NET ZERO NORTHWEST INVESTMENT CASE

Net Zero North West

FINAL REPORT

MARCH 2023

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FOREWARD

The NZNW Cluster Plan Launch Event held in Manchester in January 2023 was an important milestone in our pivotal journey to Net Zero. Over the past 18 months, we have made huge progress in the North West and now for the first time, we have a credible and deliverable route to decarbonise industry. At a national level, the Energy Security Bill was introduced to parliament, the consultation was launched on hydrogen business models and Chris Skidmore MP's Net Zero Review was published.

Significant Progress in the North West

Here in the North West momentum has continued to grow around HyNet with six new projects receiving the go-ahead from Government. Peel NRE revealed their vision for a local CO2 network at Protos in Cheshire, which is also host to a new green hydrogen project being developed by Progressive Energy. Whitby in Ellesmere Port was shortlisted as one of two locations for the UK's first Hydrogen Village, subject to consultation, with a decision expected later this year.

Collaboration is Key

Through collaborative work, the NWNZ Cluster Plan provides a road map towards industrial decarbonisation by 2040. This will involve a suite of different technologies including: hydrogen, CCS, tidal, wind, solar, low carbon dispatchable power with CCS and small modular nuclear. Taking the Cluster Plan forward requires strong collaboration between the private and public sectors. Our public sector leaders are united, and industry stands committed and ready to deliver. The Cluster Plan brought industry together behind a shared purpose and clear vision, establishing a strong framework for delivery.

Joined-Up and Coordinated Approach

NZNW are also working with LEPs and Combined Authorities to identify how we might have common approaches to planning and transportation issues for industrial decarbonisation. A joined-up approach across the North West and North Wales will be critical to co-ordinate activities around the skills pipeline and planning and delivery of major projects. Decarbonisation of industry in the North West will also have significant implications for the power grid both at the transmission level and distribution network level, which will require collaborative planning across the whole system. However, the North West is united in rising to the challenge and delivering the bold vision to be the world's first Net Zero industrial cluster by 2040.

Acknowledgement and Thanks

On behalf of NZNW, thank you to all the partners that have been involved in pulling this Cluster Plan together. A huge amount of work has gone into developing something that no other region yet has, a blueprint to reach Net Zero. Thank you to UKRI for their continued support and co-funding for the Cluster Plan. The opportunity in the North West is huge and we have reached a pivotal moment in realising our Net Zero ambitions. The North West was the cradle of the industrial revolution. But that explosion of innovation, investment and skills development did not happen by chance. It was through the adoption of a truly collaborative approach to industrial development. We now look forward to working closely with local authorities and others on planning and transport issues to position the North West as the most investor-friendly region for decarbonisation. In doing so, the North West will truly be the cradle of a new green industrial revolution.

Ged Barlow
Chief Executive, Net Zero North West

Carl Ennis
CEO Siemens GB&I
Chair, Net Zero North West

EXECUTIVE SUMMARY

Net Zero North West (NZNW) is a consortium of leading organisations from industry supported by local and regional government across the North West who have come together with the aim of developing the first low carbon industrial cluster by 2030 and the first Net Zero industrial cluster by 2040. This Draft Outline Business Case has been commissioned by the NZNW Consortium to develop the strategy for investment in decarbonisation and to get the North West industrial cluster to Net Zero by 2040 as part of the industrial clusters mission. The report also aligns as closely as possible to the North West Economic Investment Prospectus produced earlier by Siemens, and the interim findings of the North West Cluster Plan Interim Findings Report undertaken by Uniper, Equans, Progressive Energy, and Cadent, April 2022.

Strategic Case

National & Regional Context

The UK government's *'Ten Point Plan for A Green Industrial Revolution* (2020)*'*, together with the *Industrial Decarbonisation Strategy* (2021), '*Net Zero Strategy* (2021)*'* and the *British Energy Security Strategy* (2022) sets out the strategic objectives and priorities, demanded by the Climate Change Act to reach Net Zero by 2050. Through a range of initiatives, including the UKRI's Industrial Decarbonisation Challenge (IDC), the UK government is promoting some £100 billion of private sector investment by 2030 into new industries, including offshore wind and supporting around 480,000 clean jobs by the end of the decade. The UK has committed over £12 billion to domestic green investment since March 2020. Through policies and spending brought forward by the Net Zero strategy, the UK government has stated its intention to mobilise over £26 billion of capital investment to support the green industrial revolution.[1]

The North West region is one of the most significant manufacturing and chemical production centres in the UK, with Tata Chemicals, Unilever, Vauxhall, and Bentley each having manufacturing or distribution facilities across 18 major industrial parks in the region. Approximately 40 million tonnes of CO_2 are emitted annually in the North West with North West businesses produce over one-third of regional carbon emissions, amounting to 15 million tonnes per annum. Of this, 9 million tonnes of CO_2 are associated with industrial processes. Together, the largest industries in the North West emits over 6 million tonnes of annual carbon emissions. This concentration of industries in North West represents an opportunity to deploy a holistic region-wide approach to industrial decarbonisation at scale. The North West region has three crucial regional comparative advantages over most other regions of the UK, notably:

- Expected highly cost-effective production of industrial CCUS enabled hydrogen because of the North West's natural geology
- World class nuclear industry in Cumbria, centred around Sellafield, which could be expanded and used to produce cheaper industrial electrolytic hydrogen, SMRs could support this.
- Offshore wind which could also offer an affordable renewable electrolytic hydrogen production.

These regional advantages, or opportunities, form the basis for the selection criteria when analysing and prioritising projects from the project pipeline.

Alongside these three key features, however, there is also a breadth of exciting and new energy sources that the sector can tap into, from Tidal, Geothermal and deep mine heat harvesting through to

[1] Net Zero Strategy: Build Back Greener, HM Government, October 2021

Waste to Energy opportunities, ammonia production and Bio Energy and Carbon Capture technologies (BECCS).

With HyNet North West in motion and a strong low carbon ecosystem comprising of major universities, business, and government, North West England is poised to lead and become the first Net Zero industrial cluster by 2040. To realise this ambition, the *Net Zero North West Cluster Plan* (2023) sets the vision for industrial decarbonisation in North West England, outlining the investments, technologies, and ancillary infrastructure required to achieve its strategic objectives:

- Becoming a low carbon industrial cluster by 2030, and becoming (or positioning to be) the world's first Net Zero industrial cluster by 2040
- Maximising the economic opportunity regionally of decarbonisation, including: establishing domestic supply chains in newer green technologies with a highly diversified offer of energy vectors, and harnessing regional strengths and comparative advantages
- Energy security and reducing dependency on foreign energy supplies, particularly of hydrocarbons (including natural gas)
- These strategic objectives form the basis for the selection criteria when analysing and prioritising projects from the project pipeline.

Understanding the Pipeline

To make the case for investment, there needs to be a systematic review of investable projects across the North West. As such, a stocktaking exercise was undertaken through desktop research to build a long list of projects comprising of approximately 150 projects. This long list was then filtered down to some 60 projects using a robust set of criteria including project maturity, strategic fit, and linkages to the wider ecosystem which would enable a "waterfall" approach to Net Zero by 2040.

Table 1: Classification for Refining Long List of Projects

Classification One: Linkage to Ecosystem	Classification Two: Project Maturity
A System-Based Solution	Secured
A Linked Strategy	Prospect
A Stand- Alone, Distinct Solution	Lead
	Unidentified

The prioritised projects were then categorised in line with the waterfall diagram categories as follows:

- Scope 1 energy efficiency
- Electricity energy efficiency
- Zero carbon electrification
- Power sector decarbonisation
- Industrial CCUS-enabled H2
- Industrial electrolytic H2
- Industrial CCUS fossil fuel
- Bio-energy Carbon Capture and Storage (BECCS)

Applying shortlisted pipeline projects to each of these specific waterfall sectors in the "full intervention" option identifies £29,645bn of projects and programmes that contribute to the ultimate Net Zero goal in 2040. This short list of pipeline options was then ultimately refined to the "preferred option" which will be discussed in detail in the Economic Case. To select the preferred option, further analysis was undertaken against six options. This short list of projects was then ultimately refined to six "preferred options."

'Six Preferred Options'
Option 1: Do nothing
Option 2: De minimis decarbonisation pathway
Option 3: Maximised industrial CCUS-enabled & nuclear electrolytic H2 Net Zero pathway
Option 4: Mixed Net Zero pathway
Option 5: Maximised industrial CCUS-enabled H2 Net Zero pathway
Option 6: Maximised industrial electrolytic H2 Net Zero pathway

Economic Case

There are many possible pathways to decarbonisation, which are differentiated by their differing mix of decarbonisation projects being put in place between now and 2040. Using the SMART objectives, the Economic Case is about identifying the preferred pathway or the "preferred option" to reach industrial decarbonisation in North West England by 2040, but also delivers the best value for public money.

Of the six preferred options, three options achieved a benefit cost ratio (BCR)[2] of around 1.9, which is considered acceptable. The Economic Case assessment identifies two joint preferred options: a 'maximised industrial CCUS-enabled & nuclear electrolytic H2 Net Zero pathway' (Option 3) and a 'mixed Net Zero pathway' (Option 4).

Therefore, Option 4 – 'Mixed Net Zero Pathway' is taken forward as the preferred option at this point because it provides the solution most likely to meet all three of the Critical Success Factors (CSFs). It has a good diversity of energy vectors, is affordable - with potential VFM, 'hedges bets' across different future technologies to reduce risk, utilises and grows domestic supply chains in a way that has plausible delivery aspects, and draws on regional strengths.

Table 2: Option 4: Mixed Net Zero Pathway Rationale

Option 4: "Mixed Net Zero Pathway"	
Strategic Fit & Meets the Need	Provides a good diversity of energy vectors likely to maximise economic opportunity. Harnesses regional comparative advantages.
Potential Value for Money	Potentially good VFM but does not maximise scale economies.
Supplier Capacity & Capacity	Deliverable on basis of current governance arrangements but somewhat dependent on foreign suppliers, some risk around new technologies (SMRs).

Furthermore, Option 4 'mixed Net Zero pathway' option is estimated to create UK GVA demand of £36.5 billion and jobs demand of 22,500 FTE on average during the CAPEX phase (representing nearly 300,000 'job years') and nearly 12,000 FTE during the operational phase. Note these job figures are for maintenance and repairs of the asset and excludes operative jobs.

Economic (as opposed to financial) lifetime costs of building the projects and maintaining them over a 30 year lifetime, versus 'do nothing' are estimated at £11.5 billion for Option 2 'de-minimis'; £55.0bn for Option 3 'maximised industrial CCUS-enabled & nuclear electrolytic H2' and £58.5 billion for Option 4 'mixed Net Zero pathway'.

[2] Three shortlisted intervention options, including these and the de-minimis decarbonisation pathway, all achieve a benefit cost ratio (BCR) of around 1.9. This similarity is partly because the estimated costs are not sufficiently certain at this stage to distinguish between the three. This is useful, however, because it demonstrates that scale economies can be harnessed in the full net zero options to bolster their value for money to match and possibly better the de-minimis option. For simplicity, and illustratively, these BCRs assume 100% public subsidy. This is therefore a 'lower bound' estimate for the BCR in the sense that the subsidy clearly would not be 100%. On the other hand, the costs used exclude necessary power grid infrastructure upgrades likely to be very significant. A BCR between 1 to 2 is generally considered acceptable, 2 or more good.

To reach industrial Net Zero requires a 16.7MtCO2 reduction in industrial emissions from the current levels. 'Do nothing' achieves 5.1MtCO2 of this, Option 2 'de-minimis' achieves 8.4MtCO2 (around half); and Option 3 and Option 4 mixed Net Zero options achieve 16.7MtCO2 and 17.1MtCO2. respectively. The monetised economic benefit captures the economic value of carbon reductions (i.e., averted climate change) only, though there are other economic benefits not quantified by the analysis.

Table 3: Comparison of the Options

		Option 2 – De minimis decarbonisation pathway	Option 3 - Maximised industrial CCUS-enabled & nuclear electrolytic H2 Net Zero pathway	Option 4 – Mixed Net Zero pathway
Economics (in £ billions)	CAPEX	£6.7	£32.4	£34.0
	OPEX / 30 years	£4.7	£22.6	£24.5
	TOTAL	£11.5	£55.0	£58.5
Financial (in £ billions)	CAPEX	£5.0	£2.6	£29.6
	OPEX / 30 years	£5.9	£33.1	£35.8
	TOTAL	£10.9	£35.8	£65.5
Additional CO2 reductions Including do nothing MtCO2 p.a., all (Industrial only)		23.5 (8.4)	45.0 (16.7)	46.5 (17.1)
Additional CO2 reductions, over and above do nothing, MtCO2 p.a., all (Industrial only)		5.5 (3.3)	27.0 (11.6)	28.5 (12.0)
In £ Billion	Cost (CAPEX & OPEX)	£11.5	£55.0	£58.5
	Benefit (GHG reduction)	£33.7	£157.6	£167.0
	Net benefit	£22.2	£102.6	£108.5
	Initial Benefit Cost Ratio (BCR)	1.9	1.9	1.9

Financial Case

The Financial Case serves the purpose of demonstrating the affordability and funding required of a preferred option for a scheme. Whilst there are limitations in appraising such a wide range of projects managed by separate organisations as a collective it does provide us with useful insights. This exercise seeks to gain an understanding of the scale of the solution, how much CAPEX is required to achieve Net Zero, where is it best spent to gain value for money, and the value added to the region.

On an aggregate level, the pipeline identifies some £29.645bn of investable projects will fully abate an estimated 46.47MT of carbon by 2040.

Total CAPEX	Total CO2 Abatement (all)	Total CO2 Reductions (industrial)
£29,645m	46.47Mt	17.1Mt

Two main routes to investment have been identified**:** public sector and private sector. The symbiotic relationship between *pump prime state intervention*[3] in projects and programmes to generate viability; and private sector on or off balance sheet investment has been considered when looking at both investment routes including the blended route. This Financial Case highlights that government support will be required to drive the update of Hydrogen and other Net Zero technologies as the market will not drive this organically. The field is still in its infancy, but the ambitious targets are forcing government to provide early certainty on the future direction of government support.

Likewise, there are two main funding mechanisms: regulated market and free market approaches. Under a Regulated Asset Base model, a regulator grants a licence to an entity, which gives it the right to collect revenues to achieve an agreed regulated return on the assets which it delivers and operates. Free market approaches rely on the creation of a competitive market that drives investment in new assets. This includes Renewable Obligation Certificates (ROC) which are issued to operators of accredited renewable generating stations for the eligible renewable electricity they generate; and Contracts for Difference (CfDs) which incentivise investment in renewable energy by providing developers of projects with high upfront costs and long lifetimes with direct protection from volatile wholesale prices.

Commercial Case

Typically, the purpose of the Commercial Case is to outline the commercial viability, risk allocation, and procurement strategy of the preferred option identified in the Economic Case. Option 4: 'Mixed Net Zero pathway' – is not a single scheme or project, but rather utilises a diverse mix of interventions including power sector decarbonisation, industrial CCUS-enabled H2, industrial CCUS, industrial electrolytic H2, BECCS and energy efficiency measures, which together helps the North West region reach its industrial decarbonisation targets by 2040. As such, it is not possible to discuss concrete commercial terms or specific procurement strategy as there are different routes to market for each type of technology and is also dependent upon government interventions.

Large-scale renewable energy projects have numerous unknown consequences arising from complex systems, supply chain issues, high costs, raw materials, lengthy project timescales, new technologies and regulatory regimes. Understanding the project risks associated with large-scale renewable energy and low carbon projects is critical in deploying a commercially successful project. These risks include,

[3] Defined as government intervention within the economy, aimed at increasing aggregate demand, with the aim of resulting in a positive shift within the economy

but not limited to: technical, institutional, political and regulatory, financial and economics, social and environmental, and technology risks.

Pricing model including future hydrogen cost, electricity, and carbon pricing will be another key consideration for the commercial viability. Given the current situation in Ukraine, energy prices should be closely monitored, along with any knock-on effects on supply and logistic chains.

Due to changing market dynamics in the energy sector, new alterative procurement models and contractual structures have emerged combining varying degree of risks with the traditional EPC model. Due to the complex nature of major energy projects, it is common to pursue alternative models on a case-by-case basis depending on project specifications, technology, and the type of risks. Therefore, there is not a one-size-fits-all approach when it comes to procurement model, but all parties must strike the right balance in allocating risks.

Management Case

Delivering a comprehensive decarbonisation programme requires high levels of integration as well as navigating through complexities of new technology and regulations. It must also take into consideration interdependencies such as jobs, skills, and economic growth.

The management case discusses various delivery models to oversee the strategic vision and programmes. It elaborates on challenges with respect to the current planning and regulatory regime, issues with on-going supply chain, and securing finance for projects at scale. Our suggestion is to convene an optioneering workshop with a range of stakeholders on the various delivery models to test the current appetite of the proposed structures.

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STRATEGIC CASE: PART A: CONTEXT

1. Strategic Case – Part A: Context

Net Zero North West (NZNW) is a consortium of leading organisations from industry and local government who have come together with the aim of developing the first low carbon industrial cluster by 2030 and the first Net Zero industrial cluster by 2040.

In the NZNW Cluster Phase Plan, NZNW set out the programme of discovery, engagement and business case development work required to create an industry-led plan for decarbonising industrial processes. The Consortium with support from Innovate UK undertook a pathway finding research on the route to decarbonisation. The aim of the programme was to demonstrate why the North West England and North East Wales is the best place to deliver a low carbon industrial cluster. With technical expertise and ambition across the region, the North West will lead and achieve these targets, but only with sufficient investment into new projects, technologies, and skills. The Investment Prospectus published by Siemens in 2021 set out 18 investment propositions and quantified the potential in the North West of England and North East Wales as:

- 38.5 million tonnes of carbon emissions reduction
- Half a million jobs secured or created
- Economic growth in the region of £285 billion GVA

This Investment Case has been commissioned by the NZNW Cluster Plan consortium to develop the strategy for investment in decarbonisation and to get the North West industrial cluster to Net Zero by 2040 as part of the industrial clusters mission. It brings together independent research, outcomes from industry engagement and findings from the work package reports to set out an investment case, quantified by a pipeline of genuine investable projects. This Investment Case also draws upon the year-long research and analysis undertaken for the North West Cluster Plan Interim Findings.[4] In this research, Uniper explores the role of low carbon dispatchable power generation into the National Transmission System. Meanwhile Equans and Local Energy NW Hub examines initiatives for decarbonisation delivery of energy efficiency, low carbon technologies, renewable generation, hydrogen, and as separate analysis the role of electrolytic hydrogen. Together, Progressive Energy and Cadent focuses on hydrogen and CCUS infrastructure via HyNet. Please refer to Appendix B: Summary of Work Packages for a background on various work packages and inputs to help advance this Investment Case. The report also aligns as closely as possible to the NZNW Economic Investment Prospectus [5] produced earlier by Siemens.

1.1. National Policy Context

Since the signing of the Paris Agreement at COP21 in 2015, the UK is committed to achieving Net Zero emissions by 2050. As a result, there has been increasing focus on initiatives, strategies and programmes to realise this ambition. Towards this end, the activity undertaken by NZNW will make a significant contribution towards Net Zero targets supported by the current policy landscape.

Energy policy in the UK is the responsibility of the Department for Business, Energy and Industrial Strategy (BEIS).[6] Although there are numerous regulators much of the energy market is regulated by Office of Gas and Electricity Markets (Ofgem). Historically, parts of energy generation, transportation, and supply were run by the public sector. However, most of the market is now privatised where the generation and supply are competitive with transportation through networks is regulated as the operators are monopolies. The UK Government and Ofgem continue to regulate the market for customers and deliver policy to meet the Government's aims on energy. Energy policy of recent

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[4] NZNW Cluster Plan Interim Findings, April 2022 - This Interim Report summarises the progress made in the first year, and the findings of detailed research into options for decarbonising industry via the use of energy networks, dispatchable power generation, CCUS (direct capture of CO_2) and via CCUS enabled and electrolytic hydrogen. [NZNW-Cluster-Plan-Interim-Findings-April-2022.pdf (netzeronw.co.uk)]
[5] NZNW Economic Investment Prospectus, 2021 [NZNW Economic Investment Prospectus (netzeronw.co.uk)]
[6] As of February 2023, BEIS has been divided into two units: Department of Energy Security and Net Zero and Department for Science, Innovation, and Technology. As this report was originally commissioned in 2022, the report will refer to the unit as BEIS.

governments has centred around three objectives: security, affordability, and decarbonisation, often referred to as the energy 'trilemma'.

Since 2017, energy policy has been focused on aligning to the governments Green Growth Strategy. At the end of 2020, a *Ten Point Plan for a Green Industrial Revolution* and an *Energy White Paper* were published with new policies and commitments across many facets of the energy system including consumers, power, the energy system, transport, buildings, industrial energy, and oil and gas. An overview of the relevant national policy documents is summarised in this section.

1.1.1. Ten Point Plan for Green Growth, 2020

The *Ten Point Plan for a Green Industrial Revolution* sets out the blueprint for a Green Industrial Revolution for 250,000 British jobs. The plan covers clean energy, transport, nature, and innovative technologies. The plan mobilises £12 billion of government investment to create and support up to 250,000 highly skilled green jobs for the UK and stimulate three times as much private investment by 2030. Central to this plan is the focus on the industrial heartlands, which were once the centre of the First Industrial Revolution. The Prime Minister's ten points are outlined in Table 4 Objectives and Delivery to date of the Governments 10 Point Plan

The UK has committed over £12 billion to domestic green investment since March 2020. Through policies and spending brought forward by the Net Zero strategy, the UK government will mobilise over £26 billion of capital investment to support the green industrial revolution.[7]

Major power generators and emitters will need to invest not only in major adaptations on their sites to achieve energy efficiency but will need to be prepared to invest in proof of concept for new technologies. In addition to supporting capital injection, the UK government will need to be prepared to incentivise cost effective abatement through contracts for difference and sin taxes.

The UK government's *'Ten Point Plan for A Green Industrial Revolution'*, together with the '*Net Zero Strategy'* and the *Energy Strategy*, is driving an unprecedented £100 billion of private sector investment by 2030 into new British industries, including offshore wind and supporting around 480,000 clean jobs by the end of the decade. So far, the government have delivered £22 billion towards the Ten Point Plan. An overview of the delivery of this investment below.

Table 4 Objectives and Delivery to date of the Governments 10 Point Plan

	10 Point Plan	Objective	Delivery Highlights to Date
	**Advancing Offshore Wind**	Producing enough offshore wind to power every home, quadrupling how much we produce to 40GW by 2030, supporting up to 60,000 jobs.	• Over £1.6 billion invested, securing 3,600 jobs • 11GW already generated, and another 12GW in the pipeline • Up to £320 million in government support for fixed bottom and floating wind ports and infrastructure • Additional government support for other low-cost renewables technologies
	**Driving the Growth of Low Carbon Hydrogen**	Working with industry aiming to generate 5GW of low carbon hydrogen production capacity by 2030 for industry, transport, power and homes, and aiming to develop the first town heated entirely by hydrogen by the end of the decade.	• £7.5 million awarded to ITM's Gigastack Project, an early mover in the market, with potential to support up to 2,000 jobs over time • Preparing to allocate up to £100 million of revenue support to initial electrolytic projects • Launching £240 million Net Zero Hydrogen Fund later in April • Developed indicative Heads of Terms for hydrogen business model contract

[7] Net Zero Strategy: Build Back Greener, HM Government, October 2021

Delivering New and Advanced Nuclear Power	Advancing nuclear as a clean energy source, across large scale nuclear and developing the next generation of small and advanced reactors, which could support 10,000 jobs.	• Committed to provide up to £1.7 billion of direct government funding to enable one nuclear project to FID this Parliament • Investing £100 million into Sizewell C to help develop this project • Investing £210 million to develop Small Modular Reactors with Rolls Royce • Announced a £120 million Future Nuclear Enabling Fund to progress new nuclear
Accelerating The Shift to Zero Emission Vehicles	Backing the world-leading car manufacturing bases including in the West Midlands, North East and North Wales to accelerate the transition to electric vehicles and transforming the national infrastructure to better support electric vehicles.	• £4 billion of investment has flowed into the UK zero emission vehicle sector • Building two new Gigafactories, in Sunderland and Blyth • 30,425 public charge-points in the UK with 100 new rapid chargers were added to the UK network every month during 2021
Green Public Transport, Cycling and Walking	Making cycling and walking more attractive ways to travel and investing in zero-emission public transport of the future.	• 1,678 zero emission buses funded • Launched Active Travel England, increased cycling by 75%
Jet Zero and Green Ships	Supporting difficult-to-decarbonise industries to become greener through research projects for zero-emission planes and ships.	• Consulted on introduction of a UK Sustainable Aviation Fuel (SAF) mandate, requiring jet fuel suppliers to blend an increasing proportion of SAF into aviation fuel from 2025 • • • Allocated £23 million as part of the Clean Maritime Demonstration Competition
Greener Buildings	Making homes, schools and hospitals greener, warmer and more energy efficient, whilst creating 50,000 jobs by 2030, and a target to install 600,000 heat pumps every year by 2028.	• Cut VAT for insulation and heat pumps • 46% of English homes at EPC C or above, up from 9% in 2008, and 2,300 social housing homes in the process of being improved • Over 60,000 heat pumps installations estimated by industry, now offering households grants of £5,000 towards an air source heat pump so they are cost competitive compared to a gas boiler
Investing In CCUS	Becoming a world-leader in technology to capture and store harmful emissions away from the atmosphere, with a target to remove 10MT of carbon dioxide by 2030, equivalent to all emissions of the industrial Humber today.	• Committed £1 billion in public investment to decarbonise our industrial clusters • Announced the first 2 clusters in Teesside, the Humber and Liverpool City Region • Launched phase 2 of the Industrial Energy Transformation Fund, allocating £60 million to decarbonisation technologies, with a further £100 million delivered in May and October this year
Protecting The Natural Environment	Protecting and restoring the r natural environment, planting 30,000 hectares of trees every year, whilst creating and retaining thousands of jobs.	• Additional £124 million provided at Spending Review 2021 to the Nature for Climate Fund to support tree planting and peat restoration, going beyond 2019 Manifesto Commitment of £640 million • 13,290 hectares of trees planted across the UK in 2020/21 • Launched three new Community Forests, in Cumbria, Devon and the North-East • £5.2 billion invested in six year programme of flood defences
Green Finance And Innovation	Developing the cutting-edge technologies needed to reach these new energy ambitions and make the City of London the global centre of green finance.	• £615 million allocated from Net Zero Innovation Portfolio allocated • Set the JET world record, with 59 megajoules of heat energy in a single fusion 'shot' that lasted 5 seconds

In terms of support for CCUS, Hydrogen & Industrial Decarbonisation, the government is supporting cluster decarbonisation activities with a range of interventions that include, support from UKRI (via Innovate UK) and BEIS directly:

- CCUS Innovation Programme
- The Low Carbon Hydrogen Production Fund and
- The Carbon Capture and Storage (CCS) Infrastructure Fund
- Industrial Strategy Challenge Fund (ISCF)
- Industrial Fuel Switching Programme
- Hydrogen Supply Programme

BEIS is directly intervening to support industry with initiatives such as the Industrial Energy Transformation Fund, which seeks to help businesses first understand the feasibility of technology options, and then invest in new plant, equipment, and services.

1.1.2. Industrial Decarbonisation Strategy, March 2021

In 2019, the UK became the first major economy in the world to pass laws to end its contribution to global warming by 2050. To reach this target, vast and systematic change must occur across all sectors and industry. The *Industrial Decarbonisation Strategy* covers the full range of UK industry sectors: metals and minerals, chemicals, food and drink, paper and pulp, ceramics, glass, oil refineries and less energy-intensive manufacturing. The businesses associated with this account for around one sixth of total UK emissions, therefore the transformation of the associated manufacturing and industrial processes is crucial if the UK is to meet the emissions targets over the next decades.

The overarching objective of the strategy is to lay out how the UK can have a thriving industrial sector aligned to Net Zero targets, whilst not causing emissions and businesses to move abroad, and informing how government can act to support this. An indicative roadmap to Net Zero for UK industry based on the content provided in this strategy.

1.1.3. Build Back Better, March 2021

Build Back Better outlines the plan for growth for rebuilding the UK after the COVID-19 pandemic. The plan focuses on three pillars of investment to act as the foundation on which to build the economic recovery, whist levelling up the country. These three pillars and their associated focus are outlined below.

- High Quality Infrastructure: to stimulate economic growth, boost productivity and competitiveness the UK has committed to £100Bn in capital investment starting in 2021-22
- Improving Skills: the government aims to transform Further Education, encourage lifelong learning through Lifetime Skills Guarantee and build an apprenticeship revolution
- Driving Innovation: Government commitments to significant uplift in R&D investment, the creation of Advanced Research and Innovation Agency to fund high risk, high reward research. It aspires to make the UK ecosystem the best in the world for starting and growing a business, improving access to capital, skills and ideas and establishing smart and stable regulatory frameworks

1.1.4. The UK Hydrogen Strategy, August 2021

Hydrogen is emerging as a new, low carbon solution that will be critical for the UK's transition to Net Zero. Hydrogen has the potential and versatility to replace the high-carbon fuels used today. This will be crucial to reduce emissions across all UK industrial sectors and provide flexible energy for power, heat, and transport. The *UK Hydrogen Strategy* sets out how the UK government will drive progress in the 2020s, to deliver the 5GW production ambition by 2030 and then position hydrogen to help meet the Sixth Carbon Budget and Net Zero commitments.

The *UK Hydrogen Strategy* looks to address this by taking a holistic approach to developing a thriving UK hydrogen sector. It outlines a road map as to what needs to happen to enable the production, distribution, storage, and use of hydrogen whilst securing economic opportunities for the industrial cluster and more broadly across the UK. The strategy sets out clear goals and principles for developing the hydrogen economy and outlines how this will evolve towards 2050. It emphasises the short-term interventions and actions with long term direction, aiming to unlock the innovation and investments critical to meeting the potential that hydrogen represents.

1.1.5. Net Zero Strategy, Build Back Greener, October 2021

This strategy outlines the plan for the UK's contribution to avid catastrophic climate change. Following the UK's Ten Point plan for a green industrial revolution, the *Net Zero Strategy* lays the foundations for a green economy recovery and outlines decarbonisation pathways to Net Zero by 2050. The strategy sets out clear policies and proposals to reduce emissions for each sector, keeping the UK on track with upcoming carbon budgets and the 2030 Nationally Determined Contribution (NDC). Key policies within the strategy include:

- Power: Fully decarbonise the power system by 2035.
- Fuel supply and hydrogen: Deliver 5 GW of hydrogen production capacity by 2030.
- Heat and buildings: Set a path to all new heating appliances in homes and workplaces from 2035 being low carbon.
- Transport: Remove all road emissions at the tailpipe and kick-start zero emissions international travel.
- Carbon capture, use and storage (CCUS): Deliver four CCUS clusters, capturing 20-30 MtCO2 across the economy, including 6 MtCO2 of industrial emissions, per year by 2030. Deploy at least 5 MtCO2/year of engineered greenhouse gas removals by 2030.

The *Net Zero Strategy* will be submitted to the United Nations Framework Convention on Climate Change (UNFCCC) as the UK's second Long-Term Low Greenhouse Gas Emission Development Strategy under the Paris Agreement.

1.1.6. Levelling Up the United Kingdom, February 2022

This paper sets out the programme needed to level up the UK. It is rooted in providing evidence demonstrating the mix of factors needed to transform places and boost local growth: strong innovation and climate conducive to private sector investment, better skills, improved transport systems and greater access to culture, a stronger pride in place, deeper trust, and safer and more resilient institutions. This policy follows a historical context, learning from the principles deployed by the renaissance and the first industrial revolution and applies it to the 21st century. The policy outlines that levelling up will require:

- Increased productivity, pay, jobs and living standards by growing the private sector
- Spread opportunities and improve public sector services, particularly in places that are weaker
- Restore sense of community, local pride and belonging, particularly in places where they have been lost
- Empower local leaders and communities

Levelling up aims to relieve pressures on public services, housing, and green fields in the Southeast and improve wellbeing and productivity in the North and Midlands. It is therefore, about improving the success of the whole country and realising the potential of ever place and person across the UK, building on unique strengths and spreading opportunities for individuals and businesses.

1.1.7. Energy Trends, March 2022

Energy Trends is a quarterly bulletin containing statistics on all major aspects of energy in the UK. A table for percentage annual change from 2020 can be seen below.

