NORTH KENT LIDP REPORT

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https://www.kemsleycluster.co.uk/p/1

FOREWORD

By Kevin McKenna MP

As the Member of Parliament for Sittingbourne and Sheppey, I am delighted to introduce this report on the North Kent Local Industrial Decarbonisation Plan (LIDP). The Government has made clear its commitment to Net Zero and it has set out that carbon capture is part of that vision. Building green infrastructure is vital to the growth plans we have set out.

This initiative represents a significant step forward in the Kemsley Industrial Cluster's efforts to achieve net zero carbon emissions by 2050, in line with the UK Government's ambitious targets.

The Kemsley Industrial Cluster, with its unique symbiotic relationships and diverse industrial processes, stands as a beacon of innovation and collaboration. This report highlights the potential for high-impact decarbonisation within the cluster, showcasing how the implementation of advanced technologies can transform it from a carbon-emitting entity to a leader in carbon removal. By working together as part of industrial symbiosis, companies within the cluster benefit from enhanced resilience and sustainability, both environmentally and economically.

The findings of this study are not just theoretical; they are grounded in rigorous modelling, financial analysis, and stakeholder engagement. The projected outcomes, including the potential for over 500,000 tonnes of carbon removal per annum and the creation of 400-600 additional jobs, underscore the tangible benefits of this initiative.

I commend the collaborative efforts of all the project partners, including MVV Environment Ridham, Knauf, enfinium, DS Smith Paper, Countrystyle Recycling, Mace, and the University of Kent. Their commitment to sustainability and innovation is truly inspiring.

Key to the decarbonisation of the industrial sector – within the southeast and across the UK – is having committed Government funding to unlock private sector investment, develop green skills, create and protect local jobs and deliver economic growth. This report is a testament to what can be achieved when industry, academia, and government work together towards a common goal. I look forward to seeing the continued progress of the Kemsley Industrial Cluster and the positive impact it will have on our community, our economy, and our environment.

Kevin McKenna

MP for Sittingbourne and Sheppey

EXECUTIVE SUMMARY OF PROJECT AND FINDINGS

The Kemsley Industrial Cluster has unique characteristics in the approach to decarbonisation stemming from a symbiotic relationship between organisations, this results in mutual decarbonisation benefits each partner.

If technologies are implemented as modelled, a projected net negative carbon outcome can be achieved.

This study explores options and scenarios to decarbonise an Industrial Symbiosis cluster in Kemsley, North Kent, UK. Decarbonisation strategies and technologies are considered in the context of existing operational demands and current decarbonisation landscape associated with the UK Government's drive towards net zero by 2050.

Mature and maturing decarbonisation technologies have been systematically analysed using modelling and simulation, financial analysis, and socioeconomic impact analysis to determine a set of ranked decarbonisation scenarios for the cluster. This list of technology combinations has been evaluated across key performance indicators that include cluster energy demands, carbon emissions, commercial factors, anticipated capital expenditure of the technologies and job creation.

Regulatory compliance, local community stakeholder considerations, energy resilience and governmental policy have also been considered.

The Kemsley Industrial Cluster has the potential for high impact decarbonisation. In 2023 the cluster emitted 591,860 tCO2 fossil carbon emissions. Implementation of the recommended decarbonisation technologies would enable the cluster to greatly reduce carbon emissions in North Kent. Installation of carbon capture would transform the cluster from being a carbon emitting cluster to being a carbon removal cluster. Projections indicate that the combined technologies could achieve more than 500,000 tCO2, per annum, of carbon removal from the atmosphere.

The Kemsley Industrial Cluster, is a potential leader in industrial symbiosis and a pathfinder model for replication across the UK, covering a wide range of industrial processes, including power and heat generation, manufacturing, logistics, recycling and waste disposal, and offers a unique opportunity to develop a programme to decarbonise at scale utilising technology adoption and maximising energy and resource distribution in a symbolic system, and offers opportunities in addition to the c5.3 million tonnes of direct carbon removals between 2030 and 2050 and the addition of c400-600 additional jobs.

This study recommends progression to pre-FEED and FEED stages to support a Final Investment Decision for this programme. This LIDP study is the initial step to the successful reduction of carbon emissions in Kemsley, from a growing cluster of compatible organisations in the area who are committed to working together for this important shared goal.

The cluster are keen to continue together on this sustainability and decarbonisation journey and plan to apply for follow on funding to enable pre-FEED and FEED stages to be undertaken, ideally with funding that supports these stages to be taken in succession to ensure that momentum is not lost. The following services are recommended to support a robust journey to final investment decisions:

To ensure the success of the Kemsley Industrial Cluster's decarbonisation efforts, the following key areas and recommendations are crucial:

Technology Assessment and Selection evaluating and pilot testing chosen technologies to ensure they are suitable and scalable. Without thorough technology assessment, the programme risks adopting suboptimal technologies. In addition, layer in opportunities for further decarbonisation initiatives, within and outside of the current cluster partners.

Engineering and Design services are needed to create detailed designs and optimise processes for the different decarbonisation technologies under consideration including carbon capture, hydrogen, electrification and the associated infrastructure, such as carbon transport and storage. This includes process, structural, civil, electrical, and mechanical engineering. Without these detailed designs, cost comparison between the options will be less robust and the programme risks technical failures and inefficiencies.

Regulatory and Planning including Environmental Impact Assessments (EIA), biodiversity net gain, obtaining necessary permits, and developing mitigation plans. These steps will ensure compliance with relevant regulations and help mitigate adverse impacts. Failure to address environmental and regulatory concerns could lead to hurdles such as community opposition, and non-compliance with the planning process.

