# Hydrogen Electrolyser Study

## Reassessing Approaches to Connecting Large Electrolyser Sites: Work Package 2

National Grid Electricity Distribution

16 December 2022

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| S3 | 1 | Raj Nagarajan<br>Zeynep Kurban<br>Thomas Bennett | Andrew Winship | Andrew Winship | Andrew Winship | Andrew Winship | 07/11/22 |
| S4 | 2 | Raj Nagarajan<br>Zeynep Kurban<br>Thomas Bennett | Andrew Winship | Andrew Winship | Neil Murdoch | Neil Murdoch | 16/12/22 |
| S4 | 3 | Raj Nagarajan<br>Zeynep Kurban<br>Thomas Bennett | Raj Nagarajan | Raj Nagarajan | Neil Murdoch | Neil Murdoch | 31/01/23 |

**Gutteridge Haskins & Davey Limited   CN 05528602**

10 Fetter Lane, London

EC4A 1BR, United Kingdom

**T** +44 203 077 7900 | **F** +44 203 077 7901 | **E** londonmail@ghd.com | **ghd.com**

# Executive Summary

*This report is subject to, and must be read in conjunction with, the limitations set out in section 1.2 and the assumptions and qualifications contained throughout the Report.*

The main aspect of Work Package 2 (WP2) was the investigation of the requirements of hydrogen electrolyser connections and the assessment of the impact on NGED network. It was also intended to apply the criteria developed in Work Package 1 (WP1) in the identification of optimum connection location for the chosen case study projects. Although some engagement was made with developers, due to their reluctance to their projects being used as case studies, we had to adopt an alternate method based on assumptions and data available in the public domain rather than the application of the criteria using information provided by the project developer. The methodology and the analysis are discussed in Chapter 3.

The second chapter presents the key insights from WP1 on the challenges for NGED's network based on the Future Energy Scenarios and the potential role of hydrogen electrolysers in providing solutions. The currently planned projects in NGED areas are listed. The hydrogen demand projections in the near and long terms are presented based on the scenario based on the pathways analysis from the study commissioned by the Committee for Climate Change (CCC). As we have focussed on South Wales for the study, we have referred to *Net Zero South Wales 2050* by *Regen* for the projections of hydrogen demand from the industries. Finally, we have discussed the grid connected vs off grid options for the hydrogen electrolysers presenting the key factors.

The third chapter covers the network assessment describing the reasoning for the choice of the area and the nature of the hydrogen use case namely the industrial cluster. We have discussed the identification of industries, the methodology adopted to estimate their hydrogen demands and the assumptions followed by an analysis of network characteristics. This chapter also covers the relevant network reinforcement plans in the area. An analysis of renewable generation projections in the area, potential for colocation and the flexibility services has also been presented. This chapter concludes by highlighting the significance of REMA (Review of Electricity Market Arrangements) for the Transmission and Distribution Networks.

**Findings from WP1**

NGED's network will be experiencing an increasing number of constraints in all National Grid ESO Future Energy Scenarios across its network. In NGED's best view scenario electrolytic hydrogen production can be a part of solution to these challenges. Additionally, both alkaline and polymer electrolyte membrane (PEM) electrolysers can be used for providing balancing services to the grid through the Power-to-X[1] mechanism and have the potential to reduce curtailment levels. Hydrogen is considered as a competitive solution for long duration energy storage and can also deliver clean, firm power generation and peaking power.

In our assessment of potential demand to 2030, we have identified only 3 projects from our database in the NGED area. 1. RWE's Pembroke project with 100MW peak capacity by 2030 (in South Wales), 2. Protium Magor (in Wales) with 20MW Peak capacity by 2030, and 3. Langage Green Hydrogen Project at 10MW peak capacity. However, based on our conversations with various hydrogen project developers we understand that there are plans for various electrolytic hydrogen projects to be developed by 2030, which will potentially require connection to the grid if the CO2 intensity of the grid electricity is compatible with the Low Carbon Standard threshold (20g CO2 equivalent per MJ LHV hydrogen or less) or if energy from renewables combined with intermittent access to grid electricity can enable the projects to meet this carbon intensity threshold.

**Demand for hydrogen – Long term view**

The use of hydrogen for seasonal energy storage and heating of buildings will be key factors determining the trajectory of Hydrogen demand growth. The government's strategy on these aspects is unclear currently but is planned for completion by mid to late 2020s.  Therefore, the extent to which hydrogen infrastructure develops and the timing is, particularly pipelines, is currently unclear. This strategy will be influenced by the pathway for decarbonising residential homes, whether it will be heat pumps or hydrogen boilers, which is likely to be determined on a regional basis. If hydrogen is used for heat in a region, then the existing natural gas network will be converted to hydrogen starting with blending with natural gas initially. There are two approaches quoted in "Britain's Hydrogen Blending Plan" (ENA 2021), namely "strategic approach" and "free market" each with a

[1] Here X denotes power, such that hydrogen is produced using electricity, stored and reconverted to power when needed through a fuel cell or combustion process (e.g. future combined cycle gas turbines using H2). X can also denote H2 gas stored and used in non-power applications (such as fuel for transport and gas for heat).

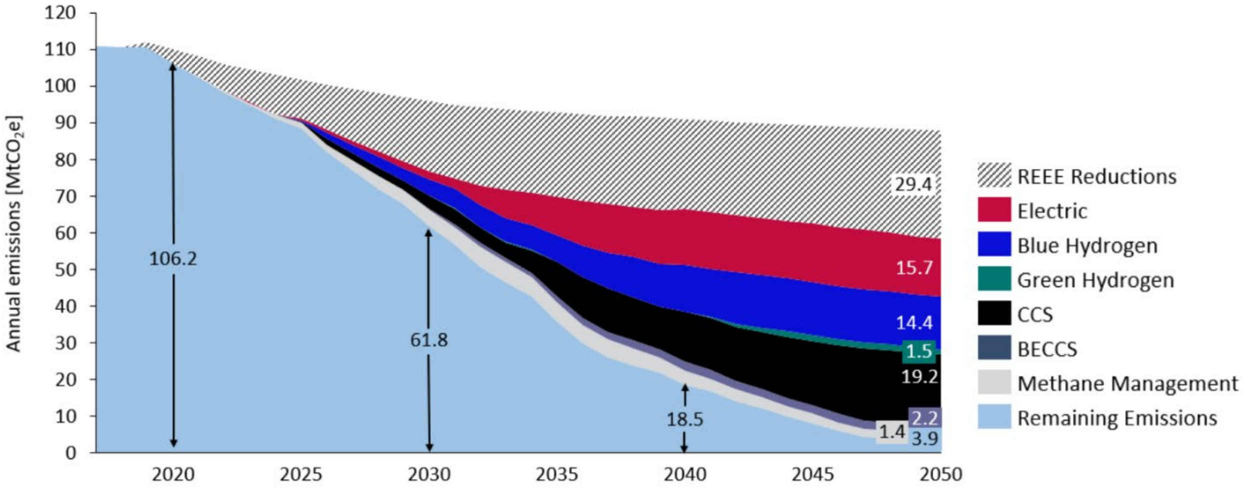
different set of outcomes regarding the sizes and location of electrolyser plants with a differing impact to the electricity network.
If electrification is pursued instead there will still be industries with hard to abate processes with a need for hydrogen. Without a robust hydrogen grid network, they will need their own electrolysers or in partnership with other nearby industries establishing small hydrogen microgrids with electrolysers which are almost certain to require distribution connections and this scenario will present the worst case for NGED's network in terms of increasing demand for connections.

**Demand for hydrogen – Near term view**

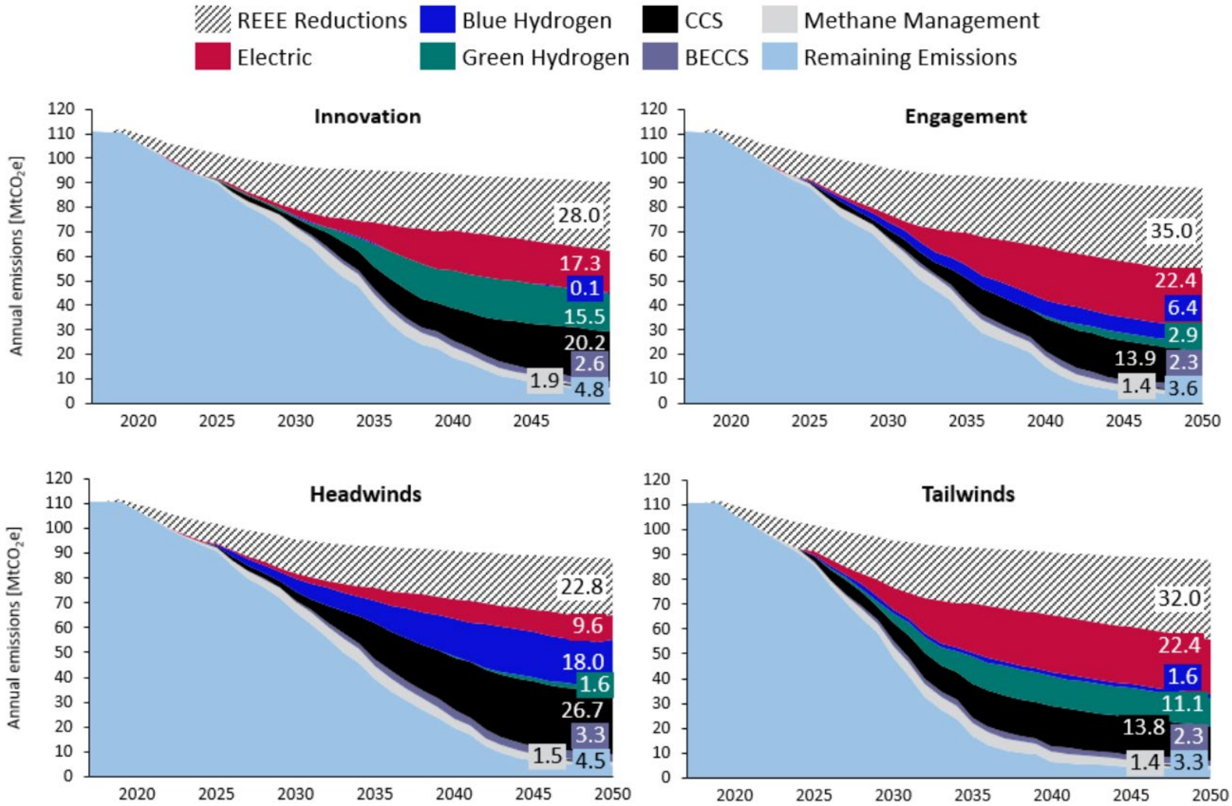
In the near term the demand for hydrogen is expected to arise from transport and industrial applications. For the transport application, the demand is far less certain currently therefore we have focussed on industrial applications.

We referred to report published in 2020 by Element Energy on the study commissioned by Committee for Climate Change (CCC) to look at potential pathways to decarbonising industry in the UK. Chapter 2.2.2 outlines the role of hydrogen in five scenarios as below.

The expected demands for hydrogen vary significantly between these scenarios ranging from 1.5TWh to 15.5TWh in 2050. Since the publication of this report in the Energy Security Strategy (2022), BEIS increased its ambitions for hydrogen production by 2030, half of which is expected to be met by green hydrogen for industrial use cases. Significant funding in the region of £240M has been announced for industrial decarbonisations.




*Emissions abatement pathway for the 1) Balanced Net Zero Pathway (Element Energy 2020)*




*Emissions abatement pathway for the other four CCC scenarios. 2) Widespread Engagement (high efficiency and electrification), 3) Headwinds (high hydrogen), 4) Widespread Innovation, 5) Tailwinds: A scenario with a combination of accelerated deep decarbonisation drivers from each of the 3 broad scenarios defined above (Element Energy 2020)*

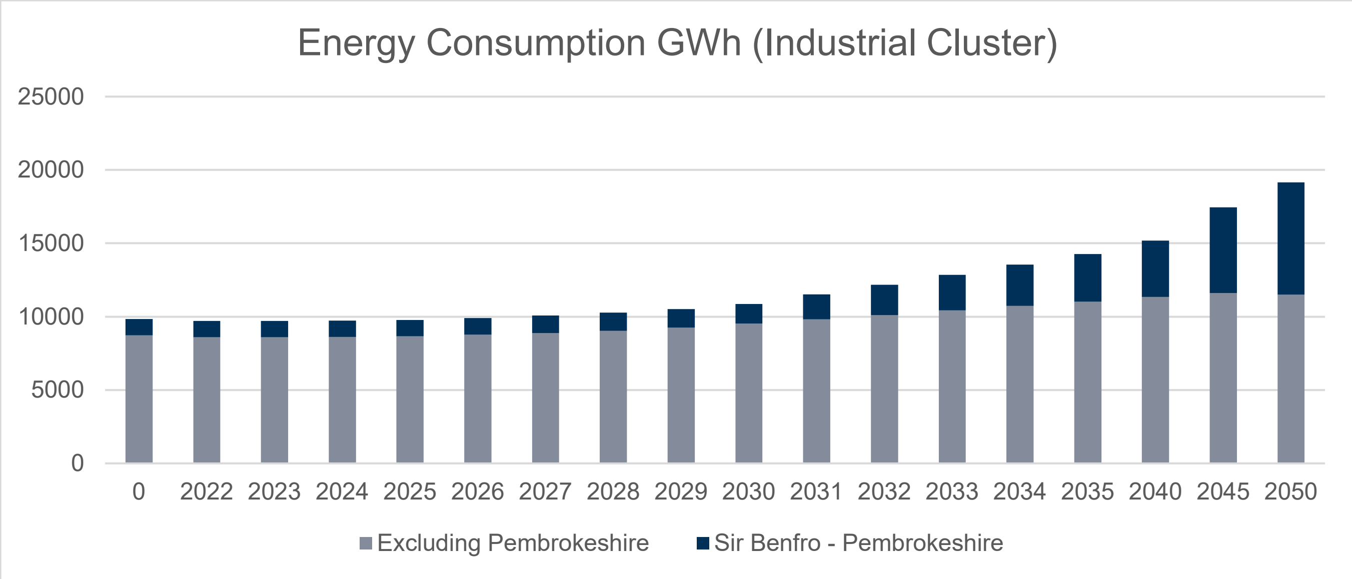
**South Wales Area**

Given the lack of data on the planned industrial projects looking at fuel switching to hydrogen, both at the national and regional level, it has not been possible to calculate the demand for green hydrogen and the respective load on the grid these projects may yield by 2030 in NGED's network area.

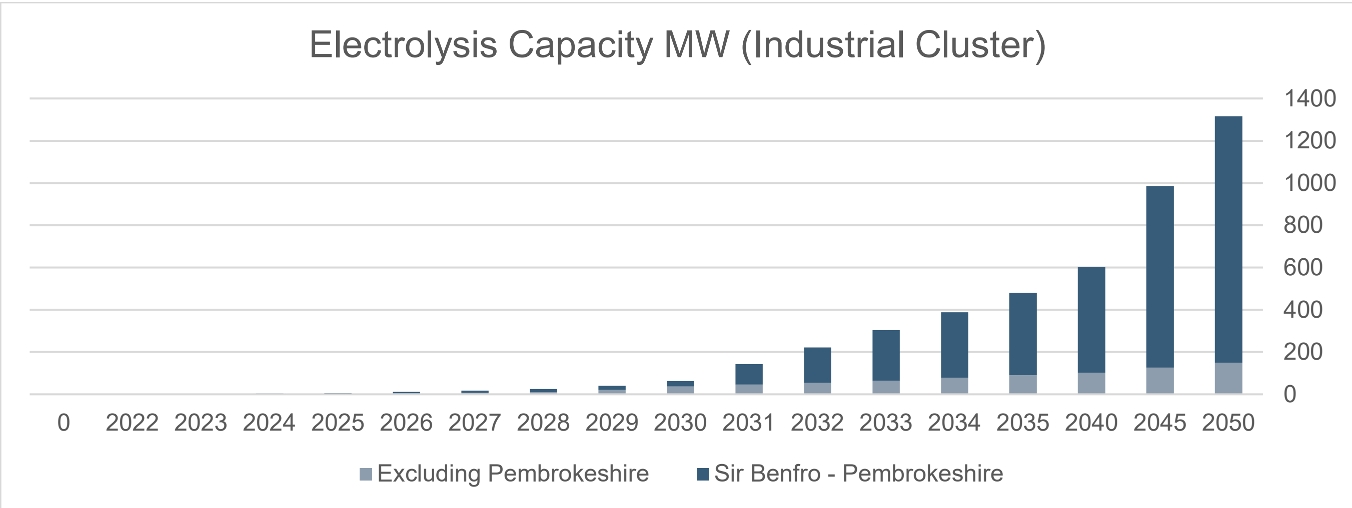
We chose south Wales and the surrounding area for electrolyser growth projections for the reasons outlined in section 3.1. The largest industrial hub within the NGED network is South Wales which is also the largest industrial hub in South Wales and second most emitting industrial hub in the country, accounting for approximately 15% of emissions.