Table 5 Energy Trends, March 2022

	Production	Imports	Exports	Demand
Total Energy	-14%	+7.7%	-13%	+3.2%
Coal	-36%	+1.8%	-14%	+2.3%
Primary Oil	-17%	+4.4%	-15%	-0.9%
Petroleum Products	+0.7%	+2.1%	-1.8%	+3.9%
Gas	-17%	+17%	-29%	+5.4%
Electricity	-11%	+28%	-7.0%	-11%

Energy consumption in 2021 remained low, up on last year but still down 8 percent on 2019 as COVID-19 restrictions affected economic output, leisure, and travel. Consumption was low at the start of the year and increased from April as restrictions eased.

Energy requirements for industrial use and services (e.g., shops, restaurants, offices) were up and returning to near pre-pandemic levels. Domestic demand remained higher than usual as people continued to spend more time at home. Transport demand increased 7 percent compared to last year but remains 23 percent below 2019 levels. Whilst petrol and diesel consumption ended the year not far short of 2019 levels, aviation fuel fell even further, down 8 percent on last year, and down 62 percent in 2019 despite trending up in recent months.

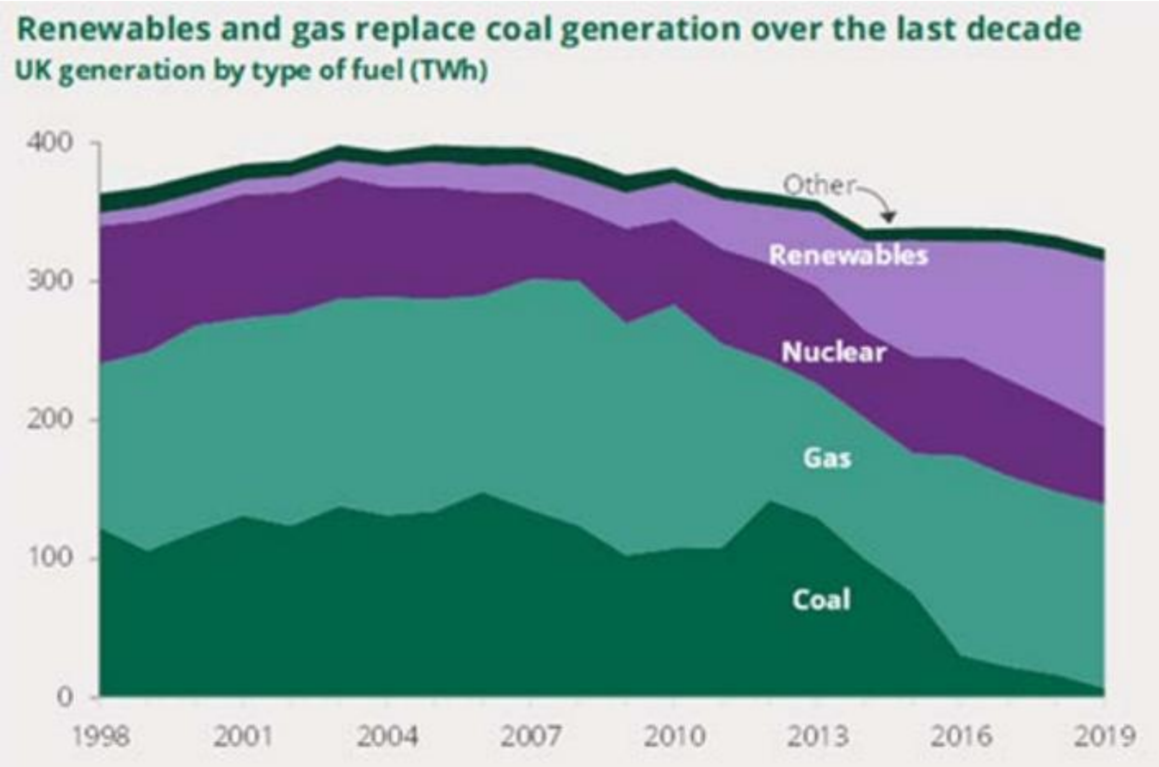
Energy production was low, down 14 percent compared to last year and the lowest level in over 50 years. Extensive maintenance in the North Sea, including the upgrade to the Forties Pipeline System, reduced oil and gas output by 17 percent though output has increased since the summer lows.

Nuclear output was also disrupted by maintenance, dropping output 9 percent to the lowest level since 1982. Increasing energy demand with lower production meant that net import dependency increased to 37.9 percent, the highest share since 2015.

Electricity output from renewable technologies dropped significantly because of less favourable weather conditions in 2021. Wind dropped 14 percent, with further falls in both hydro and solar generation. Renewables share of generation dropped from a record high of 43.1 to 39.3 percent despite a small increase in capacity. The share of low carbon generation fell more sharply, down to 54.1 percent, due to drops in both renewables and nuclear.

These recent trends can be aligned to a more historical context of energy trends over the last two decades.

Figure 1 BEIS - Energy Trends



1.1.8. UK Energy Security Strategy, April 2022

The *British Energy Security Strategy* builds on the Prime Minister's '*Ten Point Plan for a Green Industrial Revolution*', and the '*Net Zero Strategy'*. This plan comes after the recent rise of global energy prices, provoked by surging demand after the pandemic as well as the current situation between Russia and Ukraine. The plan will be pivotal in moving expensive fossil fuels to renewable energy. This strategy aims to solve wide ranging problems facing the energy industry, such as long licensing periods and red tape and accelerate the roll out of renewable energy systems with the aim of becoming energy independent. Part of this strategy is to double the hydrogen production target to 5GW of CCS-enabled hydrogen and 5GW of green hydrogen. An overview of the objectives from the strategy include:

- Improve energy efficiency, reducing the amount of energy that households and businesses need
- Address the underlying vulnerability to international oil and gas prices by reducing the dependence on imported oil and gas.
- Source more domestic gas with a second lease of life in the North Sea
- Accelerate the transition onto renewable energy resources
- Remove red tape that holds back new clean energy developments and exploit the potential of all renewable technologies
- Substantially increasing the investment into nuclear energy
- Increasing the self-sufficiency of the UK Energy System
- Aiming for 95% low carbon British electricity supply, with a decarbonised electricity system by 2035

1.2. Energy Policy Updates since April 2022

This section gives a brief overview of the energy policy updates since April 2022. There has been significant progress to date and an urgency to continue the momentum to achieve net zero by 2030.

1.2.1. Energy Security Bill, July 2022

The Energy Security Bill 2022[8] is a significant piece of legislation for supporting UK's energy ambitions and targets. The bill comprises 26 measures to achieve three board aims:

- Leveraging private investment in clean technologies and building a homegrown energy systems including carbon capture and storage (CCS), low carbon hydrogen, and heat.
- Ensuring the safety, security and resilience of the UK's energy system by establishing a new Future Systems Operator and new regulatory framework for heat networks; and
- Reforming the UK's energy system to protect consumers from unfair pricing.

Table 6: Brief Summary of the Energy Security Bill, 2022

<table>
<tr><th>Clean Technology</th><th>Energy Security</th><th>Consumer Protection</th></tr>
<tr><td>Licensing: New framework and regulatory system for hydrogen, CO2 transport, storage infrastructure</td><td>Environmental Standard: update environmental regulation for offshore oil & gas, protect habitats</td><td rowspan="4">• Extend the energy price cap beyond 2030
• Powers to CMA to review energy network mergers
• Support development of heat networks / heat network zoning
• Establishment of Future System Operator oversight for electricity and gas systems</td></tr>
<tr><td>Hydrogen trials: via 'hydrogen village' for residential consumers by 2025</td><td>Change of Control of O&G: NSTA's authority for any change of control of O&G</td></tr>
<tr><td>Battery & Hydro Storage: Remove obstacles for battery-based and pumped hydro-energy storage projects</td><td>Fuel Supply: Resilience fuel supply, direction-making power and information power</td></tr>
<tr><td>Licensing: New framework and regulatory system for hydrogen, CO2 transport, storage infrastructure</td><td>Environmental Standard: update environmental regulation for offshore oil & gas, protect habitats</td></tr>
</table>

1.2.2. Hydrogen Strategy Update, December 2022

The UK government issued an update to its 2021 Hydrogen in December 2022 with focus on creating a favourable regulatory framework to ensure the UK is competitive in the low carbon hydrogen market. UK is committed to another £25m in funding to accelerate the development of new technologies that will generate clean hydrogen from biomass and waste; £26m for Industrial Hydrogen Accelerator competition; and the £40 million Red Diesel Replacement competition.

Jane Toogood was appointed as UK's first Hydrogen Champion with the remit of bringing together industry and government to support the UK government hydrogen targets through a series of stakeholder engagements with findings to be published in 2023.

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[8] *Energy Security Bill 2022 Factsheet*

1.2.3. Chris Skidmore's Mission Zero: Net Zero Review, January 2023

After a comprehensive review based on written evidence, Chris Skidmore outlines his key recommendations and priorities. Based the report, harnessing net zero opportunities requires three aims:

- **An Urgent Call for Action**: urgency is key to unlocking the potential economic benefits of Net Zero and the importance of keeping momentum.
- **Stable policy and finance**: outlining a finance strategy under the Office for Net Zero Delivery with the aim of creating a stable environment for investment.
- **Place-based approach**: discussing the vital role of local authorities in delivering Net Zero, which can deliver more value for money. The report also notes the importance of the central-local government relationship in achieving net zero.

Table 7: Ten Priorities based on the Skidmore Review

1	Grid and Infrastructure	A strategic framework and delivery plan for the critical networks of the future to turbocharge development
2	Solar	Full-scale deployment of solar including a rooftop revolution to deliver up to 70GW of solar generation by 2035.
3	Onshore Wind	Pave the way for onshore deployment, working closely with communities to delivery local benefits
4	Nuclear	A programmatic approach for a next generation fleet of nuclear, supporting a high-tech British industry covering the whole supply chain
5	Energy Intensive & Industry	Setting a clear plan for industry decarbonisation built around long term investment in CCUS and hydrogen networks and technologies
6	Circular Economy & Waste	Stimulate the efficient and circular use of resources across the economy, galvanising action on recycling and the reuse of critical materials
7	Net Zero Local Big Bang	Unlocking the planning system and reforming the relationship between central and local government to give local authorities and communities more powers
8	Energy Efficiency for Households	Working towards gas free homes by 2035 and giving consumers greater understanding of their household through a new net zero performance certificate
9	Net Zero Nature	Embed nature and habitat restoration throughout transition plans, maximising co-benefits for climate and nature wherever possible
10	R&D & Innovation	Catalyse decision and action with and R&D and technology roadmap to 2050, pushing for more agile regulation, and supporting up to three 10-year demonstrators.

Source: Adopted from London Council, Mission Zero - The Skidmore Net Zero Review

1.3. North West England: Regional Context & Key Players

For the purposes of this work, the North West refers to Cheshire, Greater Manchester, Liverpool City Region (LCR), Lancashire, Cumbria and North Wales. The region has a long-standing history as an energy generator and industrial innovator. It is one of the six largest industrial clusters as mapped by BEIS in the Industrial Clusters Mission; Humberside, South Wales, Grangemouth, Teesside, Southampton and North West England.

Figure 2 North West and North Wales study Region

Source: North West Net Zero Hub

The North West region is one of the most significant manufacturing and chemical production centres in the UK, with the largest industries in the cluster accounting for over 6 million tonnes of annual carbon emissions. Industry is arranged on individual production and manufacturing sites and across 18 major industrial parks.

The region's notable contribution to industrial carbon emissions in turn represents one of the greatest opportunities in the UK for a region-wide approach to decarbonisation at scale. The Cluster Plan also considers geographies outside of the NW region. There are strong reasons to include energy intensive industry in North East Wales and in the Peak District in the Cluster Plan. North Wales shares with the North West the opportunity for significant growth in clean energy generation installations. They border the Irish Sea which is home to an ever-growing fleet of offshore wind turbines, landing clean power onshore at locations on the coast.

1.3.1. Net Zero North West (NZNW)

The Net Zero North West (NZNW) consortium is comprising of private enterprises leading this charge towards the Net Zero economy. This includes Peel NRE, Tata Chemicals, Siemens, Encirc, the North West Business Leadership Team, ABB and Inovyn, and formerly CF Fertilisers. These industry leaders work closely together with various partners including North West Hydrogen Alliance, Cheshire Energy Hub, and the regional LEPs.

The aims of the NZNW consortium include stimulating inward investment in industrial decarbonisation, research and innovation, engagement, skills planning and development of business/investment cases.

Within the wider ecosystem LEPs and Combined Authorities produce Local Industrial or other economic Strategies that recognise clean growth as a significant challenge and opportunity and many have also developed energy strategies which highlight the need to decarbonise industry. The majority of local authorities in the North West region have declared climate emergencies and have ambitious Net Zero carbon targets. The North West Hydrogen Alliance provides an industrial voice to drive forward innovation in the hydrogen sector to promote the low carbon economy.

Furthermore, HyNet is a pivotal project which will capture, transport and store CO2 produced by emitters via repurposed natural gas pipelines as well as produce hydrogen and blend it in to local networks. HyNet was recently recognised as a Track 1 Cluster under the Government's CCUS Programme, further positioning North West as a leading cluster to achieve industrial decarbonisation by the end of the decade.

Together, NZNW has the ambition to create a net-zero industrial cluster by 2040 as a world first. It aims to attract innovators, investors, and problem solvers to create a low-carbon exemplar that others in the UK and internationally can learn from and replicate.

Establish the world's first net-zero carbon industrial cluster by 2040 and at least one low-carbon cluster by 2030

The low-carbon infrastructure needed to support industrial decarbonisation will be in place and operational, attracting new investment and innovation. Multiple industrial facilities will already have reduced their emissions, by the greatest possible extent. Positioning UK clusters as top areas for global inward investment and driving demand for low carbon products and technologies by harnessing the power of markets, the public sector, universities, and local communities.

1.3.2. NZNW Cluster Plan

Under the banner and governance of NZNW, the UKRI funded *NZNW North West Cluster Plan* (2023) sets a coherent vision for industrial decarbonisation in the North West of England and North East Wales. It describes the investments, technologies, infrastructure changes and sequencing required to fulfil the UK's Industrial Clusters Mission and deliver a transition to Net Zero. The project focuses on two key objectives:

- Establishing a low-carbon industrial cluster by 2030, by deploying anchor investment projects including HyNet hydrogen and Carbon Capture, Utilisation, and Storage (CCUS) infrastructure
- Establishing a Net Zero carbon industrial cluster by 2040, underpinned by multi-vectored industrial decarbonisation solutions

This is being supported by a number of partners working on the Cluster Plan, including: North West Business Leadership Team, Equans, Uniper, Cadent, Progressive Energy, Scottish Power Energy Networks, the University of Chester, the North West Net Zero Hub, Liverpool City Region LEP, Cheshire and Warrington LEP (with Mace Consulting).

Approximately 40 million tonnes of CO2 are emitted annually in the North West. North West businesses produce over one-third of regional carbon emissions, amounting to 15 million tonnes per annum. 9 million tonnes of CO2 are associated with industrial processes from major undertakings. The Industrial Clusters Mission has its focus on the most energy intensive industries. In creating the *Net Zero North West Cluster Plan*, it is intended to keep in consideration all industrial processes energy use with the following strategic objectives:

- Becoming a low carbon industrial cluster by 2030, and becoming (or positioning to be) the world's first Net Zero industrial cluster by 2040
- Maximising the economic opportunity regionally of decarbonisation, including:
- Establishing and growing domestic supply chains in newer green technologies
- A highly diversified offer of different energy vectors
- Harnessing regional (and national) strengths and comparative advantages

- Energy security and reducing dependency on foreign energy supplies, particularly of hydrocarbons (including natural gas)
- These strategic objectives form the basis for the selection criteria when analysing and prioritising projects for the project pipeline.

1.3.3. North West's Comparative Advantages

The North West has three crucial regional comparative advantages over most other regions of the UK. The first is having a highly cost-effective production of industrial CCUS enabled hydrogen because of the North West's natural geology. This offers relatively cheap storage solutions for both CO2 and H2 both at Stanlow and Barrow / Morecambe. Pre-existing gas pipeline infrastructure can be utilised and repurposed cheaply, rather than rendered obsolete in the green transition.

Secondly, North West possesses a world-class nuclear industry with strengths in design, development and operation of nuclear new build. Cheshire & Warrington and Lancashire possess consultant engineering firms and National Nuclear Laboratories. New and existing nuclear developments could be expanded and used to produce cheaper industrial electrolytic hydrogen from nuclear power rather than renewables, also known as 'purple hydrogen'. The development of Advanced Small Modular Reactors (SMRs) could support that expansion and further cost reductions over traditional nuclear power plants.

Another key comparative advantage is with tidal, with the Liverpool City Region boasting one of the UK's largest tidal ranges and a long history into tidal power. The LCR has determined that there is a strong strategic case for taking Mersey Tidal Power project forward, with the project currently in its Phase 3 concept development. Finally, there is opportunity for offshore wind production with some of the UK's shallowest waters enabling cheaper fixed-bed installations than other areas can accomplish. This could potentially also offer a cheap way of renewable electrolytic hydrogen production under certain circumstances.

The North West does not have an especial comparative advantage in renewables beyond offshore wind and tidal. Solar is not significantly better there than anywhere else in the UK, nor in the way it applies energy efficiencies to industry though of itself this is cost-effective as an intervention. It does have a significant emerging cluster and possible associated emerging comparative advantage in bioenergy with carbon capture and storage (BECCS).

Notable progress includes the first stages of HyNet. Industrial decarbonisation also requires a significant element of hydrogen production given limitations of electrifying heavy industry; the main optioneering is therefore less around the quantum of hydrogen production overall, which needs to account for at least a quarter of industrial decarbonisation, and more around the means – industrial CCUS enabled or industrial electrolytic (either renewables or nuclear).

Capitalising on these natural endowments and comparative advantages, these are all positive attributes that would enable the acceleration of industrial decarbonisation in the North West region.

1.3.4. North West Low Carbon Ecosystem

The strategic case for industrial decarbonisation in the North West and North Wales region is underpinned by the scale of the CO2 savings opportunity. It is important to note that these identified projects in the pipeline sit within a wider ecosystem across the North West region.

With HyNet already underway, the North West is well-positioned as an industrial leader in achieving the legislative commitment for Net Zero by 2050. In addition to HyNet, future projects should make meaningful contribution to the decarbonisation agenda as well as the entire low-carbon ecosystem. Therefore, no projects should be considered in isolation, but must be appraised on its interdependencies on, or with other parts of the ecosystem overall.

Due to various geographical and/or technological constraints, some projects are presently classified as ‘standalone’ initiatives. However, this could all change, and the project could at some point be part of a bigger regional project. For example, the project could be linked by a network of hydrogen or carbon capture pipes. Projects fall into one of the following sub-sectors that together make up the whole low carbon ecosystem in the North West. These include:

- Green energy generation for direct use via the National Grid or private wire (Wind; solar, tidal, biomass, geothermal, nuclear)
- Energy generation as feed stock for electrolytic hydrogen production
- Hydrogen production (primarily green, blue)
- Hydrogen transportation and storage
- Carbon capture, utilisation, and storage
- Retrofitting and interventions to increase production and asset efficiency

It is worth noting that the precise definitions for the sub-sectors have been further developed in the other technical research. It is necessary to distinguish grid scale generation from onsite generation at industrial sites. This includes near site infrastructure such as heat networks and fuel cells, as well as larger scale storage. As part of further work, it is expected that the North West Net Zero Hub ‘Clean Lead’ officer will be able to provide an analysis of the Circular Economy, linking the outputs of processes into other areas of the industrial decarbonisation challenge.

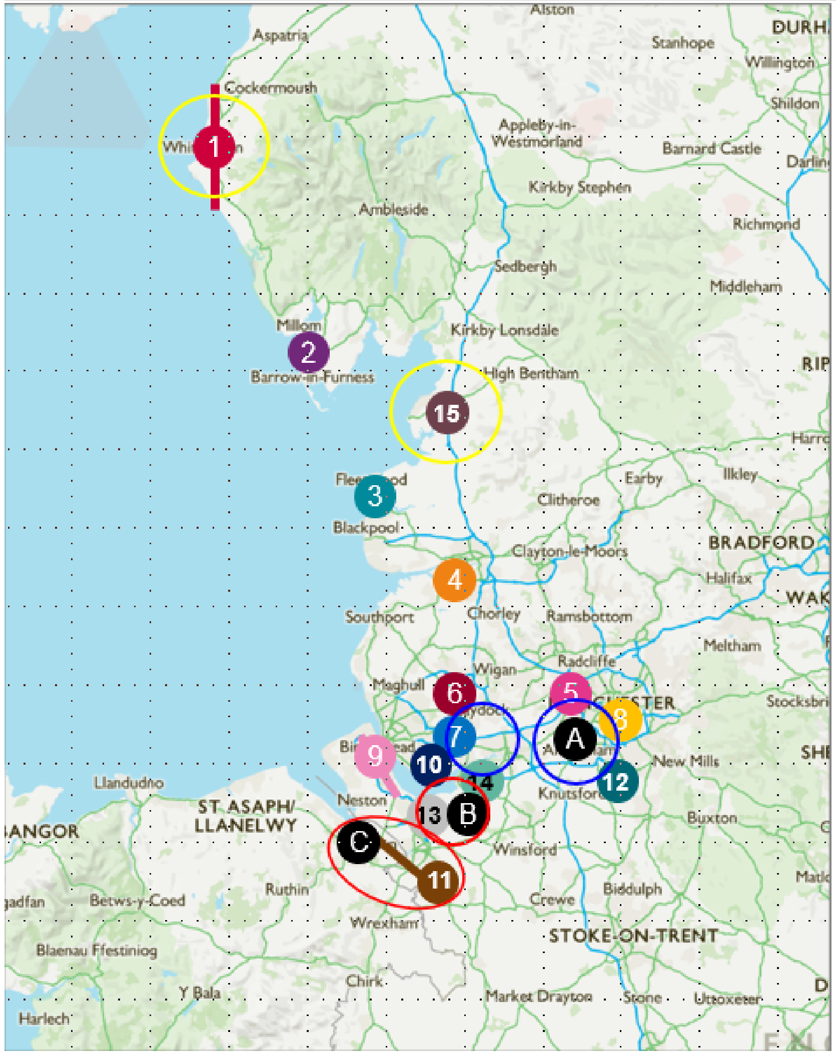
Given the industrial decarbonisation focus, it is critically important to consider industrial density across the region, and plan solutions for those areas. Figure 3 illustrates 15 of the major industrial parks in North West England. The scenario planning analysis suggest three possible areas for energy supply production. Where possible each of the pipeline projects has been mapped in the pages that follow in Figure 4 where the pipeline is mapped systematically.

This is to identify the relationships between the technologies and projects, and how they ultimately depend upon and enable each other to achieve decarbonisation. Mapping the projects in this way also helps us to identify gaps which are referenced in the system map itself.

The diagram portrays the assertion that the interconnectivity between projects is important. Projects cannot be considered simply in their own right but should be considered as part of the decarbonisation ecosystem that needs to be created to unlock maximum value from all initiatives. It also confirms that the investment opportunity is not just vested in “projects” but also in the networks that tie them together.

The illustration below shows that the geographical distribution of the schemes around the Liverpool City Region, Cheshire, Ellesmere Port and Greater Manchester area are mostly systems or linked strategies. However, the industrial parks and mine water heat projects further north, on the Lancashire coast, are necessarily standalone.

Figure 3 Location of major industrial areas, power stations and potential future large-scale low carbon dispatchable power generating sites



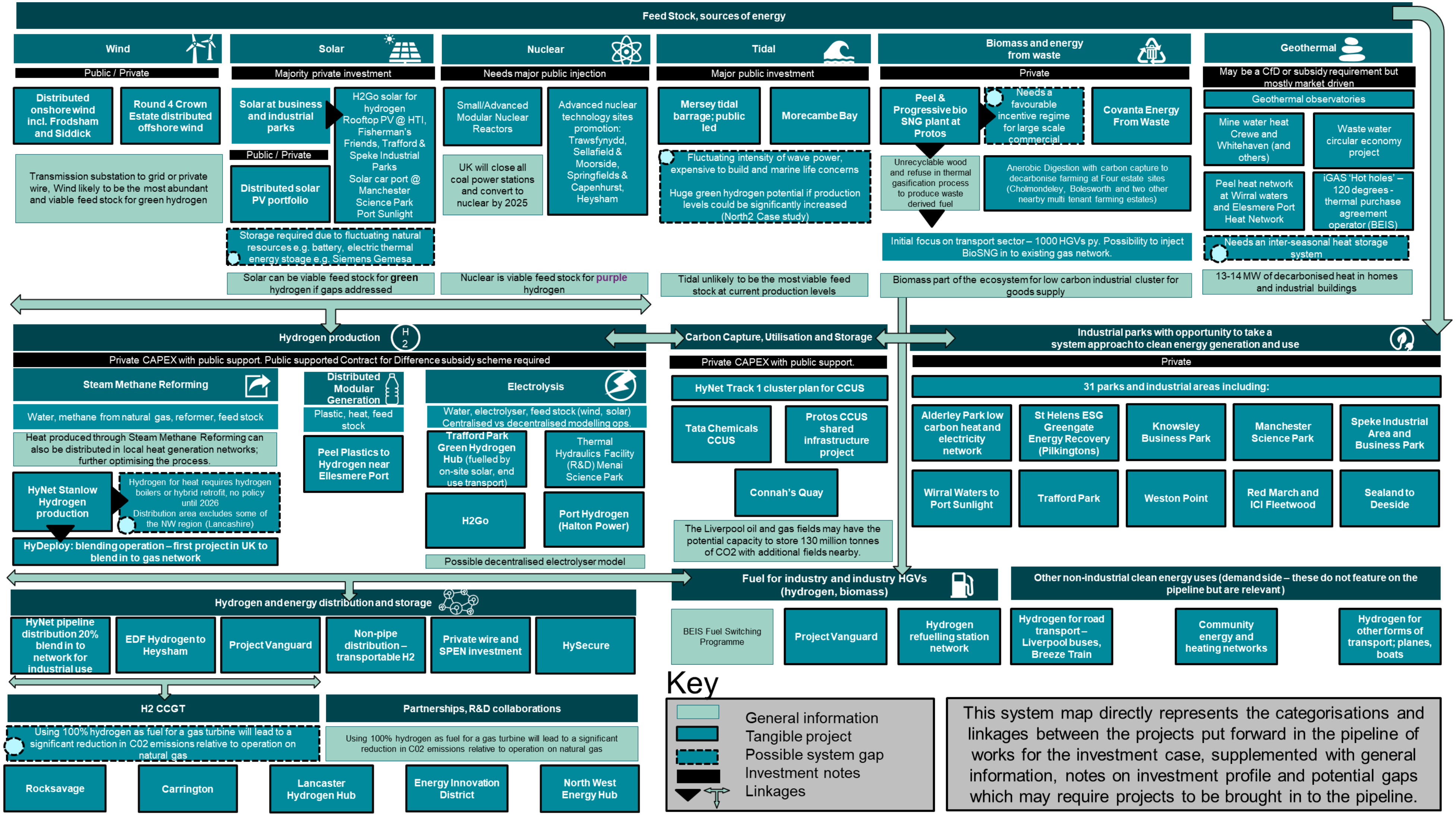
	Site/s	Businesses	Scale in hectares
1	Sellafield to Siddick	Sellafield Ltd ; Iggesund Paperboard	1,800
2	Furness Business Park & Buccleuch Dock	BAE Systems ; Retail parks Offshore wind (Duddon and Barrow)	263
3	Red March and ICI Fleetwood	Suez ; Global renewables ; Vinnolit ; Victrex ; AGC Chemicals Fishermans Friends ;HTI	200
4	Leyland Area Business Parks	Dr Oetker ; Global Renewables Freight and vehicle businesses	200
5	Trafford Park area	Intu Properties; Peel 100s of other large businesses e.g. Kelloggs, Cargill etc.	1100
6	Knowsley Business Park	Future Industrial Services ; Baker Hughes; Contract Chemical ; Dairy Crest	560
7	St Helens	Pilkington ; Torus ESB Asset Development	400
8	Manchester Science Park	Bruntwood SciTech ; Heineken, Manchester Universities	11
9	Wirral Waters to Port Sunlight	Peel ; Unilever ; Cereal Partners UK ; Essar Oil UK	950
10	Speke Industrial Area	B&M ; Prinovis ; Seqirus Vaccines ; Jaguar Land Rover Eli Lilly ; Astrazeneca ; Peel	500
11	Sealand and Deeside (Incl. Chester Industrial Estate)	Tata Steel ; Airbus ; Toyota ; Uniper ; Deeside Power ; Cadent United Utilities ; Knauf Insulation	2700
12	Alderley Park	Bruntwood ; Electricity North West and Cadent (DNOs) ; Over 200 businesses – mainly in bio / life sciences	25
13	Ellesmere Port	Peel ; Essar ; CF Fertilisers ; Vauxhall ; Urenco ; Encirc ; Nynas ; Cadent ; SPEN ; Protos	4950
14	Weston Point	Inovyn/INEOS ; Intergen ; SSE ; Viridor ; Koura ; Vynova Industrial Chemicals Ltd ; Hanson Asphalt ;DNOs (SPEN & Cadent)	300
15	Heysham Business Park	Crown Oil Group; multiple business services, consulting, construction and freight companies	18
A	Carrington Power Station	Carrington Power	126
B	Rocksavage Power Station	InterGen	100
C	Connah's Quay Power Station	Uniper	263
		Total scale of industrial area footprint	12,666

Likely to be either H2 fuelled or natural gas with CCS

More likely to be H2 fuelled due to limited local Co2 infrastructure

Further clarity required to determine credible opportunity

Figure 4 Pipeline mapped systematically



2.

STRATEGIC CASE – PART B: THE PIPELINE

2. Strategic Case – Part B: The Pipeline

To consider the way supply (through projects and programmes) can meet demand, a pipeline of NZNW projects and programmes has been produced. The long list of schemes gathered through desktop research was interrogated and refined to reach an investable pipeline of work. The purpose of the pipeline is to identify the schemes that will leverage the greatest contribution towards achieving the 2030 and 2040 decarbonisation targets set out in the Net Zero North West Phase 1 Cluster Plan.

2.1. Overall Methodology & Approach

The overall methodology for the Investment Case is divided into the following steps:

1. Build the project pipeline: identify all net-zero projects and programmes in the public domain in the 'North-West' region, create the 'Long List'. After a comprehensive desk-top review and analysis, a long list was compiled consisting of over 150+ projects and programmes. Using a set of metrics, the long pipeline list was then streamlined down to 68 projects. Please see the Appendix for the complete list.
2. Analyse the Preferred Option which is discussed in the Economic Case.
3. Classify the projects in the 'Long List' by scale, CO2 abatement, type and certainty.
4. Review the 'Long List' identified in Step 1 against the preferred option of the Economic Case (Step b) and bring forward the select projects into the 'Short List' based upon their certainty and alignment with the Economic Case.
5. Analyse the CAPEX, OPEX and CO2 abatement over time and ensure alignment with the Net-Zero-North-West goals.

The methodology uses the existing outputs from the other NZNW partner organisations as discussed in the Appendix summarising the work packages. The project pipeline has also been informed through research and stakeholder engagement with key players in the North West region.

2.2. Assumptions Driving the Pipeline

In order to produce this Investment Case, a number of assumptions on cost and value of projects and programmes have had to be applied. This is due to the immaturity of the majority of projects in the consortium (excluding HyNet NW) and the ability to access accurate data from individual project teams. However, assessment of CAPEX costs is compiled via discussions with project stakeholders. Less data is available on OPEX (operational costs). As a result, an assumption has been applied for most projects identified, an industry standard that OPEX represents circa 5% of CAPEX value per annum.

At this stage in the development of the investment proposition, a relatively broad-brush approach is appropriate to assemble the scale of the public and private sector investment required over two decades to ensure the North-West achieves its low carbon target by 2030 and zero carbon by 2040. As many of the projects are in the embryonic stage of development, it would be unrealistic to claim firm costs have been identified. Additionally, with all major engineering infrastructure projects that have multibillion-pound values, the range of accuracy of capex cost is wide. Even when concept design is reached, costs can be expected to move plus or minus 40%. Except HyNet, which has secured Stage One and Two Cluster Sequencing Competition successes and is progressing through FEED stage (Front End Engineering Design). Few other projects within the NZNW industrial decarbonisation ecosystem barely approach this level of FEED development stage. It is also assumed all existing large scale fossil fuelled power generating assets will be decarbonised through either CCS or Hydrogen in due course.