Business Case development, financial modelling, cost-benefit analysis, and securing funding, are essential to demonstrate the project's economic viability and attract investment.

Data Modelling Support and Rigour an additional layer of analytical depth and credibility. The university [of Kent] provides advanced data modelling techniques, rigorous analysis, and access to cutting-edge research. This continued partnership will ensure that the programme's data-driven decisions continue to be robust and scientifically validated, giving added assurance to investors.

Stakeholder Engagement and Communication will be vital for gaining support from local communities, government bodies, statutory bodies, local authorities and other stakeholders. A well-developed communication strategy will help manage public relations and maintain a positive programme image.

Project Management and Delivery Partner to ensure all activities are aligned with timelines, budgets, and regulatory and planning requirements. Effective programme scheduling, coordination, monitoring, and quality assurance are crucial to maintain momentum, ensure coordination of dependency drive requirements and manage time, quality and cost.

Supply Chain and Logistics planning to ensure efficient strategic procurement plan is in place and early consideration of supply chain delivery needs such as transportation of materials and equipment are understood. Effective vendor management is also critical. Disruptions in the supply chain could cause significant programme delays and cost overruns.

Legal Services to ensure that there is a proper legal entity to 'contract' with government for support, ensure all supply chain and client contracts are properly negotiated and that the programme complies with all relevant laws and regulations. Effective risk management is also crucial to mitigate legal risks. Neglecting legal aspects could result in disputes and regulatory penalties.

Health and Safety Consulting to include risk assessments, safety planning, and training to ensure a safe working environment.

Exploring Advanced Tools. Consider digital twinning and private 5G networks for real-time monitoring, predictive maintenance, and data-driven decision-making. This will enhance the cluster's ability to meet decarbonisation goals and maintain a competitive edge in the global market.

By focusing on these areas, the Kemsley Industrial Cluster can effectively support its decarbonisation efforts and contribute to the UK's net zero targets.

CONTENTS

1

INTRODUCTION

1. INTRODUCTION

1.1 Purpose of the study

Part of the UK Government's drive towards Net Zero by 2050, Innovate UK has invested up to £5 million in Local Industrial Decarbonisation Plans (LIDP) to provide support for industrial manufacturers to reduce emissions and reach Net Zero (Department for Energy Security and Net Zero, 2022). The Kemsley Industrial Cluster in Kent was successful in securing a portion of this funding, and this summary report details our analysis of the options to deliver a joint carbon reduction strategy. The Kemsley Industrial Cluster, near Sittingbourne in North Kent covers a wide range of industrial processes, including power and heat generation, manufacturing, logistics, recycling and waste disposal with a unique emission profile of approximately 50% biogenic and 50% fossil carbon emissions. The cluster in 2023 emitted 506,817 tCO_2 biogenic and 591,860 tCO_2 fossil carbon emissions. The main aim of the analysis is to understand which of the feasible and desirable decarbonisation technologies will enable the cluster to reduce these emissions and reach net zero as soon as possible and before 2050.

1.2 The project team

The LIDP project team is made up of seven organisations, of which five are industrial organisations making up the cluster:

- **MVV Environment Ridham** – provides sustainable and efficient solutions for waste-fired energy generation to waste disposal companies and local authorities
- **Knauf** – one of the UK's leading manufacturers of lightweight building products and systems
- **enfinium** – one of the UK's leading energy from waste (EfW) operators, using waste that would otherwise go to landfill to generate homegrown energy
- **DS Smith Paper** – a leading provider of sustainable packaging solutions, paper products and recycling services worldwide
- **Heathcote Holdings (countrystyle)** - a group of companies that are leaders in organics, recycling, waste management, industry innovation, agriculture and land management.
- **Mace** – a global expert in shaping the built environment, Mace has extensive experience in the energy sector and supports a number of other industrial decarbonisation programmes.
- **University of Kent** – leading the consortium through the participative simulation modelling process and developing qualitative and quantitative models to help make informed decarbonisation investment decisions.

1.3 The Kemsley Industrial Cluster

The Kemsley Industrial Cluster represents the single largest industrial cluster in Kent and Sussex (Figure 1). The Kemsley industrial cluster consists of five industrial partners in close proximity. DS Smith has the highest energy demand within the cluster operating a paper mill, the majority of this energy is generated using natural gas to produce steam for the paper manufacturing process. Knauf manufactures plaster boards also using natural gas for the high temperature calcination process, with reuse of the flue gas for drying purposes. MVV and enfinium are both waste treatment companies with generation of energy mainly in form of electricity supplied to the national grid. Countrystyle operates a recycling hub using mainly electricity on site with carbon emissions resulting from haulage activities to and from the Kemsley site.

Considering the relatively small size of the cluster, with only five companies it is still representative of a wide range of industrial processes covering energy generation, manufacturing, logistics, recycling and waste treatment.

These industrial manufacturers have close collaborations already when it comes to sustainability.

- The power generators (MVV and enfinium) use waste materials to generate electricity, but both have the capability of heat extraction in form of steam needed by DS Smith.
- The enfinium EfW facility uses black bag residual and Commercial and Industrial (C&I) waste and already provides some steam to DS Smith.
- The MVV biomass facility uses waste wood to generate renewable electricity.
- Heathcote Holdings, who operate a recycling company (Countrystyle) form a central hub in the cluster that is linked with all the remaining sites and enable many of existing exchanges of materials and waste products. They provide enfinium and MVV with some of the waste.

Over the years, this cluster's sites have formed these relationships that could be described as circular economy where recycled resources are reused extensively, (e.g. paper and board), limiting the need to use virgin materials (e.g. gypsum for board) to what is absolutely necessary.