According to the report Net Zero South Wales 2050 (Maltby P., Arrell R., 2020) the potential electricity demand from hydrogen production on the distribution network in the combined South Wales licence areas by 2030, to be around 1.8 TWh/year for the Core Hydrogen scenario and around 1.5 TWh/year for the High Hydrogen scenario.

Referring to the DFES NGED Best View scenarios, a correlation between the growth in hydrogen electrolyser capacity and the growth in electricity demand has been observed. This suggests that hydrogen is likely to be one of the key drivers of electricity demand growth in industrial sectors in the future.




***Projected Energy Consumption in areas of study and surrounding counties, NGED Best View***



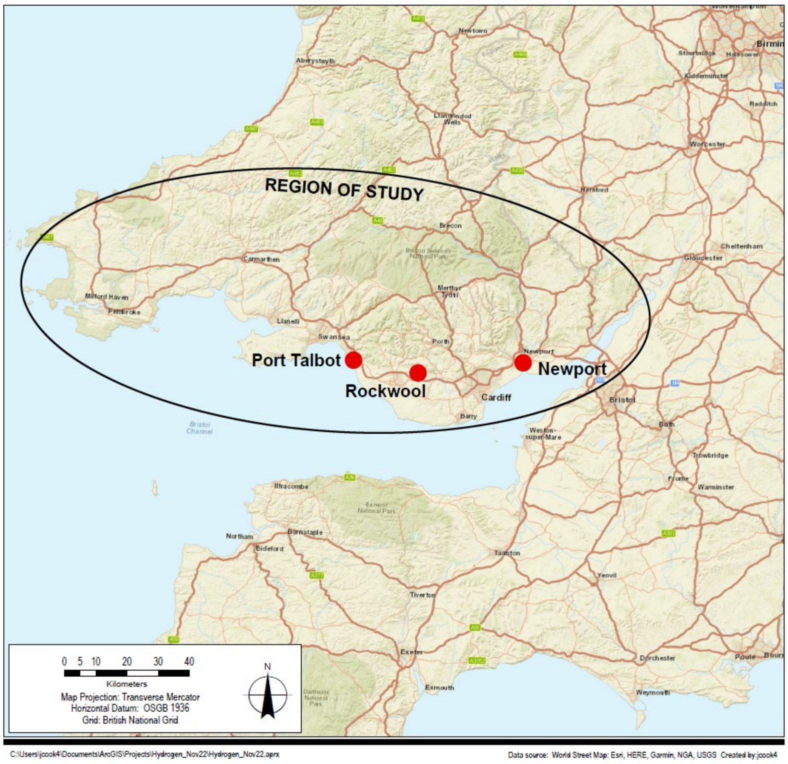

***Projected Electrolysis Capacity (MW) in areas of study and surrounding counties, NGED Best View***

### Grid connection vs Off-grid

The size and location for industrial hydrogen demand in NGED's network will determine the demand for electricity from the grid. Additionally, there is a range of factors that need consideration in the decision on grid connection vs off-grid which is discussed in 2.3.

### Network assessment

The engagement with project developers and use of real-life projects as case studies was not possible as explained above. Due to this change in scope, it was necessary to establish a new process for choosing an area of study. South Wales, an industrial cluster with high emissions was chosen and then a sample of companies within that cluster were analysed based on which had the most accessible process information and the need to investigate a spectrum of different sized industries to evaluate different impact scales. This resulted in a detailed network analysis of Rockwool, Solutia, Liberty Steel and the largest Tata Steel plant. Other sites were explored but dismissed due to either lack of information, their current network connections being transmission, or their processes being highly unlikely to use hydrogen in the short to medium term such as power plants. We found that a simple conversion of emissions to hydrogen demand lacked robustness due to the variety of processes and fuels involved at these sites and the difficulty associated with decarbonising them, particularly steel.




Therefore, we used only processes that made use of natural gas currently and so are more easily converted to hydrogen and therefore have potential to manifest before 2030. We were able to estimate the proportion of emissions coming from the processes involving natural gas and work backwards to an energy demand based on emissions data per KW/h of fuel. From here we were able to estimate the size of an electrolyser that would be required at a variety of capacity factors with lower capacity factor electrolysers putting significantly more peak strain on energy networks. We also observed that some larger sites would require transmission connections for their electrolysers if they were to use grid electricity in the future as the grid becomes greener.

We were able to verify the methodology by applying the calculation to gas fired power stations who are known to use 100% natural gas. The value that was retrieved could then be compared to what the power station would require at 100% capacity factor to estimate actual capacity factor. Finally, this was compared against historic capacity factor data for South Wales to verify it is within a reasonable margin of error.

The outcome of this analysis detailed in the report showed that there is no universal truth to the impact of hydrogen manifesting on the NGED grid. In some areas with single industries there is enough capacity connect without concern while others may be able to connect if they avoid hydrogen production during peak demand and some areas will require reinforcement. Unfortunately, due to the importance placed on co-location with hydrogen demand by developers and industries, as highlighted in WP1, it is difficult to move hydrogen demand away from industries towards parts of the grid with spare capacity and instead the grid must adapt to accommodate hydrogen where it manifests. Large industrial sites are more likely to need significant quantities of hydrogen to decarbonise and therefore would likely require transmission connected electrolysers which are unlikely to manifest before 2030 until smaller sites have acted as a proof of concept.

The key issues with rolling such an analysis out across industrial sites more widely is the need to consult with industries to understand their specific decarbonisation needs. In an industrial cluster two sites both referred to as steel mills could have entirely different processes depending on the specific product they are producing or the input they use such as ore compared to scrap steel. This becomes even more complex with sites such as Chemical Plants who could be using any variety of processes and feedstocks. This will mean a priority should be placed on making communication behind high demand sites; or potentially future high demand sites due to electrification or hydrogen use, with NGED as friction free as possible.

**Renewable generation**

For green hydrogen production renewable generation is critical both for colocation option or grid connection which will require the carbon intensity to meet the standard set. The DFES projections for the onshore/offshore wind and solar for the time horizon up to 2030 are not adequate to meet the capacity needs anticipated for electrolytic hydrogen production. This trend may be changing with the new policy announcement on subsidies and increased targets for green hydrogen.

There is a relatively higher rate of projected growth for >1MW onshore wind and solar for the period from 2030-2050, although again, not high enough to align with the High Hydrogen Scenario. This is discussed in chapter 3.3.5.

**Flexibility**

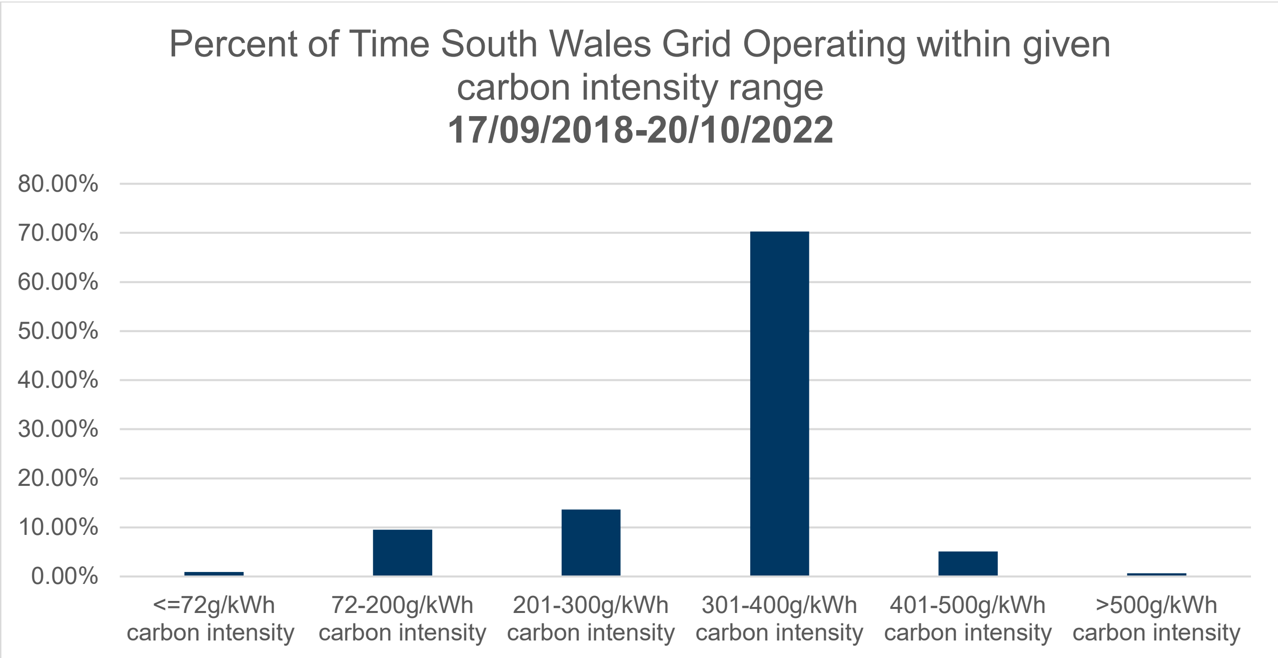
Small, distributed hydrogen electrolysers provide huge potential for demand side grid management, but the full extent of the role they will be able to play in providing grid services will depend on the pathway forward taken by the Future System Operator. It has been discussed in a government consultation, the Review of Electricity Market Arrangements (REMA, results pending, 2022), that DNOs could begin assisting the Electricity System Operator in managing grid services. Currently there are only a couple of Constraint Management zones in the vicinity of the industrial sites assessed.

**Carbon Intensity**

The carbon intensity standard for the qualification of incentives has been set to less than 72g $CO_2$/kWh for the source of energy used in the production of Hydrogen. This standard is only met a small percent of the time both nationally and regionally.

The historic half hour data for South Wales area from 17/09/22 to 20/10/22 was analysed to estimate the carbon intensity ranges and duration presented below. It can be seen for the South Wales area the stipulated standard has been met only for 0.89% of the time. This is a significant issue for electrolyser projects that will rely on grid connection for the supply reliability.

National Grid ESO's model that gives a forecast for a few days ahead and the DNO areas forecast available are also of the same time frame. Currently the future projections for the carbon intensity for medium and long term are not available. This data is critical in the assessment of the economic case for projects and therefore this is an area for consideration for development. Also, forecasts for more localised areas geographically would be greater value to the project developers.




***Carbon Intensity South Wales 17/09/2022 to 20/10/2022***

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## Appendices



## Attachments

# 1. Introduction

## 1.1 Purpose of this report

This report is the summary of an investigation of the requirements of hydrogen electrolyser connections and the assessment of the adequacy of National Grid Electricity Distribution's (NGED) network to accommodate the potential surge in demand for the period up to 2030. The investigation was a desk top study that followed on from WP1 which was mainly the discovery phase that included a survey to identify the criteria for the location of electrolysers.

This report informs NGED on the findings of the assessment, conclusions and recommendations.

## 1.2 Scope and limitations

*This report: has been prepared by GHD for National Grid Electricity Distribution and may only be used and relied on by National Grid Electricity Distribution for the purpose agreed between GHD and National Grid Electricity Distribution as set out in section 1.1 of this report.*

*GHD otherwise disclaims responsibility to any person other than National Grid Electricity Distribution arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.*

*As this is a desk-based study, the information presented is based on the accuracy of the publicly available information and the views of those responded to our requests for consultations.*

*The original scope included an electrical study for a chosen project case with the due consent from the developer to consider the voltage level, co-location, Flexibility, Active Network Management and connection location trade-off options at the selected point of connection.*

*However, the consent for such study could not be obtained for a suitable project case and therefore a different methodology was agreed with NGED and adopted for this study. This methodology is based on the selection of an area on NGED's network with large industrial emitters of $CO_2$ and the estimation of electrical demand to produce hydrogen to decarbonise their industrial processes. An indicative network assessment was then carried out for these estimated demand connections.*

*The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.*

*The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.*

*The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.*

**Accessibility of documents**

*If this report is required to be accessible in any other format, this can be provided by GHD upon request and at an additional cost if necessary.*

## 1.3 Assumptions

Various assumptions made in this study are mentioned and discussed in the respective sections of the report. The key assumptions are the basis for the calculation of the carbon emission values for the processes for which are most likely to transition to hydrogen in the short to medium term and the corresponding electrical power capacity required for the grid connection.

# 2. Green Hydrogen Projects – Implications for NGED

## 2.1 Review of Findings from WP1

The work undertaken in *Work package 1: Discovery and Criteria Development*, which preceded this part of the study, involved an assessment of the potential for electrolyser connections to NGED's network area, as well as identification of the opportunities and challenges presented by green hydrogen production for NGED. Some of the key insights from this first phase of the study, and their importance for network assessment at a more detailed level are outlined below.

### 2.1.1 Implications for NGED's network based on scenario modelling

NGED's network will be experiencing an increasing number of constraints in all National Grid ESO Future Energy Scenarios across its network. NGED's best view scenario shows that network constraints can increase by about 40% in the South West, double in East and West Midlands and more than quadruple in South Wales between 2025 and 2032 alone. NGED currently has five different ways to alleviate the projected constraint: Conventional Reinforcement; Strategic Reinforcement; Operational Mitigation; Load Management; and Flexibility Schemes. Electrolytic hydrogen production can be part of all these schemes and could be used to lower network reinforcement costs in the last three schemes above.

### 2.1.2 Electrolytic hydrogen production implications for networks

Both alkaline and polymer electrolyte membrane (PEM) electrolysers can be used for providing balancing services to the grid through the Power-to-X[2] mechanism, including stability, frequency regulation, black start, short term reserve, fast reserve, upgrade deferral, energy arbitrage, capacity firming, seasonal storage, voltage support and islanding. However, batteries are predominantly used in most markets for balancing services, especially those with short activation times.

While increasing levels of battery storage can help reduce electricity curtailment levels (arising from network constraints) and hence these costs, there is a need to better understand the economic and temporal value of electrolytic hydrogen production across different network regions. In this regard, further work is needed to understand the impact of electrolytic hydrogen production as part of NGED's upgrading strategy assessment for the next decade.

Hydrogen is considered as a competitive solution for long duration energy storage, specifically for seasonal fluctuations in energy supply and demand (for both electricity and gas networks). Hydrogen can also deliver clean, firm power generation and peaking power which are valuable functions within the energy system, especially as we transition to more renewables.

### 2.1.3 UK hydrogen projects

While there is great potential for electrolytic hydrogen production to add value to grid balancing activities, green hydrogen production projects can also add to the demand constraints in NGED's network area. Our initial assessment of this potential demand to 2030, on the basis of planned projects in the region, did not yield conclusive results for a number of reasons. Our database of hydrogen projects showed only three projects: 1. RWE's Pembroke project with 100MW peak capacity by 2030 (in South Wales), 2. Protium Magor (in Wales) with 20MW Peak capacity by 2030, and 3. Langage Green Hydrogen Project at 10MW peak capacity, which applied for

[2] Here X denotes power, such that hydrogen is produced using electricity, stored and reconverted to power when needed through a fuel cell or combustion process (e.g. future combined cycle gas turbines using H2). X can also denote H2 gas stored and used in non-power applications (such as fuel for transport and gas for heat).

planning permission in the second quarter of 2022. All these projects are currently looking to have renewables co-located with the electrolysis facility, and their requirement for grid connection in the future is not specified. No other projects, with demand data, were identified in NGED's network area (previously NGED's network area). However, based on our conversations with various hydrogen project developers we understand that there are plans for various electrolytic hydrogen projects to be developed by 2030, which will potentially require connection to the grid if the CO2 intensity of the grid electricity is compatible with the Low Carbon Standard threshold (20g CO2 equivalent per MJ LHV hydrogen or less) or if energy from renewables combined with intermittent access to grid electricity can enable the projects to meet this carbon intensity threshold.

### 2.1.4 Application of WP1 Criteria

To effectively evaluate hydrogen sites using the criteria developed in WP1 engagement with hydrogen developers would be vital. To this end we pursued engagement with SWIC and two other developers. Unfortunately, they were unable to provide the case studies required or pulled out of cooperation respectively therefore an alternative methodology for assessing the impact of hydrogen on NGEDs grid has been explored for WP2 through evaluating hydrogen decarbonisation for a selection of industrial sites. There is limited value in applying the criteria to these sites as in these scenarios the location of the electrolyser and its limitations are defined by the industrial site. We still believe there is value in the criteria that have been developed but further work would be required to apply them requiring cooperation with hydrogen developers.