A mixture of sources have been used to develop a financial model:

- Data from project websites
- Understanding of project values (as emerging from the work on HyNet for example)
- Sector-wide knowledge based on activities undertaken in the North-West (work on Port Hydrogen, for example) and across other parts of the country in sub sectors such as nuclear, solar power and offshore wind.
- Desktop research into project values.

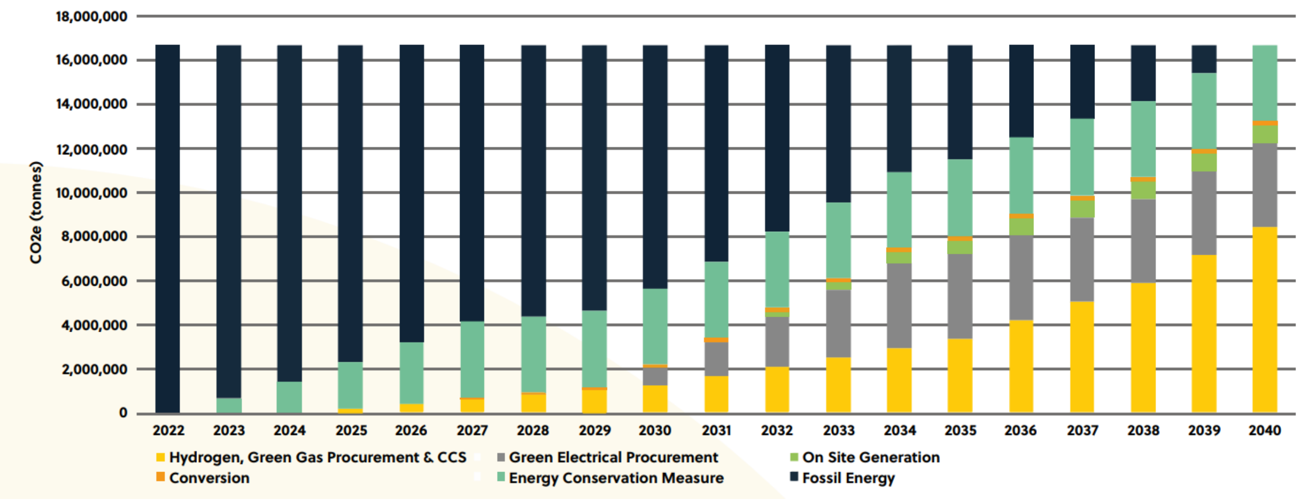
Please note that an assumption on the complete decarbonisation of existing power stations has been applied. That said however, does not necessarily reflect individual organisation's intentions.

Core to the development of the Financial Case has been the compiling of the pipeline of projects that deliver low carbon by 2030 and zero carbon by 2040. A considerable amount of effort went into building the long list of 150+ projects and then filtering of these down to a short-list of approximately 60 projects.

The pipeline should be treated as a "live" asset development tracker and not as a crystallised moment in time. The pipeline should be continuously updated as projects advance from "leads" to "prospects" and ultimately become "secured" projects. Keeping the pipeline up to date will also reflect which projects are stalling or being withdrawn, whilst other new projects can be added over the course of time, moving from earliest inception phase to become new leads and subsequently advance through the system.

One of the key features of the methodology is the adoption of the "Waterfall to Net Zero" model. This identifies the way a range of carbon abatement approaches and technologies will enable the region to reach a low carbon environment by 2030 and a Net Zero environment by 2040.

Figure 5: NW Industrial Consumers Action Plan Priorities



Source: NZNW Cluster Plan Interim Report (April 2022)

Each of the 60 projects shortlisted in the pipeline then went through a further round of analysis to arrive at a priority list of projects, by ranking the projects in terms of their ability to achieve the NZNW goals. The projects which did not make it onto the prioritised list then became the current "reserve" list. The prioritised projects were then categorised in line with the waterfall diagram categories as follows:

- Scope 1 energy efficiency
- Electricity energy efficiency
- Zero carbon electrification
- Power sector decarbonisation

- Industrial CCUS-enabled H2
- Industrial electrolytic H2
- Industrial CCUS fossil fuel
- Bio-energy Carbon Capture and Storage (BECCS)

Applying shortlisted pipeline projects to each of these specific waterfall sectors in the "full intervention" option identifies £29,645bn of projects and programmes that contribute to the ultimate Net Zero goal in 2040.

In addition to the projects and programmes themselves there is of course also the potential investment in the "interconnectors" between the elements and in this sense both power and gas distribution, predominantly through existing pipework and cable networks or new private facilities; but also through road, rail and sea transportation and importantly, storage facilities. It should also be noted that Macquarie recently made a significant investment into Transco and the confidence that multi-billion pound stake should offer to the market.

One clear conclusion from the assessment of commercial projects in the pipeline is that there is an abundance of projects which can ensure the North West Region achieves its Net Zero short and long-term targets. There are circa 47 projects and programmes identified with a combined capital value of just over £20bn. This represents the most cost- effective way of achieving desired carbon abatement goals. Another £50bn of projects have been identified which represent a reserve list of other prospective contributors shows the phenomenal level of ambition in the North- West's decarbonisation sector.

2.3. Short List Criteria

Having established these structures for identified and unidentified projects, the research was focused on the delivery and operation for a 19-year programme from 2021 to 2040. Because of the limited information available, only the released project Capital expenditure values analysed. Any gaps have been plugged with sensible assumptions to complete the analysis. There is no analysis of the operational costs to date, this will need to be included in the future development of the investment case. The carbon reduction has similarly been calculated using available data and drawing researched assumptions.

The pipeline forms the backbone of the investment business case proposition. Going forward it should be utilised by the NZNW / cluster plan team as a tracker for achieving Net Zero targets across the region. As projects rise up through the pipeline from "unidentified" through "leads" into "prospects" and ultimately to achieve "secured" status then their conversion factor improves alongside their contribution to carbon abatement.

The pipeline forms the basis for the Financial Case projecting, and in turn the investment support required from both public and private sector across the two decades leading up to 2040. The Financial Case sets out to establish, firstly the scale of the projects to achieve net-zero in the region, and secondly the "affordability" of the project. This will in turn define the level of support needed from Central Government to the projects via subsidy or other mechanism.

The pipeline of projects has been built via a comprehensive research exercise which initially identified a "long list" of more than 150 Net Zero projects and programmes. This list of projects was then refined to a short list of circa 60 projects via two main classifications.

Table 8: Classification for Refining Long List of Projects

Classification One: Linkage to Ecosystem	Classification Two: Project Maturity
A System-Based Solution	Secured
A Linked Strategy	Prospect
A Stand- Alone, Distinct Solution	Lead
	Unidentified

2.3.1. Classification One: Linkage to Ecosystem

The aspiration is that as time goes on and the live pipeline of work presented within this report develops, a range of sources of electrolytic ('green') hydrogen, derived from electrolysis using power generated from wind, solar and tidal, will increasingly 'plug-in' to the HyNet pipeline network.

To build the investment case, the tangible projects emerging within the region were analysed against a project profiling structure. This consisted of three categories for assessing the contribution that specific projects and programmes could make to the North West Net Zero roadmap. Under classification one, projects can either be within A) a system, B) a linked strategy or C) is a stand-alone, distinct solution.

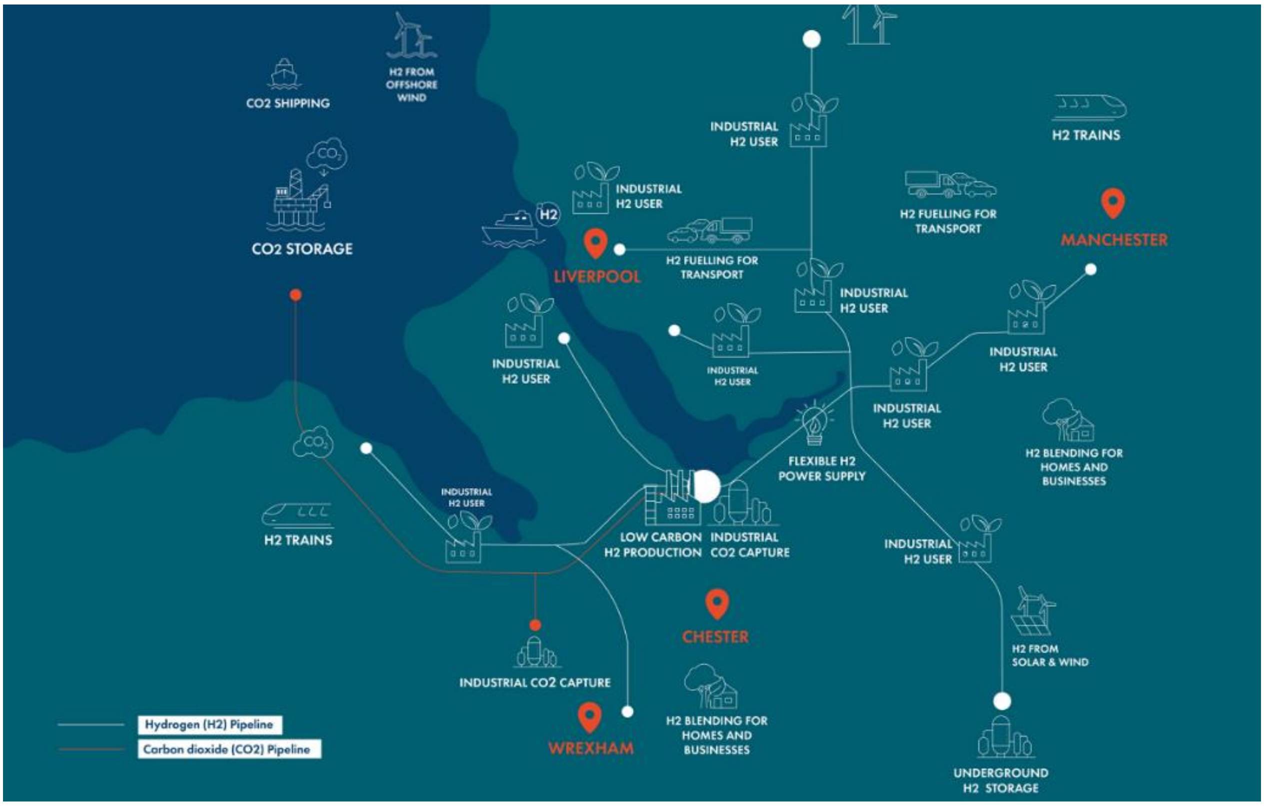
Analysing the projects together also highlighted the *greater* contribution they can make, when considered as a whole. This project categorisation could be used to assess the viability of emerging portfolios of Net Zero projects across the whole of the UK.

System Based Solutions

These are projects which enable a wide range of facilities to be brought forward on a systematic basis. Often linking together energy generators (suppliers) with distribution systems (distributors), end users (customers) and an emission capture system. Including, for example, HyNet North West.

System solutions work best where there is an infrastructure base supporting them, HyNet North West, being a supreme example of this working well. The areas' geography, with the River Mersey at the heart of the project, alongside its history as a hub for the manufacturing, industrial and commercial sectors that sets the scene for it to be a prime location for the infrastructure investment. The resultant concentration of emitters and energy intensive industries forms the strong East-West axis of built-up conurbations from Liverpool through to Manchester, forming the basis of the HyNet route.

Figure 6 HyNet Hydrogen and Carbon Dioxide Pipeline



Linked Strategies for Supply and Demand

It is the interconnectivity of the projects that forms the investment proposition. There is an importance to understand how the bigger picture view of the North West's portfolio of projects fit together. Whilst the first challenge of the commission is industrial decarbonisation, it is important to keep sight of the wider picture and route to Net Zero in 2040. For example, all the sub-categories below are intrinsically linked by supply and demand:

- Common strategies for renewable or low carbon feedstocks
- On and off-shore wind, Tidal, Solar
- Nuclear (including small modular reactors)
- Geothermal & Biomass
- Heat Networks

Sectors and Vectors including:

- Sectors: Commercial heating solutions including Thermal Purchase Agreements and Heat Sale Agreements
- Vectors: Transport in all forms:- road, rail, air, sea.

Stand-alone Solutions

These are projects that will need to be developed either when it is impossible connect them to a wider ecosystem (due to geographical challenges or the absence of viable infrastructure), or when there are technological solutions that are by design standalone.

These projects play an important role to hook localities or customers into system-based solutions. In the north-west, stand-alone solutions must be considered due to the rural nature of the region, with 250,000 Ha of its land designated as green belt, agricultural land or country park.

2.3.2. Classification Two: Project Maturity

Under classification two, there are four stages based upon project maturity: 1) secured, 2) prospect, 3) lead and 4) unidentified. Each project then has its capital value and CO2 reduction impact factored to reduce the contribution of un-secured projects to the consortium. For Category 4 "unidentified," although still in early stages, if these projects progress further then it could have a significant impact in achieving Net Zero.

A conversion factor is then applied to each of the four stages in classification two. This will then feed into the financial model in the Financial Case. However, there are several caveats to note, including:

- Indicative CAPEX values are based on real project data where available in the public domain or benchmark data
- Cashflow forecast is based on programme where available, with spend evenly distributed by year from construction start to operation unless project specific information is available
- Where no programme information is available, cashflow forecast is based on an assumed programme related similar scheme
- Indicative CAPEX values are factored based on the methodology shown in Table 9 below.
- CO2 reduction / H2 production data is inconsistently presented or recorded in information provided in the public domain. Therefore, data is based on sound assumptions.
- The pipeline has been factored in terms of project probability, an outline of this is given below.

The factored CAPEX for each of the projects has been distributed in to a cashflow to 2040. This will help identify private and public spending requirements across the next 20 years to meet Net Zero targets.

Table 9 Pipeline Metric Justification

% Hit Rate	Stage	Justification
0%	Any	•Too early to identify income
10%	Idea stage	•Developing project scope •Potential to develop from other projects
25%	Prior to full business case	•Some feasibility work done •Some stakeholder backing •Requires further development/ full 5CBP • considered or explored with some investment in pilots
50%	Developed business case	•Strong scope of work with stakeholder backing •Developed investment strategy
75%	Business case with funding identified	•Feasibility stage completed •Likely to go ahead in the next 1-10 years •Early stage planning for project to start
100%	Already started	•Project is in motion •Project outlined as secured

2.3.3. Preliminary Options List

After a robust analysis of the long list of projects in the pipeline, the short list was developed based on the strategic fit and which projects would most economically achieve the 2030 and 2040 Carbon targets. This shortlist of pipeline options was then ultimately refined to the "preferred option" which will be discussed in detail in the Economic Case. To select the preferred option, further analysis was undertaken against six options. Each option considered required the assessment of the pipeline of shortlisted options to consider how they could contribute to the option. In summary, herewith below outlines the six options considere

Options
Option 1: 'Do nothing' is essentially what the private market would deliver without any further government intervention or support to that already announced and confirmed contractually to date. It forms the base case counterfactual against which to assess each of the 'intervention' options. Under this option, there is no HyNet or any other major industrial decarbonisation projects, though arguably some energy efficiency improvements are likely to happen without government support. It also seems reasonable that power sector decarbonisation will happen to a larger extent. However, whilst there is a clear stated government ambition to fully decarbonise the electricity grid by 2035, it is noted that this is not a legally binding commitment, and that NZNW-sponsored interventions such as hydrogen gas-fired power stations (CCGT), or those with carbon capture, could support the process and may even be necessary to it.
Option 2: 'De-minimis decarbonisation pathway' is based on likely government support that been strongly signalled and consistent with wider stated government strategic objectives (e.g. the first stages of the HyNet project). This option gets us barely halfway to industrial Net Zero by 2040. However, the idea is that the investment proposition is going above and beyond interventions reasonably likely to happen anyway. Under this option, HyNet is developed out from 2025 as envisaged by the consortium as per the proposition submitted to the BEIS Cluster Sequencing for CCUS deployment, with two first of kind ATRs producing around 1GW of hydrogen energy by 2030, as well as other major industrial decarbonisation projects. Some hydrogen production could support low carbon dispatchable power, moderately increasing the contribution of power sector decarbonisation under this option versus 'do nothing'. A strong pipeline of BECCS projects means they will make a significant contribution even under de minimis.
Option 3: 'Maximised industrial CCUS-enabled and nuclear electrolytic hydrogen Net Zero pathway' utilizes a near-full mix of intervention types, producing the same the amount of hydrogen produced compared to the other 'Net Zero' options (4-6) – but with nearly all hydrogen produced through industrial CCUS-enabled and nuclear electrolytic from SMRS based at Moorside – and only a residual role for renewables hydrogen production. Unlike the other options, it includes a modest hydrogen transmission network (pipelines) in Cumbria, extending the reach of H2 across the NW.
Option 4: 'Mixed Net Zero pathway' utilises the fullest mix of intervention types to maximise diversification – power sector decarbonisation, industrial CCUS-enabled H2, industrial CCUS, industrial electrolytic H2, BECCS and energy efficiency measures. Together, the projects underpinning these intervention types get us fully to industrial decarbonisation by 2040.
Option 5: 'Maximised industrial CCUS-enabled H2 Net Zero pathway' is a variant of the mixed pathway, above, replacing half the industrial electrolytic hydrogen with industrial CCUS enabled hydrogen so that the region still make it to full industrial decarbonisation by 2040. This would most likely occur through additional CCUS enabled hydrogen beyond Stanlow, which could be based around Barrow and Morecambe Bay. It means only a very modest contribution from electrolytic hydrogen.
Option 6: 'Maximised industrial electrolytic H2 Net Zero pathway' is a variant of the mixed pathway, above, replacing significant industrial CCUS hydrogen with electrolytic hydrogen so that the region still make it to full industrial decarbonisation by 2040. Under this option, the only industrial CCUS hydrogen would be from HyNet 'phase 1'. That is, HyNet would developed out only as per the proposition submitted to the BEIS Cluster Sequencing for CCUS deployment, with two first of kind ATRs producing around 1GW of hydrogen energy by 2030, but no further. This pathway would require massive additional power generation from renewables and power network reinforcement (beyond the already significant challenges) and upgrades and this is likely to make the option prohibitively expensive.

2.4. Potential CO2 Savings

The analysis that follows considers the list of 68 projects that make up the short-list pipeline. Using the metrics described above for relative project stages, a factored and unfactored pipeline CAPEX has been derived. The factored CAPEX for each of the projects has been distributed across a cashflow to 2040. This will help identify private and public spending requirements across the next 20 years to meet Net Zero targets. In the current, live and work in progress state, the total quantified capital requirement can be quantified at over **£34 billion (unfactored) or £23.8 billion (factored).** Figure 7 below shows both the factored and unfactored CO2 saving potential of the pipeline for where project data was available.

Figure 7 Pipeline CAPEX analysis: total unfactored and factored CO2 savings in tonnes per annum

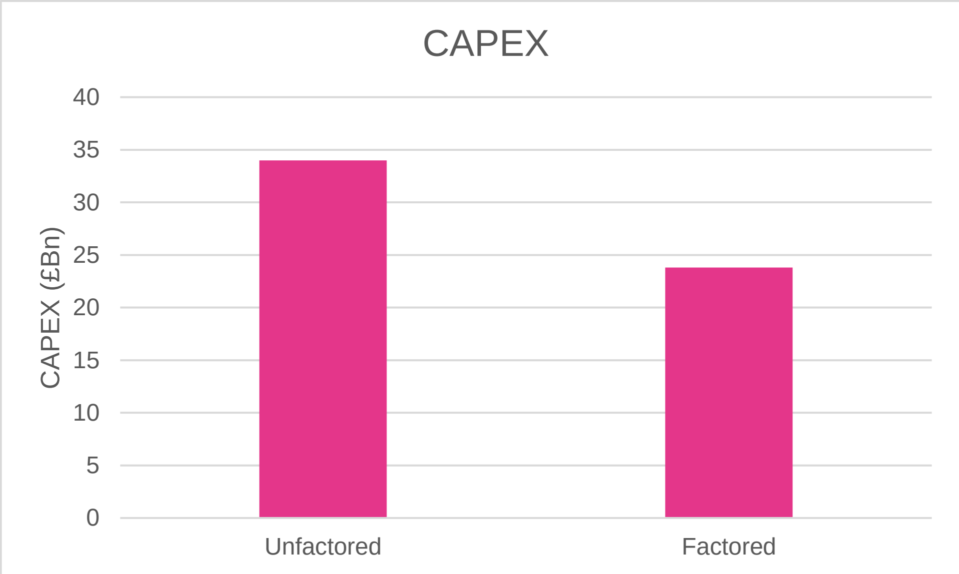
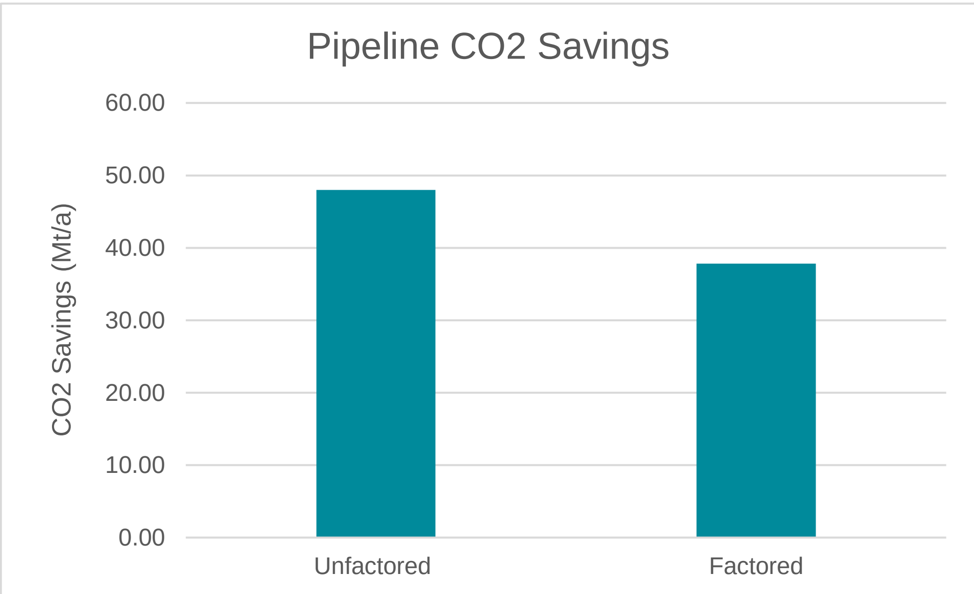


Figure 8 Pipeline CO2 analysis: total unfactored and factored CO2 savings in tonnes per annum



At 10,000,000t of annual CO2 savings, HyNet North West represents the project with the most significant CO2 reduction. This is closely followed by the roll out of five SMR's and decarbonisation of Stanlow Refinery at 8,900,000t and 8,500,000t, respectively. This is followed by Northern Tidal Power Gateways scheme and the rollout of the Crown Estate Round 4 Wind Farm.

3.

THE ECONOMIC CASE

3. The Economic Case

In the context of NZNW, the Economic Case is about identifying the pathway (the ‘option’) to North West decarbonisation by 2040 that delivers the best value for money, or in other words, how benefits relate to public costs.

“The purpose of the economic dimension of the business case is to identify the proposal that delivers best public value to society, including wider social and environmental effects.”[9]

“The economic dimension is the analytical heart of a business case where detailed option development and selection through use of appraisal takes place.”[10]

There are many possible pathways to decarbonisation. These are differentiated by their varying combination of decarbonisation projects put forward between now and 2040 in the North West. A “project” is defined as a specific piece of decarbonisation (or low carbon) infrastructure such as a 350MW hydrogen production plant using autothermal reforming (ATR), producing so-called ‘blue hydrogen’; or a nuclear small modular reactor (SMR).

As set out in the Strategic Case – Part A, NZNW stakeholders have provisionally agreed the following strategic objectives as noted in the Net Zero North West Cluster Plan:

- Becoming a low carbon industrial cluster by 2030, and becoming (or positioning to be) the world's first Net Zero industrial cluster by 2040
- Maximising the economic opportunity regionally of decarbonisation, including:
- Establishing and growing domestic supply chains in newer green technologies
- A highly diversified offer of different energy vectors
- Harnessing regional (and national) strengths and comparative advantages
- Energy security and reducing dependency on foreign energy supplies, particularly of hydrocarbons (including natural gas)

Whilst the focus of this Economic Case is inevitably on industrial decarbonisation in the North West, wider decarbonisation is considered peripherally. This Economic Case has been developed to slightly beyond Strategic Outline Case (SOC) level.

3.1. Economic Assumptions

The Economic Case assesses the economic impacts of NZNW and whether value for money for the public sector is optimised. This involves drawing up a ‘longlist’ of possible pathways (‘options’) with all the options assessed qualitatively to narrow them down to a shortlist. A fuller, quantitative, assessment of the shortlist pathways (‘options’) is then undertaken to identify which one emerges as the ‘preferred option’, primarily based on it being the best value for money.

There are several important assumptions driving the value for money assessment:

- All shortlisted options have been appraised over a 30-year period to reflect a typical major infrastructure asset’s lifetime
- Where ‘present value’ figures are presented, they use the standard 3.5 percent per annum discount factor (applied to real terms values)[11]
- All monetised values are in real terms (2022 money); they are not adjusted for inflation in future years

[9] P8 Guide to developing the Project Business Case (publishing.service.gov.uk)
[10] P20 The Green Book (publishing.service.gov.uk)
[11] The discount factor reduces to 3% per annum beyond 30 years from now (i.e. from 2052), affecting projects starting later

- The costs and benefits of the 'intervention' options are presented in net terms – that is, they are compared to and net of the 'do nothing' base case under which some decarbonisation would happen anyway
- Optimism bias has been calculated and included as standard in the economic costs of each shortlisted pathway ('option')

The assessment of economic benefits and economic costs has been undertaken in compliance with the latest HM Treasury Green Book (2022) and relevant Government Departmental guidance such as that published by BEIS and DLUHC. As set out in the HM Treasury Green Book, options should be appraised on the basis of the benefit cost ratio (BCR), which reflects the private and external benefits – here external, mainly green house gas (GhG) abatement, compared to the net public sector cost.

In addition to the calculation of the BCR for each option in line with the HM Treasury Green Book's (and DLUCH's) recommended methodology, the strategic importance and local economic impact in terms of additional jobs and GVA is also assessed.

3.2. Value for Money Assessment

Turning to value for money (VFM), instinctively, a *de-minimis decarbonisation pathway* should offer a very cost-effective pathway (and possibly offer the best VFM) given it takes the low hanging fruit of most cost-effective options to decarbonise. In other words, it is situated where the 'diminishing returns' of carbon reduction to pounds and pence investment have yet to fully kick in. But it does not offer a pathway or plan to get the NW to Net Zero by 2040, getting it barely halfway.

VFM will also be driven strongly by other factors, including economies of scale and the regional and national comparative advantages described. The de-minimis option is not able to fully capitalise on these aspects and therefore the question of which option offers best VFM is less straightforward.

Because of the need to achieve VFM, harnessing economies of scale is an essential pathway design consideration. But it comes at the risk of 'putting all the eggs in one basket', where one that major more a particular type of hydrogen production. On the production of industrial CCUS enabled hydrogen, a *maximised industrial CCUS-enabled H2 Net Zero pathway* offers considerable economies of scale that derive from replicating first of kind installations and maximising the use of shared infrastructure such as the hydrogen transmission network and hydrogen storage, but risks include technological (first of kind still to be built, success resting on one technology) and price volatility of natural gas - intertwined with energy security issues. Similarly with the *maximised industrial electrolytic H2 Net Zero pathway*, where although the technology is reasonably established the main risk is it remains expensive and costs do not fall over time as much as anticipated, with consequential impacts on the levellised cost.

Further complexity in selecting the best option arises from the issue of constraints. The Hamilton, Hamilton North and Lennox gas / oil fields have capacity for around 200MtCO2 (200 million), or around 20 years for carbon capture of 10MtCO2 per annum. This could pose an issue for *a mixed Net Zero pathway'* capturing more CO2 than this and no additional CO2 storage. A *maximised industrial CCUS-enabled H2 Net Zero pathway* could get around this constraint by creating an additional 1,000MtCO2 (1 billion) of CO2 storage capacity in the Morecambe North and Morecambe South fields in Morecambe Bay, off Barrow, connected also to HyNet. However, this increases the lack of diversification risk it increases dependency on natural gas and associated issues with that. Alternatively, it potentially positions the NW to go 'beyond Net Zero' and 'export' hydrogen to other regions of the UK.

For industrial electrolytic hydrogen a key constraint (and cost impactor) is the pre-requisite for substantial power grid upgrades that are likely required to support it, as well as renewables generation. It will already be a major challenge to decarbonise the power grid by 2035 and in parallel increase electricity generation and transmission to cope with the electrification of transport (mainly cars and vans) and domestic heating (e.g. the increased use of heat pumps in homes). Adding an additional element of demand for electricity on top of these things to make electrolytic hydrogen may be a step to far, unless using local / behind the meter renewables generation. This seems likely to be the case up until 2035. It is observed that some of the projects to increase power generation that could be used for hydrogen production, such as Mersey Tidal, are very expensive. A *maximised industrial electrolytic H2 Net Zero pathway* is likely to rely more expensive projects such as the Mersey Tidal as well as taking a significant amount of electricity generation from offshore windfarms in the Irish Sea, which again may be a stretch in the wider electricity demand context.

Finally, *Maximised industrial CCUS-enabled and nuclear electrolytic hydrogen Net Zero pathway* offers a potential solution to the issues around using renewables in hydrogen production, by substituting in nuclear electrolytic hydrogen, including through the use of SMRs attached directly to electrolysers for hydrogen production, possibly based around Sellafield or Moorside, though other locations may be viable. Some industry experts believe SMRs could be available as early as 2030.

Interestingly, Moorside could become a second hydrogen production cluster to Stanlow, with a mix of industrial CCUS enabled hydrogen and nuclear electrolytic hydrogen production. From this discussion the long list of six options emerges as summarised in the Table 10 below.

Table 10: Options Description

Options
Option 1: 'Do nothing' is essentially what the private market would deliver without any further government intervention or support to that already announced and confirmed contractually to date. It forms the base case counterfactual against which to assess each 'intervention' options. Under this option, there is no HyNet or any other major industrial decarbonisation projects, though arguably some energy efficiency improvements are likely to happen without government support. It also seems reasonable that power sector decarbonisation will happen to a larger extent. However, whilst there is a clear stated government ambition to fully decarbonise the electricity grid by 2035[12], it is noted that this is not a legally binding commitment, and that NZNW-sponsored interventions such as hydrogen gas-fired power stations (CCGT), or those with carbon capture, could support the process and may even be necessary to it.
Option 2: 'De-minimis decarbonisation pathway' is based on likely government support that been strongly signalled and consistent with wider stated government strategic objectives (e.g. the first stages of the HyNet project). This option gets us barely halfway to industrial Net Zero by 2040. However, the idea is that the investment proposition is going above and beyond interventions reasonably likely to happen anyway. Under this option, HyNet is developed out from 2025 as envisaged by the consortium as per the proposition submitted to the BEIS Cluster Sequencing for CCUS deployment, with two first of kind ATRs producing around 1GW of hydrogen energy by 2030, as well as other major industrial decarbonisation projects. Some hydrogen production could support low carbon dispatchable power, moderately increasing the contribution of power sector decarbonisation under this option versus 'do nothing'. A strong pipeline of BECCS projects means they will make a significant contribution even under de minimis.
Option 3: 'Maximised industrial CCUS-enabled and nuclear electrolytic hydrogen Net Zero pathway' utilizes a near-full mix of intervention types, producing the same the amount of hydrogen produced compared to the other 'Net Zero' options (4-6) – but with nearly all hydrogen produced through industrial CCUS-enabled and nuclear electrolytic from SMRS based at Moorside – and only a residual role for renewables hydrogen production. Unlike the other options, it includes a modest hydrogen transmission network (pipelines) in Cumbria, extending the reach of H2 across the NW.
Option 4: 'Mixed Net Zero pathway' utilises the fullest mix of intervention types to maximise diversification – power sector decarbonisation, industrial CCUS-enabled H2, industrial CCUS, industrial electrolytic H2, BECCS and energy efficiency measures. Together, the projects underpinning these intervention types get us fully to industrial decarbonisation by 2040.
Option 5: 'Maximised industrial CCUS-enabled H2 Net Zero pathway' is a variant of the mixed pathway, above, replacing half the industrial electrolytic hydrogen with industrial CCUS enabled hydrogen so that the region still make it to full industrial decarbonisation by 2040. This would most likely occur through additional CCUS enabled hydrogen beyond Stanlow, which could be based around Barrow and Morecambe Bay. It means only a very modest contribution from electrolytic hydrogen.
Option 6: 'Maximised industrial electrolytic H2 Net Zero pathway' is a variant of the mixed pathway, above, replacing significant industrial CCUS hydrogen with electrolytic hydrogen so that the region still make it to full industrial decarbonisation by 2040. Under this option, the only industrial CCUS hydrogen would be from HyNet 'phase 1'. That is, HyNet would developed out only as per the proposition submitted to the BEIS Cluster Sequencing for CCUS deployment, with two first of kind ATRs producing around 1GW of hydrogen energy by 2030, but no further. This pathway would require massive additional power generation from renewables and power network reinforcement (beyond the already significant challenges) and upgrades and this is likely to make the option prohibitively expensive.