This exchange of materials and the intricate sustainability relationships that have organically developed over decades, which we describe further in chapter 3, give this cluster a uniqueness which is referred to in the literature as Industrial Symbiosis.

Figure 1 – Cluster Location

1.4 Work package Themes.

The study was split into 5 main content work packages (WP)

WP1 Technical feasibility. WP1 has been central to all work packages, as it has determined and ranked in order of preference a set of feasible and desirable technologies and scenarios.

Technical feasibility workshops were held with the industrial partners which included factors such as technology readiness levels, practicability in the context of live operations and initial static model assumptions. Output from WP1 enabled WP2, WP3, and WP4 to focus their in-depth analysis on a specific set of options.

WP2 Modelling and Simulation. WP2 simulated emissions and energy balance of the technology's scenarios recommended from WP1 across an agreed time horizon. Systems Thinking approaches have involved modelling the industrial symbiosis in order to understand the potential for this and also considers the interplay between social economic and environmental factors.

WP3 Socio-economic Impact Analysis. This work package considered the impact of the scenarios generated in WP1 in terms of their socio-economic impact of the organisations involved in Kemsley as well as the wider region.

WP4 Strategic Business Case and Financial Analysis. Combines outputs from the other WP's and consolidates them into a strategic outline business case aligned with the HM Treasury Green Book 5 case model – strategic, economic, financial, commercial and management cases.

To support the completion of the financial case it takes the scenarios and model outputs outlined in WP1 and converts them into a financial model over a 26-year lifecycle – from 2025-2050.

The model parameters include cashflows associated with capex, opex (for energy use, labour and maintenance and carbon capture transport and storage), CO2 emissions, biogenic carbon credits and energy production for each partner and collectively as a cluster.

WP5 Communications, Engagement and Knowledge Dissemination. Under the LIDP funding, we have explored Joint Carbon Reduction options by collaboratively exploring and modelling current and future energy requirements and assessing feasible carbon reduction solutions as a cluster.

This has meant the active engagement of each partner organisation in meetings and workshops to undertake the analysis with the lead from each WP as well as come to joint decisions about the focus of the study.

This details a comprehensive process of engagement in delivering that decarbonisation vision. Collaboration and knowledge sharing is a key part of this project, and we are keen to speak with other industrial organisations, government bodies, business groups and energy providers to seek input, share learnings and identify opportunities as the project progresses.

1.5 Report Roadmap

The report is structured into seven chapters with the next six focussed on the findings from each WP. Chapter 8 brings together all the analysis to discuss the ranking of the scenarios across a range of quantitative and qualitative factors. It also provides our initial thoughts on next steps.

The report has been structured as follows:

Chapter 2 – **Communications, engagement and knowledge dissemination** – derived from WP5.

Chapter 3 – **Technical feasibility** – derived from WP1

Chapter 4 – **Modelling and simulation** – derived from WP2

Chapter 5 – **Business case, roadmap and investment planning** – derived fromWP4

Chapter 6 – **Socio-economic impact analysis** – derived from WP3

Chapter 7 – **Engagement outcomes** – derived from WP5

Chapter 8 - **Findings, conclusions and next steps** – consolidation of findings and recommendations from all the work packages.

2

COMMUNICATIONS, ENGAGEMENT AND KNOWLEDGE DISSEMINATION

2. ENGAGEMENT APPROACH

Objectives of Work Package 5: Communications, Engagement and Knowledge Dissemination:

- Engage and involve the internal and external stakeholders to gain a better understanding of the problem situation and support active participation of project stakeholders in all work packages.
- Share the process, outcomes, opportunities and recommendations from this project with other clusters and relevant stakeholders.
- Build profile of the area and cluster, both locally and nationally, and explore expanding the consortium to other organisations in the area.
- Evidence to customers how the project organisations are working to decarbonise, lower emissions and help the UK reach net zero.
- Invite further investment and participation.
- Grow awareness of the project with local stakeholders (industrial, government etc).

Critical to this are the stakeholders. Stakeholders in this study include:

- Project partners including the companies involved in the study and detailed in the introduction.
- Regional stakeholders include Sittingbourne MP Kevin McKenna, Kent Country Council, borough councils such as Swale and Iwade, regional planning directorates, umbrella organisations such as Locate Kent that enable business engagement and the Kent Estuary Growth Board.
- Broader external stakeholders include energy technology companies, the energy institute, relevant catapults, DESNZ, Innovate UK, other LIDPs, National Grid etc.

2.1 Approach to project engagement

This centres around the active involvement of stakeholders in all aspects of the study to ensure timely delivery of relevant analysis and to enable collaborative decision-making to take place regarding choices. The project team are leaders in facilitated modelling and simulation (Kotiadis et al., 2014; Tako and Kotiadis, 2018, 2015), which means that they brought practical workshop facilitation expertise to the study.

The same engagement philosophy and facilitation approach was tailored and adopted by all leads. Hence, online or face to face meetings and workshops were organised regularly (twice a month on average) with all project partners present with aims of understanding decarbonisation solutions and their impact on sites and the Cluster as well as debating the findings of analysis. Facilitative workshops are particularly effective in this context, as they promote creativity, encourage deeper exploration of issues through interaction, address differing viewpoints, and foster collaborative problem-solving (Tako and Kotiadis, 2015; Tavella and Papadopoulos, 2015). Modelling approaches from Operational Research/Systems Thinking (Rich pictures, System Dynamics Causal Loop diagramming and participatory Simulation –from WP2) were used to support stakeholder engagement and collaboration.

The workshops with the members of the cluster have explored the planning drivers for decarbonisation solutions. An essential driver for advancing the decarbonisation solutions for the cluster, such as carbon capture and storage (CCS) and the integration of hydrogen as a fuel has social benefits because they can bolster support from local authorities and the population, increasing the likelihood of project acceptance during planning consent .