## 2.2 Demand for Hydrogen

### 2.2.1 The long term view

While hydrogen is a key component of the UK government's Net Zero Strategy, the trajectory for how the demand for hydrogen will grow across different sectors is somewhat unclear. Hydrogen is being considered across all energy demand sectors; heat, power, transport, and industry. The use of hydrogen for seasonal energy storage is unclear but the government is looking to develop its strategy on this by mid-2020s, followed by the decision on whether hydrogen will be used to heat buildings by 2026. Therefore, the extent to which hydrogen infrastructure develops, particularly pipelines, is currently uncertain. The key indicator for this will be the pathway that is taken for decarbonising residential homes, whether it will be heat pumps or hydrogen boilers, which is likely to be determined on a regional basis. If hydrogen is used for heat in a region, then the existing natural gas network will be converted to hydrogen, the viability of which is already being explored with the government looking at legislating hydrogen blending up to 20% by winter of 2023 (ENA 2021).

The approach the government takes towards hydrogen blending will also be key, outlined in "Britain's Hydrogen Blending Plan" (ENA 2021), there is a "strategic approach" and a "free market" approach. The Free-Market approach will likely encourage small hydrogen producers as it will allow them to connect to gas distribution networks and sell excess hydrogen while large producers are still coming to market. The Strategic Approach will only allow hydrogen connections at key strategic points on the gas network, the purpose of which is to reduce the logistical burden of managing the blend, ensuring it doesn't exceed 20% hydrogen. If this approach is chosen, the ability for small producers to connect their hydrogen to local gas distribution lines will be severely restricted. This reduces the incentive for them to be developed as once the grid is ready to convert entirely to hydrogen allowing smaller producers to connect, large, centralised producers will have already had years to establish themselves limiting the opportunities available to these smaller sites. If this scenario manifests, the impact from hydrogen electrolysers on the electricity distribution network will be reduced, compared to the free-market approach.

If electrification is pursued instead there will still be industries with hard to abate processes with a need for hydrogen. Without a robust hydrogen grid network, they will need their own electrolysers or to establish small hydrogen microgrids in partnership with other nearby industries. These smaller electrolysers are almost certain to require distribution connections both for reliability of production if they have onsite renewables and because not all these smaller sites will be suitable for co-location of renewables and will need to rely on a decarbonising electricity grid to provide green energy. In this scenario most homes would be using heat pumps, commuters would be using EVs, and industries would be using electrified processes were possible, so combined with the additional need for small hydrogen electrolysers this is likely to be the worst-case scenario for NGEDs network in terms of increasing demand.

### 2.2.2 The near term view

In the near term the demand for hydrogen is expected to arise from transport and industrial applications, as a result a large proportion of the 10GW of hydrogen production targeted by 2030 is expected to be directed to these sectors – half of which is expected to be green hydrogen. As the sites for hydrogen demand for transport applications are far less certain than the sites of demand for industrial use, we have decided to focus on demand from industrial sites, where the demand is higher and more localised.

Prior to looking how the industrial demand for hydrogen within NGED's network area may materialise, it is worth looking at the scenarios for decarbonising industry in the UK. The Committee for Climate Change (CCC) commissioned Element Energy to look at potential pathways to decarbonising industry in the UK. The role for hydrogen is outlined in these scenarios as shown in Figure 1 and Figure 2 below (Element Energy 2020). Since the publication of this report in 2020, the UK government has published a Hydrogen Strategy and increased its ambitions for hydrogen in the Energy Security Strategy (BEIS 2022), with electrolytic (green) hydrogen production expected to account for half the amount of hydrogen targeted by 2030 for such use cases. There has been significant funding for industrial decarbonisations (£210 million 2019-2024) and several funds encompassing hydrogen, with £240M of Net Zero Hydrogen Fund dedicated to hydrogen production. These government incentives and the increased focus on hydrogen and its role in industrial decarbonisation, suggest a shift towards the Tailwinds scenario below, although many projects are still awaiting final investment decisions.

The main use cases for hydrogen in industry include the following: hydrogen boilers, combined heat & power, kilns, ovens, furnaces, dryers, and compressors, hydrogen for direct reduction (for iron and steel, as steel smelting using coke can be replaced with direct reduced iron using hydrogen). These processes are considered as hard to abate as electrification is typically considered unsuitable for the provision of high-grade heat, or the hydrogen required is for the chemistry of the processes. Also, in some cases the use of hydrogen can avoid major retrofitting needs, reducing the cost of fuel switching.

Given the lack of data on the planned industrial projects looking at fuel switching to hydrogen, both at the national and regional level, it has not been possible to calculate the demand for green hydrogen and the respective load on the grid these projects may yield by 2030 in NGED's network area.

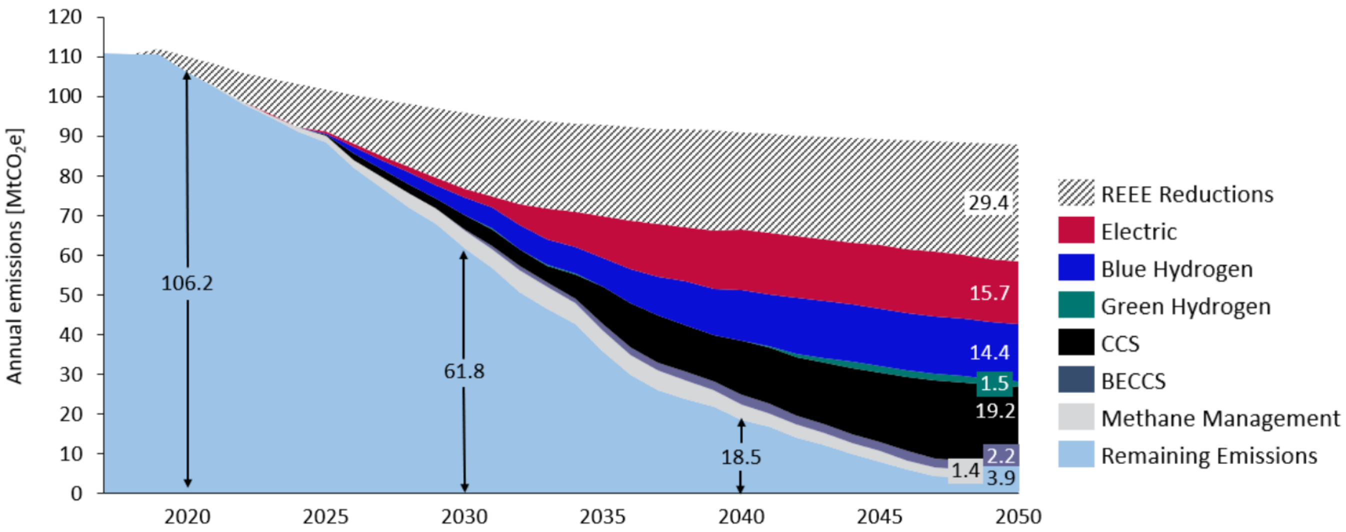



***Figure 1*** *Emissions abatement pathway for the* ***1) Balanced Net Zero Pathway (Element Energy 2020).***

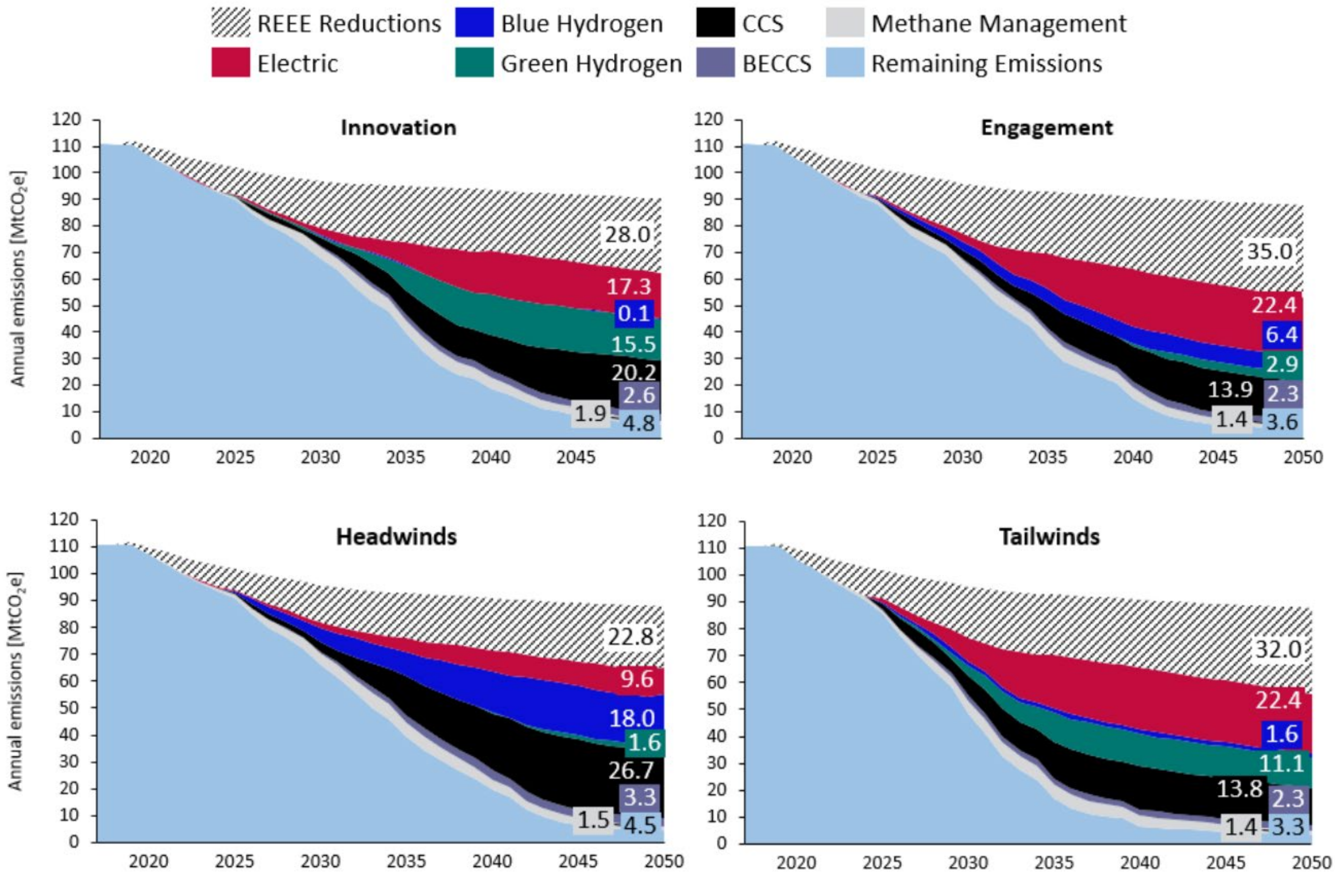



*Figure 2* *Emissions abatement pathway for the other four CCC scenarios.* ***2) Widespread Engagement (high efficiency and electrification), 3) Headwinds (high hydrogen), 4) Widespread Innovation**, **5) Tailwinds:** A scenario with a combination of accelerated deep decarbonisation drivers from each of the 3 broad scenarios defined above* ***(Element Energy 2020).***

These scenarios are outlined below, as taken from (Element Energy 2020):

*1)* ***Balanced Net Zero Pathway:*** *An 'options-open' pathway that undertakes low-regret measures and develops options sufficiently to progress towards net zero whatever state of the world occurs. The pathway includes a balanced mix of technologies in the long term, which enables decision-making to change track depending on developments in the short-to-medium term.*

*2)* ***Widespread Engagement (high efficiency and electrification):*** *People are willing to make more changes to their behaviour. This reduces the demand for the most high-carbon activities and increases the uptake of some climate mitigation measures.*

*3)* ***Headwinds (high hydrogen):*** *People change their behaviour and new technologies develop, but there are no widespread behavioural shifts or innovations that significantly reduce the cost of green technologies ahead of current projections. This scenario is more reliant on the use of large-scale hydrogen and CCS infrastructure.*

***4) Widespread Innovation:*** *This scenario sees high innovation in several carbon mitigation technologies and measures. Costs fall faster than central projections, allowing more widespread electrification and more cost-effective technologies to remove $CO_2$ from the atmosphere. Resource and energy efficiency measures play a balanced role across the economy.*

***5) Tailwinds:*** *A scenario with a combination of accelerated deep decarbonisation drivers from each of the 3 broad scenarios defined above.*

### 2.2.3 Projections for electrolyser growth in the area surrounding South Wales

For this study we have focussed on South Wales, for the reasons outlined in Section 3.1. As an indication of how this energy demand for hydrogen can grow in South Wales, it is worth comparing the scenarios above to the future energy scenarios for hydrogen demand from industry in the South Wales licence areas as produced by *Regen* in the *Net Zero South Wales 2050* (Maltby P., Arrell R., 2020).

This report aims to create integrated future energy scenarios for the gas and electricity networks in South Wales under three net zero scenario pathways: High Electrification, Core Hydrogen and High Hydrogen.

- High Electrification: Electrification is prioritised as solution for providing heat
- Core Electrification: Approximately 57% of existing south Wales gas network connections for commercial and residential converted to hydrogen by 2035
- High Hydrogen: Majority of gas network converted to hydrogen, slower transition than core due to more infrastructure to convert

It is suggested that South Wales could produce up to 1TWh of green hydrogen from distribution connected renewables by 2040 potentially increasing to 2TWh by 2050. This locally produced green hydrogen is shown to meet a small proportion of the projected local demand by 2050: 25% of the demand in the High Electrification scenario and just 14% of the demand in the High Hydrogen scenario. This suggests that not all the potential hydrogen demand across the different sectors will be met by hydrogen produced in the area and will need to be supplemented by imports. This report shows limited supply and demand in 2030 due to uncertainties at the time the report was written.

This report also shows the potential electricity demand from hydrogen production on the distribution network in the combined South Wales licence areas by 2030, to be around 1.8 TWh/year for the Core Hydrogen scenario and around 1.5 TWh/year for the High Hydrogen scenario. Note that Core Hydrogen requires less infrastructure retrofitting than High Hydrogen to facilitate a switchover hence higher demand by 2030 than High Hydrogen. By 2050 the demand of High Hydrogen exceeds Core Hydrogen significantly.

It is worth also noting the DFES NGED Best View scenarios, which shows that there is a correlation between the growth in hydrogen electrolysis capacity and the growth in electricity demand, as shown in Figure 3 and Figure 4. The data for the counties with industrial sites in the area surrounding South has been used to present the analysis in these figures, detailed in Attachment 1. This suggests that hydrogen is likely to be one of the key drivers of electricity demand growth in industrial sectors in the future. Pembrokeshire has been shown separately to illustrate the disproportionate growth in electricity demand and hydrogen electrolyser capacity compared to the rest of South Wales.

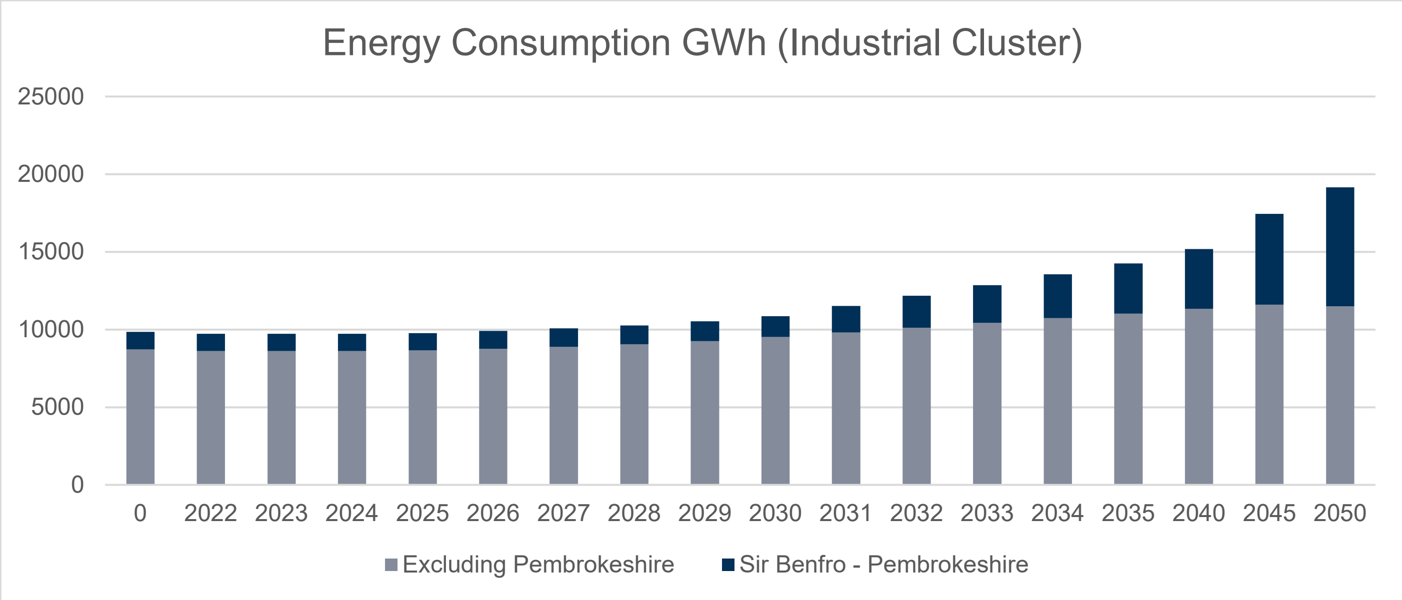



*Figure 3* ***Projected Energy Consumption in areas of study and surrounding counties, NGED Best View***