[12] Plans unveiled to decarbonise UK power system by 2035 - GOV.UK (www.gov.uk)

Error! Reference source not found. Error! Reference source not found. shows the projects under each option as discussed in the table above.

3.3. Critical Success Factors

Getting to a shortlist of options involves the assessment the longlist options discussed, based on their ability to meet a range of Critical Success Factors (CSFs) as set out in the HM Treasury Green Book and agreed with NZNW stakeholders. CSFs are conditions that any pathway ('option') must meet to progress from the longlist to the shortlist.

"Demonstrating public value requires a wide range of realistic options to be appraised (long-list), in terms of how well they meet the spending objectives and critical success factors for the scheme; and then a reduced number of possible options (short-list) to be examined in further detail."[13] The HMT Treasury Green Book CSFs agreed with NZNW stakeholders, provisionally, are:

- Strategic fit and meets the needs
- Potential value for money
- Supplier capacity & capability

The assessment of the longlist options against these CSFs is as follows:

Table 11: Longlist assessment against CSFs

	Strategic Fit & Meets the Needs	Potential Value for Money	Supplier Capacity & Capability	Conclusion
Option 1: Do nothing	Does not meet objectives	No additional benefits	No change	**Base case**
Option 2: De minimis decarbonisation pathway	Sufficiently meets objectives to 2030, potentially positions for Net Zero by 2040 e.g. with new technologies, but with significant risk it won't	Likely to represent good VFM because of lack of diminishing returns	The most deliverable on basis of current governance arrangements and suppliers	**Shortlist**
Option 3: Maximised industrial CCUS-enabled & nuclear electrolytic H2 Net Zero pathway	Provides a decent diversity of energy vectors likely to maximise economic opportunity. Maximises regional comparative advantages.	Likely to represent good VFM because of strong scale economies	Deliverable on basis of current governance arrangements but somewhat dependent on foreign suppliers, some risk around new technologies (SMRs)	**Shortlist**
Option 4: Mixed Net Zero pathway	Provides a good diversity of energy vectors likely to maximise economic opportunity. Harnesses regional comparative advantages.	Potentially good VFM but does not maximise scale economies	Deliverable on basis of current governance arrangements but somewhat dependent on foreign suppliers, some risk around new technologies (SMRs)	**Shortlist**
Option 5: Maximised industrial CCUS-enabled H2 Net Zero pathway	Does not meet objectives around maximising economic opportunity and energy security (locks in dependence on natural gas), requires full electricity grid decarbonisation without NZNW sponsorship. Lacks risk diversification.	Likely to represent best VFM because of maximum scale economies	Deliverable on basis of current governance arrangements but potentially too dependent on foreign suppliers	**Rule out**
Option 6: Maximised industrial electrolytic H2 Net Zero pathway	Provides a good diversity of energy vectors likely to maximise economic opportunity. But does not harness regional comparative advantage to the full.	Unlikely to deliver VFM because of required substantial power grid upgrades and supporting power generation, electrolysers expensive	Deliverable on basis of current governance arrangements and suppliers, some risk around new technologies and potentially to dependent on foreign suppliers. Potential generation constraints.	**Rule out**

[13] P8 Guide to developing the Project Business Case

On the basis of analysis of the six options against the CSFs, four options (and three intervention options) are carried forward to the shortlist for more detailed assessment:

- Option 1: 'Do nothing' (or 'business as usual')
- Option 2: 'De minimis pathway'
- Option 3: 'Maximised industrial CCUS-enabled & nuclear electrolytic H2 Net Zero pathway'
- Option 4: 'Mixed Net Zero pathway'

Option 1, the do nothing option, is shortlisted as the base case to compare the intervention options against.

Option 2 is taken forward, but it is questionable whether it has sufficient strategic fit and meets NZNW needs. It does not get the NW industrial cluster to Net Zero by 2040 but does meet the criteria for delivering a low carbon cluster by 2030 - so *positions* for potential Net Zero by 2040. It is likely to represent good VFM and is clearly the most deliverable of the options. However, it has the significant risk that a lack of a long-term vision and planning could jeopardise delivery of a Net Zero industrial cluster by 2040.

Option 3 is taken forward as a strong contender because it probably maximises regional comparative advantages - around industrial CCUS enabled hydrogen, world-class nuclear expertise, and offshore wind - in hydrogen production, with strong scale economy credentials. It also has the potential to develop out a hydrogen production cluster around Moorside which, scaled-up further beyond set out here, could support hydrogen supply to industrial clusters beyond the NW region. It could also support wider adoption of hydrogen (e.g. for use in domestic central heating systems) within the region.

Option 4 is taken forward as the preferred option at this point because it provides the solution most likely to meet all three of the CSFs. It has a good diversity of energy vectors, is affordable - with potential VFM, 'hedges bets' across different future technologies to reduce risk, utilises and grows domestic supply chains in a way that has plausible delivery aspects, and draws on regional strengths. However, option 3 is likely to run a close second.

3.4. Economic Costs

The financial costs presented in this section for each option are derived bottom up from the constituent projects of the pathway. As such, these costs are a mixture of preliminary Front End Engineering Design (pre-FEED)[14] and benchmark estimates from NZNW stakeholders where there has been no pre-FEED to date - i.e. with the merely conceptual projects – depending on the project.

As such, the financial costs are largely illustrative and has levels of uncertainty. Some costs are also excluded at this stage, the most significant being those associated with major power grid infrastructure upgrades to accommodate extra electricity generation and its transmission across the network, to meet the higher electricity demand associated with some of the options. However, the expert leads across the NZNW Cluster Plan[15] have affirmed the financial costs presented are reasonable and plausible. Financial costs are translated to economic costs for the Economic Case through the application of:

- A GDP deflator, where those costs are set out in nominal terms, to covert sums in future years into constant (todays) prices

[14] Front End Engineering Design (FEED) is conducted after the concept and feasibility studies, and is used to provide further clarity on project scope, programme and cost to support the investment decision and sanction process. The objective is to develop the project design to sufficient detail to support a plus or minus 15 percent project cost estimate. The American Association of Cost Engineers (AACE) employs a number of levels of analysis to categorise the accuracy level of capital costs, depending on how much engineering and design work has been undertaken and costs itemised. Where pre-FEED has not been completed for the project it will be no better than AACE level 5 in the initial stages; level 5 being a plus or minus 40 percent project cost estimations.

[15] See Appendix for the description of the Work Packages

- The HM Treasury discount rate of 3.5 percent per annum to reflect time preference and the growth in per capita consumption with time
- Optimism bias to capture the proven tendency for appraisers to be optimistically biased about key project parameters, including capital costs, operating costs and project duration

"Discounting is a technique used to compare costs and benefits occurring over different periods of time on a consistent basis…Discounting in appraisal of social value is based on the concept of time preference – that generally people prefer to receive goods and services now rather than later."[16] The optimism bias (OB) applied to the option costs have been estimated based on the Supplementary HM Treasury Green Book guidance but no mitigations have been applied.[17]

Table 12: Optimism Bias by type of intervention

	Capital / operating expenditure	
	Lower bound	Upper bound
Standard Buildings	+2%	+24%
Non-standard Buildings	+4%	+51%
Standard Civil Engineering	+3%	+44%
Non-standard Civil Engineering	+6%	+66%
Equipment / Development	+10%	+200%
Outsourcing	+0%	+41%

OB has therefore been applied at a level between the upper bound for 'standard civil engineering' and that of 'non-standard civil' engineering at this stage, at 55% uniformly across all projects. The next stage business case should look to differentiate OB by project – with OB applied to more conceptual projects - and explore mitigations of the contributing factors including as proposals are further developed. The economic costs for each shortlisted intervention option - based illustratively on 100% public subsidy - have been estimated accordingly, as follows:

Table 13: Estimated economic costs, by NZNW option

	CAPEX (£ billion)	OPEX / 30 years (£ billion)	TOTAL (£ billion)
Option 2 – De minimis decarbonisation pathway	6.7	4.7	11.5
Option 3 - Maximised industrial CCUS-enabled & nuclear electrolytic H2 Net Zero pathway	32.4	22.6	55.0
Option 4 – Mixed Net Zero pathway	34.0	24.5	58.5

The economic cost is the cost to the public sector (in capital and/or revenue) and will depend on the level of subsidy. Although 100% subsidy is not likely, it is useful as an upper bound on the economic cost. The nature of some of the financing mechanisms likely to be adopted, such as CFDs, means that predicting the level of subsidy is complicated and difficult, and would need to be informed by a Financial Case developed to outline business case stage. This would need to include an analysis of the levellised cost of energy (LCOE) estimates for the interventions versus do nothing. The underlying financial costs (and public sector costs at 100% subsidy), for reference, are:

16 P45 The Green Book
17 P2 The Green Book Optimism Bias

Table 14: Estimated financial costs, by NZNW option

	CAPEX (£ billion)	OPEX / 30 years (£ billion)	TOTAL (£ billion)
Option 2 – De minimis decarbonisation pathway	5.0	5.9	10.9
Option 3 - Maximised industrial CCUS-enabled & nuclear electrolytic H2 Net Zero pathway	27.6	33.1	60.7
Option 4 – Mixed Net Zero pathway	29.6	35.8	65.5

3.5. Economic Benefits

Carbon dioxide is a Greenhouse Gas (GHG) which contributes to global warming. NZNW would make a major contribution to the UK's new targets enshrined in law to reduce emissions by 78% by 2035, by tackling head on the hard to abate industrial sector, including by establishing a market for hydrogen. UK law requires it to bring all GHG emissions to Net Zero by 2050.

The main economic benefit – or 'value to society' - of NZNW and its objectives is the reduction in CO2 emissions, with industrial decarbonisation first and foremost. Full industrial decarbonisation with the 'Net Zero' pathways - would amount to a reduction in industrial net emissions from the current 16.7MtCO2 p.a. to zero by 2040. The industrial sector is harder than others to decarbonise because much of it cannot be electrified. However, the industrial consumption of natural gas can be replaced with hydrogen ('fuel switching') which is why hydrogen is critical to any Net Zero pathway.

The value to society of GHG emission reductions across different gases is measured in tCO2 equivalent, using carbon pricing. Implicitly, this is the value of averted climate change that would be damaging both socially and economically. The latest BEIS supplementary guidance to HM Treasury's Green Book includes traded carbon prices for use in investment appraisal. These reflect the estimated valuation of emissions consistent with getting us to Net Zero by 2050 and within the UK carbon budgets:

Table 15: Traded Carbon Prices for Investment Appraisal, £/tCO2 e (2020 money)

	2022	2023	2024	2025	2026	2027	2028	2029	2030
Low scenario	£124.00	£126.00	£128.00	£130.00	£132.00	£134.00	£136.00	£138.00	£140.00
Central scenario	£248.00	£252.00	£256.00	£260.00	£264.00	£268.00	£272.00	£276.00	£280.00
High scenario	£373.00	£378.00	£384.00	£390.00	£396.00	£402.00	£408.00	£414.00	£420.00

Source: Department for Business, Energy and Industrial Strategy (BEIS) [18]

Additionality is the extent to which activity (activity here being decarbonisation) takes place at all, or on a larger scale, or earlier as a result of the intervention.

Although the industrial sector is more challenging in terms of decarbonisation, the value of each tCO2 reduction is the same regardless of the consumer. Whilst the economic benefits of CO2 reductions for consumers beyond the industrial sector are the same as for industrial consumers, the fact that the industrial sector is harder to decarbonise means interventions targeting it are likely to have higher levels of additionality - implicitly, therefore, the additional benefits per tCO2 reduction are likely to be higher much with interventions targeting the industrial sector. The level of benefit for each option depends on its outputs and the associated outcomes and impacts, in terms of CO2 reductions, over and above 'do nothing' (i.e. additional). The project level outputs, outcomes and impacts are set out in the following table. Again, the *industrial* CO2 reductions should be taken in the context of the required 16.7MtCO2 to achieve the NZNW industrial cluster by 2040.

[18] Valuation of greenhouse gas emissions: for policy appraisal and evaluation - GOV.UK (www.gov.uk)

The quantified GHG reduction outcomes for each option - once fully up and running – are:

Table 16: Estimated Outcomes, By Option

Option	Additional CO2 reductions Including do nothing MtCO2 p.a., all (industrial only)	Additional CO2 reductions, over and above do nothing, MtCO2 p.a., all (industrial only)
Option 2 – De minimis decarbonisation pathway	23.5 (8.4)	5.5 (3.3)
Option 3 - Maximised industrial CCUS-enabled & nuclear electrolytic H2 Net Zero pathway	45.0 (16.7)	27.0 (11.6)
Option 4 – Mixed Net Zero pathway	46.5 (17.1)	28.5 (12.0)

The monetised economic benefit of these outcomes is compared to their costs using the Benefit Cost Ratio (BCR). The DLUCH guidance states that the BCR should be the ratio of net benefits (i.e. after public costs have been netted off) to public costs. The cost is the economic, as opposed to the financial. The following initial BCRs assume a 100% public subsidy:

Table 17: Estimated Initial Benefit Cost Ratios

Option	Cost (CAPEX & OPEX) £ billion	Benefit (GHG reduction) £ billion	Net benefit £ billion	Initial Benefit Cost Ratio (BCR)
Option 2 – De minimis decarbonisation pathway	11.5	33.7	22.2	1.9
Option 3 - Maximised industrial CCUS-enabled & nuclear electrolytic H2 Net Zero pathway	55.0	157.6	102.6	1.9
Option 4 – mixed Net Zero pathway	58.5	167.0	108.5	1.9

Encouragingly, the initial BCR suggests that either shortlisted Net Zero pathway represents VFM that is as good as the de-minimis pathway (difference is too marginal to call) and, because of likely stronger non-monetised benefits, both Net Zero pathways emerge as joint-preferred at this stage. *It must be made quite clear that whilst the de-minimis pathway generates a 1.9 BCR, it* ***does not*** *achieve the region's 2040 decarbonisation target.* As well as these quantified benefits, there are other economic benefits associated with each option (beyond GHG reductions) that can be monetised but that are not at this (SOC) stage, including: improved air quality; and distributional benefits.

It is noted that national GVA (and associated jobs) demand should not be included in the BCR calculations to compare different options, according to the HM Treasury Green Book guidance:

"Changes to Gross Domestic Product (GDP), or Gross Value Added (GVA) or the use of Keynesian type multipliers arising from different options cannot provide useful information for choosing between options within a scheme and are therefore not part of the Green Book appraisal process. However, macro variables may well form part of the higher-level analytical research that informs identification of policy, and policy priorities."[19]

Further benefits associated with the Net Zero options not easily or at all monetisable, include:

- Augmentation of domestic supply chains
- Increased comparative advantage and associated export potential

[19] *Page 57* The Green Book

- Supporting R&D in nuclear SMR tech / electrolytic H2 and associated knowledge spill overs
- Supporting the creation of a wider hydrogen market in the UK beyond the NW
- Greater energy security than currently

3.6. Gross Value Added (GVA) and Jobs

Economic impacts are traditionally measured by Gross Value Added (GVA) and jobs. In national accounting terms, GVA is almost identical to Gross Domestic Product (GDP). Whereas GVA (and GDP) ascribe monetary values, jobs are usually more meaningful with greater political salience.[20]

Whilst GVA (and associated jobs) demand cannot be included in the BCR, it is an important consideration in the Economic Case particularly in relation to jobs demand arising deprived areas far from conditions of full employment or those with high levels of economic activity. This is considered more fully in the HM Treasury 'place-based approach'. Jobs impacts were also part of the assessment for the BEIS Phases 1 / 2 CCUS Cluster Sequencing Processes.

'Indirect' and 'induced' effects refer to how the 'direct' impacts of a firm (e.g. of a hydrogen production plant) propagate through the supply chains of that firm and beyond through to the broader economy:

- **Direct impacts** are the jobs and GVA supported directly by the economy activities of the firm (e.g. H2 plant) concerned
- **Indirect impacts** are the GVA and jobs supported through the supply chain to the firm (e.g. H2 plant) concerned
- **Induced impacts** traditionally, are the GVA and jobs supported as a result of employees of the firm (e.g. H2 plant) and its suppliers spending their money on domestic goods and services, for example, in the shops

Induced effects are not quantified in this analysis, because their use is discouraged in certain official quarters, including by HM Treasury. The UK Office for National Statistics (ONS) does not publish induced multipliers for use (though it is noted that the Scottish Government does). It is further observed that the induced effects in the BEIS Phases 1 / 2 CCUS Cluster Sequencing Processes have a very different meaning to the traditional induced impacts described; for BEIS they are about *induced congregations* – namely catalysation of Super Places and economic agglomeration.

In this analysis, the GVA and jobs demand modelling starts with CAPEX and OPEX estimates split into 'design', 'construction' and 'manufacturing' sector items. These sectoral estimates are then entered into an economic model. This model contains, amongst other things:

- ONS sectoral data that enable us to convert investment (or contractor turnover) into GVA;
- ONS sectoral labour productivity estimates to convert GVA into jobs

This first stage of modelling allows us to estimate the *direct* GVA and jobs demand. The model then applies ONS sectoral GVA and job indirect multipliers to estimate the *indirect* GVA and jobs demand impacts. The direct *plus* indirect GVA and jobs demand impacts represent the totality of the demand impacts across the economy modelled, at the national level; though the majority of the impacts are in the North West North Wales Regions. These GVA and jobs demand impacts are modelled across the CAPEX and OPEX phases.

[20] *GVA and jobs are two sides of the same coin. In economic production, 'value added' comes from turning inputs into outputs using capital and labour (jobs). The 'value added' is the difference between the value of the outputs and the value of the inputs. For example, using ammonia and energy to produce green hydrogen in a hydrogen production plant (the capital) manned by a team of operatives (the labour) creates a 'value-added' of hydrogen from ammonia. 'Gross Value Added' simply aggregates up all the 'value added(s)' of all the firms across the economy.*

Through this approach is found that the joint-preferred Option 4 will create total GVA demand of £36.5 billion, comprised of £16.6bn GVA demand from CAPEX (£29.6bn) and £19.9bn GVA demand from OPEX (£35.8bn). This is associated with demand for 22,545 jobs on average during the 13-year CAPEX phase and 11,753 jobs on average during the 30-year OPEX phase.

Demand for nearly 300,000 'job years' is created during the CAPEX phase (13 years x 22,545 jobs in each year).

Table 18: GVA and Jobs Demand from NZNW Joint-Preferred Option 4

	CAPEX phase (2023-35)			OPEX phase (2026 - 2065)*		
	Direct	Indirect	Total	Direct	Indirect	Total
Phase CAPEX or OPEX	£29,645m			£35,807m		
Phase GVA demand	£8,277m	£8,287m	£16,564m	£9,960m	£9,960m	£19,950m
Phase average annual GVA demand	£637m	£637m	£1,274m	£332m	£332m	£665m
Phase average jobs demand**	10,705	11,840	22,545	5,581	6,172	11,753
Phase average jobs displaced**	4,971	7,431	12,402	2,591	3,873	6,464

*Average asset lifetime 30 years, when various expiry dates between 2055 and 2065 depending when built
**at any point in time during the phase

Finally, the GVA and jobs demand impacts are **not** same as the GVA and jobs impacts on the economy – namely the additional GVA and jobs impacts. Additional impacts take account of the ability of supply to meet demand in the economy (e.g. displacement) and policy deadweight. In certain sectors, such as construction at the current time, there is a shortage of labour and skills such that the labour market is very tight. This means that, for example, building out the NZNW infrastructure and maintaining it will create demand for labour (jobs), but because there is a limited pool of construction labour, these jobs will simply be taken from other construction projects, either delaying it or preventing it from going ahead. This is an example of what economists mean by displacement, otherwise known as crowding out.

In the recent BEIS Phase 1 /2 Cluster Sequencing Processes, applicants were requested to treat all construction jobs over the period 2021 to 2030 as 100% displaced (i.e. all jobs taken from other projects / zero impact on the economy). However, displacement in other sectors such as manufacturing are likely to be lower, probably 50% or less. A flipside with manufacturing is that the relevant manufactured items such as machinery installed in the ATR hydrogen production plants, or manufactured solar panels, are likely to have less domestic content (will be imported) than construction items, and hence will less impact on UK PLC GVA and jobs to begin with.

Table 19: Main Modelling Assumptions & Inputs

- Sectoral split of CAPEX of 20% FEED (Front End Engineering & Design), 40% construction including civil engineering, 40% manufacturing uniformly across all projects - Sectoral domestic content of 90% FEED, 95% construction including civil engineering, 50% manufacturing - Annual OPEX on maintenance and repairs of the infrastructure asset of 5% of total CAPEX, applied to construction including civil engineering and manufacturing CAPEX only - Major infrastructure asset lifetime of 30 years - Sectoral UK GVA per head of £54,100 FEED, £57,700 construction including civil engineering, £73,100 manufacturing per FTE (sourced from ONS) - Sectoral indirect multipliers of 1.779 FEED, 2.495 construction, 1.751 manufacturing - CAPEX phase starting in 2023 and completing in 2035 inclusive (13 years), with first project completions in 2025, with each project taking between 3 and 7 years to build out, including phasing of build out (- e.g. Crown Estate R4 offshore windfarms = 7 years, from start 2024) - OPEX phase correspondingly staring in 2026 and ending in 2065 (40 years inclusive)

Finally, high levels of displacement of construction (including civil engineering) jobs underlines the importance of labour market supply-side interventions so that jobs demand translates into job impacts on the NW economy and, hence, genuine economic benefit (i.e. additionality) there. It is noted that such supply side labour market interventions can and should be included in BCRs where labour demand exists, but such interventions do not currently form a part of the NZNW investment proposition being considered in this Economic Case. These should ideally be integral.

4.

THE FINANCIAL CASE

4. Financial Case

The purpose of the Financial Case is to establish the current capital costs for the selected options identified in the Economic Case and to opine about the funding requirements needed to supply the projects. This section of the report will outline the capital costs of the NZNW 'options' and explain how they have been calculated. As with a Strategic Outline Case (SOC) this Financial Case will focus on providing an overview of the capital costs of the preferred way forward arrived at in the Economic Case, 'Option 4 – mixed Net Zero pathway', and an analysis of the full pipeline of projects.

The Financial Case would typically review the financial situation of 'organisation' carryings out the scheme. However, as this is a market led cluster, it is understood that the private sector will come forward with its projects and deliver these under their own financial constraints and balance sheets. An explanation of 'the organisations' financial situation and funding constraints has therefore not been included in this report as the "NZNW" cluster is not an entity that will raise funding centrally. It is expected that funding for the projects will be supported by some degree of public sector involvement, specifically via the impact of a Contract for Difference (CfD) for Hydrogen pricing, and the Dispatchable Power Agreement (DPA).

This investment case has been produced to provide an accurate description of scale the opportunity created by the NZNW cluster. Looking internationally at nations who have gone down this pathway before, success in deployment of renewables and early adoption of hydrogen strong regional clusters are essential.

The work undertaken in building this investment proposition builds upon the findings of the work package reports by the NZNW partner organisations as well as the Siemens Economic Investment prospectus produced and released earlier last year. This report will specifically look at how the investible projects will generate a supply to meet the significant demand created by the cluster of projects. The Financial Case will tangibly show the proposition for each option and some clear identity.

4.1. Investment Routes

Two main routes to investment have been identified: **public sector** and **private sector**. The symbiotic relationship between *pump prime state intervention*[21] in projects and programmes to generate viability; and private sector on or off-balance sheet investment has been considered when looking at both investment routes including the blended route.

Public Sector Investment or Intervention

In the form of grant, recoverable grant or loan to support the development and creation of infrastructure to underpin the commercial viability of projects, or interlinked projects. It can also be defined as a mechanism of pricing subsidies, contracts for difference or agreed strike prices to help give certainty to private companies. Or similar mechanisms to confirm purchase price/value, of energy produced whether, for example power produced or heat, or carbon captured.

Private Sector

Companies funding investment in their own projects, via their own capital funding or debt raising (institutional or via shareholders). Also defined as inward investment from organisations looking to become equity investors in a venture.

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[21] *Defined as government intervention within the economy, aimed at increasing aggregate demand, with the aim of resulting in a positive shift within the economy.*

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Companies funding investment in their own projects, via their own capital funding or debt raising (institutional or via shareholders). Also defined as inward investment from organisations looking to become equity investors in a venture.

4.3. Scale of the Pipeline

A Financial Case can only be as strong as the quality of the financial data available. This data comes from the commercial pipeline of decarbonisation investments to achieve the north-west's route to Net Zero. Through comprehensive desktop based and stakeholder review of projects, a long list of decarbonisation projects was collected as well as details on both CAPEX and OPEX costs.

In summary, the outcome is visibility of more than £35bn of identified investable existing projects alongside an additional option to bring forward, from the earliest stage, a range of yet to be crystallised, new projects. The Financial Case is built off the back of capital expenditure and operational expenditure cost analysis which is shown overleaf. Alongside this analysis, affordability issues and state funding streams must be considered. In terms of state intervention, or funding, is that the majority of this will come predominantly through CFD (Contract for difference) or subsidy or strike price of Hydrogen, or the recently established Dispatchable Power Agreement issued by the Low Carbon Contracts Company Ltd.

Direct support for hard infrastructure will be less significant, if offered at all, but its application will likely support underlying enabling infrastructure providing linkages or interconnectors rather than "projects". However, it should be noted that BEIS offer support to businesses with fuel switching via funding initiatives such as the Industrial Hydrogen Accelerator programme. This commission is seeking to support projects at a site level looking to develop between 1MW and 10MW of local Hydrogen production.

It is helpful to understand the breakdown of total CAPEX by project category as this shows the relative scale of the investment required by each of the 'interconnectors' that make up the systematic approach to the decarbonisation road map. It is likely that the different segments that contribute toward the total CAPEX will be associated with separate regulatory frameworks that in turn affect the funding mechanisms required. Therefore, defining the level of support needed from Central Government to the projects via subsidy or other mechanism.

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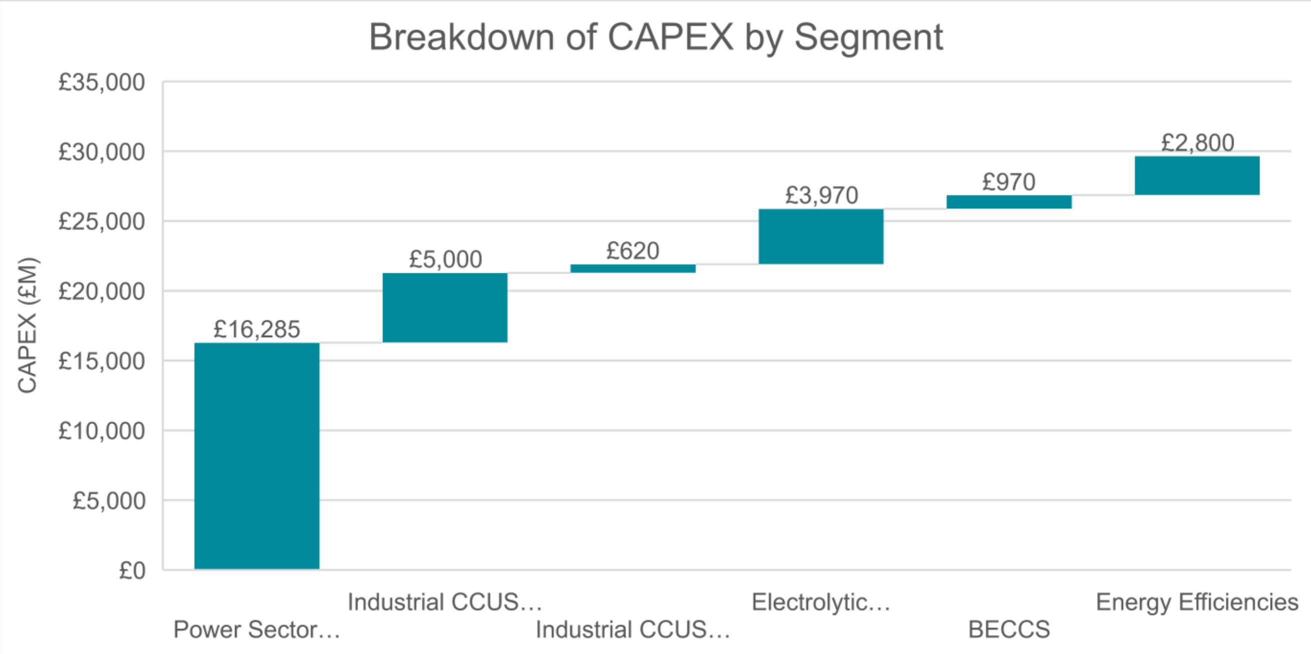
[22] Defined as government intervention within the economy, aimed at increasing aggregate demand, with the aim of resulting in a positive shift within the economy

Total CAPEX	Total CO2 Abatement (all)	Total CO2 Reductions (industrial)
£29,645Bn	46.47Mt	17.1Mt

Figure 9 Breakdown by CAPEX

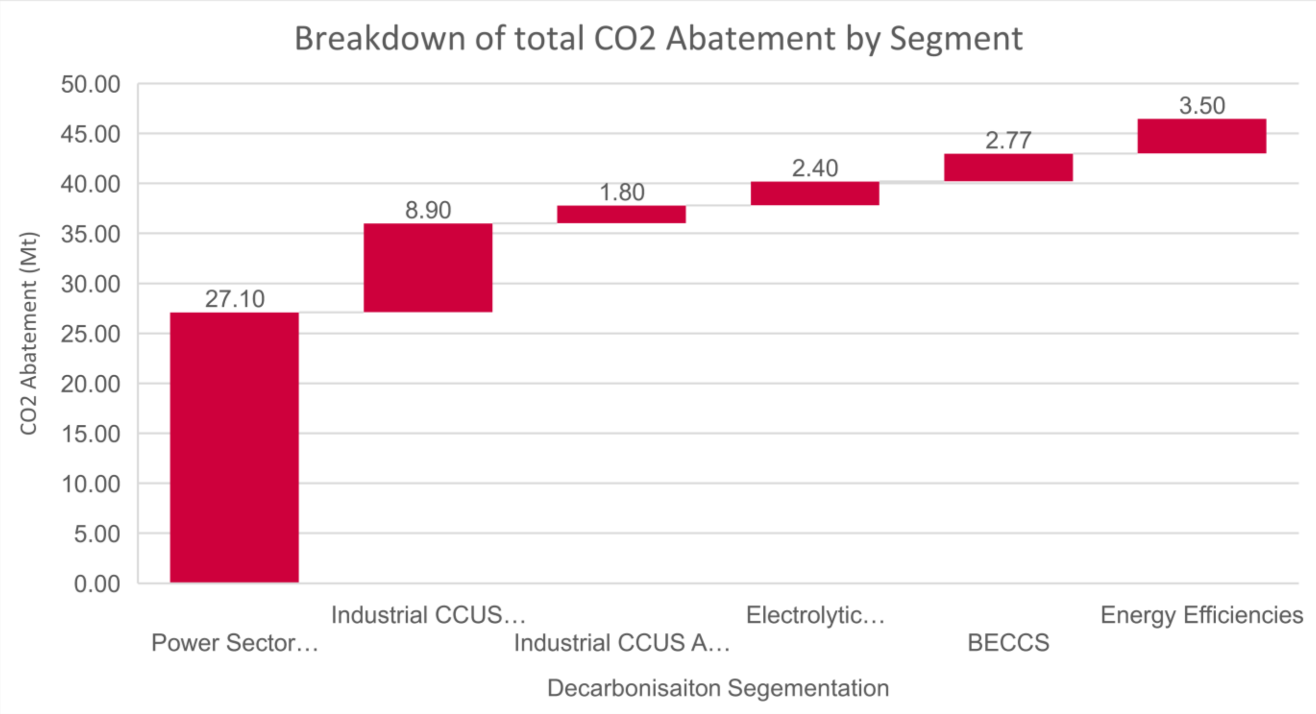
Total CAPEX: **£29.645Bn**



Most of the total CAPEX will be required to decarbonise the power sector, through the conversion of the 4 power producers present in the timeline. It should be noted that due to the live status of the pipeline, these figures are subjected to change. Alongside with the required CAPEX, are the breakdown of relative CO2 abatement. This can be visualised in figure 12 below.