A report produced by the Department for Energy Security and Net Zero and Department for Business, Energy & Industrial Strategy (2021) also found that public engagement is critical for building trust, promoting fairness, and fostering collective responsibility, all of which are essential for the success of decarbonisation projects. The relationships between the concepts have been summarised in the causal loop diagram from WP2 (Figure 2). This was discussed and confirmed during an external engagement workshop with local authorities and planning officers

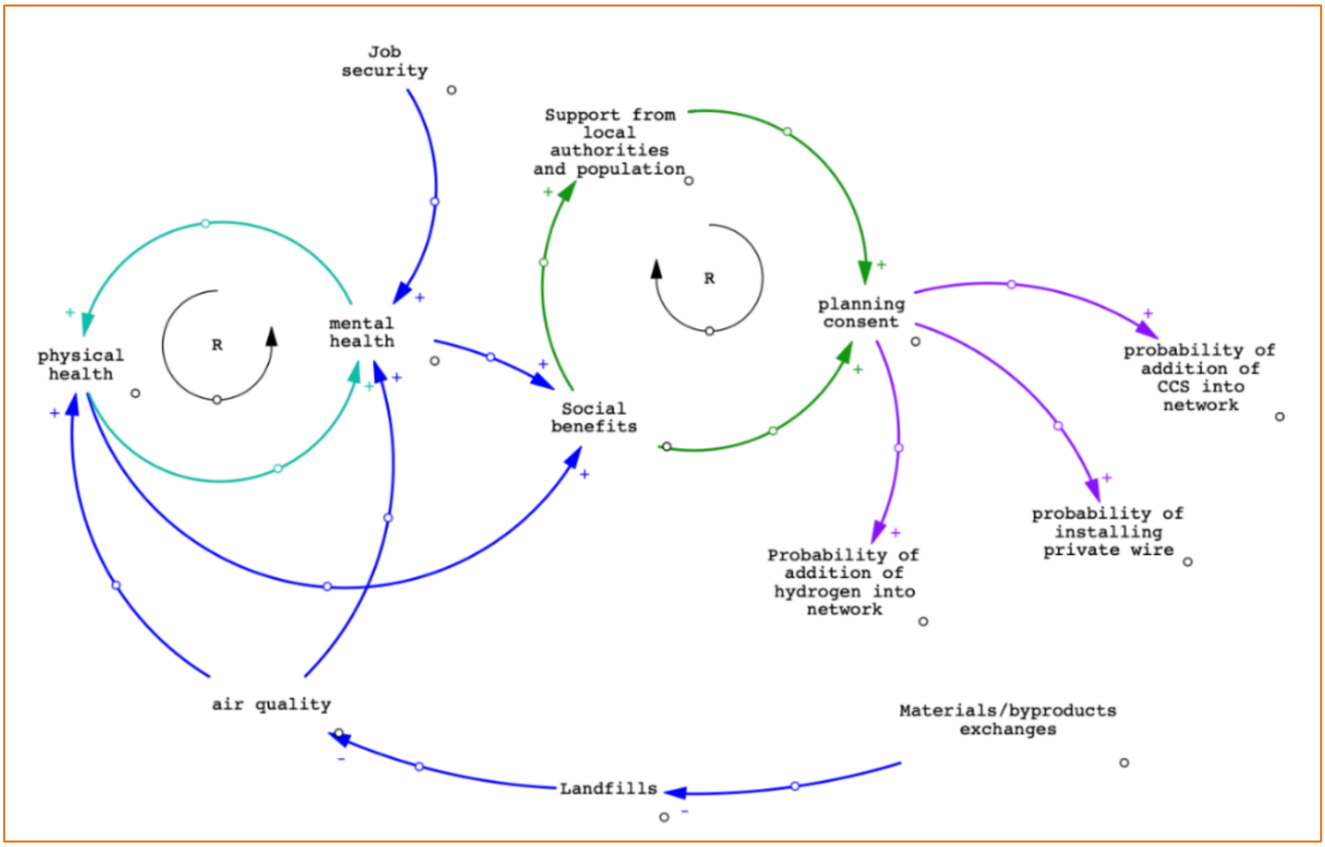

Figure 2 – Extract of Casual Loop Diagram from WP2 (Modelling and Simulation)

2.2 Overview of external stakeholder engagement

A Communications, Engagement and Knowledge Dissemination Plan was developed at project inception to provide an overview of the key stakeholders in relation to the Kemsley Cluster Local Industrial Decarbonisation Project (LIDP), and the various activities and communication tools that will be delivered as part the project.

Key external stakeholders

Key stakeholders were identified in consultation with the project team and some Council stakeholders (Figure 3). These stakeholders are interested in our project outcomes and are key partners for future stages (e.g., advocacy, planning approvals, further investment). They have been included in project communications, invited to stakeholder workshops, and engaged where appropriate throughout the project.

