the delivery of the SLES or a partnership, such as a Joint Venture (JV), being formed between a range of local organisations. The outputs and roles explored are presented in Appendix C.

6. Recommendations and risks

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Our key findings and recommendations

THE PREFERRED OPTION

As shown in Figure 6, expanding Liddeston Ridge with a 2.5MW wind turbine and a private wire connection results in the lowest annualised cost and carbon emissions. A summary of the CAPEX and OPEX of the components of the wind and private wire option is shown in Table 4.

However, there are further investigations that are required in order to fully assess the feasibility of the preferred option and move to the development stage. This is a two part process of firstly investigating the feasibility of a private wire connection including operating costs and regulatory constraints; and secondly the feasibility of installing a wind turbine at Liddeston Ridge including technical feasibility, costs and planning risks.

Our recommended steps are explained in the decision making flowchart shown in Figure 10 overleaf. The flowchart aims to help the Port understand the process to get to the best 'Do Something' option.

Key items	Capacity (MW)	CAPEX (£M)	OPEX (£/kWh)
Wind turbine	2.5	2.97	0.016
Private wire	7.5	4.40	Not included in feasibility study
Electrolysers	0.57	0.43	0.022% of capex
Batteries	0.56	0.27	7.3£/kW/year
Resistance heating	0.59	0.05	0
Hydrogen import			0.135
National Grid import			0.260
National Grid export			0.100
Natural gas import			0.023
Total		8.12	

Table 4: Cost summary for proposed system

6. Recommendations and risks

ARUP

Our key findings and recommendations

UNDERSTANDING THE KEY NEXT STEPS

The preferred option is expanding Liddeston Ridge with a wind turbine and a private wire connection to distribute electricity to the waterfront energy centre. The first step is to assess the feasibility of **wind generation** and **a private wire connection** in parallel:

- The first step would be to undertake a feasibility study of installing a 2.5MW **wind turbine** at Liddeston Ridge should begin by considering the previous reasons for wind generation being ruled out, i.e. bats and to get a budget quote for the cost of a grid connection. Then, a technical feasibility including maximising the energy yield; ground investigation and outline design; the environmental and visual impact and mitigation; planning and consenting and whole-life costs should feed into an outline business case.
- In terms of a **private wire** connection, a key next step is to understand the local market for lower cost green energy – for instance would Tesco be a user with their variable refrigeration loads. We would recommend holding stakeholder events to see if there is interest from tenants to undertake a community energy scheme and purchase green energy. This would determine whether there is enough interest for a private wire connection to the port.
- It is also important to investigate the access to wayleaves for the routing of the private wire, understanding who the landowner is for the route, and if it is possible to work with Pembrokeshire County Council to run it in the highway.

If a private wire connection is deemed to be feasible, batteries or electrolysis should also be considered and sized appropriately based on the capacity of the generation assets and demands to act as a balancing option.

- To undertake an electrolyser project at the port, grant funding would be needed because it's not commercially viable at this scale yet, this could be explored as part of the next phase of MH:EK and through discussions with PCC and Welsh Government.
- If a private wire is not feasible due to lack of demand, commercial, legal or managerial challenges, engaging with PCC and WPD around virtual energy trading would be beneficial.
- From our work on trading platforms for MH:EK, we found that the market for energy trading schemes is still in its infancy and that there are regulatory hurdles to be overcome to facilitate the sale of electricity in peer-to-peer trading. A few projects including the Port's Energy Local project, are happening at the smaller scale, but not where there are technical challenges such as grid constraints. This is an area where change and innovation is needed in the market. The stakeholder event would be a meaningful next step for this also.

The flowchart in Figure 10 shows a number of options and routes for renewable energy generation and distribution to the energy centre. Considering combinations of feasible 'Do Something' options such as solar expansion or existing solar generation; distributed either through a private wire or PPA arrangement; and combined with batteries and electrolysis to balance supply and demand will still be beneficial rather than 'Do Nothing' or 'Business As Usual'. Commercial models for the options being considered should also be developed.