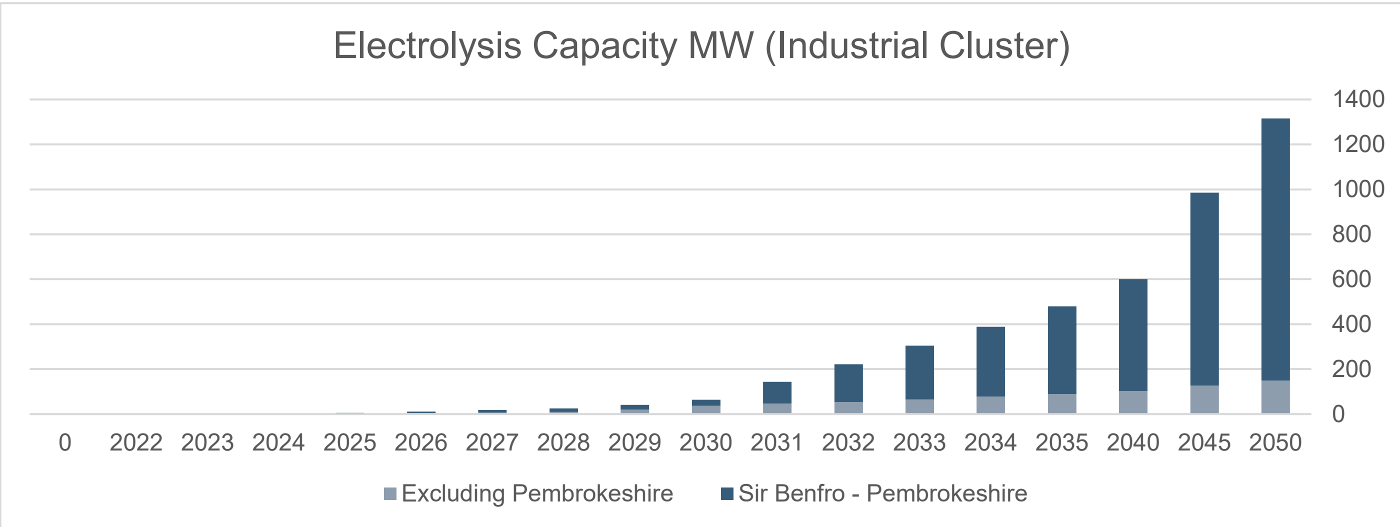



*Figure 4* ***Projected Electrolysis Capacity (MW) in areas of study and surrounding counties, NGED Best View***

It is evident from this data that the contribution of electrolyser demand growth is a significant part of the electricity demand growth in the area. It can also be concluded that the demand growth accelerates steadily from 2030 through to 2050. The factors influencing this profile with rather negligible growth until 2030 are the uncertainties surrounding the hydrogen utilisation reach, the industry structure, the evolving economics of renewable generation and storage and government policies. The projection is that by 2030 the industry would have matured and there will emerge more clarity on the utilisation pathways, economics of large-scale production, technologies and the market structure.

## 2.3 Electrolyser connections: grid vs off-grid

The size and location for industrial hydrogen demand in NGED's network will determine the demand for electricity from the grid. This is not a simple formulation. Firstly, the demand for hydrogen needs to be known, and then the mix of electricity supply from renewable energy sources (RES) versus the grid. The additionality criterion set out by the Hydrogen Business Model requires the electricity used for hydrogen production to be from new low carbon electricity generation, such that low carbon electricity is not diverted from other use cases, avoiding negative impacts on wider decarbonation" (BEIS, 2022) – this is further discussed in WP1). Under this additionality criterion, projects are assessed against preferred sources of energy as new purpose-built, curtailment of existing assets, extension of the life of existing assets and recommissioned assets. As a result, there are multiple factors at play in determining the grid connection requirements, which requires an understanding of the following:

- Whether the hydrogen produced needs to be on-site, which is currently the preferred option for many industrial users
- Whether the site has land availability to locate the required capacity of new renewables (co-location of RES with electrolysers)
- Whether the site has sufficient RES capacity to power the required supply for hydrogen
- Whether supplemental electricity from the grid is needed to meet the required demand for hydrogen even if the electrolysers are co-located with a RES

While many of those industrial sites looking to access government funding are also looking at generating hydrogen on-site, by co-locating the electrolysers with renewables, this is not possible for many industries looking to switch to hydrogen. In Work Package 1 we have outlined a set of factors that will constitute the considerations for siting the electrolytic hydrogen production projects, referred to as the 'Site Selection Criteria'. The additional factors that will be considered in the decision to connect to the electricity network, in addition to those above, are:

– The potential for hydrogen electrolysers to access electricity from new distributed renewable generation (developed independently of electrolytic hydrogen projects)
– Access to behind the meter renewables via PPAs
– Distance to potential substations
– The connection capacity available (network constraints) and the cost for connection (per MVA capacity)
– $CO_2$ intensity of the grid ($CO_2$e/kWh) – Low Carbon Hydrogen Standard (LCHS) mandates < 72 $CO_2$e/kWh LHV (<20g $CO_2$e/MJ LHV)
– Opportunity for Flexibility Services (Sustain/Dynamic/Secure/Restore)

It should be noted that additional requirements need to be satisfied for siting electrolytic hydrogen projects, beyond those factors above focussed on the electricity network, these are:

– The location of large-scale storage facilities, which are currently being explored for hydrogen storage.
– Proximity to fresh water, and possible desalination needs
– Proximity to wastewater disposal (e.g. sewer availability)
– Access to gas network infrastructure (for blending into existing gas network)
– Proximity to roads (for Trailer or pipeline distribution).

While in these early days new renewables are required for projects receiving government funds, there are key advantages of grid connection of electrolysers, which project developers are seeking, these include:

- The reliability of power supply enabling an uninterrupted process, which is important for ensuring security of supply as many industrial processes require continuous operation. Although this can be managed to a degree via hydrogen or battery electric storage, this creates an added cost and footprint to the project.
- Opportunity to benefit from grid services and the opportunity to participate in flexibility services for the grid.

Depending on how the $CO_2$ intensity of the grid changes over time the proportion of renewables versus grid electricity will most likely change in the plans for these projects. Not having sufficient clarity on this grid $CO_2$ intensity change over time will drive projects to prefer significantly higher proportions of renewables for power acquisition. This was discussed in more detail in WP1.

# 3. Network Assessment

## 3.1 Choice of Network Area for Study

To assess the impact of the electrolyser demand connection surge on the NGED network, a specific region within a NGED licence area was chosen. Given that the industrial transition to hydrogen is a most likely development in the near term, we looked at the potential for hydrogen demand for some industrial users in the South Wales area.

Given that we were not able to obtain data on the type and amount of fuel uses for the industries we have identified as high emitters, we looked at the $CO_2$eq emissions of the industries in the South Wales region. It should be noted that due to the diversity of processes and fuel uses within the same industries, it is difficult to determine the energy demand profile of individual sectors. For example, a steelworks that might be able to entirely electrify its processes may be located just a few kilometres away from a site practically unable to use electricity for any of its high emission processes. This means estimation of hydrogen demand for a given industry needs to be done on a case-by-case basis by looking at what processes are being used to identify decarbonisation pathways they may be investigating at a given site

The primary determining factors of the impact on NGED network are the likely locations and size of the electricity demand they represent. The other factor is the generation connection capacities on NGED network for connection of the new renewable generation. These are new renewable generation that are likely to be built to provide for the energy requirements of the electrolyser plant. The developers of these renewable energy projects would ideally like grid connection to have the option of exporting excess energy onto the grid to benefit from the revenue generation opportunities via the provision of grid services.

The electrolyser's electricity demand depends on the quantities of hydrogen required. With the development of a hydrogen gas network presently non-existent and the very low likelihood of it being developed by 2030, the hydrogen production needs to be geographically as close as possible to the site of use to minimise the cost of switching to hydrogen. With that in mind, to choose an area of the network to carry out this assessment, a search of the large industrial and process plants that use heat generated from fossil fuel was made. These are plausible off takers of hydrogen, reducing their $CO_2$ emissions by switching to hydrogen for their needs of thermal energy for their processes. To identify these industries, their respective $CO_2$ emission data and their geographical disposition across the country, the National Atmospheric Emissions Inventory database (NAEI 2022) was used.

As can be seen in Figure 5, the largest industrial hub within the NGED network is South Wales and was selected as the region of study. South Wales is the second most carbon emitting industrial hub in the country, accounting for approximately 15% of emissions for the six highlighted sites.

A significant number of industries in the region are considered as hard to abate as electrification of their processes is not easy to do, and hydrogen is considered as the more viable option for fuel switching for purposes outlined in the previous section.

Some industries in South Wales already have plans to decarbonise with hydrogen being one of the main options in the decarbonisation pathway (RWE 2022, Prior G. 2022). This is being spearheaded by the South Wales Industrial Cluster (SWIC 2022). This is one of the six industrial clusters with plans for large scale hydrogen production and potentially dedicated pipelines to service local industry. SWIC has 37 partners including NGED, and its industrial members account for most of the industrial $CO_2$ emissions in South Wales.

The industry members of this cluster were reviewed to help us identify industries potentially looking at switching from natural gas to hydrogen – based on the industrial processes whereby hydrogen is seen as the most viable option for decarbonisation. The industrial corridor from Pembroke Docks to Port Talbot in the East was specifically chosen for identification of the industries to focus on.

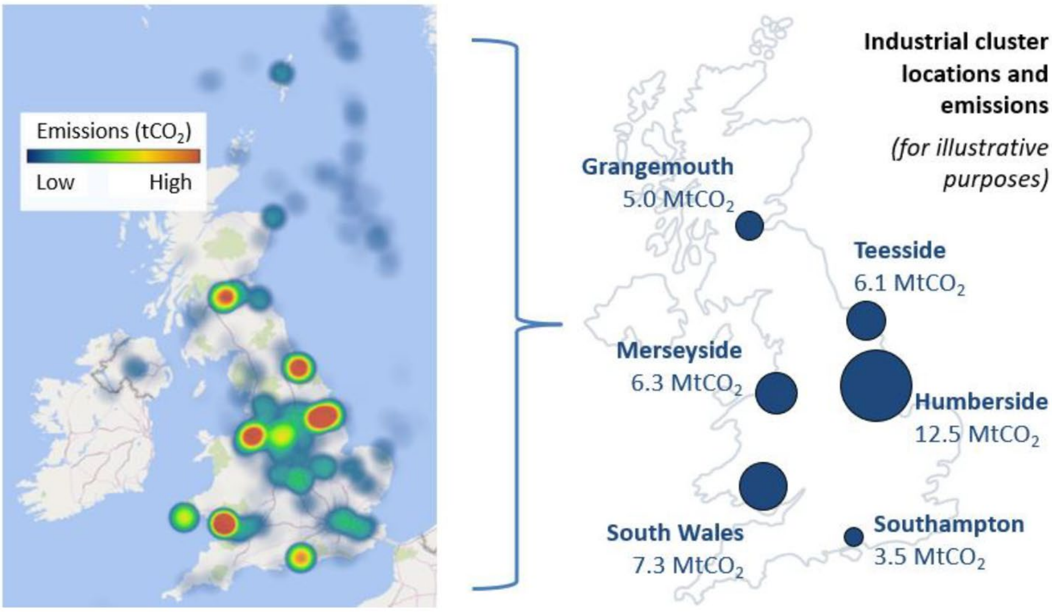



*Figure 5* *2018 Heat map of emissions from large industrial sites correlates with the UK's six major industrial Cluster locations (Element Energy 2020).*

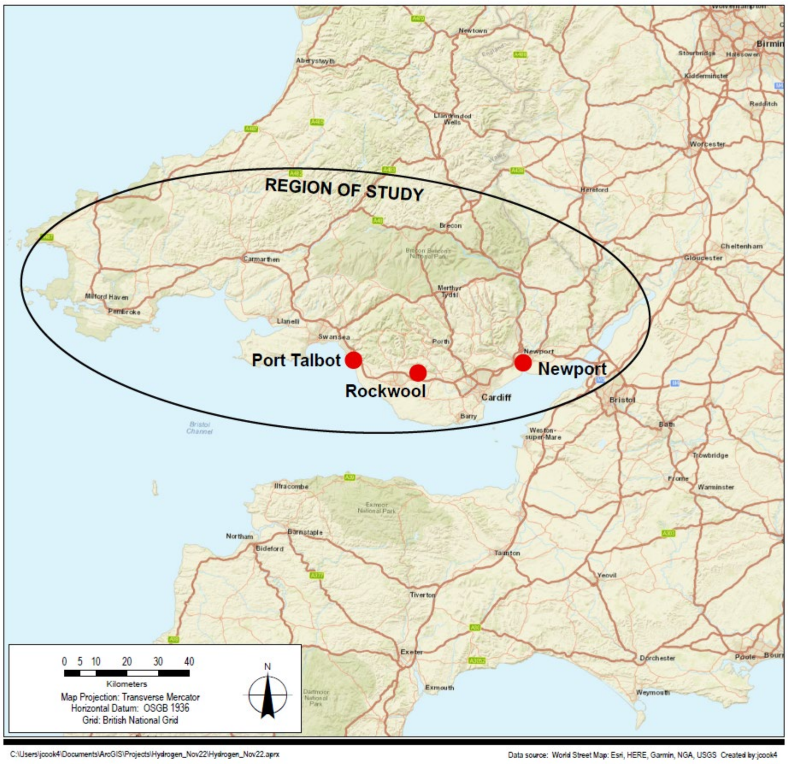



*Figure 6* *Depiction of area of study and key locations*

## 3.2 Hydrogen users in South Wales

### 3.2.1 Identifying potential hydrogen users

When investigating hydrogen users, we first looked at the highest emissions sources. Of the top five emitters of greenhouse gasses (recorded in $CO_2$eq), three are power stations, one is a steel works, and one is a refinery. We were able to conclude that these sites are unlikely to see a large shift to hydrogen in the short to medium term as they would need huge electrolysis sites and significant changes to their processes. Due to the carbon intensity requirements of green hydrogen if these sites do pursue green hydrogen to decarbonise, it will be alongside their own renewables to ensure they meet the government mandated carbon intensity requirements. If they were to draw on grid power as it decarbonises, the size of the electrolysis sites would require transmission connections, which many of these sites already have. These large emitter industries are already in the planning pipeline for a partial transition to hydrogen, RWE (2022), the owners of Pembroke Power Station, the second largest $CO_2$eq emitter, are planning a 100-300 MW electrolyser on site powered by dedicated offshore wind with views to expand to GW-scale operations in the future subject to the development of the UK 'hydrogen backbone' that has been outlined by National Grid for 2040.

For the reasons outlined above we instead decided to investigate a selection of smaller industries in the region which are more likely to connect to NGED network for the electrolyser plants. To assess the potential impact of smaller industries on grid demand we selected three sites with significantly varying processes to evaluate how their use of onsite hydrogen generation could impact NGEDs distribution network in the local area. These sites were Liberty Steel, Newport; Solutia, Newport; and Rockwool, Bridgend. Additionally, we identified specific processes at Port Talbot steelworks that could be decarbonised using hydrogen without retrofitting their main processes, which we included in our analysis. Small sites are starting to actively pursue hydrogen as a solution to decarbonisation with Rockwool UK currently researching a potential end-to-end hydrogen solution for its Bridgend plant (Prior 2022).