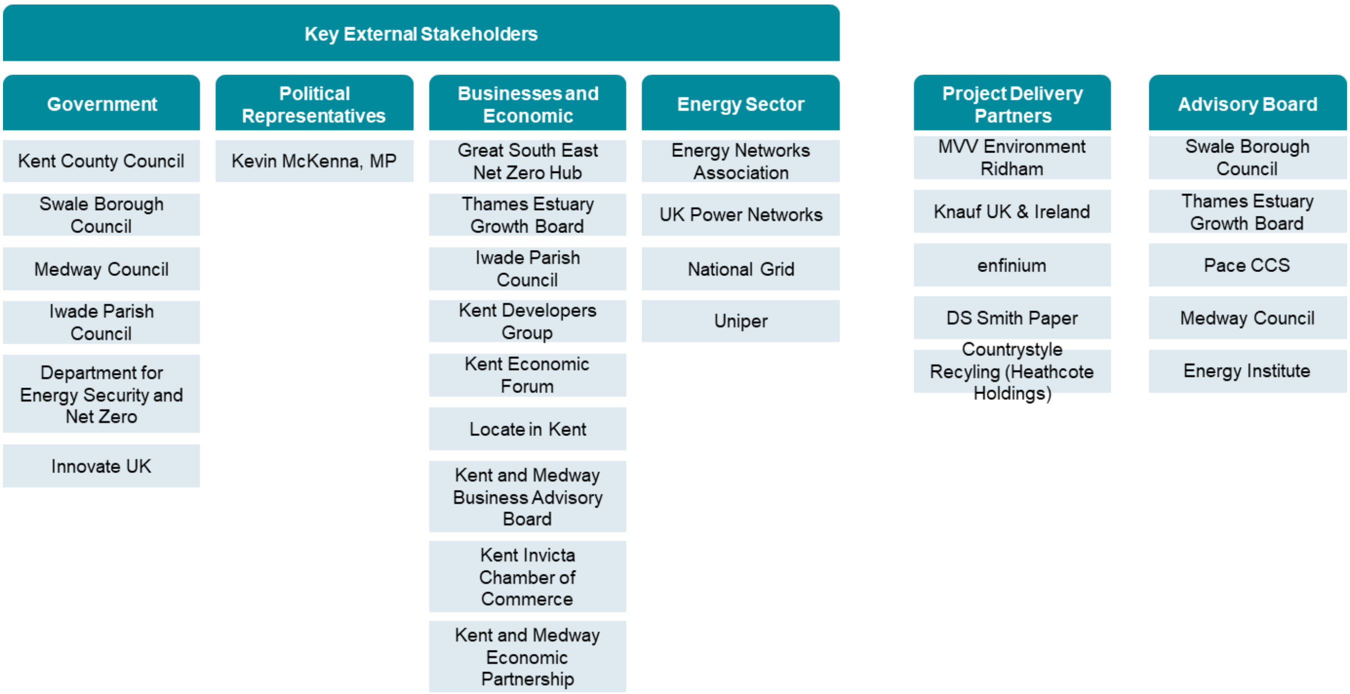

Figure 3– Stakeholder Map (WP5)

2.3 Communication tools

Project communications centred on the development of a website for the Kemsley Cluster, and project collateral. These tools (Table 1) were designed to target a broad audience, appropriate for all identified external parties, and were developed and approved by the wider project team.

Table 1– Communications tools

Tool	Audience	Progress
Website	Public-facing	• The Kemsley Cluster website was launched on 21 October 2024 as an online presence where people can find out information about the project and provide another avenue for people to get in touch with the project team. • The website initially included the project background factsheet wording, along with a "contact us" email widget and links to each organisation website involved in the project. It was then updated to include the general project press release, and finally the outcomes and findings of the LIDP project (using the executive summary text). • As of 31 January 2025, the website has had 1,272 visits.
Collateral	Public-facing documentation, either hard copy or digital, that provides insight or promotes the project.	• ***Project background factsheet:*** used to provide context when engaging stakeholders and was used to develop the initial website content. • ***General Press Release:*** also developed and uploaded to the project website for project team organisations and key stakeholders to use as needed when discussing the project more broadly. • ***Report Executive Summary & Overarching Slide Deck:*** to share the process and outcomes from the project in an accessible way to key stakeholders and the wider public.

2.4 Stakeholder workshops

In addition to ongoing stakeholder engagement activities and the communications tools outlined above, we held three stakeholder workshops to build relationships, get feedback on our proposals, and share lessons learned with other LIDP clusters and relevant stakeholders (Table 2). Each workshop (e.g. Figure 4) was attended by representatives from each project organization. Feedback and discussion from these workshops are provided in Chapter 9 of this report.

Table 2 – Workshops and engagement

Session	Format	Purpose	External Stakeholders
Kemsley Cluster LIDP workshop – 7 November 2024	In person	Local focus on hearing regional stakeholders feedback, understanding planning and consenting requirements and discussing local decarbonisation targets and plans.	• Swale Borough Council • Medway Council • Kent County Council • Energy company (Hydrogen supplier) • Greater South East Net Zero Hub • National Grid • Locate in Kent • Thames Estuary Growth Board
Kemsley Cluster LIDP online workshop – 29 January 2025	Virtual	Involved a wider audience, presenting our processes, findings and next steps and providing an opportunity for Q&A.	• Swale Borough Council • Medway Council • Kent County Council • Locate in Kent • Energy company (hydrogen producer) • Energy company (Hydrogen Supplier)
Local Industrial Decarbonisation Conference 2025 – 25 February 2025	In person	Focused on knowledge dissemination and sharing with other LIDP clusters and relevant government bodies such as Innovate UK and the Department of Energy Security and Net Zero (DESNZ).	• Innovate UK • Department for Energy Security and Net Zero • Other LIDP clusters • Advisory Board members • Kevin McKenna, Sittingbourne MP

2.5 Conclusion

The communication tools and engagement activities developed as part of the Communications, Engagement and Knowledge Dissemination Plan were developed to have knowledge dissemination as a golden thread running through all actions associated with this work package (Figure 4).

In addition to the project website, collateral materials and stakeholder workshops, knowledge dissemination will also take the form of academic papers and conferences. As part of their role on the project, the University of Kent will be submitting academic papers in months and years to come.