6. Recommendations and risks

ARUP

Our key findings and recommendations

UNDERSTANDING THE KEY NEXT STEPS

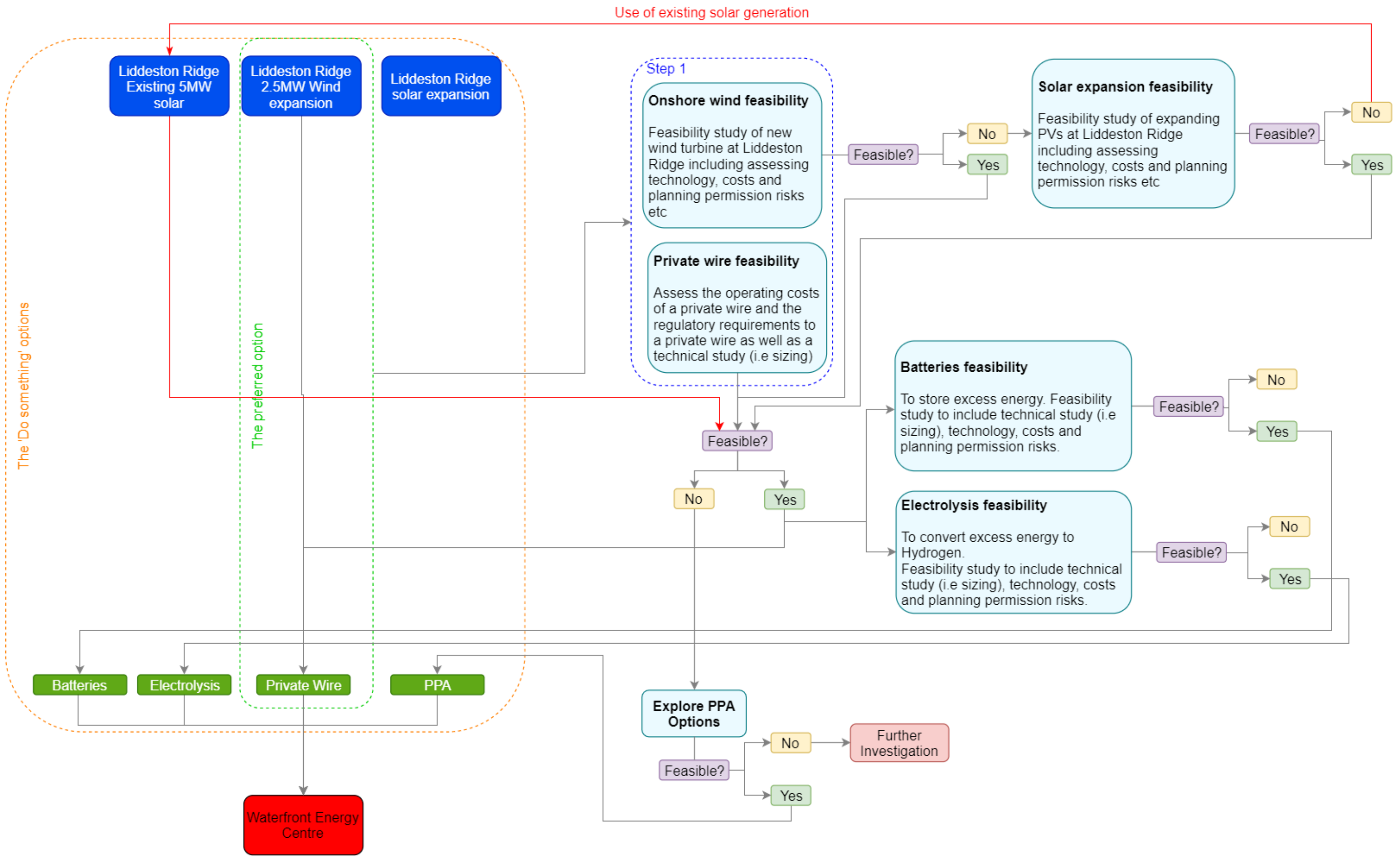

Figure 10: Decision making flowchart (See also Appendix D)

6. Recommendations and risks

ARUP

Key risks associated with project delivery

PROJECT RISKS

Table 5 highlights key risks associated with the delivery of the recommendations alongside the mitigation measures that can be taken.

Risk	Impact	Likel-ihood	Seve-rity	Mitigation
Changes due to Ofgem Targeted Charging Review	Ofgem is changing the way that transmission and distribution network users are charged and residual charges will now be based on capacity of the connection for non-domestic users. These changes are due to come into place in Spring 2022 and could impact the Port's electricity import and export prices	H	L	Keep abreast of changes in charges and re-consider any changes when more information on the new charges is available.
Wind expansion not receiving planning consent	If the wind turbine at Liddeston Ridge does not receive planning consent, the economic and environmental benefits associated cannot be realised.	M	M	If wind does not receive consent defer to solar and private wire solution.
Private wire regulations	For behind the meter private wire and peer-to-peer trading, there are a few options for licencing which need further investigation. Some of the options could have more cost associated with them the others.	M	M	Engage with Independent Connection Provider (ICP)/ESCos to understand what models are the most appropriate.
Existing PPA price changing	If the Port is unable to maintain the 10p/kWh export price the economic attractiveness of the scheme may be compromised. In the optimised system however, export only accounts for a small amount of electricity flows and this is unlikely to cause significant impacts to the cost.	M	L	Port to consider terms of current export agreement.
No third party to lead delivery	The commercial analysis highlighted the appetite for a third party to lead the project delivery. If no party is interested it will be challenging for the project to go ahead.	M	H	Early engagement with potential project partners

Table 5: Project risk matrix

7. Delivery plan

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Next steps to deliver the required output

THE STRATEGIC CASE

Creating a local energy system makes strategic sense for the Port as they will be able to provide their own electricity rather than depend on more expensive grid imports. Expanding Liddeston Ridge with wind, conditional on planning permission, or solar otherwise is a low regret decision as it is the lowest cost and carbon solution regardless of the future direction of the Port heating system. Once further investigation is undertaken around the operational costs of a physical private wire connection to the waterfront, this could be a route to further hedge against increasing energy costs.

THE ECONOMIC CASE

The upfront investment required for the preferred system is £8.12million. While this scenario requires upfront capital, the system has an annualised cost of £2.0million (including annualised capex and opex), half that of the annualised £4.5million business as usual case. Therefore, producing electricity onsite and distributing via private wire will allow the Port to unlock significant economic savings.

The proposed system also has half of the annual carbon emissions associated with it compared to the BAU scenario. The Port will also have increased energy security due to decreased dependence on grid import making it more resilient to market price changes. Adding batteries into the system will further improve this resilience.