Figure 10 Breakdown by CO2 Abatement

Total CO2 Abatement: **46.47Mt**



4.3.1. Analysis of the Preferred Option

Option 4 "Mixed Net Zero pathway" is taken forward as the preferred option at this point because it provides the solution most likely to meet all three of the CSFs as discussed in the Economic Case. Option 4 has been selected for good diversity of energy vectors, is affordable with potential VFM, 'hedges bets' across different future technologies to reduce risk, utilises and grows domestic supply chains in a way that has plausible delivery aspects, and draws on regional strengths.

Option 4 'Mixed Net Zero Pathway' bundles over 30 individual projects. Table 20 summarises the total CAPEX and OPEX for Option 4 over the lifespan of 30 years. At this juncture, it is not possible to analyse the cost and revenue implications or the proposed funding arrangements of the 'preferred option.' To take the Financial Case forward a holistic view of the capital, revenue, and whole life costs of the projects within the pipeline is required.

Table 20: Option 4: Mixed Net Zero Pathway Summary Sheet

Economics (in £ billions)	**CAPEX**	£34.0 billion
	OPEX / 30 years	£24.5 billion
	TOTAL	£58.5 billion
Financial (in £ billions)	**CAPEX**	£29.6 billion
	OPEX / 30 years	£35.8 billion
	TOTAL	£65.5 billion
Additional CO2 reductions Including do nothing MtCO2 p.a., all (industrial only)		46.5 (17.1)
Additional CO2 reductions, over and above do nothing, MtCO2 p.a., all (Industrial only)		28.5 (12.0)
Cost (CAPEX & OPEX)		£58.5 billion
Benefit (GHG reduction)		£167.0 billion
Net benefit		£108.5 billion
Initial Benefit Cost Ratio (BCR)		1.9

Note: Table 21 is consolidated from Table 12, Table 13, Table 16, Table 17 in the Economic Case

4.4. Funding Mechanisms

There are two main funding mechanisms that the government can use: a regulated market and a free market. These approaches are described below.

4.4.1. Regulated Asset Base Model

Under a Regulated Asset Base model, a regulator grants a licence to an entity, which gives it the right to collect revenues to achieve an agreed regulated return on the assets which it delivers and operates.

This approach is commonly used for capital intensive infrastructure and in situations where a natural monopoly exists, for example gas and electricity distribution and transmission networks.

In most cases, it is the regulated entity which delivers and operates the assets. However, in some cases investment, ownership and operation of the specific assets is undertaken by a third party, with the required revenues collected by the regulated entity from its consumers.

The principle of the RAB regime is that the entity is overseen by a Regulator, likely to be Ofgem, and the operating entity is permitted to make an agreed return. This is then reassessed periodically on the assets it owns. The return is received irrespective of the performance of the assets, resulting in low risk and hence allowing a low cost of capital.

4.4.2. Free Market Approaches

Free market approaches rely on the creation of a competitive market that drives investment in new assets. This may be achieved by creating an obligation on suppliers to a particular market which can be discharged at lower costs by supporting investment in new plant or by creating a market instrument which is awarded competitively to incentivise investment in new plant. Both approaches have been used to support decarbonisation of electricity generation:

The Renewable Obligation

The purpose of this is to put an obligation on electricity suppliers to supply a set percentage of their electricity to the market with renewable generation or pay a set ‘buyout’ price to discharge the obligation, the level of which was above the cost of producing renewable generation.

Contracts for Difference (CfDs)

This type of contract has been used increasingly since 2014, AS it allows support for renewable generation. The CfD is a long-term contract between an electricity generator and a government counterparty, the Low Carbon Contracts Company (LCCC). The contract enables the generator to stabilise its revenues at a pre-agreed level, known as the Strike Price for the duration of the contract.

Under the CfD, payments can flow from LCCC to the generator, and also the other direction. When the market price for electricity generated by a CFD Generator (the Reference Price) is below the Strike Price set out in the contract, payments are made by LCCC to the CFD Generator to make up the difference. However, when the reference price is above the Strike Price, the CfD Generator pays LCCC the difference as illustrated below.

Figure 11 Graphical representation displaying the function of a CfD contract

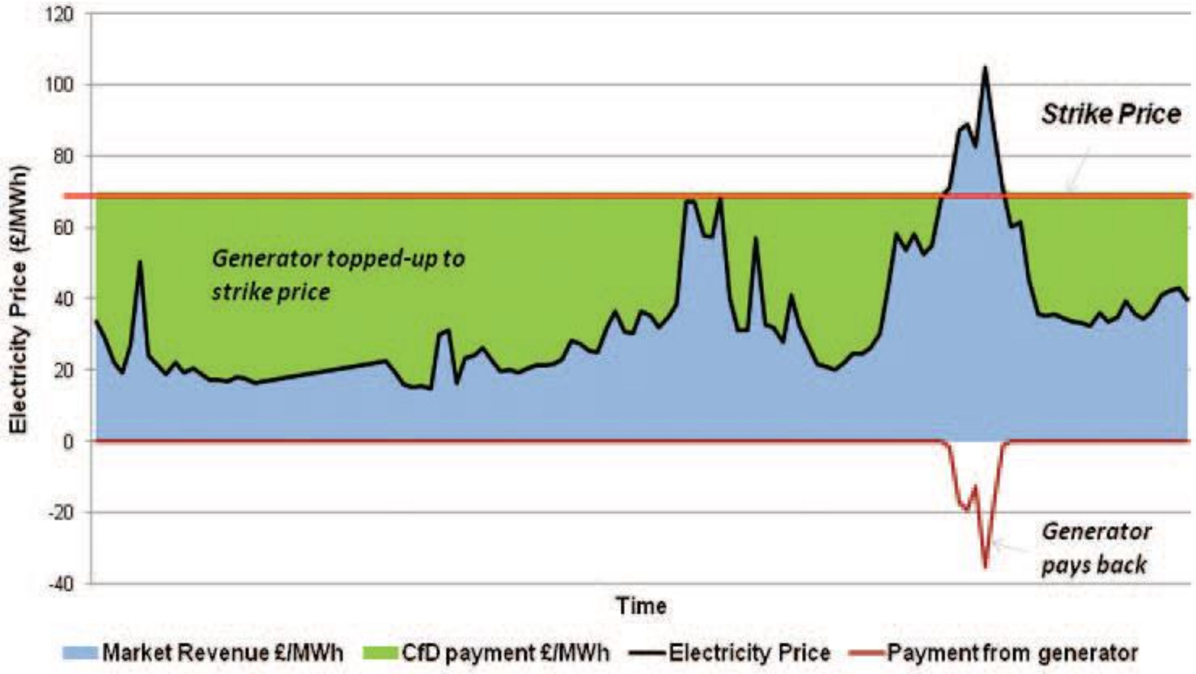


Table 21: Requirements List

Requirement	RAB	Obligation	CfD
Enable bankable investments, delivering to multiple markets	Achievable with very low cost of capital	Annual cash flow not well-defined limiting bankability	Achievable as well-defined, long-term cash flows
Support growth of a nascent market for hydrogen	Achievable. RAB licensee incentivised to invest to grow	Achievable although long term sales contracts can be challenging for innovative technologies	Achievable. Proven to be successful in renewable electricity markets
Reduce support costs over time	Reduction in costs relies on adoption of lower cost technologies. Requires strong regulator	Achieved if large uptake in project investments at less than buy out costs	Achievable. Competitive auction shown to be effective in electricity
Not perturb existing market	As the market expands, impact on suppliers and consumers increases	Better suited to creation of new market	Achievable

4.5. Conclusions

To take the Financial Case forward a holistic view of the capital, revenue and whole life costs of the projects within the pipeline is required. This will require more detailed engagement with the relevant stakeholders who should provide details on their projects. However, where limitations exist due to the speculative nature of planning future investments, clear and defined assumptions and methodologies must be applied to better determine the whole-life-cost of the projects and their respective revenues. Most projects listed within the pipeline are in early stage and so accurate information is limited. On the contrary, late stage projects that have been sufficiently developed contain commercially sensitive information which is likely hard to obtain.

This will then allow the rift between project costs and funding to be visible - identifying which projects will be able to perform under their own private financing and are investible on their own, from those which are essential to achieving the strategic goals of the cluster (Net Zero by 2040) but require government support to be taken forward. It is worth noting that the vast majority of energy projects require some form of Government support or price support via consumer bills.

The central policy and levers that will be available for Hydrogen in the near future are progressively becoming clearer. This will have a significant impact upon the viability of certain projects and the direction the cluster takes. At the time of writing, indicative Heads of Terms had been published by BEIS for the Hydrogen Business Model, through which the final details will impact the direction that is taken. This situation should be monitored closely and incorporated into future development of the investment case.

5.

THE COMMERCIAL CASE

5. Commercial Case

Typically, the purpose of the Commercial Case is to outline the commercial viability of the preferred option identified in the Economic Case. As part of this, procurement strategy and the risk allocation are also analysed and presented in the Commercial Case. The preferred option - Option 4: 'Mixed Net Zero pathway' – is not a single scheme or project, but rather utilises a diverse mix of interventions including power sector decarbonisation, industrial CCUS-enabled H2, industrial CCUS, industrial electrolytic H2, BECCS and energy efficiency measures, which together helps the North West region reach its industrial decarbonisation targets by 2040. As such, it is not possible to discuss concrete commercial terms or specific procurement strategy. Further discussions will be required to further develop the operating and commercial model in this Investment Case. Instead, the Commercial Case will provide a high-level guidance on factors and considerations that may influence a project's commercial viability.

5.1. Project Risks

Risk is defined as "exposure to the consequences of uncertainty." Large-scale renewable energy projects have numerous unknown consequences arising from complex systems, supply chain issues, high costs, raw materials, lengthy project timescales, new technologies and regulatory regimes. Understanding the project risks associated with large-scale renewable energy and low carbon projects is critical in deploying a commercially successful project.

Risks can occur at any points of the project lifecycle from early stage conceptual development through to mid-to-late stage development during the feasibility, project structuring or transactions. Together, these risks that could threaten the development, implementation and operation of energy projects. Among these project risks includes the following:

Table 22: Type of Project Risks

Technical Risk	Load Uncertainty	Poor estimation of load size, growth, and schedule
	Power Quality	Interconnectors, incompatibility, ineffective control systems
	Equipment Failure	Failure of hardware, equipment
	Technology Issue	Complexity, lack of knowledge
	Limited Supply Storage	Disruption to the power generation, impacts on supply
Institutional Risk	Stakeholders	Multiple parties in disagreement, conflict, disputes
	Operational	Administrative errors, lack of oversight and monitoring
	Geography	Isolated or challenging location to reach for repairs and operation and maintenance
Political & Regulatory Risk	Public Policy	Changes in taxes, tariffs, duties, lack of subsidies
	Political Instability	Social and civil unrest, war, conflict
	Planning & Approvals	Delays in planning permissions and permits
Financial & Economic Risks	Business Model	Ineffective business model
	Cost of Materials / Diesel	Price variation impacts the operation of systems
	Macroeconomics	Inflation, FX rates impacts commercial viability
	Credit	Risk of default
Social & Environmental Risk	Environmental Harm	Public resistance relating to the environment
	Weather	Adverse weather, lack of wind, sun, water
	Force Majeure	Environmental disasters (earthquakes, hurricane, etc).

5.2. Pricing Guidance & Payment Mechanisms

The scale of the subsidy on offer to these projects is a key sensitivity, and will determine what the markets will offer for Blue Hydrogen, Electrolytic Hydrogen and the price of Carbon. All of this is yet to be confirmed formally by Government, therefore at this point it is only speculation, based upon the most recent guidance offered by Government.

Payment mechanism incentivise the supplier to deliver services in accordance with the requirement in line with the contractual agreement. The payment mechanism and pricing structure reflects the appropriate balance between risk and return between the contracting parties.

5.2.1. Anticipated Hydrogen costs

As of the end of April 2022, the UK Government guidance on the Levelized Cost Of Hydrogen (LCOH) is contained in the BEIS report issued in August 2021 "Hydrogen Production Costs 2021" within which there is the acknowledgement that:

> *"The evidence base is fast-moving and that there are gaps in our knowledge. We are therefore inviting views on this report and the data published alongside it to continue to improve our evidence base."*

Levelised costs aim to coalesce all costs associated with manufacture, taking CAPEX and OPEX costs and amalgamating these into an average cost per MWh over the lifetime of a production plant. Levelised costs do not take into account revenue streams. Distribution, storage and compression costs are also excluded from the calculations due to the wide range of ways the demand side will expect the molecules to be provided to the market. These are expected to be added on top of the price of hydrogen to the end-user dependent on delivery/storage method.

The Government report also acknowledges that one of the key reasons for the uncertainty in defining prices is that the technologies which may manufacture hydrogen in the future are not sufficiently mature, nor tested. This should be seen as an opportunity for public sector to de-risk the technology through implementing early schemes that provide valuable data and research opportunities.

The Report refers consistently to the impact that "First of a Kind" (FOAK) "Second of a Kind" (SOAK) and "Nth of a Kind" (NOAK) H2 technology projects will have on pricing mechanisms. Technology price reductions over time (as a result of growth in technology maturity) are very much "best guess" projections. For instance, there is an assumption that there will be a 7% reduction in Proton Exchange Membrane (PEM) electrolysis costs per doubling of global production capacity using this method of H2 production- and the report notes that in 2018 there was no more than 50MW of PEM production worldwide; these points are made here to portray the immaturity of the technology market at this point in time and why there is still so much uncertainty in creating pricing structures.

The Government is also working to set out its strategy for Hydrogen costs to ensure that LCOH does not represent a Strike Price as such and that many more factors are considered in arriving at this commercial mechanism.

5.2.2. Electricity pricing

In considering LCOH the Government report has looked at three sources of electricity. Firstly, electricity from the grid, highlighting two distinct pricing rationale; the Industrial Retail Price, and the Industrial Long Run Variable Cost (LRVC). Secondly, electricity from dedicated electricity generation sources; in this case it is relevant only for production of Electrolytic hydrogen using pure renewables. It is also worth noting that in terms of LCOH electrolysis via Nuclear is not considered either. Thirdly, electricity from generation curtailment (defined as, when there is an excess of electricity in the grid which would otherwise go to waste); again, only appropriate for electrolysis produced hydrogen.

5.2.3. Fuel pricing

In considering LCOH, Government has also considered two alternative pricing structures for natural gas: Industrial Retail Price; and Industrial Long Run Variable Cost (LRVC) Biomass fuel assumes prices used for biomass conversion and BECCS plants. These assume the use of wood pellets. Once again, however, BEIS cannot confirm whether prices are set as retail or wholesale.

5.2.4. Carbon pricing

The assumption is that hydrogen production will, as electricity production does, face a carbon price for all carbon emissions occurring onsite. Prices faced by hydrogen producers will be based upon the EU Emissions Trading System (EU ETS) but going forward, the system would switch to a UK ETS. CCUS enabled hydrogen producers will be subject to CO2 Transport and Storage costs. However, as more CCUS infrastructure and systems are implemented and proven, further innovation is likely to help lower the associated cost of CO2 transport and storage. At present the T&S fee structure and methodology is still in the development stage. Currently, the best assumption is £28/Tco2 based upon an earlier 2018 Uniper report.

5.2.5. Hurdle rates

Representing a manufacturer's Return on Investment (ROI) High hurdle rates naturally reflect a higher risk project whilst conversely Low Hurdle rates represent lower risk. Again, given the wide range of hydrogen production technologies and projects anticipated, BEIS have set a standard 10% hurdle rate for the purpose of establishing LCOH.

5.2.6. LCOH rates set in August 2021

Having set out the above price influencers, the Government's Hydrogen Production Costs 2021 report then highlights a range of LCOH for a range of technologies as highlighted below

Figure 12 LCOH for CCUS- enabled SMR/ ATR/ ATR+GHR based upon 300MW or 1000MW scale production

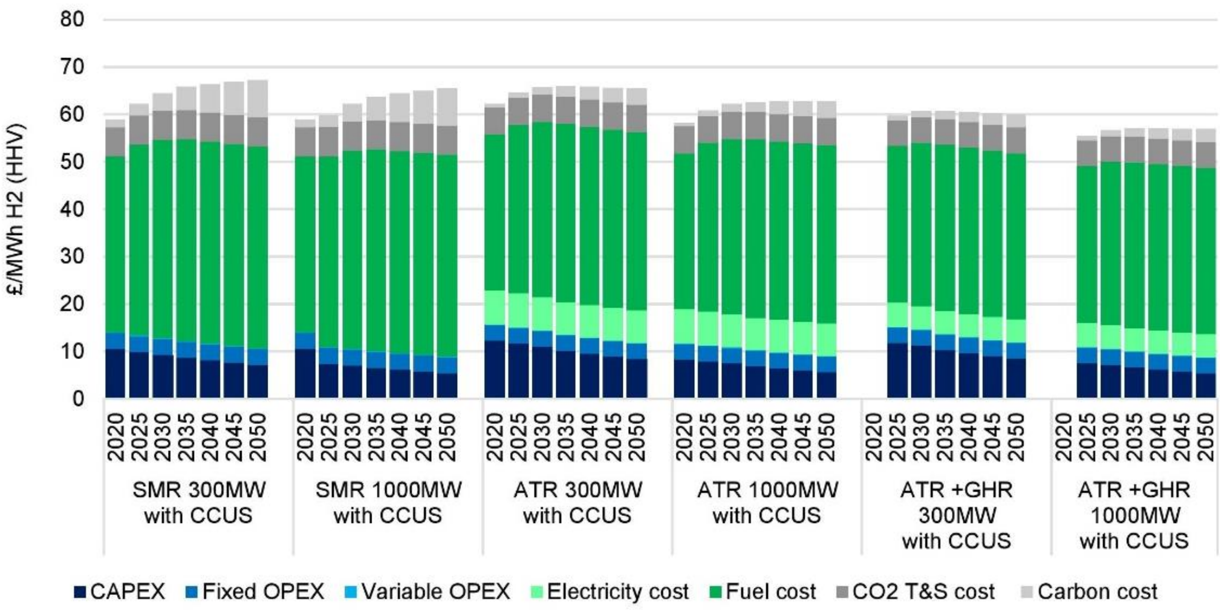


Figure 13 LCOH for electrolysis technologies connected to different electrical sources

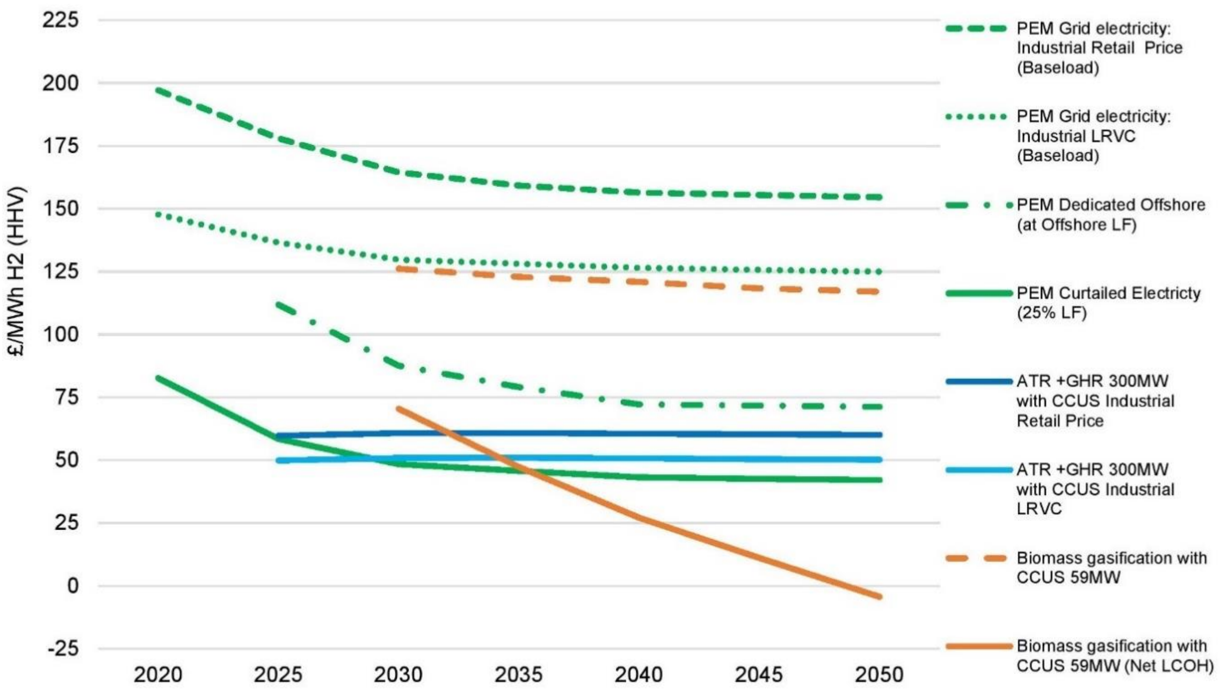
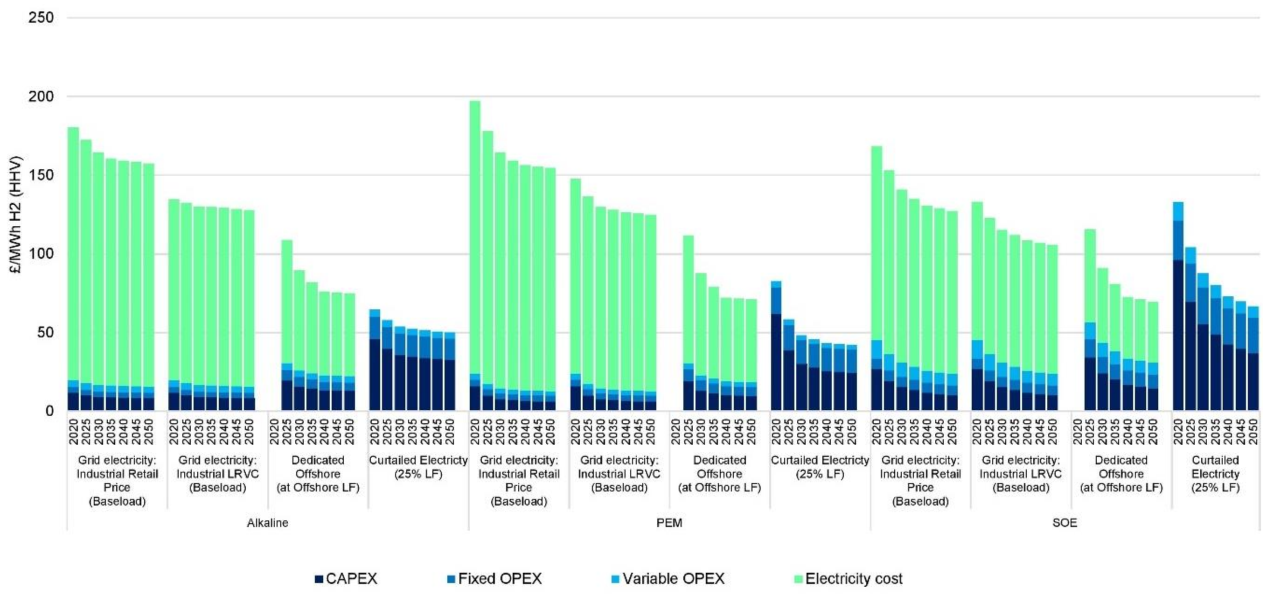


Figure 14 Comparison of LCOH production estimates over different technologies and time



Industrial apportionment of grid decarbonisation: Government official statistics (DUKES) show industry consumed 30% of the nation's electricity and 17% of its overall energy in 2020, in MtOE. Electrification of road transport will likely reduce industry's electricity share towards the overall 17% by 2040. Therefore, it is assumed 25% of electricity is consumed by industry, on average, over the 2022-40 period.

5.3. Procurement Models

Typically, the developers of large-scale energy projects could rely on lump-sum engineering, procurement, and construction (EPC) contracts, also known as turnkey construction contract, for project procurement. In addition to delivering a complete facility, the contractor must deliver that facility for a guaranteed price by a certain date.

Due to changing market dynamics in the energy sector, new alterative procurement models and contractual structures have emerged combining varying degree of risks with the traditional EPC model. Due to the complex nature of major energy projects, it is common to pursue alternative models on a case-by-case basis depending on project specifications, technology, and the type of risks. Therefore, there is not a one-size-fits-all approach when it comes to procurement model, but all parties must strike the right balance in allocating risks.

5.4. Routes to Market & Scope for Government Intervention

The purpose of the Commercial Case is to outline the commercial viability, risk allocation, and procurement strategy of the preferred option identified in the Economic Case. That said, it is important to note that Option 4: 'Mixed Net Zero Pathway' is not a single energy scheme or project, but rather utilises a diverse mix of interventions including: power sector decarbonisation, industrial CCUS-enabled H2, industrial CCUS, industrial electrolytic H2, BECCS and energy efficiency measures. This diverse mix of energy projects, together the North West region reach its industrial decarbonisation targets by 2040. As such, it is not possible to discuss concrete commercial terms or specific procurement strategy.

In place of this, Table 23 provides some consideration on the opportunity and challenges associated with each 'waterfall segment' as well as the type of public sector support provided during various stages of the project lifecycle from R&D to commercialisation.

Table 23: Opportunities & Challenges by Waterfall Segment

	Opportunity	Challenge	Government Interventions
Power Sector Decarbonisation	Decarbonising heat has multiple potential solutions including heat pumps, hydrogen, heat networks and biomethane. Progress in any of these will support a step-change in residential and commercial heat production.	Carbon Capture components are still in pilot plant and prototype stage for many high-emission sectors such as steel & concrete. Research on bespoke solutions for treatment of flue gas impurities is not yet advanced. The potential collaboration between carbon capture and utilisation has not been established on a large scale.	Public Sector Decarbonisation Scheme
Industrial CCUS Enabled Hydrogen	UK Advanced GGR and DAC technologies have just passed feasibility stage. Frontrunning technologies are approaching pilot stage. Carbon Utilisation once running at scale, can have significant economic benefits due to supplementing heat duty etc.	CO2 capture rates for CCUS systems needs improving. Current rates result in residual emissions. Significant scale-up of Hydrogen networks and storage is required Scaling-up CCUS technologies and GGR approaches from pilot to commercial first-of-a-kind demonstrations needs to happen over the next 10–15 years to allow widespread roll-out from the 2030s	Net Zero Hydrogen Fund The Carbon Capture and Storage Infrastructure Fund Industrial Hydrogen Accelerator Programme
Industrial Electrolytic Hydrogen	The UK is a co-lead of the Clean Hydrogen Mission, which aims to reduce the cost of Hydrogen production across the value chain to improve cost competitiveness of the systems. If renewable energies were used to run the process, the system would be zero carbon.	Further demonstration as a feedstock for fuel and industry in a wide range of applications is required. The conversion of existing gas systems to ensure suitability for Hydrogen is still in its infancy. Pilot projects have displayed that currently, production of Electrolytic Hydrogen is commercially unviable compared to suitable alternatives. Significant infrastructure is required to connect Hydrogen to areas outside of key clusters, limiting its current usefulness.	Net Zero Hydrogen Fund Industrial Hydrogen Accelerator Programme Industrial Energy Transformation Fund NZIP Industrial Fuel Switching
Bioenergy with carbon capture and Storage (BECCS)	A potential to achieve negative emissions to drive Net Zero carbon. The adaptability of Biomass means that it can be used to support NZ across many sectors by coupling with other initiatives such as Hydrogen production.	Identifying the optimum area for utilising BECCS, considering a wider system of supply chain, energy vectors and production. Ensuring the scaling-up of Biomass and feedstock production is sustainable. Advanced and flexible gasification technologies are not yet available on a plant scale.	Hydrogen BECCS Innovation Programme
Energy Efficiencies	UK Wide Energy efficiency measures could support up to £6 billion gross value added (GVA) and 175,000 jobs by 2030 according to a BEIS analysis based on the Energy Innovation Needs Assessment. The Future Homes Standard aims to have all new-build homes utilise low carbon heating and improved energy efficiency by 2025, ensuring little or no future retro-fit work will be required at these properties.	Further policies are required to progress the use and implementation of existing technologies. Existing Business Models require further progress to support commercials and efficiency. Further research into biological feedstocks and bio-degradable end products is necessary. Use of low carbon materials such as steel and concrete require further trialling on large-scale projects to ensure wide-spread backing, supporting supply chain availability and insurances.	Industrial Energy Transformation Fund Net Zero Innovation Portfolio

6.

THE MANAGEMENT CASE

6. Management Case

Delivering a comprehensive decarbonisation programme requires high levels of integration as well as navigating through complexities of new technology and regulations. It must also take consideration on interdependencies such as jobs, skills, and economic growth. Time is an essence if the UK government wishes to meet their carbon reduction targets. The challenge then is the scale and pace that is required to support the decarbonisation agenda and the ability to pivot seamlessly from strategy to on-the-ground delivery.

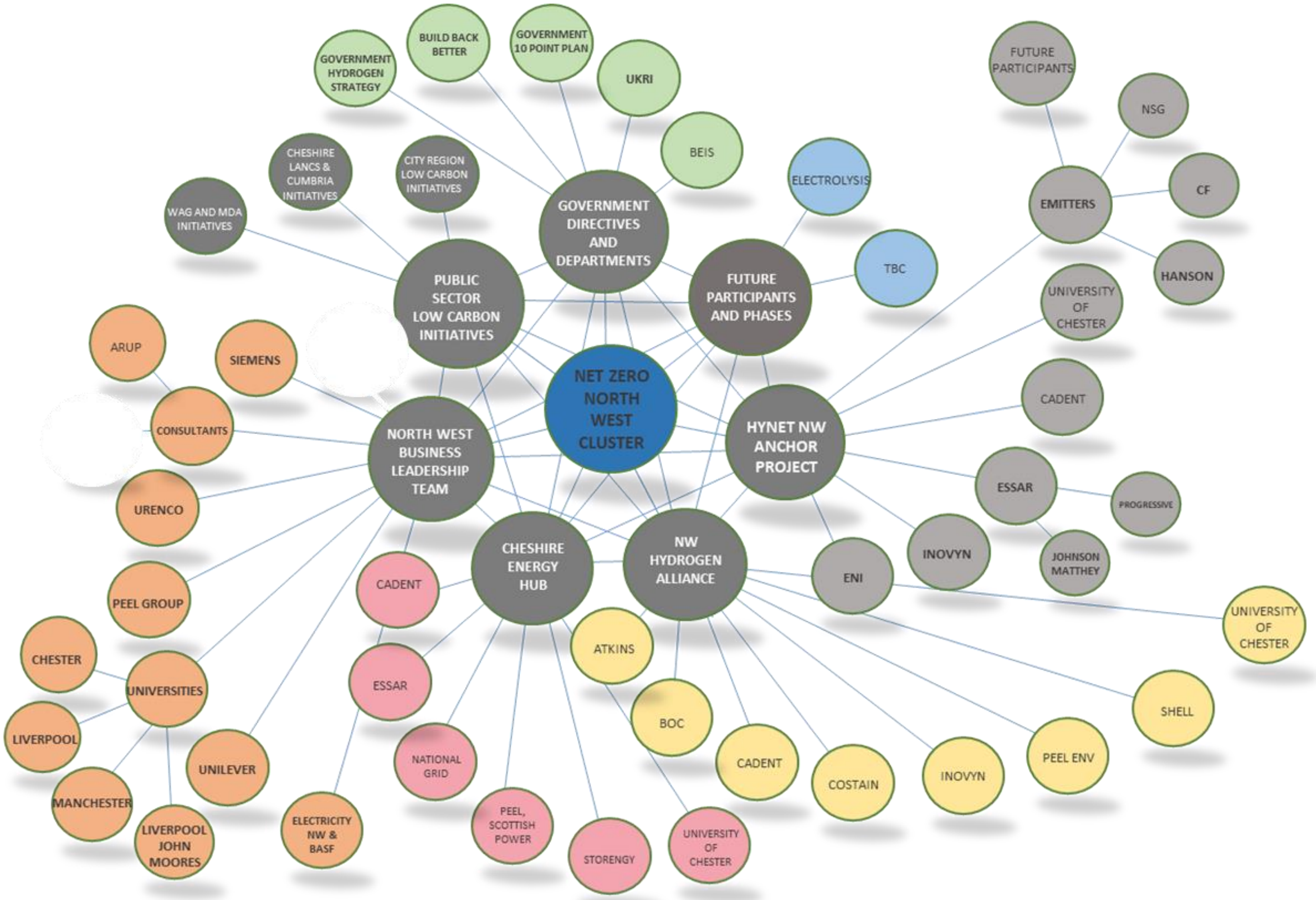
The level of commitment and fortitude for an ambitious programme should not be underestimated. Market forces alone will not be able to achieve the UK government's ambition to reaching Net Zero by 2050.This is precisely why there is a critical need for coordination across government, industry, businesses, universities.