Figure 4 – Kemsley Cluster LIDP workshop, November 2024

3

TECHNICAL FEASIBILITY

3. RESPONSE TO PROBLEM – REVIEW OF TECHNICAL SOLUTIONS

3.1 Technical feasibility

The first stage of the project assessed the technical feasibility of potential decarbonisation solutions using a methodologic approach. After defining eligibility and performance criteria for applicable decarbonisation technologies, work package 1 investigates technical feasibility together with the industry partners, aims to arrive at feasible and desirable set of scenarios which meet the project objects for the cluster as a whole using a holistic perspective on sustainability.

Process

After initial discussions through online meetings, a face-to-face workshop took place which, combined with site visits of each industry partner to reach a better understanding of the different processes including energy generation and consumption, the source of the carbon emissions, derived the measurement values to be used in subsequent balancing and modelling approaches.

An important part of the workshop has been the definition of eligibility and performance criteria to determine possible decarbonisation technologies and the definition of boundary conditions to set rules for equal evaluation. Table 3 below sets out the partners' agreed criteria.

Table 3 – Definition of eligibility and performance criteria as well as boundary conditions for simplified energy and mass balance calculation

Eligibility and performance criteria	Boundary conditions
More than 90% decarbonisation potential	Simplified balancing approach without energy storage solutions
Reasonable effort to adjust the current operation	Carbon offsets from outside of the Kemsley cluster are not allowed
Proven technology with high technical readiness level	Consideration of the same carbon transport and sequestration carbon sink for all scenarios
Competitive decarbonisation costs compared to other options or carbon price	Indirect impacts of deploying solution e.g. construction, utility supply emissions neglected
Negligible emissions of the supply chain	Zero emissions of National Power Grid from 2030
Sufficient energy security with contingency	Zero emissions for synthetic fuel usage considered
Acceptable H&S risks	Energy balance baseline is maintained unchanged

As result of engagement through workshops a matrix has been determined showing the potential decarbonisation possibilities for each industry partner, marked as (x) shown in Table 4 below. Potential sources of renewable energy generated within the cluster are marked as (o) to identify symbiosis by promoting additional exchange of energy and resources. The defined eligibility and performance criteria allow various possibilities for the energy consuming partners DS Smith, Knauf and Countrystyle but for the energy generating partners, MVV and enfinium, the options are limited to just carbon capture.

Table 4 – Theoretical scenario possibilities and sources of renewable energy for each partner

Option	DS Smith	Enfinium	Knauf	MVV	Countrystyle
CC – Carbon Capture	X	X		X	
ST – CHP Steam supply	X	O		O	
H – Hydrogen	X	O	X	O	X
E – Electrification	X	O	X	O	X
SF – Synthetic Fuel		O		O	X
BM – Biomass	X		X		O
BG – Biogas	X		X		X

The product of the number of decarbonisation possibilities for each partner represents the theoretical number of possible 96 scenarios which defines the longlist for subsequent evaluation. The flow diagram in Figure 5 shows the steps to reduce the theoretical longlist to a reasonable shortlist of four overarching scenarios for further evaluation within work packages 2, 3 and 4.

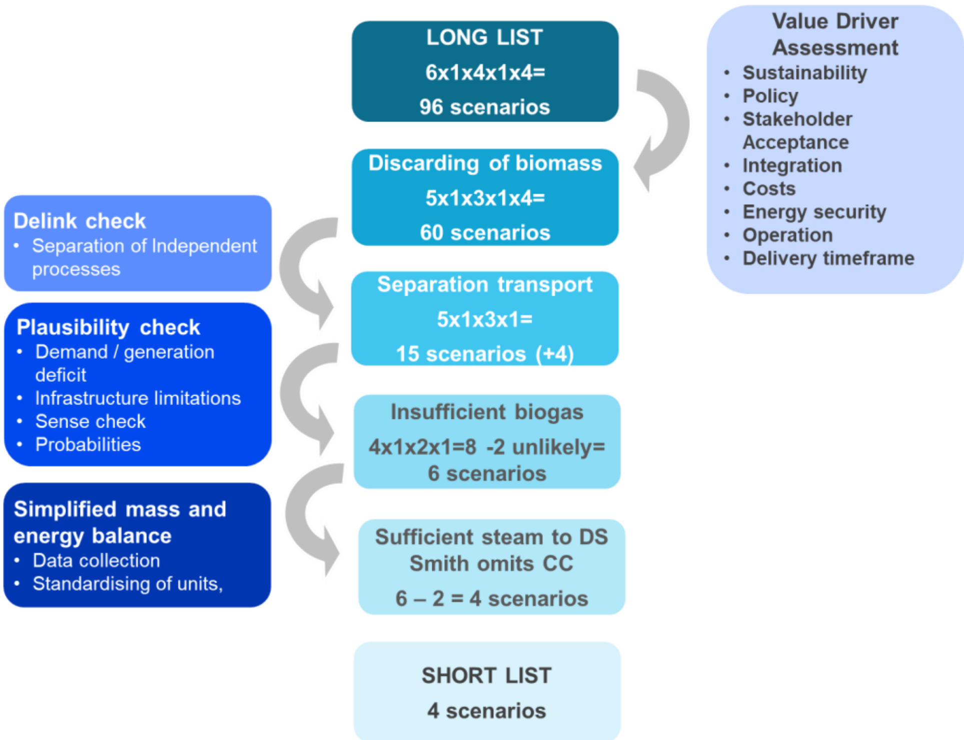

Figure 5 – Flow diagram for the evaluation of scenarios from longlist to shortlist

The shortlisted four scenario options are:

1. Steam supply for DS Smith, hydrogen for Knauf and carbon capture with steam offtake for enfinium and MVV;
2. Steam supply for DS Smith, electrification for Knauf and carbon capture with steam offtake for enfinium and MVV;
3. Hydrogen for DS Smith and Knauf, carbon capture with steam offtake for enfinium and carbon capture w/o steam offtake for MVV;
4. Electrification for DS Smith and Knauf, and carbon capture with steam offtake for enfinium and carbon capture w/o steam offtake for MVV.