### 3.2.2 Estimating hydrogen demand from $CO_2$ emissions

We were unable to obtain specific information about current energy demands and what proportion of those energy demands are supplied by a given energy source for individual industries, adding significant complexity to the process of estimating hydrogen demand. As a result, we have estimated energy demands for a selection of distribution connected industries based on Welsh Government $CO_2$eq emissions data (Welsh-Government, 2020) and research of the processes involved at each location. There were a few consistent assumptions we were able to make, the key one being that processes involving fuels other than natural gas often had more complex abatement requirements or required more significant intervention to be converted to hydrogen, often requiring processes to be entirely changed. Processes using natural gas however often were related to the need for rapid controllable heat and could easily be converted to hydrogen, therefore we assumed that only natural gas processes would be converted to hydrogen by 2030. With that in mind, by identifying processes currently using natural gas and estimating the proportion of emissions produced, we were able to convert that proportion of emissions into an energy value as each kWh of a fuel burned produces the same quantity of emissions. The results of the analysis can be seen below with electrolyser ratings for a variety of capacity factors. The assumptions for each industry can be seen in Appendix A, the sheet with the calculations will be provided as additional files.

| Industry | Emissions CO2e (kg/y) | Estimated proportion abatable by green hydrogen by 2030 | Required Hydrogen (MWh/y) | Required Energy for Electrolysers (MWh/y) | Hydrogen Electrolyser Capacities | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Capacity Factor | Capacity required (MW) | Capacity Factor | Capacity required (MW) | Capacity Factor | Capacity required (MW) |
| **Solutia UK Limited Newport** | 42976000 | 20% | 46720.66 | 77867.77 | 95% | 9.36 | 75% | 11.85 | 50% | 17.78 |
| **Liberty Steel Newport** | 34473000 | 90% | 168645.43 | 281075.72 | 95% | 33.78 | 75% | 42.78 | 50% | 64.17 |
| **Tata Steel Port Talbot** | 6643839000 | 2.50% | 902842.72 | 1504737.86 | 95% | 180.81 | 75% | 229.03 | 50% | 343.55 |
| **Rockwool Bridgend** | 75075000 | 12.50% | 51010.35 | 85017.26 | 95% | 10.22 | 75% | 12.94 | 50% | 19.41 |

***Table 1 Estimated Hydrogen Demand and Electrolyser Capacity***

From this analysis we can see that large emitters such as Port Talbot Steelworks, even when only converting a small proportion of their processes to hydrogen, would require transmission connected electrolysers or large, co-located renewables such offshore wind to meet their conversion requirements. Given that this conversion to hydrogen requires large capital expenditure, these sites may be instead pursuing carbon capture and storage, from existing processes, which would be a cheaper option. Without clear knowledge on the decarbonisation pathway selected by a given, high emitting industry, it is not possible to determine the impact on the distribution network. In the case of switching to hydrogen, these high energy users (high emitters) are likely to require direct electrical transmission connections.

With the smaller sites, however, distribution connections would be reasonable to meet their potential demand. Grid connections are likely even with co-located renewables as it would provide industries with higher security of supply. Without a grid connection, sites would have to significantly overbuild renewables and accompany them with electricity storage. When co-located renewables are built NGED would also potentially see generation connection requests so during periods of excess generation industries can benefit from exports.

Although these values can be used by NGED to establish expectations, without direct consultations with industries over their plans for decarbonisation it is not possible to say at which industrial sites electrolysers will be deployed and how they will be powered. To take steel production as an example again, Port Talbot has 3 credible pathways to decarbonisation. They could pursue carbon capture, which seems to be their preference as it allows them to continue using their existing processes and they have a port to allow for carbon exports. They could also pursue direct reduced iron using hydrogen, likely turning them into one of the largest consumers of hydrogen in the country. Or finally, they could begin recycling scrap steel produced in the UK that is currently being exported, making their process rely entirely on electricity. However, alternative decarbonisation pathways like carbon capture and storage also have significant uncertainty as CCS clusters that involve storing the captured $CO_2$ are yet to be developed and commissioned.

## 3.3 Network characteristics

### 3.3.1 Demand and Generation Headroom

For the industries identified and analysed for the estimation of hydrogen demand to connect their electrolysers to the grid, there needs to be adequate headroom at local substations, otherwise additional costs and potentially delays could occur while necessary reinforcement work is completed. For these industrial sites, if the headroom on individual feeders supplying electricity to the site is insufficient this could be the larger cost as some sites are a significant distance from their primary substation, with Rockwool being roughly 3km away from Pencoed where it is connected.

The generation headroom is also a key factor in the businesses' decisions to transition to hydrogen. Colocation of a hydrogen electrolyser with renewable generation assures the benefits of using the green energy source for hydrogen production, most importantly the financial incentive and the compliance with the 'additionality' clause.

The sites mentioned in 3.2.1 were examined in detail in relation to NGED's network capacities in the vicinity of the industrial users. For this assessment a maximum distance of about 15km was considered from the site to the nearest substation of 11kV or above voltage level. The Network Capacity Map data from NGED has been used for this assessment.

### 3.3.2 Solutia UK and Liberty Steel – Newport

Table 2 below has the summary of demand headroom at the substations in the Newport cluster within the distance of 15km from these industrial sites, the closest of which can be seen on Figure 7. Solutia is connected to Newport South Primary substation. The estimated electrolyser capacity for 95% capacity factor is of the order of 10MVA. Newport South BSP has a demand headroom of 28MVA which can accommodate this demand quite adequately.

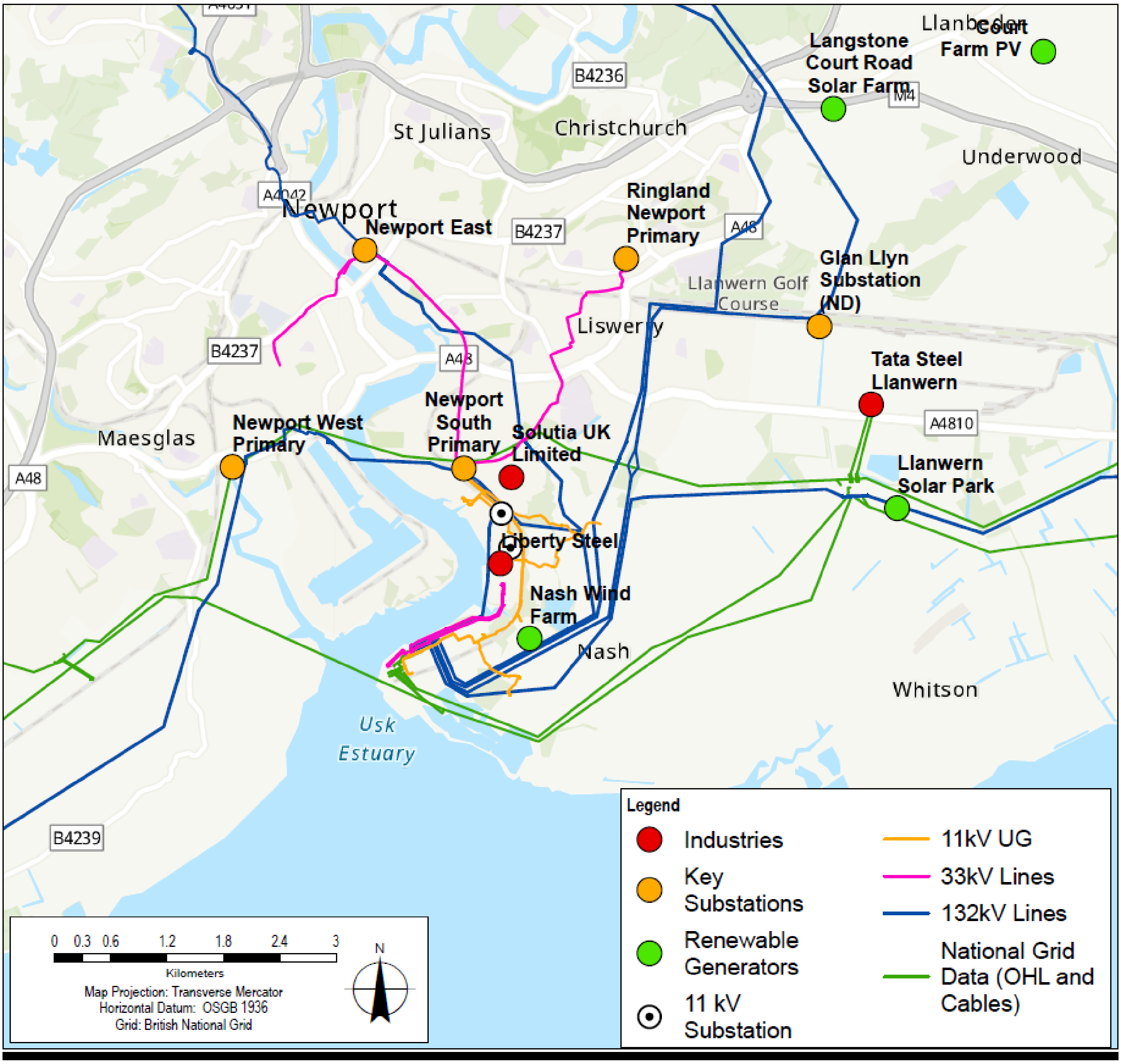
There is a generation headroom of 14MVA at Newport South Primary substation which will be useful if the business considers colocation option. It is worth noting that at times when the electrolyser is in operation, the net export to the grid from the co-located generator could potentially be zero as all the power generated will be consumed by the electrolyser. Solutia might not look to switch to green hydrogen in the short term as they currently produce their own grey hydrogen onsite. Green hydrogen is something they may potentially pursue to decarbonise their site (if CCUS is not an option) or if the site needs to be upgraded. Solutia currently have 5MW of wind generation on site, enough to power some but not all of their potential hydrogen needs. The presence of other wind farms in the area, such as the Nash Waste Water Works Turbine, suggests planning permission could be obtained for additional co-located renewables (BEIS 2022).

Liberty Steel, like Solutia, is in the same geographical area with an estimated electrolyser demand capacity requirement of about 35MVA. Liberty Steel also has on-site generation, in this case 9MW of biomass generation (BEIS 2022). This again could be used for on-site hydrogen generation with less reliance on the grid.
Both sites would still result in an increased demand on the grid as they would still need to power the facilities and processes previously powered by their on-site renewables. Although there is significant solar energy generation in the area, with a large solar farm totalling 75MW capacity, from the limited temporal data available (NGED 2022), it is not currently enough to reduce local grid carbon intensity below 72g/kWh to qualify for the financial incentives offered to green hydrogen. A second 75MW solar farm that submitted its planning application in March 2022 may be enough to change this allowing for green hydrogen from the grid during sunny days (BEIS 2022).

Additionally, these businesses will need battery storage to mitigate the impact of intermittency and lessen the degree of reliance on grid electricity during the periods of low wind or solar generation.

| Substation Name | Type | Downstream Voltage | Average Distance from Hydrogen Demand (KM) | Demand Headroom (MVA) | Generation Headroom (MVA) |
|---|---|---|---|---|---|
| Newport South | Primary | 11 | 1 | 6.73 | 19.11 |
| Newport South | BSP | 33 | 1 | 28.45 | -21.43 |
| Newport East | BSP | 11 | 3 | 0 | 14.16 |
| Newport West | BSP | 11 | 3 | 0 | 6.3 |
| Ringland Newport | Primary | 11 | 3 | 8.92 | 22.65 |
| Magor | Primary | 11 | 8 | 17.14 | 21.53 |
| Magor | BSP | 11 | 8 | 0 | 14.16 |
| Llantarnam | BSP | 66 | 8 | 8.78 | 1.38 |
| Llantarnam | Primary | 11 | 8 | 4.33 | 15.5 |
| Rogerstone | Primary | 11 | 9 | 18.89 | 35.98 |
| Cwmbran | BSP | 11 | 11 | 10.77 | 18.27 |
| Trowbridge | BSP | 11 | 11 | 16.31 | 22.78 |
| St Mellons | Primary | 11 | 11 | 10 | 7.09 |
| Panteg | BSP | 66 | 14 | 35.44 | -15.41 |
| Panteg | Primary | 11 | 14 | 3.95 | -3.85 |
| Caldicot | Primary | 11 | 15 | 7.2 | 4.99 |
| Sudbrook | Primary | 11 | 17 | 15.8 | 9.63 |
| Sudbrook | BSP | 33 | 17 | 16.47 | -1.75 |

*Table 2 Demand/Generation headroom Solutia and Liberty Steel*




C:\Users\jcook4\Documents\ArcGIS\Projects\Hydrogen_Nov22\Hydrogen_Nov22.aprx

Data source: World Topographic Map: Esri UK, Esri, HERE, Garmin, Foursquare, GeoTechnologies, Inc, METI/NASA, USGS Created by:jcook4

*Figure 7 Newport Industrial Cluster*

## 3.3.3 Rockwool

Rockwool connects directly to Pencoed Primary via three 300 EPR cables with one being for redundancy that can be seen on Figure 8. Pencoed substation has 12 MVA of headroom which is tight to meet the demand just over 10MW required for 95% capacity factor generated by switching all natural gas operations over to hydrogen. This assumes the results of their consultation deem that a grid connection is required for their hydrogen decarbonisation plans and a distribution connection is deemed most appropriate.

Rockwool could potentially connect directly to windfarms currently served by the Ogmore Vale substation approximately 7km north or sites approximately 3.5km northeast serviced by Upper Boat BSP (BEIS 2022). During periods of high wind these sites suffer curtailment due to voltage and/or thermal constraints on the line (NGED 2022). Such an arrangement could cut capex and benefit all parties by providing cheaper electricity and reducing constraints. For Rockwool this at best would be a supplemental source of energy. Despite this the opportunity is likely to grow as currently there is 72.5MW of wind around the Ogmore Vale site, with another 30 MW of planning requests submitted to the local council, which if they move forward without significant reinforcement improve the curtailed energy opportunities in the area.

| Substation Name | Type | Downstream Voltage | Average Distance from Hydrogen Demand (KM) | Demand Headroom (MVA) | Generation Headroom (MVA) |
|---|---|---|---|---|---|
| Pencoed | BSP | 11 | 3 | 12.07 | 18.56 |
| Bridgend Grid | BSP | 33 | 6 | 3 | -3.85 |
| Litchard | Primary | 11 | 6 | 6.99 | 13.7 |
| Mill St Tonyrefail | Primary | 11 | 6 | 15.3 | 11.06 |
| Waterton Industrial | BSP | 11 | 6 | 19.77 | 4.6 |
| Bridgend Trading Estate | Primary | 11 | 7 | 9.87 | 14.39 |
| Pontyclun | BSP | 11 | 7 | 17.26 | 12.04 |
| Llangewydd | Primary | 11 | 8 | 5.5 | 7.98 |
| Llynfi | Primary | 11 | 8 | 6.44 | 12.74 |
| Ogmore Vale | Primary | 11 | 8 | 8.95 | -0.54 |
| Talbot Green | BSP | 11 | 8 | 14.18 | -9.96 |
| Cowbridge | Primary | 11 | 10 | 5.58 | -0.91 |

***Table 3 Demand / Generation Headroom - Rockwool *Data absent from capacity database***

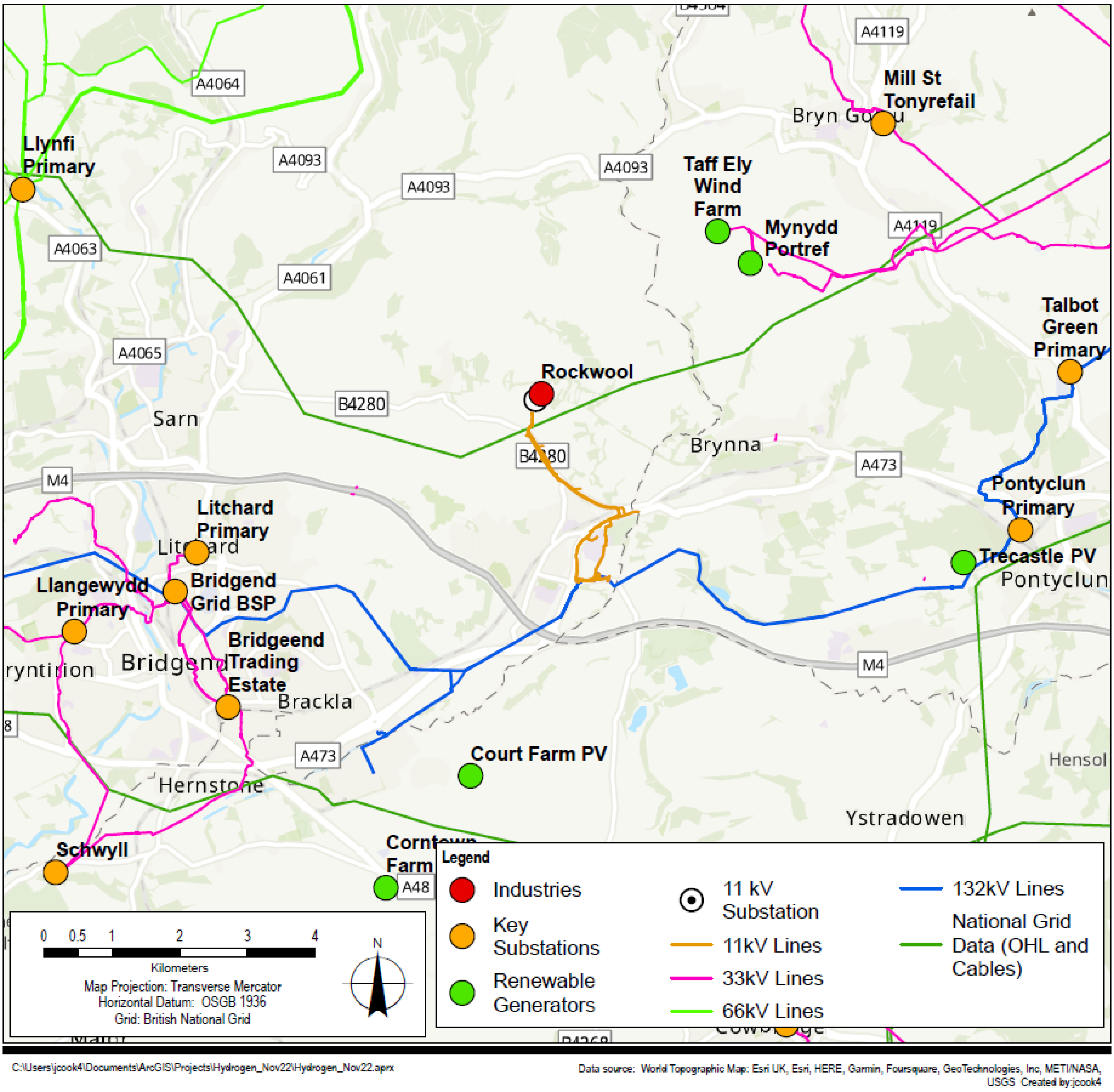



*Figure 8 Region around Rockwool Insulation*

## 3.3.4 Tata Steel

Port Talbot steelworks connects directly to Grange BSP. Capacity data for Grange was unavailable. However, given the size of the site and the network layout it would be more than viable for an electrolyser project to connect to either Pyle BSP to the south or Briton Ferry BSP to the North. Both substations without reinforcement would be able to provide upwards of 30MVA. This would only occur in a situation in which Tata Steel pursued hydrogen blending as a short-term method of reducing their emissions, otherwise the electrolyser site would be too large and require a transmission connection which as can be seen on Figure 9 is very close to the industrial site. The new Ferryside GSP planned for adding 240MVA of new capacity for reinforcement and de-loading Swansea North GSP (NGED, 2022) will potentially create additional capacity that could be tapped into for the requirements at Tata Steel.