THE COMMERCIAL CASE

To deliver a commercially viable local energy system, the most appropriate commercial model that the Port will likely adopt is Partnering: either through sub-contracting or joint-ventures with others with the relevant expertise and experience.

The techno-economic model results (shown on Page 14) show a new wind turbine with a physical private wire is the most cost and carbon friendly option to move electricity around the site. To enable this option, the Port may need to take the role of Promoter and Asset Owner including responsibility to operate and maintain the wind turbine but bring in contractors to design and build the wind turbine. Similarly, the Port may need to bring in an ICP and/or an Independent Distribution Network Operator (IDNO) to build and operate the private wire connection. The procurement of other organisations will include additional costs. Having a site ESCo such as companies that can be found here is therefore likely to be one of the most suitable options to deliver the proposed scheme.

Further investigation is required around regulatory constraints for private wire, and the licensing arrangements required as highlighted in the risk register.

THE FINANCIAL CASE

The upfront capital cost for the preferred option is £8.12million. In line with the HM Treasury Green book guidance, an optimism bias of 6-66% should be allowed for Non-standard Civil Engineering projects. At this stage of the project, the upper bound 66% is applied, as there is not enough information to reduce the optimism bias. Therefore, a total amount of £13.5million should be budgeted for.

The potential investment routes are:

- Development stage: Government innovation funds; Port funding
- Implementation stage: ESCo, Port funding

Potential revenue streams: we have assumed that Contract for Difference is zero, because of the uncertainty around the price for onshore wind, however this should be announced in February 2022 for projects to be commissioned in 2023-25. In the current models, the revenue for the Port is in terms of reduced electricity bills for the Port buildings.

7. Delivery plan

ARUP

Next steps to deliver the required output

Financing options include the use of an ESCo who organises everything including financing for the project, and the Port can enter into a long term contract with them to pay a set price for electricity over a number of years.

THE MANAGEMENT CASE

To deliver the preferred option, this section sets out the recommended approach to project management including project planning, governance, risk management and stakeholder management. This is to be further developed during future stages of the project.

The key principles of project management should be adopted as follows:

- Definition of roles & responsibilities
- Defined programme, stages and milestones
- Maintain a risk and opportunities register
- Lessons learnt and best practice from other projects to be applied to approaches, risks and opportunities
- The business case is reviewed and updated in line with the design, planning and procurement stages.
- Change management to be defined in contracts and an agreed management system to be put in place.

A high level implementation programme is provided in Figure 11 overleaf, assuming a commencement on the development phase in 2022. The programme identifies broad timescales for activities related to funding and delivery of the project.

Stakeholder engagement is a key component of the project delivery and key activities are also identified on the programme. A Stakeholder Management Plan, a live document capturing the project context, communication with stakeholders and stakeholder engagement analysis should be prepared and updated throughout the project delivery.

Collaboration, transparency, timely exchange of information will be critical to ensuring the right culture, behaviours and ways of working developed. Information and data management approaches in line with the Energy Data Taskforce report should be adopted to ensure effective decision making and progress towards a Modern Digitalised Energy System.

A risk management strategy should be adopted to assist all parties to understand the risks associated with the delivery, operation and decommissioning of the project. A risk register is included in Section 6 and should be a kept live throughout the lifecycle of the project.

It is likely that the Port would be contracting other entities to deliver the project as discussed in the *Commercial Case*. Contracts should be managed under a recognised and relevant contract suite, based upon an industry standard and with a demonstrable track record of bankability.

Contingency plans should be put in place at the start of the project in line with the project risk assessment, to mitigate and manage significant risks and opportunities with regards to project cost and programme.