❖ *The separation into green and blue hydrogen results in six scenarios to test*

The next step involved selection of different technology processes for each decarbonisation option, most appropriate for the cluster. Selection prioritised technologies that are commercially available, have a mature readiness level, cost estimates and performance parameters, which will serve as inputs for the economic model.

For WP1 modelling purposes, the evaluation period for the shortlisted scenarios has been agreed with 20 years as a typical timeframe for financing such investment projects from 2030 till 2050. The implementation schedule of each of the decarbonisation options varies depending on planning and permitting requirements, procurement lead times or infrastructure installations.

Except post combustion carbon capture, all other shortlisted options can be implemented before 2030. In relation with enfinium's and MVV's corporate sustainability strategy, a realistic timeline for installation of carbon capture was agreed with service commencement in 2035. This would also allow for setting up the necessary transport and storage solutions.

The service commencement of carbon capture after 2030 resulted in different cluster results for the periods before and after 2035. Reasonable sub-scenarios have been defined to evaluate the agreed timeframe from 2030 till 2050 in WP1.

The static energy and mass balance as simplified approach for annual demand, supply and emission figures has been calculated for each sub-scenario as shown in Figure 6 and Figure 7 below for Scenario 1 before and after carbon capture implementation.

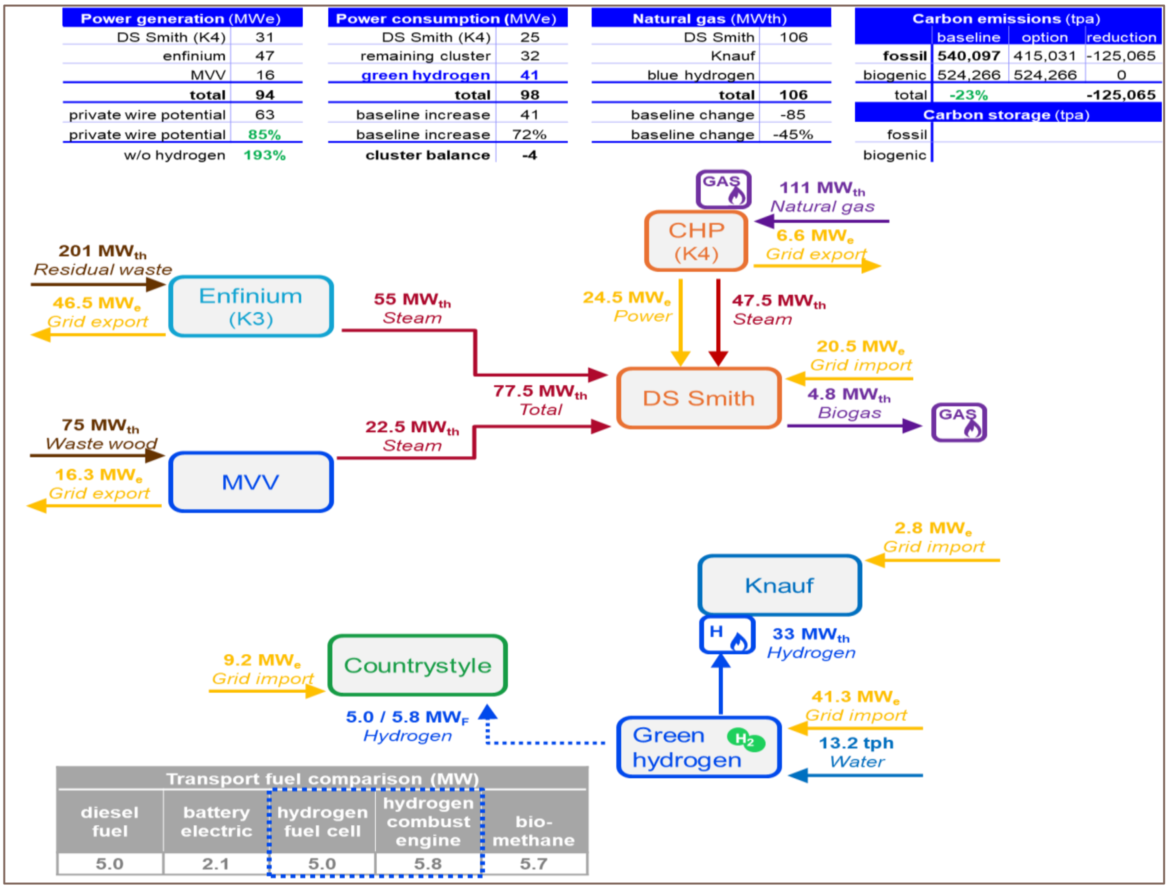

Figure 6 – Energy and mass balance prior to carbon capture

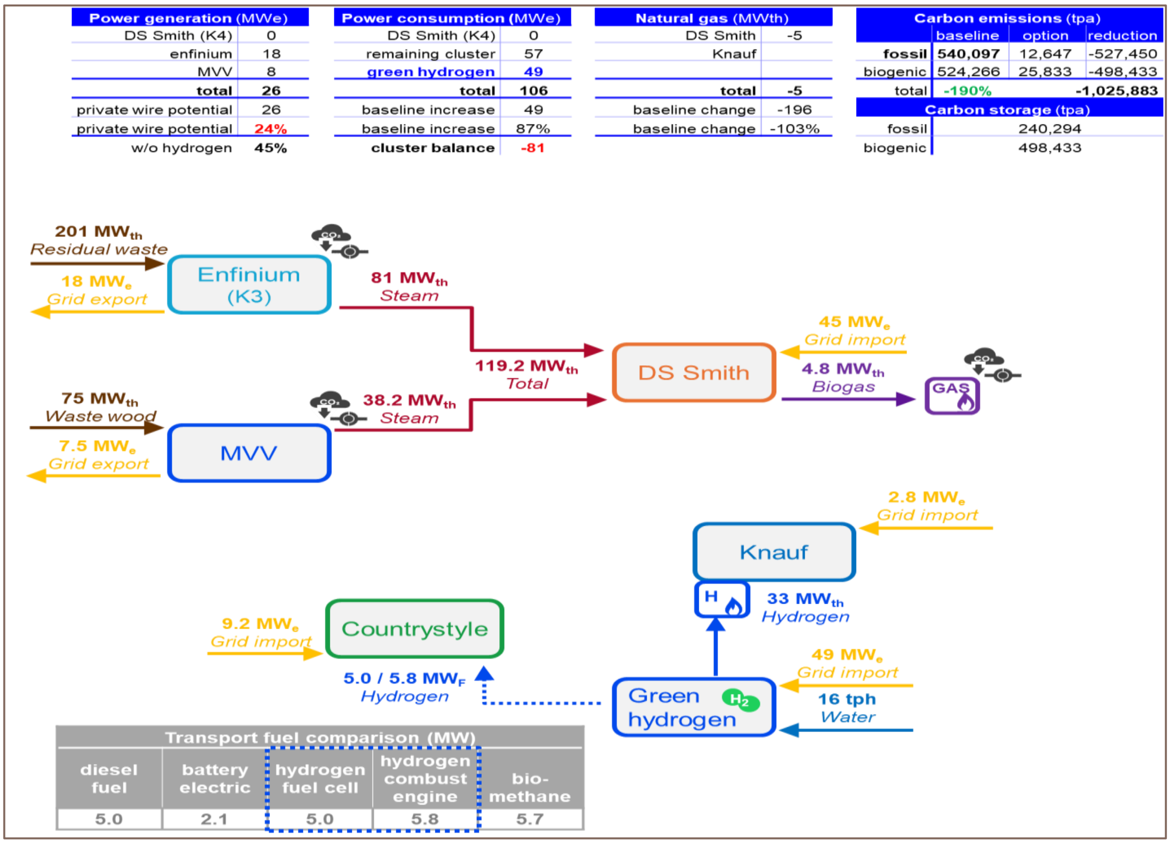

Figure 7 – Energy and mass balance after carbon capture

The sub-options that differentiate between green and blue hydrogen technology implementation, resulted in six scenarios to be further analysed:

1. Steam supply (both MVV and enfinium), green hydrogen and carbon capture.
2. Steam supply (both MVV and enfinium), blue hydrogen and carbon capture.
3. Steam supply (both MVV and enfinium), electrification and carbon capture.
4. Steam supply (only enfinium), green hydrogen and carbon capture.
5. Steam supply (only enfinium), blue hydrogen and carbon capture.
6. Steam supply (only enfinium), electrification and carbon capture.

Hereafter these scenarios will simply be called as,

Scenario 1: Steam supply, green hydrogen and CC.

Scenario 2: Steam supply, blue hydrogen and CC.

Scenario 3: Steam supply, electrification and CC.