Figure 15 NZNW Ecosystem illustrates the expansive 'North West Net Zero' ecosystem and key stakeholders involved in various elements in delivering the Net Zero strategy from LEPs and local authorities; membership bodies and industry groups; and major firms involved in energy systems. Note that this diagram is for illustrative purposes demonstrating the breadth of stakeholders and major energy firms involved in various initiatives - it is not exhaustive.

This section outlines options for management arrangements and delivery mechanisms to support delivery of a programme, including roles and responsibilities as well as the decision-making process. The chapter begins with outlining the key considerations and challenges associated with implementing a complex 'mixed pathway' of projects to achieve Net Zero. This chapter also draws upon three international industrial decarbonisation case studies based in The Netherlands, Germany, and the USA to give insights on how other major industrial clusters are delivering their Net Zero targets and its applicability for the North West region.

The gaps and weaknesses will be analysed through the lens of 'cross-cutting' themes to give a steer on the appropriate management and governance structure which would enable deployment of the proposed 'mixed pathway' at scale and at pace. The aim of this chapter is not to give a definitive answer, but rather a range of options for consideration and to aid future discussions with key stakeholders.

Figure 15 NZNW Ecosystem



Note: This is not an exhaustive diagram and for illustrative purposes only

6.1. Key Considerations & Challenges

Delivering a large-scale private sector-driven energy 'mixed pathway' programme is not straightforward. As mentioned earlier, the ability of the NW region to become the first Net Zero industrial cluster requires close integration of technologies, enabling infrastructure and network to create value chain that would unlock commercial viability. It involves navigating the complex planning system for major energy projects, understanding the end-to-end supply chain, grappling with challenges with geographical siting issues, and supporting private sector to secure catalytic "kick start" public sector finance.

For this to happen would require strong alignment in policy drivers, planning permission, regulation, foresight and strategic thinking, and clear understanding of R&D advancement and investment to de-risk early-stage development. These are a few key points for consideration when deciding on the appropriate management and governance structure to take this programme forward.

Table 24: Levels of Coordination Across Multiple Areas

Planning Process	System-Wide Thinking & Enabling Infrastructure	Project Scale for Funding & Financing
Supply Chains	Workforce & Skills	Inward Investment

6.1.1. Navigating the Planning Process

With Wales as adjacent neighbours, the planning regime for major infrastructure projects is complex due to the devolved status. Planning consent depends on the specific location of projects, onshore or offshore and its megawatt (MW) output capacity. As the tables below illustrate, the planning regime gets more complicated as the energy projects increase in output capacity. For larger onshore energy projects (except wind farm) over 50MW in England, a Development Consent Order (DCO) is required. In Wales, special permission via the Development of National Significant (DNS) is required for projects over 10MW and a DCO required for projects over 350MW.

Table 25: Planning Permission for Onshore & Offshore Wind in England & Wales

ONSHORE				
UK	Output Capacity	**Consent needed**		
		Energy projects (other than onshore wind farms)	**Onshore wind**	**Standalone energy storage**
England	<50MW	Planning Permission (Local Planning Authority)		
	≥50MW	Development Consent Order (DCO) (UK Secretary of State for BEIS)	Planning Permission (Local Planning Authority)	
Wales	<10MW	Planning Permission (Local Planning Authority)		
	10MW – 350MW	Planning Permission (Welsh Ministers – Development of National Significance (DNS) regime)		Planning Permission (Local Planning Authority)
	≥350MW	DCO (UK Secretary of State for Business, Energy and Industrial Strategy)	Planning Permission (Welsh Ministers – DNS regime)	Planning Permission (Local Planning Authority)

OFFSHORE				
UK	Output Capacity	**Consent(s) needed**		
		Offshore elements		**Onshore elements**
England	<1MW	Marine Licence (Marine Management Organisation "MMO")		Planning Permission (Local Planning Authority)
	1 – 100MW	Section 36 Consent (MMO)	Marine Licence (MMO)	Planning Permission (Local Planning Authority)
	≥100MW	DCO (UK Secretary of State for BEIS)		
Wales	<350MW	Section 36 Consent (MMO)	Marine Licence (MMO)	
	≥350MW	DCO (UK Secretary of State for Business, Energy and Industrial Strategy)		

Source: Norton Rose Fulbright

Under the Planning Act 2008 (PA08) a DCO is required for "nationally significant infrastructure projects" (NSIP) in England and Wales. For energy projects in England, over 50MW output capacity onshore or 100MW offshore, or over 350MW for Welsh projects, a DCO is required and are granted by the Secretary of State for BEIS. It is a lengthy process, however, DCO gives full consent powers giving a suite of powers to construct the project and is ideal for complex offshore projects where marine license is also granted in the process. That said, BEIS and other regulatory bodies are also proactively working to change the planning regulation to ease the administrative process.

For example, in 2020 UK Government confirmed that electricity storage schemes will only require conventional planning permission rather than the DCO to help expedite enabling energy infrastructure. The UK government recently launched a major consultation to review the National Policy Statement for Energy[23] Infrastructure to ensure the policy are fit-for-purpose to ensure the UK meets its Net Zero targets. It is envisaged that a degree of flexibility will be incorporated into the policy to support the decarbonisation agenda, whilst also give confidence to developers and investors. There could and some would argue should be a role to be played by the established organisation to help inwardly investing businesses navigate the planning process and support the brokering of meetings/ coming together of local and central government to help achieve a holistic "ecosystem" energy and decarbonisation solution.

[23] Planning for new energy infrastructure: revisions to National Policy Statements - GOV.UK (www.gov.uk)

6.1.2. System-Wide Thinking: Siting, Co-Location, and Enabling Infrastructure

Investing in enabling infrastructure such as supporting long-distance transmission, is critical in reaching Net Zero by 2050. Government will play a key role in setting the policy drivers, but equally important is cross-government coordination between various departments as well as with local government for more comprehensive 'system-wide thinking.'

Siting and co-location issues and other enabling infrastructure will need to be carefully considered to ensure the whole energy eco-system is in place to avoid potential barriers. For example, renewable energy technologies would require proximity to grid connection, whilst biomass needs access to transport links and hydropower requires sources of water. To address these issues, a practical approach could be integrating energy components into a regional master planning strategy. Nonetheless, the Government will continue to invest and plan for enabling infrastructure over the next decade to ensure new technologies can be deployed at scale without major delays. Additionally, grid capacity will likely become a risk to project delivery, which carefully needs to be considered when thinking about the enabling infrastructure.

6.1.3. Securing Financing at Project Scale

According to a report by Innovate UK and the Green Finance Institute[24], approximately 82% of all UK greenhouse gas emissions are within the scope of influence of local authorities. As such, local authorities have an instrumental role in propelling the Net Zero agenda. However, with stretched resources and budgetary constraints, local authorities need new innovative financing model.

Securing financing and funding for major energy projects can be challenging especially for unproven technologies. The UK Infrastructure Bank (UKIB), launched in 2021, seeks to provide £22bn of infrastructure finance to tackle climate change in line with the government's Net Zero emissions targets, and support regional and local economic growth across the United Kingdom.[25] Local authorities have the option to access to finance through UKIB where loan conditions (60 basis points above Gilt) are more favourable than commercial loans. This would enable clean energy projects to get off the ground, whilst minimising start-up risks which might not otherwise attract private investment with a view of gaining crowd-in private capital once the project starts producing a return.

As one of its first investments, UKIB is investing £107 million to support the redevelopment in the South Bank Quay development in Teesside Valley to service the offshore wind sector with manufacturing, storage, and mobilisation of wind technology. Building on momentum and statutory footing to enable UKIB to lend directly to local authorities, the UKIB will work together with local and regional governments to invest in major energy projects. Alongside the policy drivers, the establishment of the UKIB is welcoming news to local authorities and private developers as they continue develop new energy project.

The issue of project scale is often view as a barrier in attracting private finance. Most local authority projects are small scale in nature, ranging from domestic retrofit of £10K-£50K to small-scale 1 MW solar farms of <£5million. Investors prefer large-scale investments of £30-£50 million or the aggregation of projects to make the investment viable given the time required for the due diligence process.

6.1.4. Managing Complex Supply Chains

Businesses and project developers are grappling with supply chain delays due to knock-on effects of production, logistics, and transportation issues. In the short-term, these supply chain issues may delay or even derail clean energy and renewable energy projects due to rising cost of steel and other raw

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[24] Mobilising Local Net Zero Investments: Challenges & Opportunities for Local Authority Financing (July 2022)
[25] UKIB Strategic Plan, June 2022

materials. Political instability, regulatory changes, and price fluctuation all put pressure on cost of completing energy projects, and thereby increase project risks.

Hopefully, these supply chain issues and the backlog due to transport and logistic bottleneck will resolve in time to allow for supply to keep pace with demand for raw materials. Equally, it is important to understand the supply chain and infrastructure bottlenecks. The ability to have foresight of the project pipeline means one can have coordinate the supply chain with different providers. Building out the supply chain would enable quicker deployment of technology, provided the supporting infrastructure is in place. Nonetheless, it is important to stay inform of the latest developments as supply chain constraints could have larger repercussions for the energy sector.

6.1.5. Upskilling & Future Workforce

Early investments in skills are critical for the success of decarbonisation. In a report by HSBC[26] a gap in fundamental technical and engineering skills in the power sector could create a material bottleneck. It was concluded that the skills of today may not only impede innovation, but also may not be sufficient to deliver the full abatement potential to reach the Net Zero targets.

Getting the right skills at the right time will likely require policy changes, addressing the labour market and workforce. To address market failures, policymakers will need to create incentives for employers to train staff for the skills of tomorrow. This will require coordinating supply and demand for new low-carbon skills, monitoring the future skills gap regionally and nationally, and providing new educational and training strategies.

6.1.6. Attracting Inward Investments

Subject to a successful business case, Liverpool City Region (LCR) will be designated as one of eight Freeport zones equipped with a range of economic incentives such as tax reliefs, business rates retention, and customs. With some delegated planning powers, the LCR Freeport will be able to create a favourable and stable environment for businesses to flourish.

Using the £25m seed capital, LCR Freeport will create a low-carbon, multi-modal, multi-gateway trade platform with a network of sites attracting high-value investments, supporting sustainable growth increase levels of innovation, as well as lead on solutions to meet the region’s Net Zero Carbon targets for 2040. Capitalising on the LCR Freeport status, coupled with a strong pipeline of projects coordinated at a regional level, the North West can be the first to reach Net Zero by 2040.

[26] Skills for the Low Carbon Transition, HSBC Centre for Sustainable Finance, June 2021

6.2. International Industrial Decarbonisation Clusters

According to the World Economic Forum, there is huge growth in industrial clusters since the Net Zero initiative was established COP26 in 2021. With a critical mass of industrial clusters on the pathway towards decarbonisation means that there is scope and opportunities for these industrial clusters to learn from each other and share knowledge to accelerate towards Net Zero.

To provide further insights, this section includes three international industrial decarbonisation cluster case studies in The Netherlands, Germany, and the USA, all which are well-established initiatives with strong national policies. All three case studies share commonalities including co-location of renewable energy sources such as wind farm or nuclear power; potential location for CCSU in "sinks" in geological sites i.e.) coal mines, salt caverns; and proximity to a major port for logistic and transport purposes. The case studies cover four thematic areas such as delivery structure, financing and funding, and key challenge which will enable the NZNW Industrial Cluster to make informed decisions regarding the management structure and future strategic initiatives.

The case studies highlight the benefits of having strong partnerships, combining respective expertise with shared value and common objectives is the foundation towards reaching its Net Zero objectives. However, there are notable comparisons and differences amongst all clusters as illustrated in Table 26. Each of the case studies has a different governance structure – industry-led supported by Government; state-funded agency; and a non-profit entity.

6.2.1. Botlek-Permis, Rotterdam

Located adjacent to the Port of Rotterdam[27], Botlek and Pernis are industrial regions operating within the largest industrial cluster in the Netherlands and are responsible for emitting 13.9 tonnes of CO2 emissions. In 2019, the Dutch government announced its Climate Agreement along with their commitment to reducing the country's greenhouse gas emissions of 49% by 2030.[28] To support the industrial clusters to achieve their reduction in greenhouse gas emissions, the initiative Manufacturing Industry Decarbonisation Data Exchange Network (MIDDEN)[29][30][31] was launched by the Dutch Government. MIDDEN's aim is to build a structured knowledge base on Dutch industry and provide a variety of decarbonisation options for the industrial regions by working in partnership with universities, branch organisations, public organisations and the companies within the clusters in a similar way as the NZNW Cluster. Three anchor projects is earmarked for the success of the Botlek-Permis industrial decarbonisation including:

- **Porthos** – A project in which CO2 captured from various companies within the Port of Rotterdam and later transported via an offshore pipeline and stored in empty gas fields beneath the North Sea. Porthos will store around 37 Mt CO2, approximately 2.5 Mt CO2 per year for 15 years.
- **The H-Vision** –The H-Vision would commence with the production of low carbon blue hydrogen to substitute refinery gas as a fuel in the industrial cluster. The residual gases from the refinery sector are to be used as feedstock for the blue hydrogen (95% purity) production process, along with some additional natural gas input (10%).[32]
- **HyTransport** – An initiative to construct an open access high purity green hydrogen pipeline. HyTransport would present the companies within Rotterdam with a way to

[27] The Port of Rotterdam under the Rotterdam Port Authority is an unlisted public company owned by Municipality of Rotterdam (70%) and the Dutch Government (30%) with turnover of approximately €770M and 1,270 employees.
[28] MIDDEN - Decarbonisation options for the industry cluster Botlek/Pernis Rotterdam | PBL Planbureau voor de Leefomgeving
[29] MIDDEN stands for Manufacturing Industry Decarbonisation Exchange Network - was created by PBL (Netherlands Environment Assessment Agency, a national institute for strategic policy analysis in the fields of environment, nature and spatial planning) in partnership with TNO (Innovation for Life), an independent research organisation which targets sectors such as Energy Transition, Strategy and Policy.
[30] PBL - PBL Planbureau voor de Leefomgeving |
[31] TNO - Mission and strategy | TNO
[32] MIDDEN - Decarbonisation options for the industry cluster Botlek/Pernis Rotterdam | PBL Planbureau voor de Leefomgeving

purchase or supply green hydrogen and see the Port of Rotterdam become a hydrogen hub. The pipeline is set to be operation late 2024/early 2025.[33]

Despite being two large industrial regions in their own rights – Botlek and Pernis fall under the larger Port of Rotterdam Industrial Cluster. The Port of Rotterdam, a public company, is under the leadership of the Port Authority of Rotterdam to ensure the development of the industrial cluster excels in a coordinated approach. Currently the companies within the Botlek and Pernis regions are self-funded, with the decarbonisation projects being created as progressive steps for the regions industrial companies moving forward. Additionally, funding has been secured for the upcoming project Porthos via the European Commission who has proposed awarding €102 million. The potential success of this project could be turning point worldwide for reducing carbon emissions.

6.2.2. NRW Energy 4 Climate, Germany

North Rhine-Westphalia is home to 37 of Germany's top 100 corporations – making it the largest industrial region in the country. Annually the industrial activity in the region emits 51.2 million tonnes of CO_2e.[34] To support the government's ambition of achieving carbon neutrally, North Rhine-Westphalia's state government created NRW.Energy4Climate, a state agency, to accelerate energy transition and ensure climate change targets are met within the region. The new state agency's role is to assist the highest emitting sectors in the region: energy, industry, heat and building and mobility.

Several of the active projects in North Rhine-Westphalia have a thematic focus on **hydrogen**, which aligns with the German Government's 2020 published hydrogen roadmap. This includes GET H2 an initiative to create a competitive hydrogen market with 130-kilometer network to connect hydrogen production between Lingen (Lower Saxony, Germany) and industrial customers in NRW.[35]

NRW.Energy4Climate have expertise in each sector which can help advise and tailor advise to that specific project, as well as having people placed in roles across sectors who can aid the holistic development of the cluster. Additionally, team members also work within municipalities which will aid the cluster are a local government level and be able to assist of matters of funding and regional policies.

NRW.Energy4Climate fully funded by the state government in North-Rhine Westphalia. The state government is committed to stepping up its efforts to inform and advise companies about options for reducing carbon emissions. NRW plans to continue using the workshops and advise offered by NRW.Energy4Climate to drive further change in the state to achieve their Net Zero targets.

6.2.3. H2Houston, HyVelocity Hub

The Gulf Coast is currently one of the nation's largest hydrogen producers and is home to a diverse array of energy resources, including 48 hydrogen production facilities and more than 1,000 of hydrogen dedicated pipelines. Under the leadership of the Center of Houston, 'HyVelocity Hub' consist of industry, university and leading energy companies and organisations working to advance the clean hydrogen ecosystem in Texas, Southwest Louisiana and along the U.S. Gulf Coast. HyVelocity seeks to rapidly scale the clean hydrogen supply and demand that leads to a market-based, end-to-end innovation ecosystem.

As a non-for-profit the Center of Houston relies heavily on fund raising to enable their organisation to function. The Center of Houston have recently applied for funding from the U.S. Department of Energy Regional Clean Hydrogen Hub – a programme which includes up $7 billion to establish six to 10 regional clean hydrogen hubs across America.

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[33] MIDDEN - Decarbonisation options for the industry cluster Botlek/Pernis Rotterdam | PBL Planbureau voor de Leefomgeving
[34] *NRW - Welcome to North Rhine-Westphalia | Land.NRW*
[35] *GET H2 - GET H2 – Mit Wasserstoff bringen wir gemeinsam die Energiewende voran. (get-h2.de)*

Table 26: Comparison of Clusters

	NZNW	Holland	Germany	USA
Context	Net Zero North West unites industry, providing a strong voice and holistic vision for industrial decarbonisation.	Independent agency MIDDEN has advised how the companies within the industrial regions of Botlek and Pernis can use their upcoming projects for decarbonisation and interlink them successful between companies to advance the clusters overall decarbonisation process.	NRW.Energy4Climate a state funded agency formed to advise and accelerate decarbonisation projects in the North-Rhine Westphalia region. Whilst being a first point of contact in	The Center of Houston a non-for-profit affiliate of the Greater Houston Partnership has set out a hydrogen roadmap as part of its HyVelocity Hub launch which will a range of companies in the Houston region join together in the effort to make the region a leading hydrogen hub.
Thematic Focus	Hydrogen, CCS	CCS, Hydrogen, Electrification	Hydrogen, CCS, Defossilation, Electrolysis	Hydrogen
Key issues	Complexity of projects, policies, potential parties in disagreements	Lack of governance of the cluster, potential parties in disagreements	Gaps in research, increase in fuel prices, local residents objecting to projects	Funding and Policies
Net Zero Target Year	2050	95% reduction by 2050 – no date published for 100%	2045	2050
Current Emissions Emitted	16.7 MtCO2e in North West Region	13.9 MtCO2e in Botlek and Pernis Region	227 MtCO2e in North-Rhine Westphalia	167.8 MtCO2e in Houston
Projects	HyNet, MerseyTidal	H-Vision, HyTransport, Porthos	InnoGuss,Align CCS and Take-off, GetH2, Refhyne	High-velocity Hub
Funding	Public and Private Sector Investment	Mainly private funding with state funding on few projects	State funded	Public and Private funding with hope to achieve further public funding
Organisation set up	Partnership	Partnership under Port Authority of Rotterdam	State Agency Governance	Non-for-profit affiliate of the state

6.3. Delivery Structure

As illustrated in Section 6.2 in the international case studies, there are different delivery structures, all which have been successful in progressing the Net Zero agenda in their respective region. In the case of the Botlek-Permis, Netherlands, this is a partnership arrangement with key industrial players with the Port Authority of Rotterdam leading the initiative. Whereas in North-Rhine-Westphalia, Germany, a regional state agency was created to overseeing the delivery and governance. Finally, in Houston, Texas, USA, a not-for-profit is spearheading the HyVelocity.

The main driver across all the case studies is strong collaboration with the right stakeholders who share a common goal towards achieving Net Zero and strong overarching governance to deliver major projects. Whilst each international decarbonisation cluster represents different geographies and at various stages of development towards Net Zero, all the clusters have a strong partnership approach with good policy framework and support from national government and a clear Net Zero pathway.

Regardless of the new ‘delivery model,’ the new management structure needs to harness existing relationships and influence. With any robust organisation, a pro-active Board will work seamless together to set the strategic vision and accountability of the overall programme delivery, together with strong leadership from the senior executive.

This section explores various options in setting up a robust delivery model to oversee the strategic vision and programmes. These options range from keeping the status quo to carving out a regional body, and potentially a national energy agency. The delivery structure takes into consideration of the key challenges relating to planning, inward investment, skills, and project pipeline.

6.3.1. Status Quo / Business as Usual

The first option is to do keep status quo or in other words: business as usual. There is considerable interest and activity from industry to drive forward the Net Zero agenda. As illustrated in

Figure 15, there is breadth and depth of stakeholders within the wider NZNW ecosystem which collectively can be a powerful industrial voice to lobby government for more R&D funding and investment. However, there are disadvantages with continuing with the business-as-usual position such as the lack of alignment to principles recognised as best practice by Government in the Construction Playbook. As such, this could weaken the regional case for investment. These principles include but are not limited to the following:

- Comprehensive commercial pipelines, market health and capability assessments and a portfolio-based, longer term contracting approach
- Acting together drives mutual understanding and resolves problems quicker, sharing lessons learned is critical
- Focusing on value-based procurement and strategic outcomes
- It should be noted that these principals are already incorporated into NZNW’s partnership model, however it could be more closely aligned through an evolved governance approach.
- Lost opportunities to create linkages between projects for at-scale investment propositions and procurement efficiencies.
- Lost opportunities to aggregate project data (especially CO2 reduction) thus the true impact of investment across the region will not be clear or recognised.
- Duplication of effort to identify and develop technologies, when targets could be met sooner with coordinated and efficient use of regional resources

6.3.2. Designating a Northwest LEP as Regional Lead

The second option is to create a "Special Decarbonisation Unit" within a nominated LEP or Combined Authority in the North West Region. This coordinating body, with dotted line reporting to government, will oversee and manage the pipeline, working closely with industry and other LEPs to drive forward the industrial decarbonisation strategy on behalf of the region.

The North West is home to a high concentration of industrial manufacturing and chemical companies including TATA Chemicals, Encirc and Unilever as well as home to the automotive industry with Vauxhall and Bentley. The designated Northwest LEP could host of the "Special Decarbonisation Unit" representing the North West, along the same set-up as the Northwest Net Zero Hub in which the Liverpool City Region Combined Authority is the accountable body. This "Special Decarbonisation Unit" will strictly focus on the industries, however, there will be synergies and cross-collaboration in areas such as communications and promotional campaigns.

The Special Decarbonisation Unit could be organised into different teams depending on the strategic objectives and vision. For example:

- Partnerships, Strategy & Communications focusing on promoting the Net Zero agenda across the region; working with government and the Net Zero Hub on awareness campaigns and community engagement event; and roll out a strong partnership arrangement with industry, business, and universities.
- Industrial Decarbonisation Hub focusing on working closely together with industries to roll out their decarbonisation plans with the view to the be the first Net Zero industrial cluster. As UK industry sectors account for one sixth of total emission with the North West home to numerous of industries, supporting industries with new technologies and adaption plans will contribute significantly in reaching its targets.
- Major Projects (via new "Special Projects") focusing on large-scale and complex energy projects that requires major financing and master planning, liaising with UK Infrastructure Bank for financing if applicable. This team will undertake large-scale regional decarbonisation project that would require high level coordination and collaboration across industry, universities and government/public sector bodies.
- Policy and Technical Assistance (via a Policy and Technical Assistance "PAT" unit) will focus on policy including workforce planning and skills and setting carbon targets. The PAT unit will also have funding earmarked for various technical assistance initiatives for pre-feasibility studies and technical studies which could be managed by the local Net Zero regional hubs.

As this is a Special Unit hosted by a LEP or combined authority, the organisational structure discussed in Section 6.5 does not apply. An Executive Director with considerable background in energy will provide senior leadership, reporting to the Chief Executive of the LEP/CA and accountable to BEIS. Personnel can be staffed from various LEPs/other bodies as secondment opportunities and technical expertise can be recruited externally. Lessons can also be drawn from the five regional Net Zero Local Energy Hubs on issues of governance and operations.

6.3.3. Regional Energy Agency

Another option with a regional focus is to overhaul and expand the remit of the regional North West Net Zero Hub (NWNZ Hub) with greater authority and statutory powers to deliver the decarbonisation programme. In its current form, five regional Net Zero Hubs were created by BEIS to increase public sector capacity to bring forward energy schemes and investment pipeline identified in LEP energy strategies. All five regional Net Zero Local Energy Hubs have the overarching aim of bringing investment into energy infrastructure projects. Although funded by BEIS, the five regional Local Net Zero Energy Hubs have the flexibility to agree on strategic objectives aligned with local needs, working closely with Local Authorities and Combined Authorities as accountable bodies. Currently, the five regional Net Zero Local Energy Hub's remit include the following:

- To support LEPs and local/combined authorities to deliver the ambitions within their new energy strategies
- To raise awareness of good practice, funding opportunities and green finance approaches
- To promote 'local energy' schemes; research the market, and understand the supply chain.
- To provide technical support to public bodies developing business cases and funding applications as well as development an online portal with resources and case studies.
- To enable local areas to attract private and/or public finance for energy projects

With new roles and responsibilities under a new name such as "North West Regional Energy Agency (NWREA)," the NWREA would retain its original scope but its responsibilities could expand to include:

- Take ownership and drive the regional decarbonisation strategy for North West England under a new Executive Director.
- Be accountable to government with strong robust governance structure and strong Board in place to steer the strategic vision of the NWREA.
- Accelerate the pipeline of investable large-scale heat decarbonisation and energy efficiency retrofit projects in coordination with other regions and government.
- Work closely with education sector to formulate bespoke workforce planning and skills capacity for the NW region.
- Collaborate with major industries to support their decarbonisation journey.

Some internal re-organisation may be required as well as a strategic recruitment drive to bring in additional posts with expertise in energy and decarbonisation. In addition to opening positions to the external market, secondment opportunities would be available to employees currently working within the partner LEPs, local/combined authorities or within other government departments.

6.3.4. Industry-Led Body

Another alternative delivery structure is an industry-led body. NZNW represents a strong allegiance, industry-led cluster planning with considerable interest in transforming the industrial landscape across the North West. As the region with the largest concentration of advanced manufacturing and chemical production in the UK, the North West will blaze the pathway as the first low carbon industrial cluster. As such, it is possible that the existing NZNW organisational structure could evolve and transform into a delivery body to coordinate and promote the Net Zero agenda.

Its main remit would be strictly to lead the industrial decarbonisation agenda, working closely with industries within the North West region, LEPs, BEIS/ESNZ, and other partners to drive forward the pipeline. The "new" NZNW would be responsible for bringing together all energy projects into a single repository categorised by the project's viability, deliverability, and tangibility as well as its contributions to carbon reduction targets.

Further discussions would be required to refine the precise role and responsibilities and what statutory framework would be needed. An industry-led body with the appropriate governance and organisational structure could take on a form like a state-owned enterprise such UK Infrastructure Bank, International Nuclear Services, or Network Rail. To pursue this approach, a workshop with a range of stakeholders including NZNW, North West Local Energy Hub NW Board, and LEP/other representatives would be required to flesh out the details and resources needed.

6.3.5. National Energy Agency

One final option to accelerate the deployment of the decarbonisation programme is to set up a new National Energy Agency with statutory responsibilities. Under the aegis of BEIS/ESNZ, a dedicated National Energy Agency would spearhead and take ownership of England's decarbonisation programme.

It should be noted that "new" is somewhat a misnomer. Due to the challenging timescales to meet the Net Zero targets by 2030, it would not be feasible to build a new Energy Agency from ground up. Rather, the new Energy Agency would take inspiration from successful government models and international best practice. A possible straightforward pathway is to review the internal structure of the relevant government department BEIS[36] including its 42 agencies and public bodies such as UKRI, Nuclear Decommissioning Agency, Committee on Climate Change, and so forth.

The "new" is an amalgamation of discrete work streams and initiative under BEIS/ESNZ that relates to energy efficiency, decarbonisation, or low carbon and reorganising the workstream into the "new" Energy Agency. In other words, the new Energy Agency is a re-organisation of government bodies with its sole purpose of leading the decarbonisation agenda with greater enabling power underpinned by a new strategic framework and stronger governance structure.

For example, the UK Industrial Strategy Challenge Fund which is currently under UKRI could be moved under the responsibility and ownership of the new Energy Agency. Likewise, the five regional local Net Zero hub could sit under the aegis of the new Energy Agency, and the Committee on Climate Change would be affiliated with the new structure. The new Energy Agency would not duplicate or replicate the work already undertaken by the Net Zero Local Energy Hubs, but rather they would be providing additional funding and capacity to enable the delivery of various decarbonisation programmes.

[36] As of February 2023, BEIS has been divided into two units: Department of Energy Security and Net Zero and Department for Science, Innovation, and Technology.

6.4. Analysis of Options

The complexity and interdependencies within the decarbonisation programmes require a holistic approach. A new 'delivery model' or enabling institution would allow for whole systems thinking and strategic collaboration across the public and private sectors. This section analyses the delivery structures set out in 6.3 against the key challenges discussed in Section 6.1.

Table 30 is multi-dimensional and should be read alongside the illustration in Figure 18, as these two are related with corresponding colour code designations for each of the delivery structures. Firstly, Table 30 seeks to discuss the opportunities, challenges, and intervention gap as it relates to the key challenges of 1) planning processes; 2) system-wide thinking; 3) financing and funding; 4) supply chain issues; 5) skills and workforce; and 6) inward investments including two cross-cutting themes of project pipeline and innovation. The analysis is based on discussions with a small focus group at a workshop held in Liverpool in July 2022. Please note that this analysis of options is subjective.

Secondly, it then seeks to assess the proposed five delivery structure's ability to influence the thematic areas under key challenges. On a scale of low, medium and high, each delivery structure was assessed according to its ability to change policy and/or tap into wider networks to influence decision-making.

For each thematic area, the delivery structures were ranked accordingly from 1-5, with 1 being the highest ability to influence. For example, under the theme 'skills and workforce,' the delivery model 'national' was ranked 1, whilst BAU was ranked 5. This is because the national government via Department of Education has oversight of educational policies, agendas, and initiatives that supports the Net Zero agenda. The two regional delivery models were both ranked 2, because they would have similar influence and oversight of the skills agenda on the regional level. Whereas, BAU has limited influence on the skills agenda compared to others delivery structures.

From Table 30, the 'ability to influence' section is then translated into a diagram illustrated in Figure 18 with the scale ranking low to high for each thematic area for each delivery structure. In addition, it also shows the ranking amongst the delivery models from 1 to 5 as indicated by the number in the dot.