7. Delivery plan

ARUP

TIMETABLE OF NEXT STEPS TO DELIVER THE REQUIRED OUTPUT

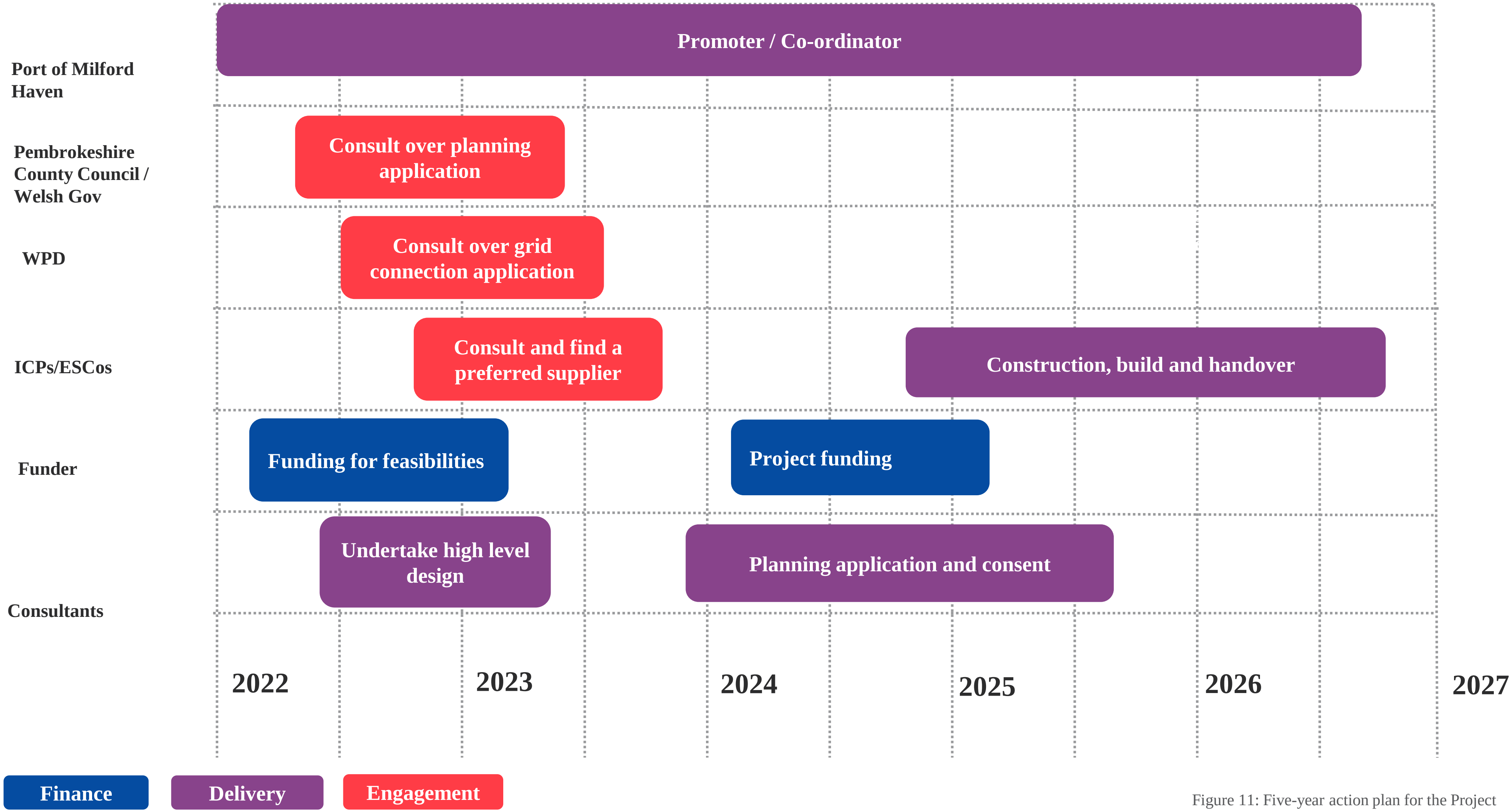

Figure 11: Five-year action plan for the Project

8. Additional steps

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Options for added value to current commission

Through this Phase of work, we have had insight into additional work that has the potential to greatly benefit the Port in their decarbonisation journey. We have categorised options into three broad categories as shown in Figure 12. These options can be additive, with any combination adding value to the Port's existing study. Option 1 would bring various strand of work happening throughout the Port together to form a clear and actionable decarbonisation strategy. Option 2 would consider further demand and supply options that could be integrated into the energy system explored throughout this project bringing more of a community lens to the work. Option 3 is a package of stand-alone tasks that follow on from this work and each of the points in this option could be performed either in isolation or as part of a package.

1. Port decarbonisation strategy	2. Virtual community project	3. Additional items to extend Phase 2
More zoomed out analysis of Port and all of the different assets	Identifications of different demands to virutally include in current SLES proposition	Stand-alone battery feasibility study
Work to establish net zero targets and pathway to achieving	Stakeholder engagement with demands	Stand-alone wind feasibility study
Would include generation / export analysis of wind	Include new demands within modelling	Stand-alone solar fesibility study
	Potential to include discussions with suppliers around the area	Stand-alone generation / export analysis of wind
		Further sensitivity analysis