Unfortunately, hydrogen produced from grid electricity in this area wouldn't be considered green due to the carbon intensity levels, which according to short term data (NGED 2022) are comparable to the regional average discussed in 3.3.9. This may change depending on the success of a proposal to develop a 150MW wind farm connecting to the Margam substation (Coriolis Energy, ESB, 2022).

| Substation Name | Type | Downstream Voltage | Distance from Hydrogen Demand (KM) | Demand Headroom (MVA) | Generation Headroom (MVA) |
|---|---|---|---|---|---|
| Grange* | | 11 | 0 | | |
| Victoria Road | Primary | 11 | 3 | 6.43 | 13.53 |
| Ynys Street | Primary | 11 | 3 | 5.44 | 8.76 |
| Briton Ferry | BSP | 33 | 7 | 35.23 | 18.08 |
| Briton Ferry | Primary | 11 | 7 | 1.92 | 5.56 |
| Pyle | BSP | 33 | 7 | 36.7 | -54.29 |
| Pyle | Primary | 11 | 7 | 10.04 | -33.83 |
| Wern | Primary | 11 | 8 | 14.8 | 22.83 |
| Jersey Marine | Primary | 11 | 9 | 9.97 | 3.52 |
| Llandarcy | Primary | 11 | 10 | 13.14 | 25.31 |
| Nottage | Primary | 11 | 10 | 12.65 | 11.07 |
| Commercial St Neath | Primary | 11 | 11 | 5.19 | 13.14 |
| Llynfi | Primary | 11 | 11 | 6.44 | 12.74 |
| Tir John | BSP | 33 | 11 | 28.31 | -6.57 |
| Tir John | Primary | 6.6 | 11 | 11.9 | 8.73 |
| Caerau | Primary | 11 | 12 | 13.74 | -0.67 |
| Swansea Waterfront | Primary | 11 | 12 | 29.85 | 39.28 |
| Gethin Street Swansea | Primary | 11 | 13 | 14.28 | 14.53 |
| Strand Swansea | Primary | 11 | 13 | 6.53 | 13.26 |
| Upper Bank | Primary | 11 | 13 | 1.85 | 11.16 |
| Llangewydd | Primary | 11 | 14 | 5.5 | 7.98 |
| Uplands Swansea | Primary | 11 | 14 | 7.87 | 13.02 |
| Bridgend Grid | BSP | 33 | 15 | 3 | -3.85 |
| Litchard | Primary | 11 | 15 | 6.99 | 13.7 |
| Morriston | BSP | 11 | 15 | 0 | 20 |
| Schwyll | Primary | 11 | 15 | 1.73 | 3.78 |
| Bridgend Trading Estate | Primary | 11 | 16 | 9.87 | 14.39 |
| Clase | Primary | 11 | 16 | 5.22 | 2.54 |
| Ogmore Vale | Primary | 11 | 16 | 8.95 | -0.54 |
| Ravenhill | Primary | 11 | 16 | 1.89 | 14.09 |
| Sketty Park | Primary | 11 | 16 | 3.08 | 7.97 |
| Swansea West Grid | BSP | 33 | 16 | 24.8 | 54.18 |
| Waterton Industrial | BSP | 11 | 18 | 19.77 | 4.6 |

***Table 4 Demand / Generation Headroom – Tata Steel *Data absent from capacity database***

*Table 4 Demand and Generation Headroom – Tata Steel *Data absent from capacity database*

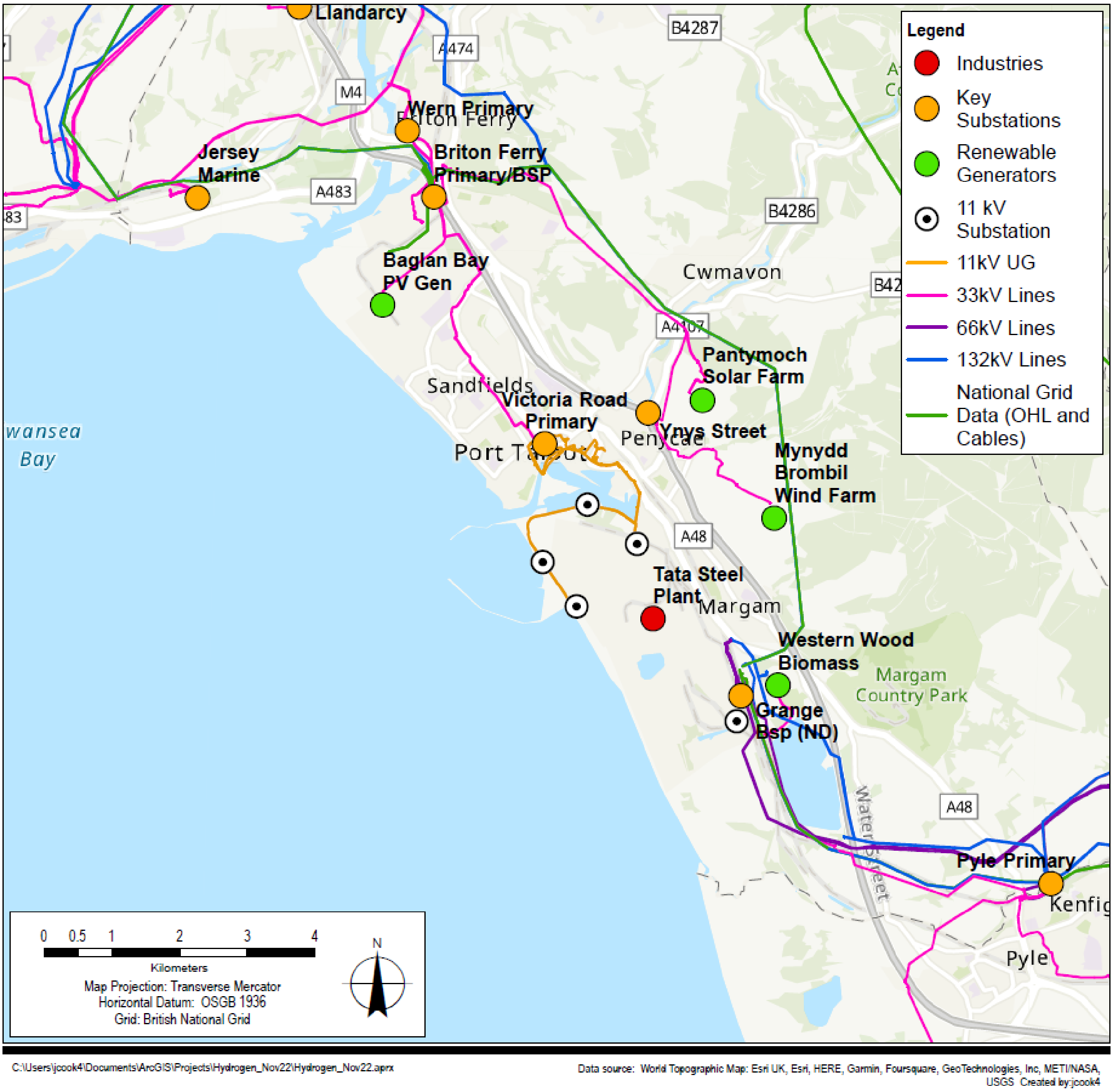



*Figure 9 Region around Port Talbot Steelworks*

### 3.3.5 Renewable generation

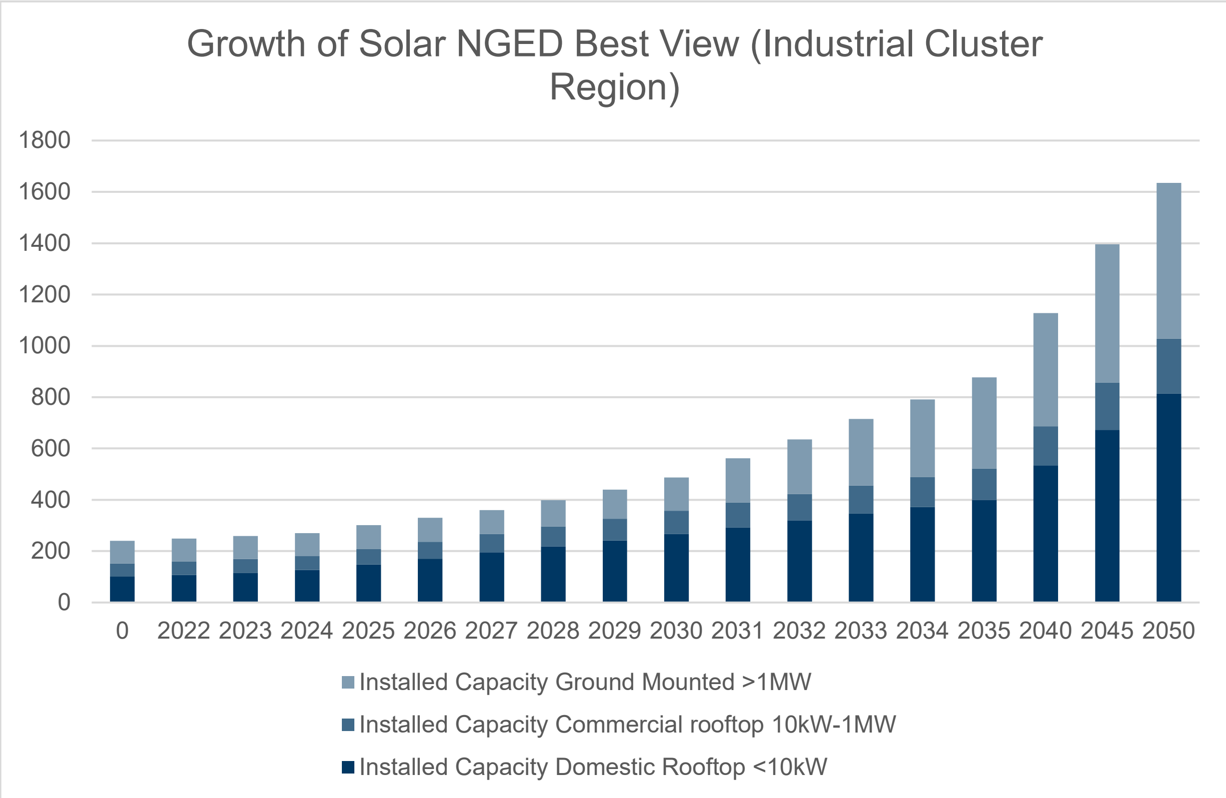



*Figure 10 Growth of Solar NGED Best View (Industrial Cluster Region)*

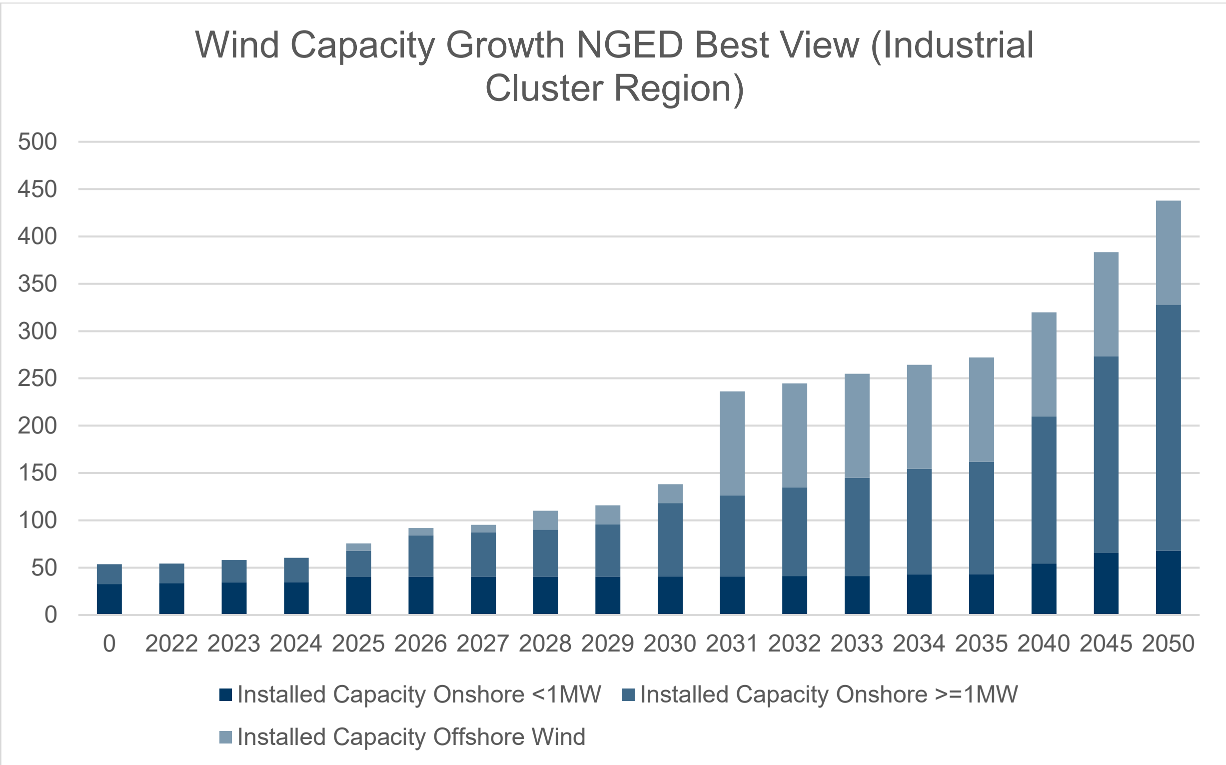



*Figure 11 Wind Capacity Growth NGED Best View (Industrial Cluster Region)*

The DFES projections for the on-shore/off-shore Wind and Solar are given in the figure 10 and 11. For the time horizon up to 2030 the increases in both wind and solar projects are not enough to meet the capacity needs anticipated for electrolytic hydrogen production. This trend may be changing with the new policy announcement on subsidies and increased targets for green hydrogen.

There is a relatively higher rate of projected growth for >1MW onshore wind for the period from 2030- 2050 again not high enough to align with the High Hydrogen Scenario. The growth projections for Solar in rooftop category is less than that of ground mounted. But there is clear capacity growth acceleration from 2030 to 2050.

It is worth highlighting that the “NGED Best View”, derived from regional FES data, models a lower capacity projection for the region than can be seen in other sources. This can be seen best on the BEIS (2022) database that shows multiple areas in South Wales with significantly more installed renewable capacity than that is represented in the base year of the Best View projection. These sites are in many cases not recent developments and have been in operation for many years and so it is not an issue with the dataset being outdated. This limits the projection’s use to assessing potential trends rather than estimating total installed capacity for any given year.

### 3.3.6 Co-location potential

Renewables project development is reasonably established in South Wales. Solutia UK site, for example, already has two wind turbines which are less than 1km from residential streets in Newport. This means the ability for industries to co-locate their own renewables onsite is high. Despite this for their hydrogen supplies to be reliable they would likely still need a grid connection to maintain a high-capacity factor for their electrolysis. Alternatively, industries could spend more and overbuild hydrogen and renewable capacity, allowing them to run their electrolysers with a lower capacity factor and still meet their hydrogen demand. This would depend highly on the availability of government funding and how the wholesale price of electricity changes moving forwards towards 2030 as both will have significant impacts on which pathway is most economically viable for industries. As can be seen on Table 2, Table 3 & Table 4 there is considerable generation headroom in the region that would allow sites to export any excess renewable generation.