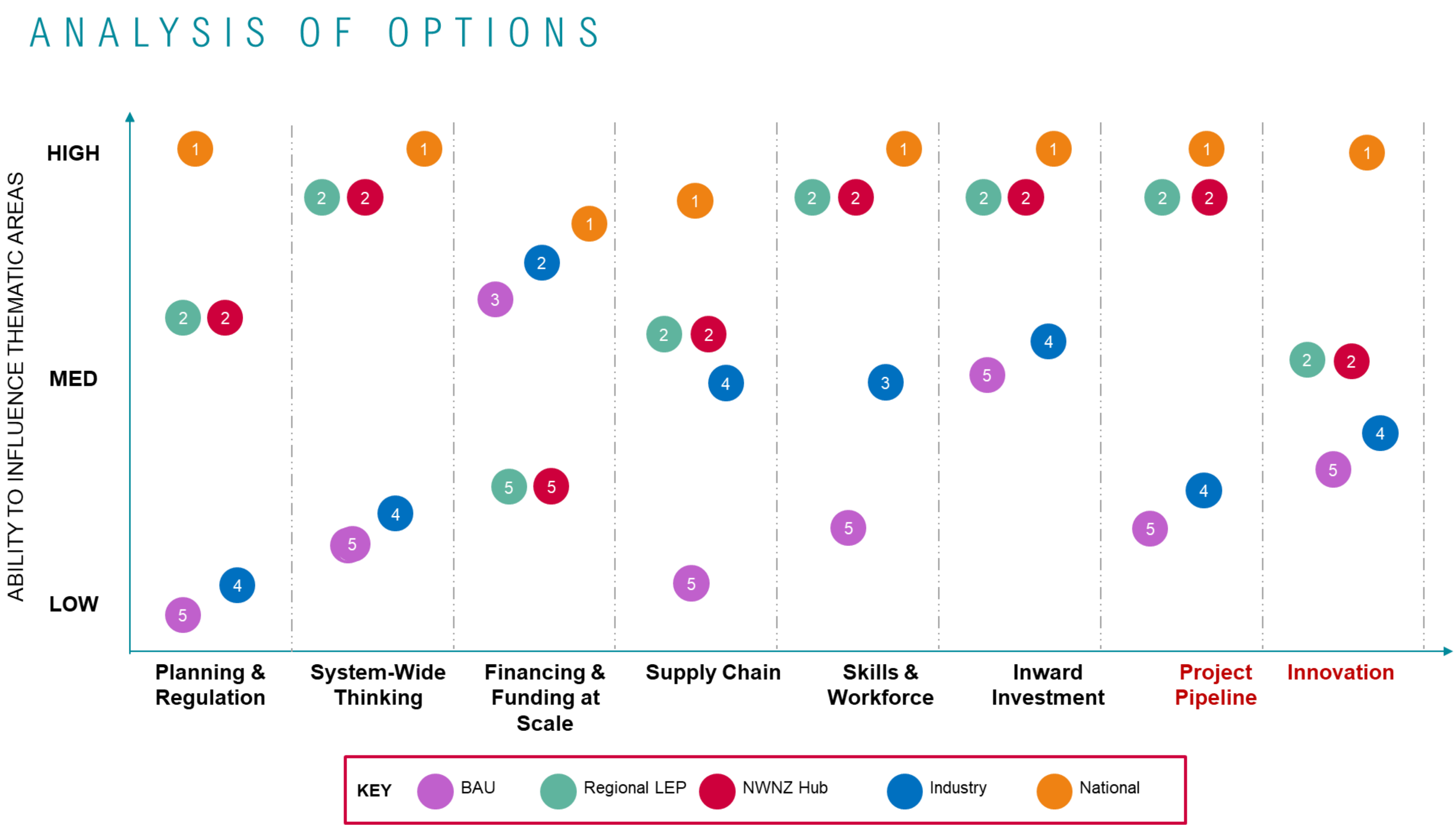
The two regional bodies – regional LEP-led or NWNZ Hub – will have identical positions across all the thematic areas. Similarly, neither approach will have advantages over the other because the current set-up of the NWNZ Hub sits within the Liverpool City Region Combined Authority. The NWNZ Hub may have a small advantage in that a governance, staff, and operational structure are already in place. However, its ability to influence the policy agenda or have oversight on skills, planning, or inward investment remain the same. The case study on the North-Rhine – Westphalia (Germany) is an example of how a regional agency can be set up to drive the Net Zero agenda.

It should be noted that industry-led will always outrank BAU as there is expectation that the new delivery body will seek to improve on the status quo, taking into consideration lessons learnt and feedback from wider stakeholders.

Table 27: Analysis of Opportunity, Challenges & Intervention Gap

	Themes	OPPORTUNITY	CHALLENGE	INTERVENTION GAP	Ability to Influence Thematic Areas BAU	Regional LEP	NWNZ Hub	Industry	National
KEY CHALLENGES	**Planning Process & Regulation**	DNOs ED2	Ofgem decision on RIIO 2 Business Cases Complex Planning Regime	Consultation in progress to revise the planning requirements	Low	Med	Med	Low	High
					5	2	2	4	1
	System-wide Thinking	Coordinated energy projects with enabling infrastructure; understand the critical pathways towards Net Zero	Lack of regional 'energy-system' planning to see the interdependencies	Policy changes to encourage systems-thinking	Low	High	High	Low	High
					5	2	2	4	1
	Financing & Funding at Scale	Large-scale solar, battery, and onshore wind can provide a good return. Hydro power delivers an acceptable return	Large-scale investments of £30-£50m or a 'portfolio' of projects to attract private finance Novel technologies still risky and need government support	Further technical support for early project development Mechanisms to 'pool' projects together for investments Collaborations with financial institutions and government	Med/ High	Low	Low	Med/ High	Med/ High
					3	4	4	2	1
	Supply Chain Issues	Supply chain quantified	Supply chain shortage and logistical challenges	Foresight and planning by a coordinating body to reduce bottleneck	Low	Med	Med	Med	High
					5	2	2	4	1
	Skills & Workforce	Increased awareness of opportunities for existing SMEs in Net Zero projects	Availability of workforce to meet scale of demand due to Brexit and post-covid19	Policy drivers to incentivise upskills in line with future market demands	Low	High	High	Med	High
					5	2	2	3	1
	Inward Investment	LCR as a Freeport NWNZ Hub Prospectus NZNW Investment Prospectus LEP's role on Inward Investment	Create more incentive to attract inward investment Collaborate with DIT to raise profile Showcase projects to investors	Enhanced government (DIT) support for international engagement	Med	High	High	Med	High
					5	2	2	4	1
	CROSS CUTTING AREAS				**BAU**	**Regional LEP**	**NWNZ Hub**	**Industry**	**National**
	Project Pipeline	NWNZ Hub sub-regional pipelines	Keeping up to date / ongoing coordination and monitoring at level of cluster / NW	Coordination failure	Low	High	High	Low	High
					5	2	2	4	1
	Innovation	Funds for industrial decarbonisation Investment in R&D	Funding landscape for early-stage and high growth companies is still fragmented in NW England	Support for early project development (de-risk) to commercial viability	Med	Med	Med	Med	High
					5	2	2	4	1

Figure 16: Analysis of Options



6.5. Organisational Structure

Regardless of the chosen delivery structure discussed earlier whether to create a new Energy Agency, Regional Energy Agency or giving more authority to an industry-led body, there also needs to be a strong organisational and/or operational structure to oversee the delivery. Although Table 28 Proposed Organisational Arrangements is for illustrative purposes only, it is a plausible organisational model to enable effective delivery of the decarbonisation programme. The below information outlines the potential roles of the various parts of the organisational structure.

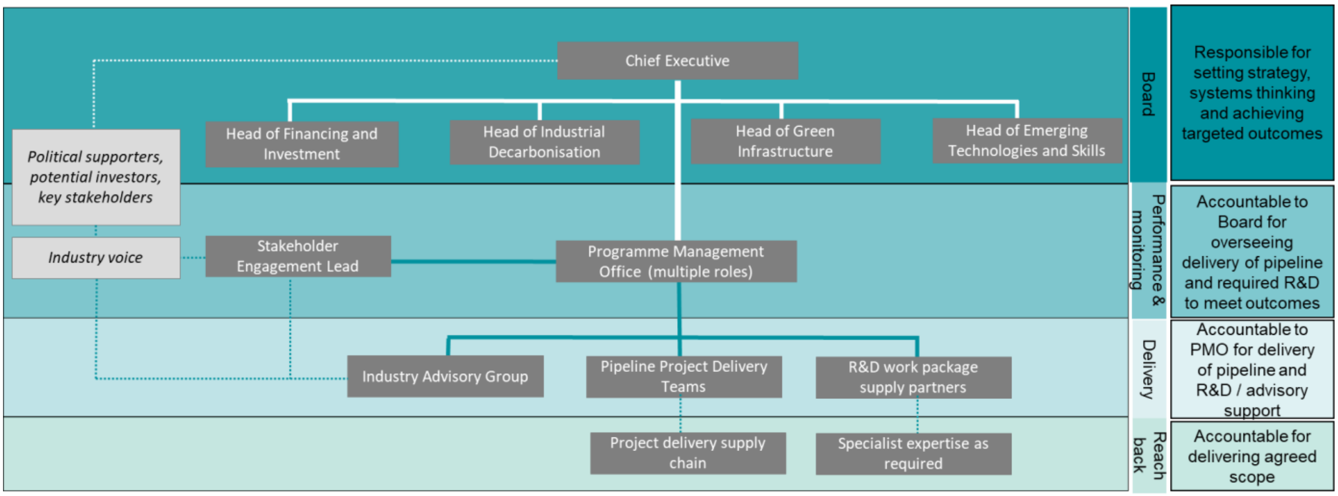
Chief Executive

The appointed Chief Executive possesses strong political and industry relationships across the North West and North East Wales region with significant influence in order to secure buy-in from stakeholders. With excellent leadership skills, gravitas, and knowledge of the energy sector, the Chief Executive will be proactive and inspire action, delivering the strategic direction and vision set by the Board. Working collaboratively with business leaders, central government, universities, and the greater North West region will lead the implementation of the large-scale decarbonisation programme.

Board Members

The Board should comprise of representatives from industry, universities and the public sector in the similar approach as the current NZNW structure. A nominated North West “regional led” from one of the LEPs or Combined Authority could also sit on the Board to give a voice on regional matters. The Board should also include well-respected individuals with specific technical expertise to give strategic inputs as required: energy specialists; special interest/industry voice group (Energy Savings Trust); BEIS representative; Green Investment Group, UK Infrastructure Bank or investor; UKRI representative; Department of Education (for skills and apprenticeships); Energy Systems Catapult, and local university.

Table 28 Proposed Organisational Arrangements



Senior Leads & Delivery Teams

Supporting the Chief Executive is the senior leadership team of directors who will oversee their respective units and teams. Working together seamlessly to combine interdependencies will help accelerate the decarbonisation programme at pace. An indicative list includes:

- **Finance, Funding and Investment Lead:** setting and overseeing the financing and investment strategy; securing and maintaining public and private sector investor relationships; developing and managing funding bids; and monitoring financial and investment performance.

- **Industrial Decarbonisation Lead:** setting the operational strategy for the delivery of the pipeline of industrial decarbonisation programme identified within this investment case; keeping the pipeline live; maintaining oversight of delivery and performance with support from the PMO and securing; and maintaining the industrial relationships, partnerships and activities required to achieve delivery of the pipeline.
- **Green Infrastructure Lead:** identifying the infrastructural requirements to support delivery of the pipeline of works; understanding the context across the geography and demography of the North West region in order to influence the pipeline and investment strategy.
- **Innovation, Technology & Skills Lead:** liaising with industry to identify the case for investment in viable research; pilot and first-of-kind schemes; developing relationships with private sector investors, education sector, universities, and other innovation hubs.

Project Delivery Teams

These are the delivery teams who are already responsible for the delivery of the projects in the pipeline that has been identified. Significant engagement is required to bring them on-board and help them see the value in joining the new NZNW governance arrangements, including contributing to investment propositions and providing data and reporting to the PMO.

Operations & Partnerships

In addition to the technical delivery team, there also needs to be a unit to look after operational matters including processes, procedures, and reporting. Partnerships and collaboration will be exceptionally important in driving forward the Net Zero carbon agenda, buy-in consensus from stakeholders and the wider community. As such there will be a need for inter-related departments including:

- **Programme Management Office** will be the central pivot between strategy and delivery. It will set out stringent performance monitoring processes and procedures to hold projects and delivery teams accountable and will provide reports to the Board. The PMO is likely to comprise of several roles including a Lead and specialists in commercial and data management and reporting.
- **Strategic Partnerships/Stakeholder Engagement Lead** will be responsible for identifying, managing and maintaining relationships with political influencers, industry and investors, including supporting and advising the Chief Executive and Board with their relationship management. The Stakeholder Engagement Lead should work closely with the Industry Advisory Group to translate the industry voice into the strategic vision and outcomes set by the Board.

Advisory Groups

A number of advisory groups will be set-up to provide strategic advice and act as a voice for a specific sector. Provisionally, advisory groups could include the following:

- **Industry Advisory Group:** This group is likely to be formed of the existing industry partners and advisors to NZNW including the North West Business Leadership Team playing a prominent role in the NZNW structure to date. The group is at the forefront of industrial decarbonisation, including being significant emitters, owning assets that require investment for efficiency or conversion and sponsoring their own projects. The group will be able to advise the Board on strategic direction and investment priorities for the region.
- **R&D Advisory Group:** This is the existing supply chain of specialist providers involved in research and business case development material to support the NZNW cluster phase plan and overall strategy towards achieving a low carbon industrial cluster by 2030 and a Net Zero industrial Cluster by 2040.

6.6. Operational Matters

Operational matters include action, step, matter or things necessary or incidental to the day-to-day provision, management and administration of an organisation. Regardless of delivery or organisational structure, the operational set-up will be critical in the day-to-day management. There will be several administrative and operational points to address where the programme management office will play a central role in delivery, monitoring and reporting.

Programme Management Office

The role of Programme Management Office will pivot between the strategy and project delivery, working seamlessly with senior leads, project sponsors, and partners. For the pipeline of works to achieve the benefits set out at Section 3.5 in the Economic Case, the strategy underpinning the pipeline needs to evolve under the responsibility of the Programme Management Office (PMO). Guiding principles should be taken into consideration, including:

- The pipeline should be governed by an agreed set of regional programme management arrangements administered by the PMO. This will strengthen the investment profile of the region by taking a consistent and at-scale approach for maximum impact in achieving Net Zero.
- The pipeline should remain a live and evolving document. New strategic, large-scale projects with impactful outcomes should be captured as they emerge to bring forward opportunities.
- Currently, the pipeline requires capital investment by the private sector at an indicative figure of £29,645Bn (short-list of projects only).
- New industries will need to be regulated as they develop from the government.
- Continuous research, development and innovation will need to be funded by the private sector, BEIS, UKRI to investigate further the technologies and schemes. An indicative list of pilot and first of a kind schemes being undertaken outside the North West region are available at Appendix C.
- Investment in skills development to meet the specialist expertise and job requirements is also needed in line with the development of new technologies.

Process, Procedures, Monitoring & Reporting

Under the responsibility of the PMO, the process, procedures, and monitoring & reporting requirements will need to be defined. The processes and procedures will follow BEIS format and guidance in line with best practice. It is envisaged that a brief 1-page report will be submitted monthly outlining activities undertaken to date, with a longer report submitted quarterly. An annual report will be required. The method to capture energy savings and carbon reduction, and number of jobs created will also need to be defined in due course.

Risk Register

Please note the risk register would replicates the master NZNW risk register and be subject to review and amendment. As reiterated earlier, it is not possible to assess specific risk factors at present as the pipeline is currently only speculative.

6.7. Conclusion

It is our view that market forces alone will not be able to achieve the UK government's ambition to reach Net Zero by 2050. Given the complexity and interdependencies of systems, collaboration is the "new" kind of leadership. The government, in collaboration with key industry partners, need to take the lead in making this Net Zero ambition a reality. The size and scale of the challenge combined with the need to work at pace necessitates a new "enabling institution" ideally with the appropriate planning and decision-making powers, or the ability to influence the planning process It would need to coordinate across various sectors spanning the built environment, manufacturing, transport, infrastructure, and land use as well as across thematic areas of skills, innovation, planning, and financing.

A more robust delivery and governance model with strong leadership is required to coordinate across various sectors, whilst incorporating various policies. As the international case studies illustrated, there is no "one way" or the "right way" in setting the delivery model. Whether it is industry-led, partnership, regional government agency, or a non-profit, it requires strong collaboration and leadership from industry, government, and business. Some 'initial' funding from national government with contribution from stakeholder groups to get the new delivery model up and running may be required. Leaving the situation "status quo" would likely result in fragmentation, duplications, and inconsistencies which can cause delays rather than expediting the collective implementation efforts.

Better coordination in managing the project pipeline, pooling together, or aggregating projects to create viable propositions is necessary for investments at scale and at pace. As such, a strong coordinating body with planning and decision-making powers akin to an urban development corporation or freeport status to create a favourable environment is recommended to steer the region towards achieving its Net Zero agenda. Critical enabling infrastructure, new business models and strong policy and regulatory framework are required to create a stable environment with financial support from central government to mitigate risks associated with implementation.

Industrial clusters will evolve. The management of industrial decarbonisation will be an on-going process with close *coordination* between policy and industrial partners for *clarity* and *confidence*, as well as *collaboration* together with the industrial partners to shift to Net Zero by 2040. Our recommended next step is to convene a series of stakeholder workshops to review these findings and inform a delivery model to implement the Net Zero agenda and drive forward the pipeline.

Disclaimer

The research underpinning this Investment Case was undertaken between January 2022 – May 2022 with the first draft produced in June 2022. As such, this report was up-to-date at the time of research and writing this Investment Case. In December 2022, a short extension scope was included specifically for the Management Case to explore other international industrial decarbonisation clusters in Europe and beyond.

Since June 2022, there have been major political shifts with two Prime Ministers, new policy announcements, and re-organisation of the Department of Business, Energy and Industrial Strategy (BEIS). This Report does not differentiate between the new departments and refers to BEIS simply as BEIS.

For further information about this report or the pipeline please contact Cheshire and Warrington LEP in the first instance strategy@cheshireandwarrington.com

7. Appendix

Appendix	Description of Appendices
Appendix A	List of source material providing project data and research
Appendix B	Summary of Work Packages
Appendix C	Pilot And First of a Kind Case Studies (out of region)

Appendix A: List of Research and Data

No	Title of Document	Organisation	Key Information
1	Northern Powerhouse Energy & Clean Growth Report	Northern Power House / KPMG	Priority areas and cross cutting enabling factors
2	HyMotion Report	Cadent / Progressive Energy	Network-supplied hydrogen unlocks low carbon transport opportunities
3	NZNW Report Phase 1	Progressive Energy	Shaping an Industrial Cluster Plan
4	Whitepaper: Unlocking Electrolytic hydrogen	Siemens Gamesa	Key to delivering low cost electrolytic hydrogen
5	The-North-West-Energy-and-Hydrogen-Cluster-Prospectus	North West Business Leadership Team	Timeline of Projects in the NW, list of stakeholders
6	Net Zero North West Economic Investment Prospectus	Siemens / NZNW	3 priority areas and 18 investment areas
7	Hydrogen Demand Criterion	Element Energy	Feasibility Study for Liverpool City Region Combined Authority and INOVYN
8	Hydrogen to Heysham	EDF	Looking at the potential for hydrogen production and demand in Heysham / Lancaster
9	Energy systems a view from 2035	Arup	Energy market in 2035. Systems approach
10	ETC-Global-Hydrogen-Press-Release	Energy Transition Commission	Broad literature review on energy transition and readiness of technologies for clean hydrogen . Systems perspective on transition
11	Hydrogen Transport - Fuelling The Future	Arup	This perspective focuses on the core modes of transport that can benefit from transitioning to hydrogen.
12	Hydrogen transport: overcoming the refuelling roadblock	Arup	Systems approach to Hydrogen transport.
13	5 Minute Guide to Hydrogen	Arup	Overview of Hydrogen
14	SMR Brochure	Rolls Royce	Overview of the potential for SMR for new nuclear going into the future
15	Tracking the Trends	Deloitte	Social Investment, getting Private-Public Partnerships right. The Path to decarbonisation
16	Nuclear Energy for Net Zero – Manchester Strategy	University of Manchester	This paper sets out to examine the possible roles for nuclear energy in a 'level playing field' approach to Net Zero by 2050, making use of the various mechanisms on an overall best economics basis, with an objective, well-developed economic assessment system.
17	Ellesmere Port-Smart-Energy-Master-Plan	Cheshire Energy Hub	Optimised concept design with an associated ten-year investment plan for the industrial heartland around Ellesmere Port
18	The Role of Hydrogen in Powering Industry	All Party Parliamentary Group	Report done by joint industry in government on the role of hydrogen in the future of the UK
19	GM Hydrogen and Fuel Cell Strategy	Manchester Met University	How clean energy can help deliver Greater Manchester's 2038 decarbonisation ambition.
20	The Electrolytic hydrogen Economy	PwC	An analysis of the future economics of renewable energy identifies the most promising markets for importing and exporting
21	Investing to drive the hydrogen energy revolution	Turner & Townsend / Cadent	

22	How can digital transformation help us achieve Net Zero?	Atkins	
23	UK Hydrogen Strategy	HM Government	Roadmap for Hydrogen Use in the UK
24	10 point Plan for a Green Industrial Revolution	HM Government	Building back better, supporting green jobs, and accelerating the path to Net Zero
25	The North West Nuclear Arc Science and Innovation Audit	NW Nuclear Arc	highlights science and innovation. and identifies the major economic contribution the nuclear industry makes. Shows systems and synergies between institutions and organisations in nuclear
26	Local Energy North West Hub	Energy Hub	Raising awareness of best practice and funding options, and enabling programmes, this resource will help local energy hubs to drive public and private investment in clean energy infrastructure.
27	Inovyn Hydrogen Projects	Inovyn	A detailed list of the various Inovyn Hydrogen Projects
28	Innovate Future Transport	Innovate UK	It takes a view of where we will be by 2050 and outlines the likely steps along the way to achieving this. The aim is to gather UK government and industry around a single vision that will inform the way we all invest in the future of transport to deliver economic growth and societal benefit. It is also to provoke debate.
29	Sixth carbon Budget – UK path to Net Zero	Climate Change Committee	Outlines the UK's path to Net Zero / sector pathways / investment requirements / international commitments etc

Appendix B: Summary of Work Packages

The costs discussed within the Investment Case are informed by the work package reports, which has been produced by: Equans, Uniper, Cadent, Progressive Energy, SPEN and Local Energy. Together, these reports set the scene and projects were reviewed in detail the scale of opportunity, and the measures required to help achieve Net Zero by 2040.

Work Package	
Work Package 4	Industrial Decarbonisation Solutions, led by Equans
Work Package 5	Electrolytic Hydrogen Recommendations, led by Equans
Work Package 6	Grid Scale Low Carbon Dispatchable Power, led by Uniper
Work Package 7	HyNet and its Role in Net Zero, led by Progressive Energy & Cadent
Work Package 8	Electricity Distribution Network Impact led by Scottish Power EN
Work Package 11	Regional energy analysis led by Local Energy

This section summarises the scale of the scale of projects required to abate the CO2 emissions of the North-West.

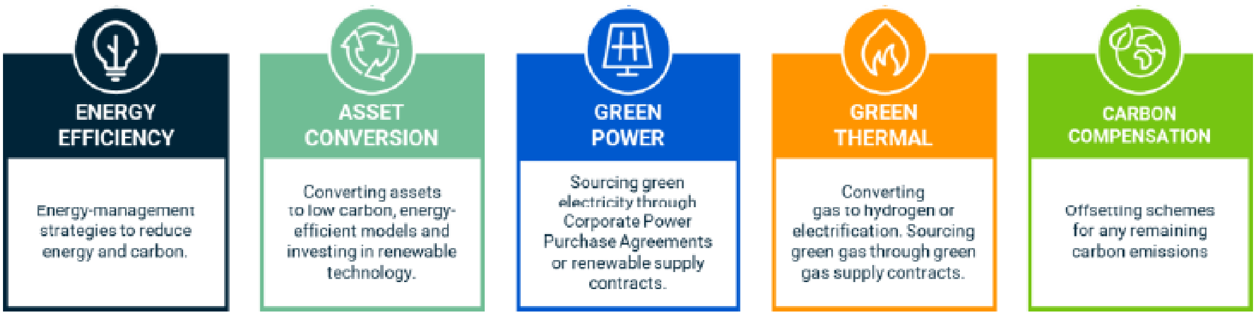
Work Package 4: Industrial Decarbonisation Solutions

The report recommends industrial companies within the North West produce individual Net Zero carbon action plans that align with the NZNW 2040 ambitions to become the world's first Net Zero industrial cluster. It suggests this must be done through a holistic approach to decarbonisation, focussing not on individual technologies but integrated energy systems. These systems should tackle efficiency first, prior to the more complex infrastructure requirements. These recommendations align with the proposal to maintain a live NZNW pipeline governed by holistic arrangements.

Road Map to Net Zero

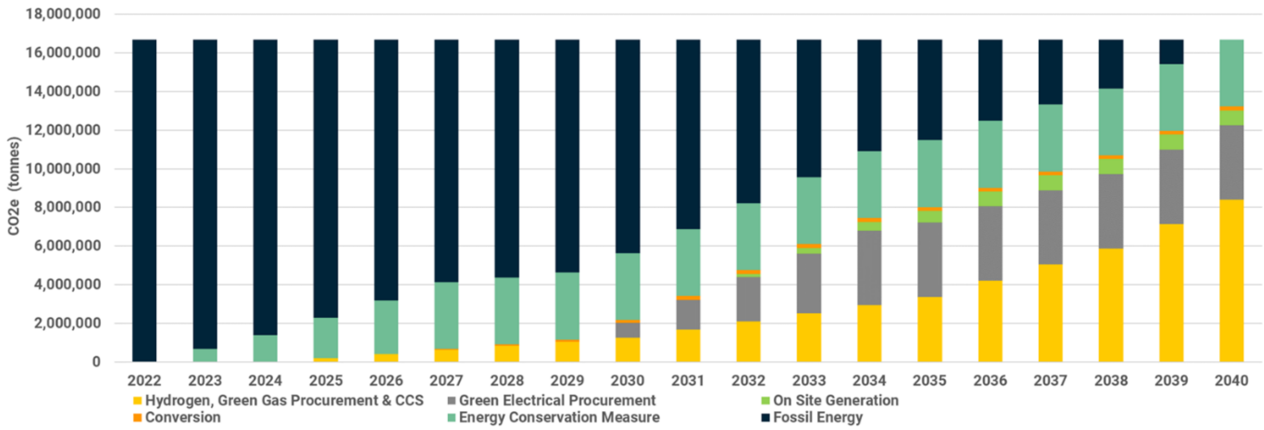
The report presents a Net Zero road map which includes five categories for emissions reduction, these are outlined below:

Figure 17 WP 4 Categorisation of each carbon reduction methods (P87))



The report outlines that energy efficiency, procurement of green power and low carbon H2 (green thermal) are the key measures to delivering substantial carbon savings in the North-West. It suggests the first key step of decarbonisation is through energy efficiency and improved performance resulting in increased capital through savings, which in turn can fund projects. Following this attention should be paid to maximising energy performance, decarbonising of site processes, and heat reduction through the use of different technologies such as hydrogen as an alternative fuel. Hydrogen is expected to be readily available to some parts of the North-West sector from 2025, however its demand will need to be complimented by combined heat & power (CHP), heat pumps (HP) and electrification assuming electricity is procured from renewable sources. The rate of conversion relies on the availability of hydrogen and the decarbonisation of the grid. On-site generation includes power generation from solar and wind which can supply carbon free power to all the sectors in North West. The report outlines the following pathway to Net Zero which has been designed based on the order of priority of implementation and commonality of technologies and considering the availability of new technology and alternative fuels such as Hydrogen, this is shown below.

Figure 18 WP4 North West Overall Carbon Neutral Delivery Plan (P86)



Demand

The analysis included in the report is based upon EQUANS' sector assumptions derived from Energy Savings Opportunity Scheme (ESOS) audits, European Union Emissions Trading System (ETS) emitters and UK National Atmospheric Emissions Inventory (NAEI). It has been focused on the North West across 27 industrial sectors with 181 manufacturing sites, incorporating five common technology themes across the sectors: Energy Efficiency, Low Carbon Technologies, Renewable Generation and Hydrogen. The report evaluates the characteristics of industrial consumers by sector in the North West.

Additionally, the report considers practical routes for decarbonisation delivery. It does this by providing an assessment of future technologies and creates deliverable investment, technology and infrastructure blueprints for the North West's transition to low carbon and Net Zero. Using this approach, the report provides a sector based overview of the CAPEX requirements needed to achieve the CO2 abatement to decarbonise the region.

These figures are significantly lower than those represented in the pipeline of works within this report. This is because the pipeline in this report considers not only projects on specific industrial sites but the upstream renewable feed source and other downstream and demand projects that contribute to the entire decarbonisation system.

Figure 19 WP 4 Sector *Carbon and financial savings (P86)*

Sectors	Total Savings (tCO2e)	Fiscal Savings (£)	Capital Investment (£)	Payback (years)
Automotive	153,256	£12,251,487	£42,986,966	3.5
Cement	3,057,649	£56,639,715	£224,186,184	4.0
Chemical	1,133,322	£42,606,095	£183,683,894	4.3
Food & Drink	971,931	£81,366,430	£350,923,191	4.3
Glass	583,313	£20,766,393	£70,392,507	3.4
Iron & Steel	63,952	£3,122,436	£11,505,395	3.7
Paper & Pulp	926,812	£50,170,175	£204,859,096	4.1
Pharmaceuticals	276,272	£23,777,854	£82,809,492	3.5
Other Sectors	9,104,792	£524,629,055	£1,816,997,514	3.5
Totals	16,271,300	£815,329,642	£2,988,344,238	3.7

Figure 20 WP 4 Sector *Carbon and financial savings from each category (P87)*

Technology/Opportunity	Total Savings (tCO2e)	Fiscal Savings (£)	Capital Investment (£)	Payback (years)
Energy Efficiency	3,463,048	858,021,706	2,792,336,023	3.3
Conversion	194,542	-1,850,667	71,656,926	N/A
On-site Generation	774,143	79,656,383	520,000,526	6.5
Green Electricity Procurement	3,845,847	N/A	N/A	N/A
Hydrogen, Green Gas Procurement & CCS	8,409,717	N/A	N/A	N/A
Totals	16,687,296	£935,827,422	£3,383,993,476	3.6

The report then analyses the technological requirements to decarbonise each of the different sectors using a ‘bottom-up’ approach. From this, the report predicts the CAPEX requirements needed for each technological opportunity, incorporating five common technology themes across the sectors: Energy Efficiency, Low Carbon Technologies, Renewable Generation and Hydrogen. The summary of which can be seen below. A £2bn CAPEX line item was included for energy efficiency schemes in the pipeline, with the conversion, on-site generation and green electricity procurement items represented by projects throughout the pipeline.

Work Package 5: Electrolytic Hydrogen Recommendation

There is considerable opportunity to optimise LCOH (Levelized Cost Of Hydrogen) for Electrolytic Hydrogen in the region through Onshore Wind within close proximity to HyNet. The lowest LCOH is achieved when electrolysers are directly connected to Offshore Wind and able to blend into the HyNet network. At less than £2/kg, this electrolytic hydrogen provides the most competitive LCOH compared to LCOH produced by HyNet. Offshore and onshore wind projects feature within the pipeline for this reason.

A major opportunity for producing electrolytic hydrogen is to connect the electrolysers to Offshore Wind turbines at the onshoring location and behind the meter, which would, at this stage, form part of the ‘unidentified’ projects beyond the pipeline.

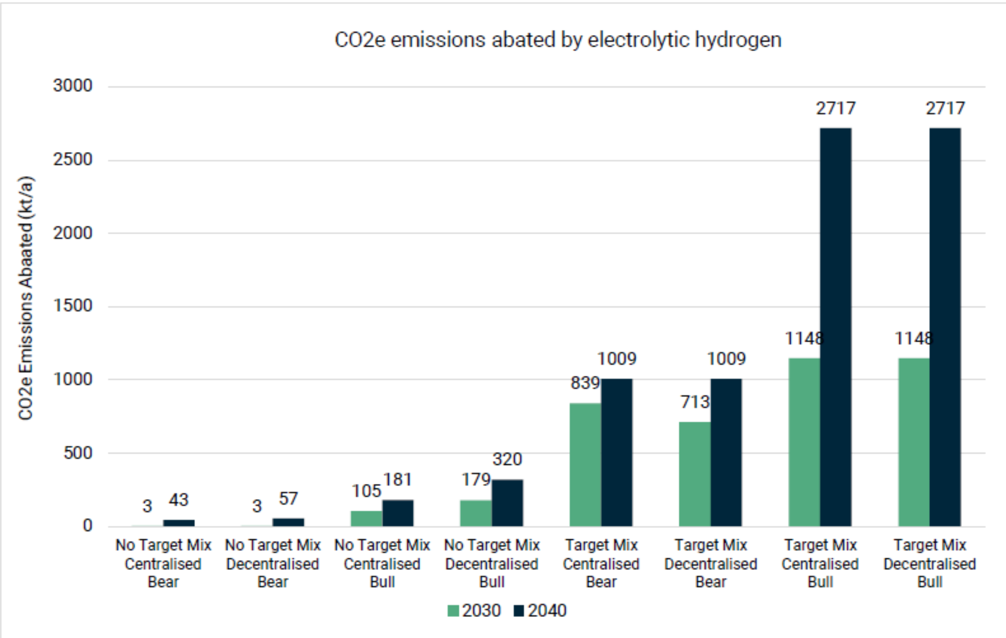
Hydrogen Business Models are essential to provide long term revenue certainty for hydrogen producers, similar to that of the power CfD. There is potential for Offshore Wind power producers to secure long term contracts, by proxy, through this mechanism. This also allows reduced network connection costs, creating additional economic value for these Offshore Wind developments. In 2020, approximately, 3.6TWh of Offshore Wind was curtailed in the UK, primarily due to network constraints. There is opportunity to connect renewable energy sources behind the meter, such as solar PV or tidal private wire to electrolysers at onshoring locations to reduce curtailment. However, electrolysers will need to compete with our electrical storage options to be selected as the preferred solution for reducing curtailment.