Figure 12: Options for added value

Appendices

Appendix A: Modelled system

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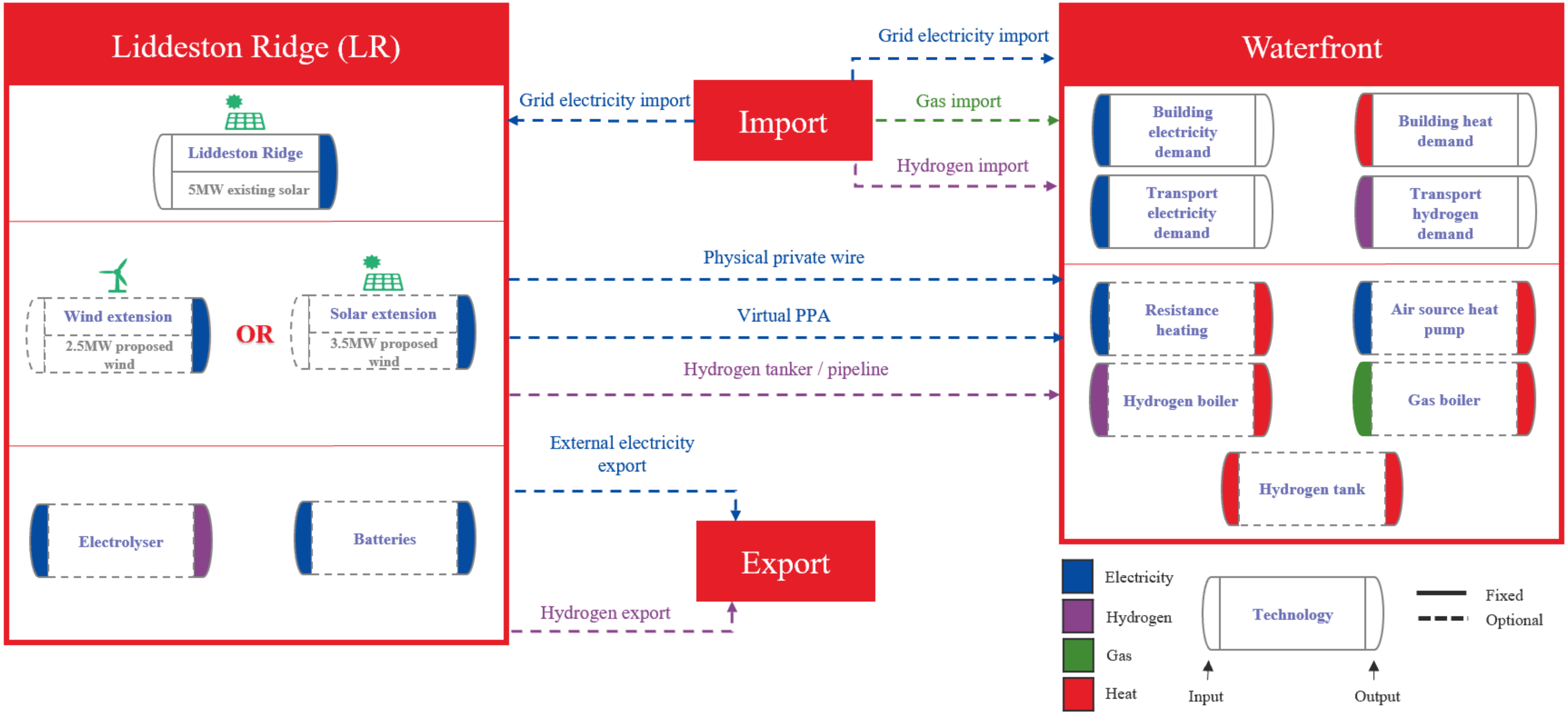
System diagram



Appendix B: Assumptions log

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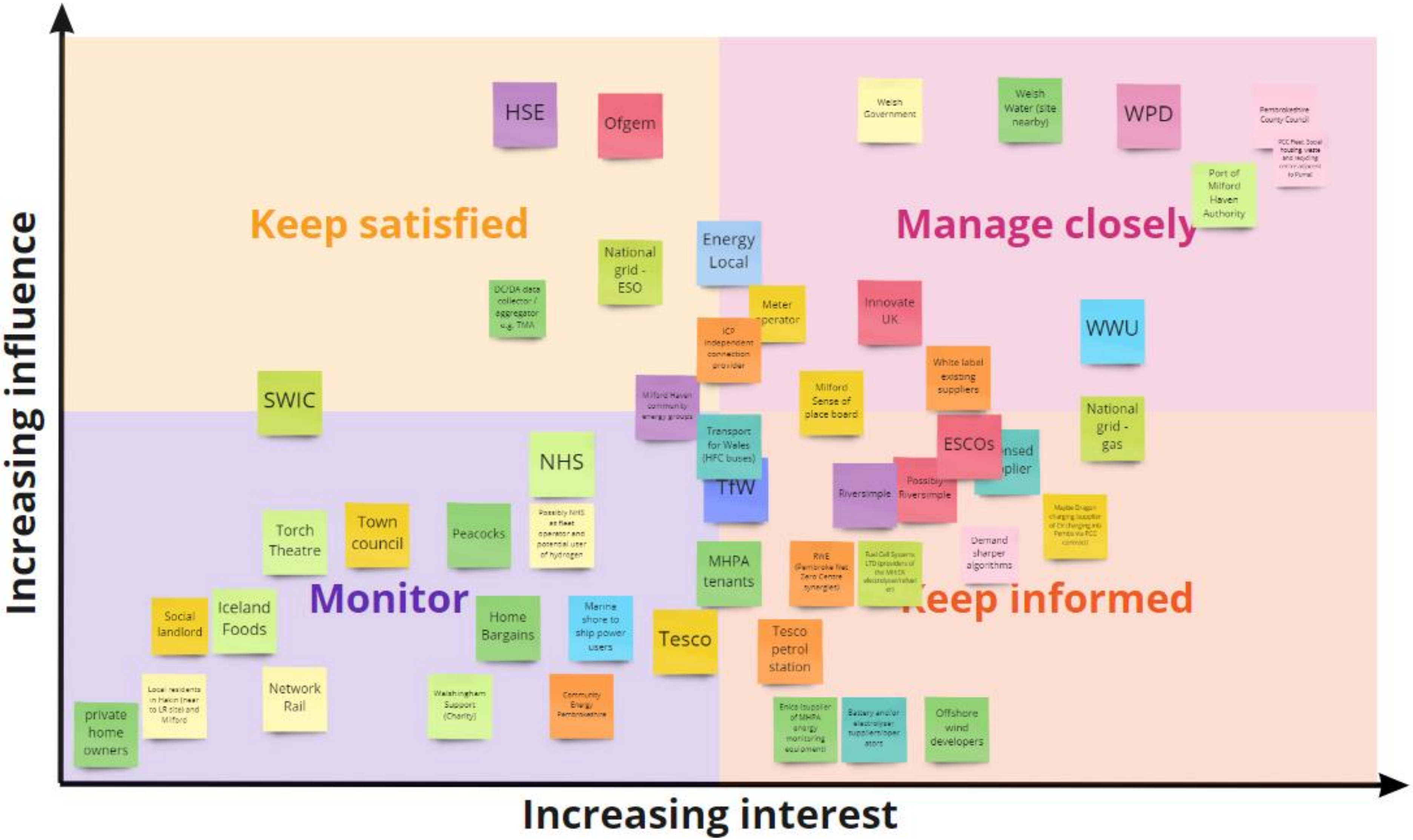
A summary of assumptions made throughout our analysis