However, it should be noted that, the South Wales Industrial Cluster programme coordinators have informed us that there are also many industrial users, such as those close to Cardiff, who do not have the potential to co-locate renewables on their site, or they are situated in areas with low RES potential.

### 3.3.7 Flexibility potential

Small, distributed hydrogen electrolysers provide huge potential for demand side grid management, but the full extent of the role they will be able to play in providing grid services will depend on the pathway forward taken by the Future System Operator, once it is in place. It has been discussed in a government consultation, the Review of Electricity Market Arrangements (REMA, results pending, 2022), that DNOs could begin assisting the Electricity System Operator in managing grid services. Assuming the market develops as such, electrolysers will be capable of ramping up and down production within certain limits relatively quickly and so would be able to offer frequency control and assist the balancing mechanism from the demand side. If this became part of electricity market the improvement of the ability of electrolysers to respond to market price signals and network management instructions would be incentivised further by developers. This would require communication infrastructure to be in place between NGEDs network control centres and a large array of smaller demand and supply side assets as well as hydrogen electrolysers. Such a deployment would put higher peak demand on some of NGED’s substations as these distributed sites would need to build excess capacity to account for running with a lower capacity factor.

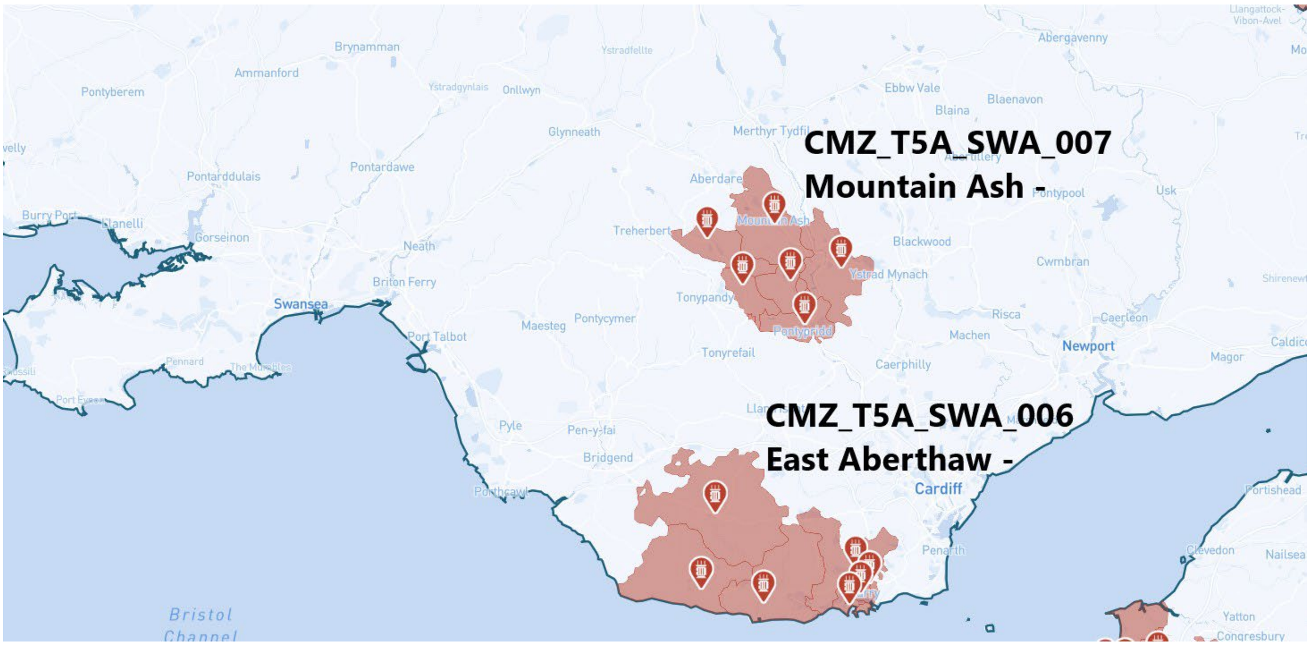



*Figure 12 Flexibility Map – Constraint Management Zones in the area*

Currently there are only two Constraint Management zones in the vicinity of the industrial sites assessed Shown in Figure 12.

Constraint Management Zone CMZ_T5A_SWA_0006 - East Aberthaw includes East Aberthaw Primary, Cowbridge, Boverton and Court Road Barry substations with availability for generation turn up and demand turn down services using Dynamic and Restore products. There is availability throughout the year and the potential maximum power is about 11MW around the evening peak demand period increasing to about 13.5MW in 2026 for the NGED Best View Scenario.

Constraint Management Zone CMZ_T5A_SWA_0007 Mountain Ash includes Mountain Ash, Middle Fan, Wattstown, Lady Windsor, Nelson and Gas Yard with availability for generation turn up and demand turn down services using Secure and Restore products. There is availability in the winter months and the potential maximum power is about 1.5MW in 2022 increasing to a maximum of 3.8MW in 2026 for the NGED Best View Scenario.

These potential volumes of Flexibility are not large enough to be an attractive proposition for high-capacity electrolysers, but given the size of Solutia's need they are quite attractive. If more renewable generation connects to serve the electrolysers then these zones will increase in both numbers and volumes and offer significant benefits.

### 3.3.8 Network reinforcement plans

NGED Network Development plan April 2022 for South Wales was reviewed to identify the reinforcement plans in the plans for the industrial clusters being examined.

The major constraint relief scheme that can facilitate electrolyser growth is the planned Ferryside GSP proposed to relieve the constraint at Swansea North GSP, which is the largest in the licence area. This work is likely to be in commission by 2025.

This scheme will add 240MVA and could offer more significant capacity to electrolysers, particularly for TATA steel should it want to expand its hydrogen production capacity in the long term.

### 3.3.9 Carbon Intensity

The carbon intensity standard for the qualification of incentives has been set to less than 72g $CO_2$/kWh for the source of energy used in the production of hydrogen. This is a very low figure for the UK Electricity system with the generation mix in operation currently. The duration of time when this standard has been met is a very small percentage nationally on the UK grid and regionally to a very large extent.

The historic half hour data for South Wales area from 17/09/22 to 20/10/22 was analysed to estimate the carbon intensity ranges and duration presented in Figure 11. It can be seen for the South Wales area the stipulated standard has been met only for 0.89% of the time.

This is a significant issue for electrolyser projects that will rely on grid connection for the supply reliability. Co-location with renewable generation option will require higher installed capacities than the electrolyser demand sizes due to low load factors of wind or solar generation. Battery storage systems will help to boost utilisation but at significant additional costs and are not equivalent to grid connection reliability and constancy as a source of supply of energy.

The future projections for generation mix show the grid electricity becoming greener over time with the government's Net Zero targets but the data on the carbon intensity trends for the short and medium term at least are important for the project developers in assessing the economic case for the new projects.

National Grid ESO's model that gives a forecast for a few days ahead and the DNO areas forecast available are also of the same time frame. Currently the future projections for the carbon intensity for medium and long term are not available. This data is critical in the assessment of the economic case for projects and therefore this is an area for consideration for development. Also, forecasts for more localised areas geographically would be greater value to the project developers.

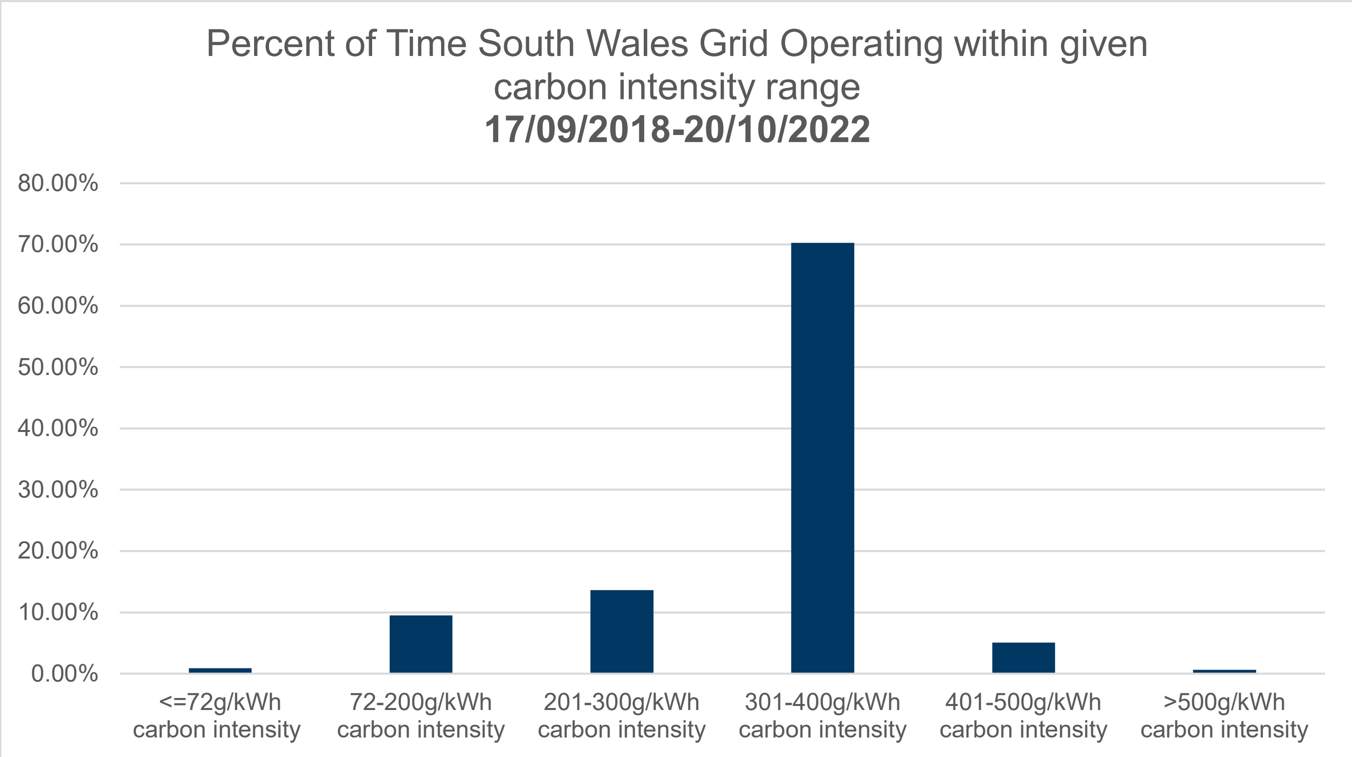



***Figure 13*** ***Carbon Intensity South Wales 17/09/2022 to 20/10/2022***

## 3.4 Government policy changes / implications

Government policy is in a time of transition for the energy market, the results of REMA (Review of Electricity Market Arrangements) could potentially have large impacts for both transmission and distribution networks in the UK. There is potential for a regional pricing structure so areas with large amounts of renewable generation would see lower wholesale prices. This would significantly alter the feasibility of grid connected hydrogen electrolysers in many areas including South Wales which is likely to see roughly a doubling of wind and solar capacity by 2030 as well as the deployment of the first large commercial wave energy sites in the region at Pembrokeshire. Moving past 2030 grid connected hydrogen electrolysers will become more and more common as renewables increasingly dominate with low-cost electricity.

# 4. Conclusions and recommendations

Following on from Work Package 1, this study aimed to look at the potential network impact of deployment of electrolysers, based on planned projects in NGED's licence area. Given that we were unable to identify specific projects with data in any of NGED's licence area, we decided to focus on industries with high emissions that were most likely to switch to hydrogen. South Wales was selected as our area of study, given that it is home to a cluster of industries, one of the six highest emitting regions in the UK.

To assess the impact of potential electrolyser connections on NGED's network, we selected four industrial sites, considered amongst the highest $CO_2$ emitters in the region. From these we eliminated the large energy users that will have a potential demand requiring connection to the Transmission System.

It is worth noting that although we had meetings with a number of developers looking to build electrolytic hydrogen projects, who were in fact looking to obtain connection to NGED's network, we were unable to obtain details on the location and size of connections needed. We have been informed that the stakeholders developing projects are very reluctant to give away any information on planned projects. Following these attempts, and due to time constraints, we did not seek any additional information from the industries identified to better understand their plans for decarbonisation and hydrogen production and/or use. Therefore, we made several assumptions based on limited input from CR Plus, desk-top research on processes of the selected industries to identify the fuel types and proportions that would be used in their processes. Without the data on the actual fuel use amounts, to identify the amount hydrogen that may be required in a potential fuel switch project, we estimated the proportion of $CO_2$ emissions attributed to natural gas usage from the industries we selected for the study (using $CO_2$ emissions data from European ETS). We then made further assumptions on the proportion of hydrogen produced via grid electricity as opposed to a renewables supply, to calculate the potential electricity demand (for electrolytic hydrogen production) from the selected industrial site. While the numbers are imprecise in our methodology, this method provides an indicative level of electricity demand arising from fuel switching to hydrogen at these sites in the near term, given the requirements mandated by the low carbon hydrogen standard and the hydrogen business model (i.e. the additionality criterion for electrolytic hydrogen production). With the required data from the respective industries, this methodology could be used to get more accurate estimates, especially if the grid $CO_2$ intensity was used to determine the proportional electricity allocation from the grid and renewables to ensure the hydrogen produced has a sufficiently low $CO_2$ intensity (20g $CO_2$e/MJ LHV or less), assuming grid electricity would be required in addition to renewables.

To determine the potential impact of these sites converting to green hydrogen on NGED's network, having calculated the potential electricity demand from a given site, we then looked at the capacity available in the substations less than 15km from the industrial site.

Based on this rudimentary assessment, we found that the adequacy of connection capacity is mixed for the sites assessed. For Solutia UK and Liberty Steel there is sufficient capacity availability in less than 15km radius from the sites. The estimated capacities required for 95% load factor are of the order of 10MW for Solutia and 34MW for Liberty Steel noting that if both were to connect, reinforcement would likely be required. However, for Rockwool the capacity adequacy is on the borderline but for larger demands for Tata Steel at Port Talbot the capacity required is much larger than the currently available headroom. This capacity is estimated to be 65MW for Rockwool and 180MW, for Port Talbot, the former exceeding the excess capacity on the Pencoed Substation to which it is connected by a factor of 5 and the latter reaching the order of Transmission scale of connection capacity. The new Ferryside GSP in the Network Development Plan could serve to meet the needs of Tata Steel's electrolyser demands.

It should be noted that these results are indicative, based on several assumptions, and a more accurate and complete assessment of the electricity demand from these sites would be needed, for both electrolytic hydrogen production and other use cases, to be able to assess the demand from these sites and hence the potential constraints these industries may experience.

Furthermore, this study only looked at industrial use of hydrogen and we assumed electrolytic (green) hydrogen was produced on site (or in close proximity) as opposed to hydrogen being acquired from elsewhere, which may include blue hydrogen produced from methane with carbon capture and storage. We did not include any green hydrogen demand arising from other use cases in the region analysed (the sites selected in South Wales), e.g. for transport applications, whereby hydrogen is likely to be deployed in the near term. Heat and Power generation applications of hydrogen were not considered given the uncertainty of hydrogen deployment in these sectors before 2030.

The hydrogen markets and industry structure is another factor that will influence the scale and the rate of uptake of hydrogen. A centralised approach with large hydrogen production centres exporting into nationwide transport using existing gas networks will lead to a different outcome than the smaller decentralised production of hydrogen to service the needs of the industries, space heating and transport locally. This structure will rely on the DNO network for the needs of the electrolysers. This will in turn lead to the need for more renewable generation connection in the DNO's networks because the project developers will be looking for availing government incentives for which the carbon intensity standard is a prerequisite that can only be met by a dedicated renewable energy generator or a grid connection point at which the carbon intensity levels are within the required threshold.

These requirements again will have implications for the DNO network. The required amount of renewable generation for an electrolytic hydrogen project will depend on $CO_2$ intensity of the grid and the projections for how it will change over time (on average), so that developers and plan can design projects accordingly.

Higher levels of distributed connection of electrolysers will invariably result in an increase in the number of 'active' network boundaries in which the electrolysers in combination with renewable generation and battery storage solutions will seek to offer grid balancing and Flexibility services. Currently there are only two constraint management zones in the network area considered in this study, but in such a scenario as above these numbers are likely be higher. This presents integration challenges and management responsibilities requiring policy initiatives and technical infrastructure.

The biggest challenge faced by NGED in highly industrial regions will be dealing with the diversity of industrial sites and their changing needs through their decarbonisation journeys. Unlike households, who can be assumed to follow similar decarbonisation pathways once established and therefore whose impact can easily be generalised industries will need to be consulted with on a case-by-case basis due to the variety of processes currently in use and the variety of potential alternatives available, even within a single industry sector. Moreover, many of the smaller sites that are more likely to directly impact NGED networks have limited information available publicly regarding their processes, energy use and decarbonisation plans. This limits the ability for accurate estimates to be made without the time-consuming process of consulting directly with each industry. Often even larger firms that own multiple sites perform different processes across their sites, and data on these processes are not publicly available.