There are long term opportunities for purple / pink hydrogen, produced via electrolysers connected to small modular reactors. These SMR's have a consistently high load factor, which is ideal for electrolytic hydrogen production.

Demand

The opportunity for hydrogen comes from its ability to reduce the carbon intensity of processes that are 'hard-to-abate', processes requiring high energy intensity, currently reliant on fossil fuels to which electrification is not a viable option. Based on the amount of electrolytic hydrogen consumed, and the assumption that the vast majority of this is displacing natural gas, it is possible to examine the amount of emissions abated by electrolytic hydrogen across the scenarios summarised in the graphic below:

Figure 21 WP 5 Emissions abated by electrolytic hydrogen in 2030 and 2040 for each of the modelled scenarios (P55)



Capacity

The below shows the electrolyser and renewables capacities installed for each of the scenarios. There is a positive correlation between the volume of the electrolytic hydrogen requirements and the installed capacities (Target Mix and Bull) . From these graphs it can be observed that the Bear to Bull markets change and the No Target Mix to Target Mix modifications are responsible for most of the step changes in capacities. This is because higher consumption equals higher production which necessitates increased capacities. However, there is also a step change between the Target Mix | Centralised | Bull and the Target Mix | Decentralised | Bull scenario with an additional 4.2GW of electrolyser and 6GW of renewables installed in the decentralised scenario, as highlighted by Box 1 in the graphs below.

Figure 22 WP 5 Installed electrolyser capacity in 2030 and 2040 for each of the modelled scenarios (P53)

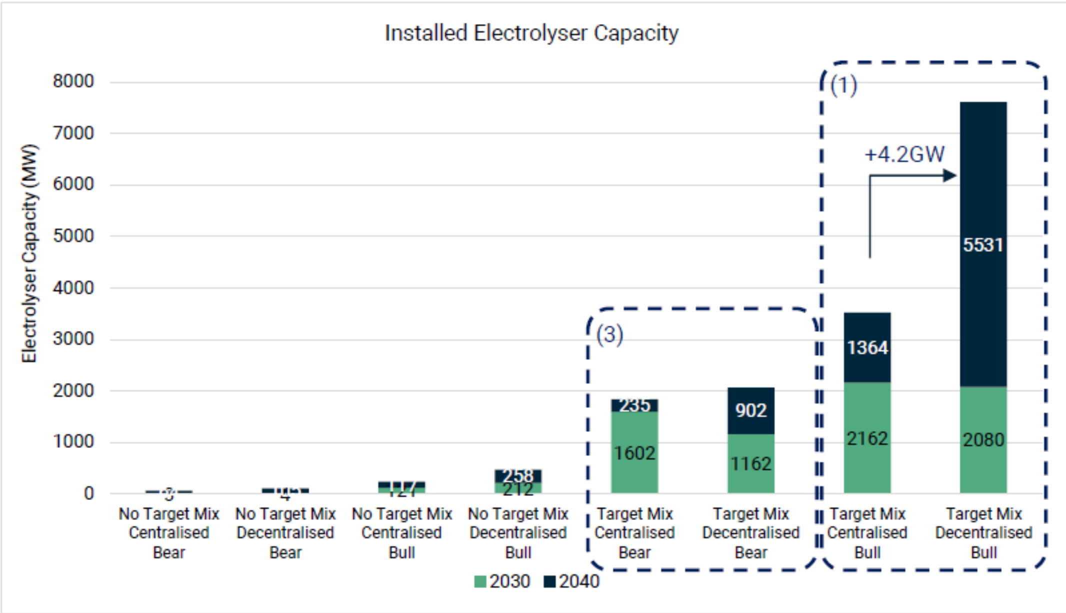


Figure 23 WP5 Installed renewables capacity in 2030 and 2040 for each of the modelled scenarios

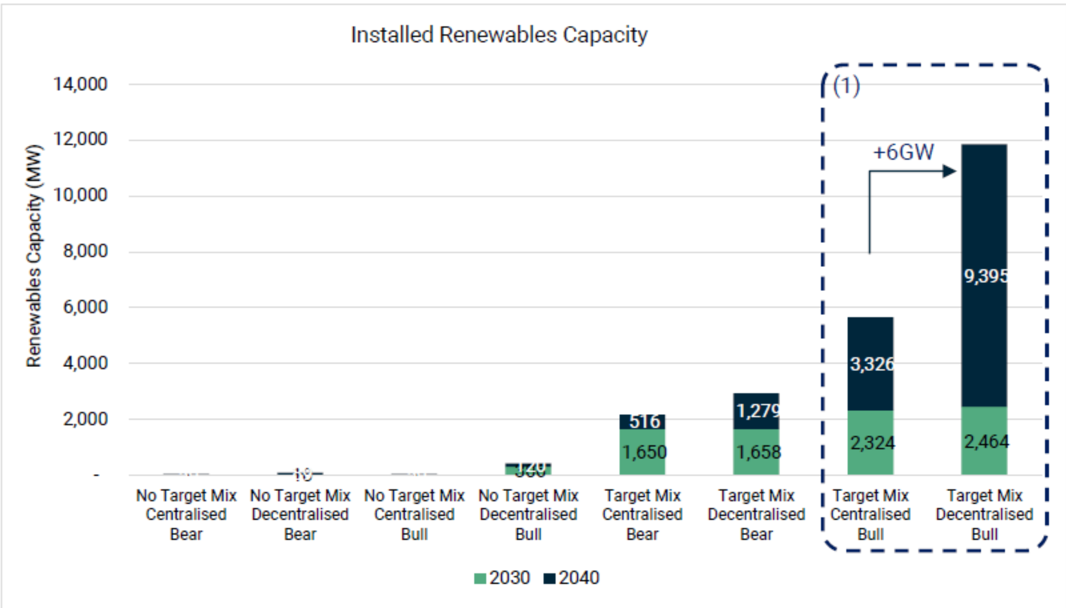
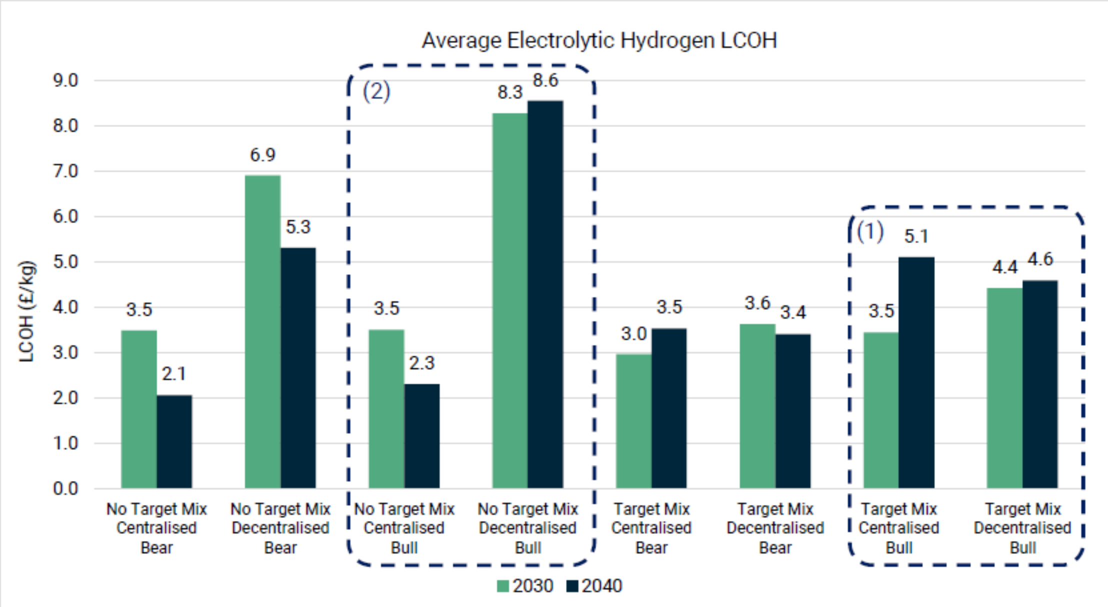


Figure 24 below shows average LCOH (Electrolytic). The trend between decentralisation and reduced LCOH is only evident in the highest consumptions scenarios (i.e. Target Mix 2040). The benefits of centralisation in lower consumptions scenarios, such as Box 2 below, can be seen.

Figure 24 WP 5 Average electrolytic hydrogen LCOH in 2030 and 2040 for each of the modelled scenarios (P54)



Work Package 6: Grid Scale Low Carbon Dispatchable Power Generation

This report sets out a pathway to Net Zero, hinged upon changes required by the power generation sector. Much of this required decarbonisation is likely to be achieved via greater penetration of renewables, however, to maintain security of supply, low carbon dispatchable power is shown to be required throughout the forecast period to 2050. Forecasts suggest Hydrogen Turbines and Natural Gas Turbines with Carbon Capture will be the most likely technologies to provide a significant portion of the required low carbon dispatchable power. The exact mix, capacity and generation is open to significant variation across future predictions. There is significant opportunity for deployment of dispatchable low carbon power generation in the North West Region Based on the proposals made as part of HyNet and wider projects.

Some significant challenges must be overcome before deployment of such assets can be considered as reliable projects:

- Proof of technological capability at scale is required for both Hydrogen Gas Turbines and Natural Gas Turbines with CCS;
- Suitable business models and regulatory frameworks are required to ensure investor confidence; and
- Suitable and sufficient infrastructure developments will be required on Hydrogen, Carbon Dioxide and power networks

Electrical Demand

- In general, all forecasts see an increase in total electricity demand to 2050, with the 'Widespread Innovation' scenario detailed by the CCC suggesting a 3 fold increase in annual electricity demand if including demand for electrolysis.
- The 2020 Future Energy Scenarios (FES) produced by National Grid ESO forecast an increase in the peak electricity demand (that seen on a cold winter's weekday evening) through to the mid 2040s for all scenarios, with a 30-50% increase being suggested.
- It is detailed by the National grid in their 'Consumer Transformation' scenario that up to 2.8 times more generating capacity may be required in 2050 compared to today.

- High levels of renewable penetration means significant variability in available or delivered power by future technologies. Therefore, the remaining generation mix provides suitable levels of both capacity, flexibility and dispatchability.

In addition to variation of demand forecasts, energy mixes and technologies across the models and scenarios in the report show variation year on year as thinking and assumptions evolve. Figure14 shows a comparison of the forecast trends in the 2020 and 2021 National Grid Future Energy Scenarios. It shows both demand and generating capacity forecasts have increased from the 2020 predictions to 2021. For the peak demand forecast for the Consumer Transformation scenario, this increase is significant, at almost 20%, this highlights the volatile nature of predictions in this space.

Capacity

Due to the significant variation in low carbon dispatchable generation forecast in the future energy scenarios for a common vision for the UK proposed by the National Grid, the report considers 2 potential deployment scenarios for H2 Gas Turbine Capacity and Generation adoption; Consumer Transformation and System Transformation. These scenarios were then aligned with the scenarios being developed by project partners and collated trends which outline 2 scenarios; Big Electric and Big Hydrogen. Using this, the figure below shows the potential capacity and generation volume of Hydrogen Turbines in the cluster.

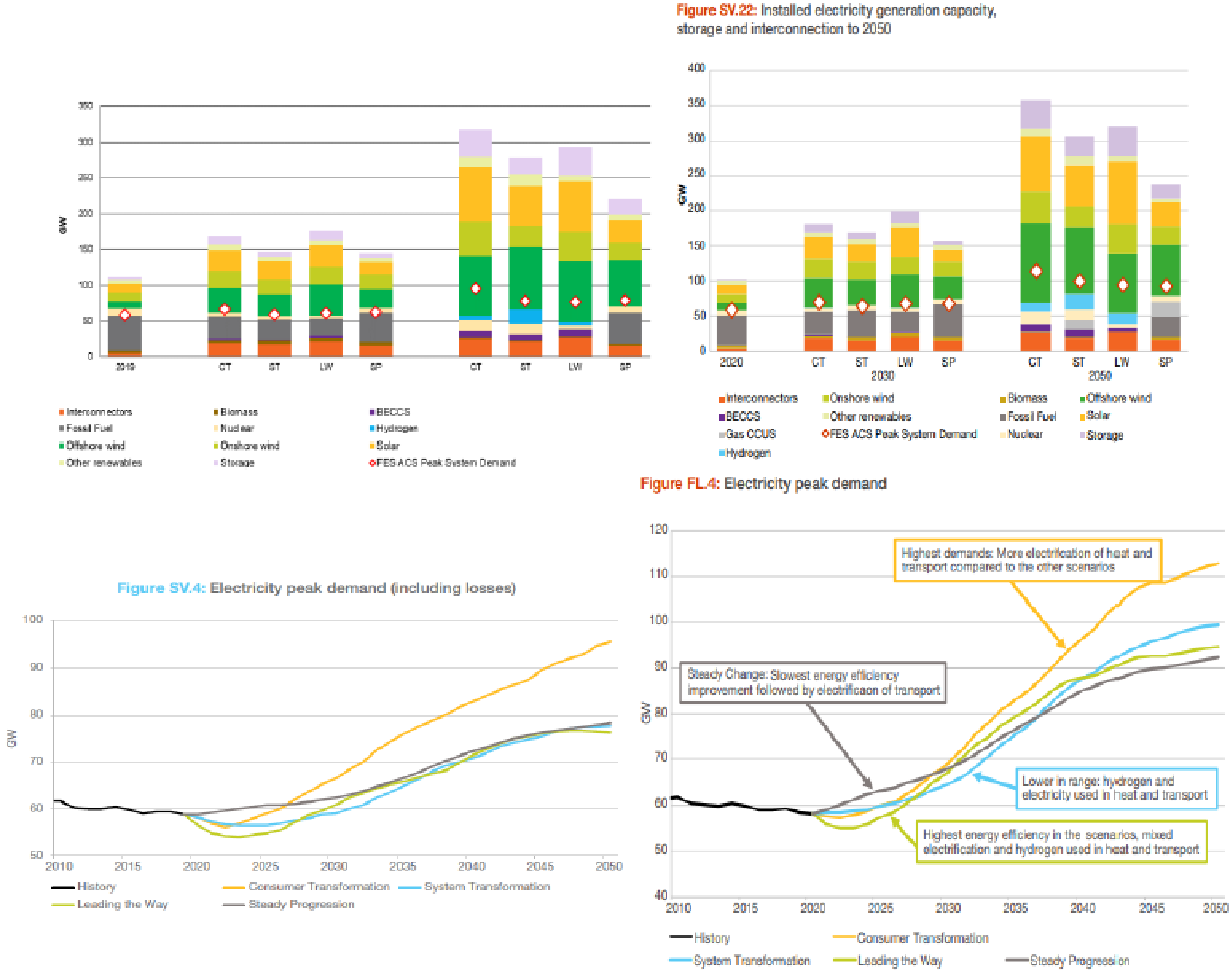


Figure 25 WP 6 Graphs from the 2020 and 2021 National Grid Future Energy Scenarios (7) (139), showing the variation in predicted installed generating capacity and peak demand (P68)

Figure 26 WP 6 Table to show potential capacity and generation volume of Hydrogen Turbines in the Cluster

Regional View			Big E 2030 Bull	Big E 2030 NG CT	Big E 2040 Bull	Big E 2040 NG CT Trans 1/6
	Generation	TWh	1.05	0.00	2.40	0.87
	Capacity	GW	0.40	0.00	1.65	0.6
	Load Factor		30.00%	-	16.58%	16.58%
	Efficiency		53.00%	39.99%	39.99%	39.99%
	H2 pa	TWhr	1.98	0.00	6.01	2.18

Regional View			Big H 2030 Bull	Big H 2030 NG ST	Big H 2040 Bull	Big H 2040 NG ST Trans 1/6
	Generation	TWh	0.88	0.00	2.07	1.21
	Capacity	GW	0.40	0.00	1.89	1.10
	Load Factor		25.00%	-	12.50%	12.50%
	Efficiency		53.00%	48.90%	48.90%	48.90%
	H2 pa	TWhr	1.65	0.00	4.24	2.47

For the 2030 Bull scenarios, 53% Gas Turbine efficiency was used in line with the assumptions applied to the CCC Sixth Carbon Budget scenarios. Where % Hydrogen for power is considered, the Big Electric scenario being proposed has a greater Hydrogen demand for power than the Big Hydrogen Scenario. This is due to two factors; a comparatively higher total hydrogen demand in the Big Electric case compared to the Big Hydrogen proposed by WP5 (38% for WP5 compared to 23% for CT vs ST), coupled with a lower GT efficiency for the National Grid Consumer Transformation scenario. Figure 27 below, shows the Hydrogen demands in the cluster as a result of this, including Hydrogen for power.

Figure 27 WP 6 Table showing Hydrogen demands in the cluster as provided by WP5, including Hydrogen for power

	2030				2040			
TWh/a	Bull (Transition)							
Industrial Demand	20.45		12		24.9		16.8	
Residential Demand	2.4		0.9		31.1		0	
HGVs	0.45		0.1		1.25		0.45	
Rail	0.36		0.22		0.66		0.36	
Total H2 demand (w/o power)	23.66		13.22		57.91		17.61	
	NG CT	Bull	NG ST	Bull	NG ST (1/6)	NG ST (%)	NG CT (1/6)	NG CT (%)
Power	0	1.98	0	1.65	2.47	4.24	2.18	6.01
% power	0.00%	7.74%	0.00%	11.12%	4.08%	6.82%	11.02%	25.45%
Total H2 demand	23.66	25.64	13.22	14.87	60.38	62.15	19.79	23.62
					1/6th of total	%H2 for power	1/6th of total	%H2 for power

Work Package 7: Industrial Decarbonisation Systems

Full network conversion will be a complex and long process. HyNet is primarily focused on a new-build network to connect industry and the network blending points, followed by delivering a blend of hydrogen (with natural gas) into the existing distribution network. The initial phase of injection will reach around two million gas customers and will represent a meaningful level of decarbonisation with effectively zero disruption to households and businesses. The following 2 graphs show the growth of storage requirements, blending and power demand through to 2030.

Figure 28 WP 7 Growth In Total Storage Requirements through to 2030 (P42)

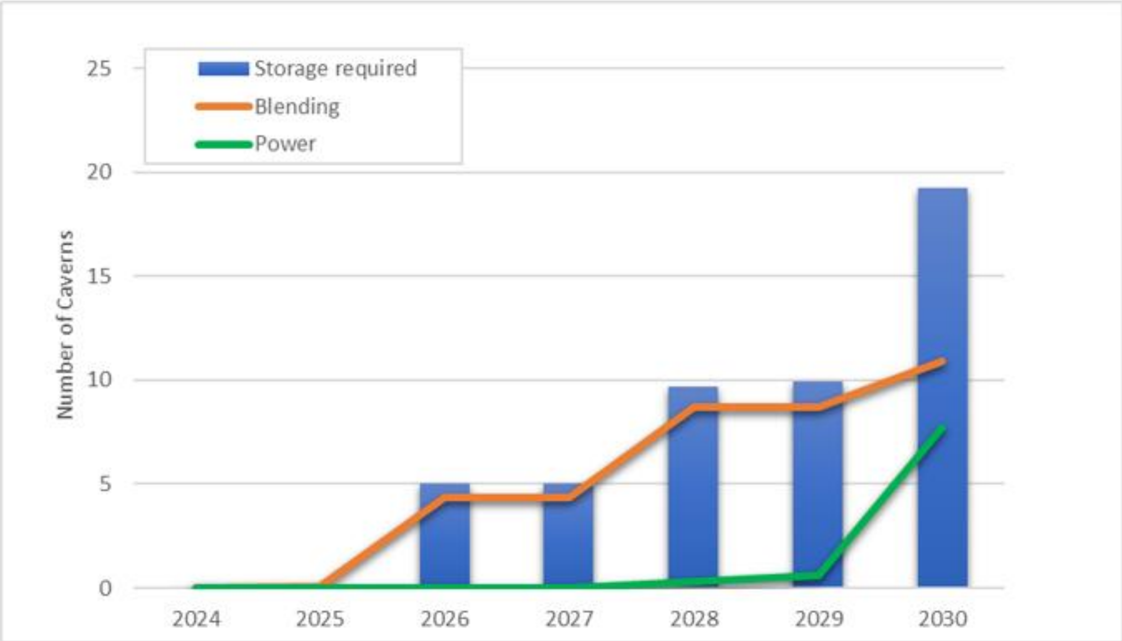
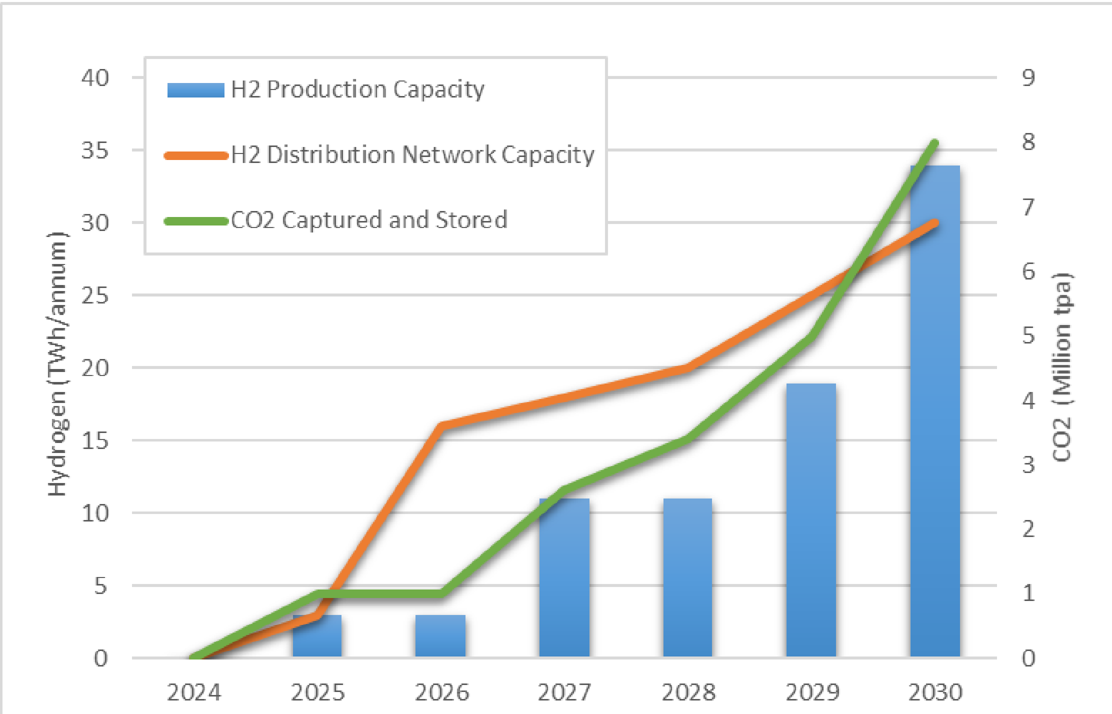


Figure 29 WP 7 Infrastructure deployment to 2030 (P56



Demand

Assumptions predict that the hydrogen demand profile from industry will be relatively ‘flat’ once there are multiple manufacturing sites connected to the network. However, demand from both power generation and heating will be highly variable.

During the 2030s, the Hydrogen network may be extended to supply the residential sector after a potential future policy decision being made on the use of hydrogen to heat homes.

- Progressive analysis shows that capturing 10MtCO2pa for transport and storage in the HyNet CO2 network is a credible scenario by 2030.
- The HyMotion report predicts a scenario in 2030 for demand for hydrogen for use in transport, which results in demand of 1.06TWh/annum.
- The below table predicts the total Hydrogen demand in 2030, to give total demand of 22-29TWhpa in 2030. The 7TWh difference between the two scenarios reflects the following potentially variable speeds of:
- Policy development and the finalisation of suitable business models to fund hydrogen (and CCS) deployment;
- Deployment of the hydrogen network, given the need to get planning consent (including DCO consent) for the main feeder lines of the network;
- Deployment of the CO2 pipelines, which again are subject to DCOs; and
- Decision-making by industry boards in respect of switching sites to operate on hydrogen.

Table 29 WP 7 total hydrogen demand in 2030 (P69)

<table>
<tr><th>Sector</th><th>Bull Hydrogen Demand (TWhpa)</th><th>Bull Hydrogen Demand (TWhpa)</th></tr>
<tr><td>Industry</td><td>19.78</td><td>12.45</td></tr>
<tr><td>Large Power Generation</td><td colspan="2">4.86</td></tr>
<tr><td>Network</td><td colspan="2">3.36</td></tr>
<tr><td>Transport</td><td colspan="2">1.06</td></tr>
<tr><td>Total</td><td>29.07</td><td>21.73</td></tr>
</table>

In terms of the Hydrogen demand in 2040, HyNet’s primary focus is on industry in the early years to 2030. There is only a further 4TWh on top of the 2030s 19.7TWh of demand from major industrial emitters in 2040, with the vast majority of network and supply expansion being to serve other sectors of the economy. Highlighted in the table below:

Table 30 WP 7 total hydrogen demand in 2040 (P75)

<table>
<tr><th>Sector</th><th>Bull Hydrogen Demand (TWhpa)</th><th>Bull Hydrogen Demand (TWhpa)</th></tr>
<tr><td>Industry</td><td>23.77</td><td>17.19</td></tr>
<tr><td>Large Power Generation</td><td colspan="2">11.37</td></tr>
<tr><td>Network</td><td>35.43</td><td>24.06</td></tr>
<tr><td>Transport</td><td colspan="2">5.24</td></tr>
<tr><td>Total</td><td>75.80</td><td>57.85</td></tr>
</table>

Capacity

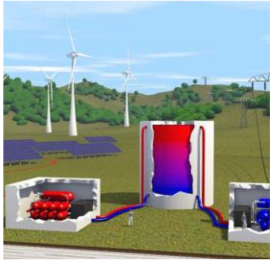
Low carbon Hydrogen Capacity to 2030 is shown below:

Table 31 WP 7 HyNet Hydrogen Capacity through to 2030 (P 75)

	2025	2026/7	2028	2030
Annual LCH™ Deployment (TWhpa)[1]	3	6	12	12
Cumulative LCH™ Deployment (TWhpa)[1]	3	9	21	33

Notes: Hydrogen production is presented gross of parasitic load of around 10% of hydrogen used to fuel the LCH™ process

Appendix C: Pilot & First of a Kind Case Studies (Out of Region)



Siemens Gamesa Electric Thermal Energy Storage Solutions

Siemens Gamesa and Siemens Energy are launching development projects leading to a fully integrated offshore wind-to-hydrogen solution. Siemens Gamesa will adapt its development of the SG14-222 DD offshore wind turbine, while Siemens Energy will develop a new electrolysis product for offshore use.

The aim is to find an innovative solution that fully integrates an electrolyzer into a dedicated platform at the base of an offshore wind turbine as a single synchronized system for offshore hydrogen.

There is a target a total investment of approximately EUR 120 million in the development of this innovative solution.

This decentralized offshore wind-to-hydrogen solution will support the mainstream production of electrolytic hydrogen at scale in three main areas:

1. Enable more and better wind sites to be utilized using island-mode

2. Maximize the amount of wind power that is converted to electrolytic hydrogen by reducing transmission losses

3. Reduce costs further by modularization.

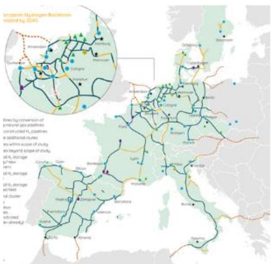
NortH2 (The Netherlands)

NortH2 aims to produce up to 4 gigawatts of electrolytic hydrogen by 2030, fulfilling one of the goals set by the Dutch Climate Agreement.

NortH2 aims to upscale this to more than 10 gigawatts by 2040 where electrolytic hydrogen output, initially produced in Eemshaven and later possibly offshore as well, will total around one million metric tons on an annual basis, cutting carbon emissions by over eight to ten megatons a year.

The consortium, consisting of Gasunie, Groningen Seaports, Shell Nederland, Equinor and RWE, has the support of the Groningen provincial authority.

NortH2 is also looking at possibilities to convert the generated wind power into hydrogen directly at the wind turbines: electrolysis at sea. As wind turbines are placed further out to sea, hydrogen production close to the source becomes more attractive as the energy generated must be transported to land. This can be done via heavy electricity cables, but it is cheaper and more efficient to transport hydrogen gas molecules.



European Hydrogen Backbone

A European Hydrogen Backbone (EHB) vision was published by eleven companies in 2020, proposing a dedicated hydrogen network spanning ten countries and utilising both converted and new pipelines

The early plans to 2030 indicate 11,600km of pipeline network with scope to grow in to a pan-European network with a length of 39,700 km by 2040. Further network development can be expected after 2040

The project will require close collaboration between EU Member States and neighbouring countries and a stable, supportive, and adaptive regulatory framework.

H2 Mobility Shell Venture

H2 Mobility are establishing nation-wide hydrogen infrastructure across Germany with an interim goal to operate 100 hydrogen stations in seven German metropolitan areas (Hamburg, Berlin, Rhine-Ruhr, Frankfurt, Nuremberg, Stuttgart and Munich), and along the connecting arterial roads and motorways

At all stations, cars and light commercial vehicles (vans) can refuel with 700 bar and a requirement of 5 kg (in some cases up to 8 kg) of hydrogen. Six selected locations also offer 350 bar refuelling for buses.

The stations will be located alongside existing filling stations with a compact design relying upon standard fuel pump components

H2 Mobility receives funding from the public sector through the Ministry of Transport and Digital Infrastructure and the European Commission.

Brande Hydrogen (Western Denmark)

Siemens Gamesa is developing a hydrogen production plant in Western Denmark. The project couples an electrolyser with an existing onshore 3-MW turbine, with the possibility to run the system in ‘island mode’, without any connection to the grid.

Brande Hydrogen will provide a clear understanding of the integration of the electrolyser with a variable renewable energy source, and the efficiency of the electrolyser system over time.

Siemens Gamesa was awarded the contract by the Danish government as part of a regulatory energy test zone which exempts Siemens Gamesa from some of the energy regulations in the country, the first of its kind in Europe.

The investment awarded brings technology closer to integrating unprecedented amounts of renewable energy into the energy system.

The Brande Hydrogen project aims to demonstrate that electrolytic hydrogen can be produced without using any power from the grid and serves as an essential test bed for making large-scale, cost-efficient hydrogen production a reality.

Hunter Valley Australia

Energy Estate has brought together leading energy companies to form a ‘hydrogen valley’ in the Hunter region.

The Hunter Hydrogen Network (H2N) project – a large-scale hydrogen production, transportation and export project – has proposed a plan to enable the development of the hydrogen economy in the Hunter Valley, in partnership with hydrogen users and exporters.

Sihwa Lake Tidal Power Station

Sihwa Lake Tidal Power Station is the world's largest tidal power installation, with a total power output capacity of 254 MW, located in the North of South Korea.

The tidal barrage makes use of a seawall constructed in 1994 for flood mitigation and agricultural purposes. Ten 25.4 MW submerged bulb turbines are driven in an unpumped flood generation scheme; power is generated on tidal inflows only, and the outflow is sluiced away.This slightly unconventional and relatively inefficient approach has been chosen to balance a complex mix of existing land use, water use, conservation, environmental and power generation considerations.

The station's mean operating tidal range is 5.6 m (18 ft), with a spring tidal range of 7.8 m (26 ft). The working basin area was originally intended to be 43 km^2 (17 sq mi) and has been reduced by land reclamation and freshwater dykes to 30 km^2 (12 sq mi), likely to be reduced further.

The power station was built in 2011 and started to operate in 2012. The project cost US$560 million was borne by the South Korean Government.

Mace
www.macegroup.com