1. The system can be modelled by two nodes as shown in appendix A. The maximum capacity of additional solar at Liddeston Ridge is assumed as 3.5MW. This was based on a resource assessment performed for the land area available in Phase 1 of this project.
2. The maximum capacity for a wind turbine at Liddeston Ridge is assumed as 2.5MW. This was based on a resource assessment performed for the land area available in Phase 1 of this project.
3. The export electricity cost is assumed to be 10p/kWh as per the Port's agreed export tariff from May 2022. It is assumed that this cost will continue even if the Port decides to install an internal private wire or virtual PPA to its own assets.
4. The costs of a physical private wire within the Port is assumed from the 2018 Hoare Lea report "Services and infrastructure masterplanning, Milford Haven" . No cost escalation has been applied to this report.
5. The cost of transporting electricity through the existing grid is assumed as 5p/kWh as this is the cost taken from Energy Local analysis and assumed to be of a similar magnitude for electricity distribution from Liddeston Ridge to the Waterfront.

Appendix C: Commercial workshop

ARUP

Stakholder brainstorming and mapping



Appendix C: Commercial workshop

ARUP

Stakeholder role description and responsibilities

1. Promoter

Description

The Promoter is a party with the motivation to establish successful projects, which takes responsibility for driving delivery.

The role tends to be time limited, lasting until the next phase is delivered (albeit subsequent phases may also need to be promoted).

Responsibilities

- Defining physical nature of the project.
- Commissioning detailed studies to establish viability.
- Identifying funding options.
- Defining the scale and timing of demand for services.
- Publicising the opportunity and communicating the benefits to key stakeholders.
- Attracting developers, investors, operators and customers.

2. Community Liaison

Description

The party responsible for Community Liaison, communicates any impacts of the scheme with project stakeholders.

For example, Community Liaisons would be responsible for engaging with lease holders and consumers to relay information about the scheme and mitigate any concerns.

Responsibilities

- Recognising community issues.
- Engaging with the community to identify the root cause of issues.
- Working to brainstorm potential solutions.
- Relaying proposed solution to gauge community buy-in.

Appendix C: Commercial workshop

Stakeholder role description and responsibilities

3. Customer

Description

The Customer (domestic or non-domestic) purchases energy/services or benefits the Supplier using a reduction in energy/service cost in comparison to the counterfactual.

The Customer may contract to purchase energy/services from the Supplier who may also be the Owner, Operator, Landlord or a specialist third party. End users/beneficiaries are nearly always customers.

Landlords are often bulk purchasers of energy, and make onward sales of energy to their tenant customers.

Responsibilities

- Agreeing terms of energy purchase agreement/ demand reduction equipment lease-purchase agreements
- Paying an agreed price for the service.

4. Governance

Description

The Governance role includes setting objectives, prescribing policies and rules of conduct and overseeing performance. These objectives, rules and policies will need to be prescribed by the contract(s) under which the programme is operated. They may be promoted through wider stakeholder engagement in the programme's direction.

The governance role may be taken by the Port Authority itself or an appointed board or committee within the programme structure. Ideally, the Governing Body should ultimately be accountable to a wider set of stakeholders.

Responsibilities

- Assigning roles and responsibilities.
- Setting overall direction, ethics policy and objectives for the elements of the programme within the remit of the governing body.
- Taking high level commercial decisions.
- Monitoring programme performance standards.

Appendix C: Commercial workshop

ARUP

Stakeholder role description and responsibilities

5. Regulator

Description

The Regulation role is focussed on consumer protection and to prevent abuse of the monopoly position of assets. This regulatory function is exercised by a party that is independent of the owner of the assets, and of Landlords.

Electricity networks are regulated by Ofgem in the UK, however heat networks are currently unregulated. Heat network regulation is contractually tied into the governance or operation agreement. An independent body called the Heat Trust sets standards to provide protection for heat customers and it is best practice for a heat supplier to join this scheme.

There is not currently a regulatory body for sale of hydrogen.

Responsibilities

- Monitoring performance standards.
- Resolving disputes between operators and customers.
- Enforcing fair pricing.

6. Funder

Description

The Funder provides or arranges finance.

Depending on the financial structure and risks associated with the project, funders may demand security against the funding they provide. An example of such security includes Parent Company Guarantees (PCGs) or performance bonds.

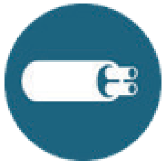
Where funding is a loan, this role ceases once finance has been repaid or the asset has been sold to another party.

Responsibilities

- Providing funding or arranging sources of finance, if satisfied that the scheme represents an acceptable risk.
- Signing funding agreements, depending on the type of funds being provided (e.g. debt or equity).
- Obtaining appropriate security from the beneficiaries of funding.

Appendix C: Commercial workshop

Stakeholder role description and responsibilities



7. Asset Owner

Description

The Asset Owner legally owns the physical assets. Ownership could be split for different classes of assets for example, demand reduction, generation assets, primary network and secondary networks.