These challenges are compounded by the uncertainty surrounding hydrogen more generally, specifically the development of a hydrogen gas network, and if it is to develop, the shape the market will take for supplying hydrogen to the grid during the interim years where it is a blended with natural gas. The impact of hydrogen on NGEDs grid currently has a very wide degree of uncertainty and that uncertainty will continue until the deployment, and method of deployment of hydrogen via the existing natural gas pipelines is confirmed, beyond the existing plans for hydrogen blending. Many industries are likely to delay their decisions on switching to hydrogen until there is more certainty around hydrogen's future. This will be the key factor in defining whether the hydrogen sector is dominated by a few large, centralised producers of hydrogen or many distributed producers and users.

Therefore, industry engagement is imperative for NGED to understand the stakeholders plans and challenges, and therefore the actions it needs to take to ensure that hydrogen plays the role it needs to for the UK to meet its carbon reduction targets. NGED can help facilitate the creation of a mechanism that enables industries and others looking to connect to NGED's network, to share data in an anonymised manner, so that such assessments and analyses can be done, on the potential impact of electricity demand increase arising from electrolytic hydrogen projects. This can be done for the South Wales region via SWIC, as NGED is already a member of this cluster consortium.

The data collected and updated should be used to formulate strategic options for network or policy initiatives that facilitates the development of electrolytic hydrogen projects going forward. Early engagement will also ensure decisions are made timely to overcome potential connection challenges, and for benefits of electrolyser connection to the grid to be captured for NGED.

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# Appendix A Industry Assumptions

**Assumptions for Industry Processes**

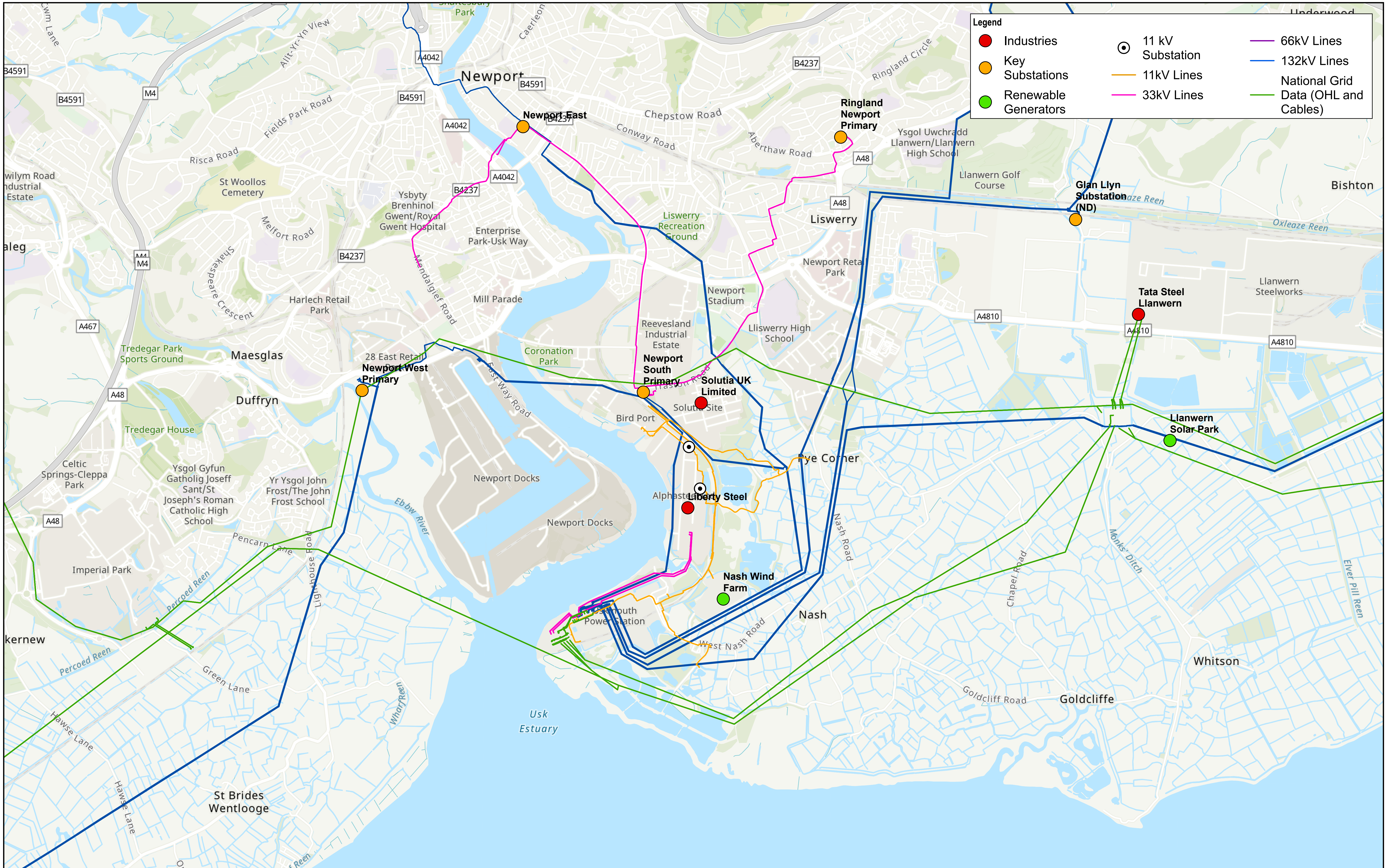
General assumptions that apply to all sites: We have assumed that processes involving natural gas will be the most easily switched to hydrogen. Processes using coal or coke require a greater level of intervention to convert to hydrogen, in some cases involving the employment of entirely different processes. Therefore, these processes, although explored, have not been considered for conversion to hydrogen by 2030 and therefore do not come into hydrogen demand figures.

Port Talbot Steelworks – alongside one other steelworks Port Talbot is the only location to use coke fired blast furnaces and coke ovens. Two sites using these processes account for 95% of the iron and steel industries emissions (BEIS, 2021). Therefore, the vast majority of emissions must be from these processes, otherwise the disparity between this site and other steelworks would not be so large. Producing coke from coal also generates a large quantity of waste gases which is used as a fuel for secondary processes reducing the demand for grid natural gas (Tata Steel, 2022). Therefore, we are assuming that a very small proportion of the plant's emissions are from grid sourced natural gas and could be easily substituted for hydrogen ~ 2.5%. The processes involving the coke ovens and blast furnaces could be replaced with direct iron reduction (DRI) that makes use of electric arc furnaces and hydrogen, but this is unlikely to occur by 2030. This is because the technology is unproven at large scale and would require a rework of almost the entire plant. It would likely be pursued when the existing infrastructure is up for refresh and DRI is a more mature technology, although there is also the possibility of converting to the processing of recycled steel cutting out hydrogen in favour of just needing arc furnaces. Tata Steel currently appears to be most interested in carbon capture as it will allow them to keep existing processes while cutting emissions (Tata Steel 2021).

Liberty Steel – Focuses on secondary processing. Primary energy demand is natural gas for reheating purposes to produce hot rolled steel. Therefore, we are assuming the vast majority of emissions will be caused by the reheating process using natural gas with a small number of emissions being from grid sourced electricity (Liberty Steel, 2021). This resulted in assumed values of 90% natural gas and 10% electricity for emissions sources. Liberty Steel are currently investigating direct reduced iron with hydrogen but not in the UK where they believe recycling is more viable. The only use of hydrogen being investigated in the UK is for reheating during secondary processing.

Rockwool – Uses natural gas to melt basalt (Prior G., 2022), likely the single largest step in terms of energy consumption. This is followed by a large, motorised spinner which creates rock fibres. Finally, the curing oven fired by natural gas (Rockwool N.D.) Therefore, we estimated approximately 80% of emissions would be from natural gas, with the remaining 20% being attributed to electricity.

Solutia - Highest level of uncertainty, although some of their processes use hydrogen produced from natural gas as a feedstock and some processes will need high temperatures provided by gas. It is difficult to evaluate from the outside what the proportions are. 20% value is speculative




Data Disclaimer
Includes National Grid Data October 2022
and
Western Power Distribution Data November 2020

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Grid: British National Grid

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National Grid Electricity Distribution
Heracles - Hydrogen Electrolyser Study

**Industries being studies in Newport Cluster, surrounding substations and renewable generation**

Project No. 12575613
Revision No. -
Date 03/11/2022

**Appendix B**

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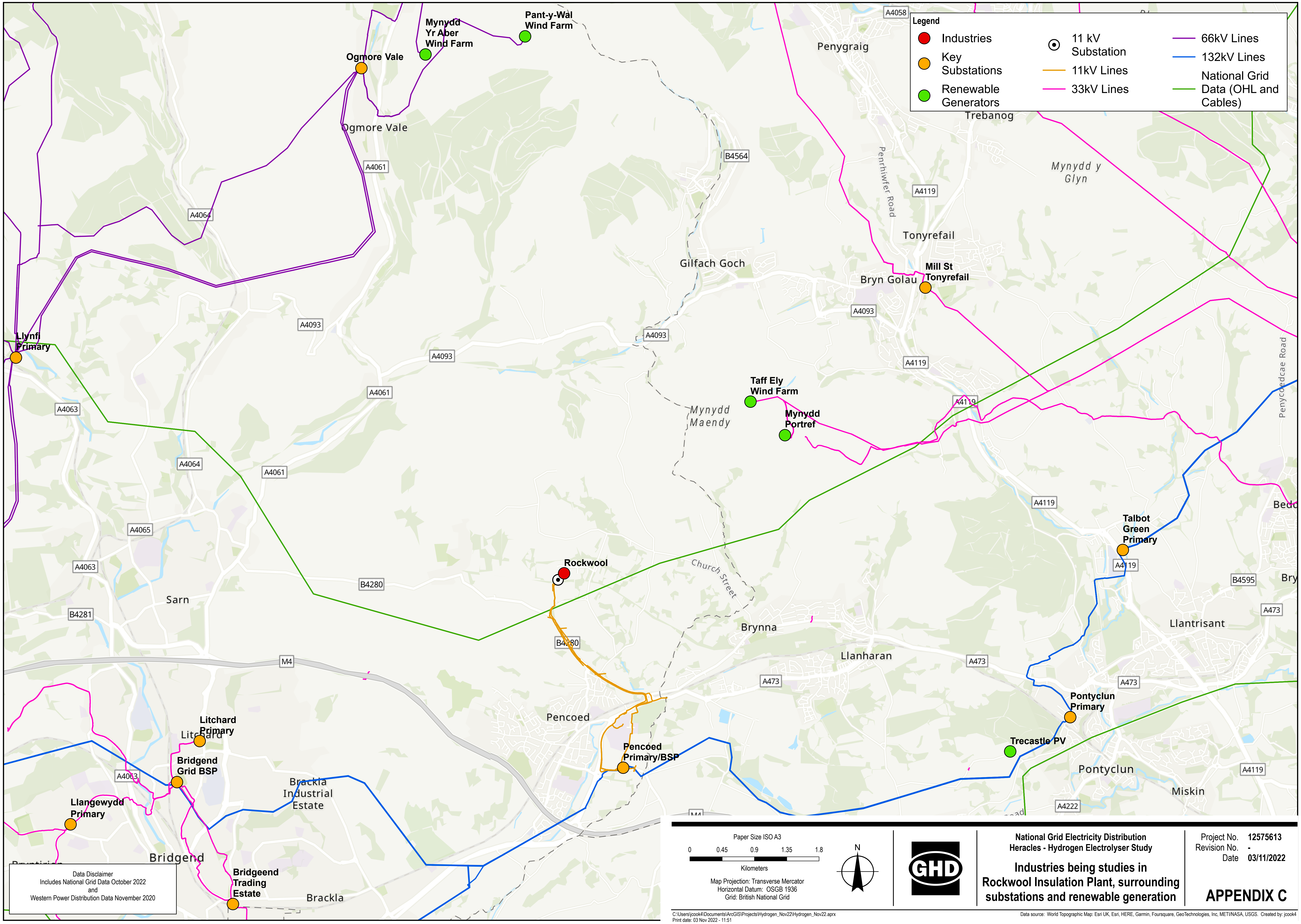


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**National Grid Electricity Distribution**
**Heracles - Hydrogen Electrolyser Study**

**Industries being studies in Rockwool Insulation Plant, surrounding substations and renewable generation**

Project No. **12575613**
Revision No. **-**
Date **03/11/2022**

# APPENDIX C

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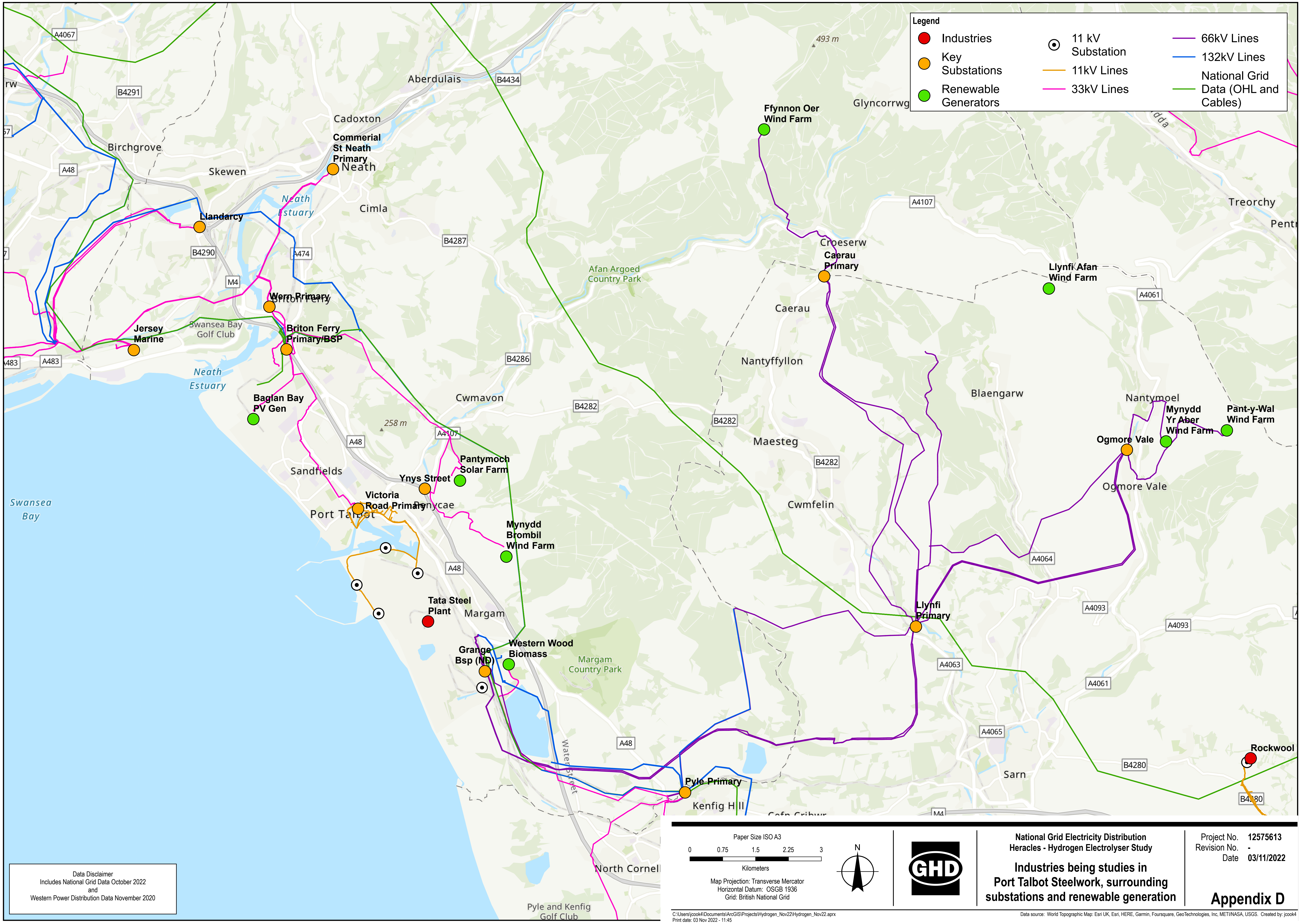


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National Grid Electricity Distribution
Heracles - Hydrogen Electrolyser Study

**Industries being studies in Port Talbot Steelwork, surrounding substations and renewable generation**

Project No. 12575613
Revision No. -
Date 03/11/2022

**Appendix D**

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# Attachment 1
## South Wales Electrolyser Study Dataset.xlsx

1.1: Electrolyser Capacity Demand Summaries

1.2 Compiled Substation Information

1.3 Hydrogen Demand Calculations

1.4 NGED Best View Wind projections

1.5 NGED Best View Solar projections

1.6 NGED Best View Marine projections

1.7 Demand Changes

1.8 Renewable Sites BEIS

1.9 South Wales Carbon Intensity

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