Ownership of assets may vary over the life of the project. This is normally a long term function and survives completion of installation and repayment of finance.

Responsibilities

- Securing an income stream to match its responsibilities and to cover its risks.
- Insuring or procuring insurance for the assets.
- Ensuring the assets are maintained and components replaced when life expired.
- Contracting with installers, maintenance providers, and service companies.

8. Property Developer

Description

Property Developers are the parties responsible for constructing or maintaining buildings. These buildings are built for customers that are likely to need energy/services.

Time and certainty are critical factors for Developers of Property. Electricity and heat network connections must be agreed and delivered within the Developer’s window of opportunity, or the deal may collapse.

Responsibilities

- Delivering the completed site, including secondary and tertiary networks/assets.
- In some projects, making financial or in kind contributions to the network/asset delivery body.
- Demonstrating to purchasers or tenants of units on the Development that the network has suitable governance structures, acceptable contract terms and continuity of Energy/service supply.

Appendix C: Commercial workshop

ARUP

Stakeholder role description and responsibilities

9. Land Ownership

Description

The role of the Land Owner, in this context, is to grant leases and easements for the siting of network assets and provide rights of access for the installation, operation and maintenance of plant and equipment.

This arrangement may arise where a third party with no other interest in the network lets land for an energy centre or pipe route, or where an operator or supplier of energy installs plant and equipment on a client’s site.

Responsibilities

- Granting leases for energy centres , substations or any assets that require land.
- Granting easements for network routing/ asset installation.
- Providing rights of access for installation, operation maintenance and replacement of plant and equipment.

10. Landlordship

Description

In the context of energy, The Landlord role, for buildings connected to energy networks, usually involves responsibilities for some network assets within the building, which may include the secondary and tertiary systems.

Some classes of residential landlords have specific statutory duties relating to energy supply under the Housing Act and the Landlord and Tenant Act, which may affect the terms and pricing formulae of any energy network connection to a tenanted building. An energy supplier to a tenanted building is likely to have contractual relationships with both landlord and tenant-customers. The Landlord’s responsibilities may be executed by an estate management company (ManCo).

Responsibilities

- Ensuring building occupiers are connected to the energy network.
- Controlling access to maintain the secondary and tertiary networks, including ensuring that tenant leases reserve the necessary rights of access.
- May include insuring some (e.g.secondary and possibly tertiary) network assets.
- May include maintaining and replacing the tertiary network assets for rental tenants.
- Where applicable, undertaking relevant Tenant Consultations.

Appendix C: Commercial workshop

ARUP

Stakeholder role description and responsibilities

11. Installation

Description

The Installer designs and installs the energy network. Typically, this is the energy centre and primary network, with the secondary network being the responsibility of the Property Developer.

Independent Connection Providers (ICPs) are accredited companies that are entitled to build electricity networks to the specification and quality required for them to be owned by a Distribution Network Operator (DNO) or independent DNO (IDNO), and are generally contracted by the Developers of Property.

Installers such as ICPs take on design and construction risk and usually retain some liability for defects in the plant and equipment for a period after completion of the network. Responsibility for delivering different parts of the network may be split between different parties.

Installation can be combined with operation (DBO or DBOM) and doing so may be advantageous in terms of aligning incentives, reducing risk and simplifying contractual arrangements.

Responsibilities

- Installing a network which complies with the specification.
- In some projects, commissioning networks and connecting new customers.
- Installing network extensions.

12. Operator

Description

Electricity and heat networks are operated distinctly in the UK. Electricity networks are regulated and operated by DNOs that have geographic monopolies. Physical private wires however, may be operated independently. On the other hand, there are several emerging Operators of various sizes that offer their services to operate heat networks.

An Operator is responsible for the operation and maintenance of the energy network in such a manner as to ensure that energy of suitable quality and quantity can be delivered to Customers.

The single Operator model where one entity is responsible for end-to-end Energy delivery is transforming with the emergence of specialised operators for generation plants and for networks.

Responsibilities

- Ensuring that energy of suitable quantity and quality is delivered to customers.
- Where relevant, complying with the requirements of any electricity export licences or power purchase agreements.
- Ensuring performance standards are met.
- Undertaking maintenance, repair and (in some cases) replacement works.
- Reporting to customers, landlords and the Governance body.

Appendix C: Commercial workshop

ARUP

Stakeholder role description and responsibilities

13. Supplier

Description

The supplier of energy/services is a logically distinct role from the physical delivery of energy/services to customers, as can be seen in the nationally regulated UK electricity and gas markets.

Electricity and gas markets have mandatory separation of generation and distribution roles, however, in the case of heat networks the same organisation is generally responsible for all three functions.

Energy suppliers often subcontract aspects of this role, such as metering, billing and customer services, to specialist firms.

Responsibilities

- Procuring energy/services delivery.
- Where relevant, metering.
- Billing.
- Undertaking price reviews.
- Attracting and securing new customers
- Collection of revenues.
- Managing customer debt and default.
- Communicating with customers.

14. Supplier of last resort

Description

Within a local energy system, it is best practice to have a supplier of last resort to provide heat, electricity, hydrogen or gas if a scheme's provider is unable to do so.

This is particularly important within a heat network or microgrid setting as failure to do so could lead to energy blackouts.

Responsibilities

- Taking over Operator and Supplier responsibilities where required (including in some cases taking on Asset Ownership)
- Arranging for replacement of Operator and/or Supplier roles.

Appendix C: Commercial workshop

Matching stakeholders to roles

See following page

Roles mapping

Pembrokeshire County Council	1. Physical private wire to port assets & other	2. Virtual private wire to port assets & other	3. External sale of renewable electricity	4. Onsite hydrogen generation	5. Hydrogen import and export
Peacocks **1. Promoter**	ESCOs; WPD; Port of Milford Haven Authority; Port of Milford Haven Authority	Port of Milford Haven Authority; Energy Local	Pembrokeshire County Council; Port of Milford Haven Authority	RWE (Pembroke Net Zero Centre synergies); Offshore wind developers; Port of Milford Haven Authority; Pembrokeshire County Council	WWU; RWE (Pembroke Net Zero Centre synergies); Offshore wind developers; Port of Milford Haven Authority; Pembrokeshire County Council; SWIC
2. Community Liaison	Milford Sense of place board; Community Energy Pembrokeshire; Innovate UK	Innovate UK; Milford Sense of place board; Energy Local; Community Energy Pembrokeshire; Community Energy Pembrokeshire; Milford Haven community energy groups	Milford Sense of place board; Community Energy Pembrokeshire; Innovate UK	Milford Sense of place board; Community Energy Pembrokeshire; Innovate UK	Milford Sense of place board; Community Energy Pembrokeshire; Innovate UK
3. Customer	MHPA tenants; Home Bargains; Tesco; Torch Theatre; Iceland Food; Peacocks; private home owners; Welsh Water (site nearby); Local residents in Hakin (near to LR site) and Milford; Social landlord; Pembrokeshire County Council → Most demand here too	Town council; NHS; Pembrokeshire County Council; Community Energy Pembrokeshire; Marina shore to ship power users; Walsingham Support (Charity)	Pembrokeshire County Council	TfW; Pembrokeshire County Council; NHS; Possibly NHS as fleet operator and potential user of hydrogen	Possibly Riversimple; Network Rail; Riversimple; Transport for Wales (HFC buses); Pembrokeshire County Council; NHS; Possibly NHS as fleet operator and potential user of hydrogen
4. Governance	Port of Milford Haven Authority; Pembrokeshire County Council	Port of Milford Haven Authority; Pembrokeshire County Council	Welsh Government; Port of Milford Haven Authority; Pembrokeshire County Council	Port of Milford Haven Authority; Pembrokeshire County Council	Port of Milford Haven Authority; Pembrokeshire County Council
5. Regulator	Ofgem; Ellexon	Energy Local; Ellexon	Ofgem; Ellexon	HSE; WWU; Ofgem	WWU; HSE; Ofgem
6. Funder	ESCOs; Welsh Government; Innovate UK; BEIS	Welsh Government; Innovate UK; BEIS	Welsh Government; Innovate UK; Welsh Government; BEIS	Offshore wind developers; Port of Milford Haven Authority; SWIC; Pembrokeshire County Council; Innovate UK; Innovate UK; BEIS	Innovate UK; Offshore wind developers; SWIC; Innovate UK; Welsh Government; BEIS
7. Asset Owner	Port of Milford Haven Authority; e.g. Pivot Power; WPD (?)	WPD; WWU; Port of Milford Haven Authority; e.g. Pivot Power; Pembrokeshire County Council	Port of Milford Haven Authority	Offshore wind developers; Pembrokeshire County Council; Port of Milford Haven Authority	Offshore wind developers; Pembrokeshire County Council; SWIC
8. Property Developer	Port of Milford Haven Authority; ICP	Port of Milford Haven Authority	Port of Milford Haven Authority	Port of Milford Haven Authority; TfW; MHPA tenants	Port of Milford Haven Authority; TfW; Welsh Water (site nearby); MHPA tenants
9. Land Ownership	Port of Milford Haven Authority	Port of Milford Haven Authority	Port of Milford Haven Authority	Port of Milford Haven Authority; WWU; TfW; Welsh Water (site nearby); SWIC	Network Rail; WWU; TfW; Port of Milford Haven Authority; SWIC
10. Landlordship	Port of Milford Haven Authority	Port of Milford Haven Authority	Port of Milford Haven Authority	Port of Milford Haven Authority	Port of Milford Haven Authority
11. Installation	ICP; WPD; Enica (supplier of MHPA energy monitoring equipment)	Enica (supplier of MHPA energy monitoring equipment)		Fuel Cell Systems LTD (providers of the MHESK electrolyser/refueler)	
12. Operator	Port of Milford Haven Authority; Meter operator; WPD	DC/DA; Demand sharper algorithms; RWE (Pembroke Net Zero Centre synergies); Port of Milford Haven Authority; Licensed supplier; Meter operator	Meter operator; DC/DA; Licensed supplier	Battery and/or electrolyser suppliers/operators	National grid; WWU
13. Supplier	ESCOs	Licensed supplier; ESCOs; Maybe Dragon charging (supplier of EV charging inb Pembs via PCC contract)	Licensed supplier; ESCOs	Battery and/or electrolyser suppliers/operators; ESCOs	ESCOs
14. Supplier of Last Resort	WPD	Licensed supplier		Air Liquide or similar industrial supplier?	Air Liquide or similar industrial supplier?

Appendix D: Decision making flowchart

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Flowchart to understand the key next steps