Scenario 4: Green hydrogen and CC.

Scenario 5: Blue hydrogen and CC.

Scenario 6: Electrification and CC.

Work packages 3 and 4 will also differentiate between Baseline A and B to indicate whether private wire (PW) is considered (Baseline B) or not (Baseline A). For all six scenarios, private wire is being considered; therefore, no differentiations are necessary.

3.2 Initial Findings of the simplified energy and mass balance calculations

The proposed private wire installation amortises quickly and generates millions of savings for each cluster partner over a 20-year period, which can be used to fund the proposed decarbonisation measures. The carbon emission reduction results from the simplified cluster balance calculations are shown in Table 5 below. Additional steam supply from MVV to DS Smith was proposed 10 years ago, with the technical design drafted but the previously approved planning application now expired, would gain a 10% reduction of the cluster's carbon emissions.

MVV calculates the steam price equal to the revenue difference from the power loss caused by the steam extraction which goes along with a linked reduction of Renewable Obligation Certificate (ROC) allocations granted until 2035. Initial discussions between DS Smith and MVV have shown that MVV's loss of ROC subsidies artificially doubles the steam price roughly and makes the green steam supply uneconomical for DS Smith. Clarification is needed on whether the ROC allocation could be adjusted to the theoretical power generation in full power mode when steam extraction takes place. Such an approach would not increase the taxpayer costs since the value of issued ROCs would stay unchanged but will contribute to emission savings through reduced natural gas consumption over several years until 2035.

Table 5 shows the outcomes of emissions reductions for the technology scenarios. The findings show that all scenarios reach similar reduction values which concludes that the strongest impact for the cluster can be achieved through carbon capture considered as the sole decarbonising option for the cluster's power generation activities.

Table 5 – Expected carbon emissions reductions across the scenarios gained from the simplified cluster balance calculations for the defined period from 2030 till 2050

Scenarios	Fossil carbon emissions (MtCO2)	Biogenic carbon emissions (MtCO2)	Greenhouse gas removal (MtCO2)	Total fossil (MtCO2)
Baseline	10.8	10.5	N/A	**10.8**
Scenario 1: Steam supply, green hydrogen & CC	2.5	3.3	-7.7	**-5.3**
Scenario 2: Steam supply, blue hydrogen & CC	2.8	3.3	-7.7	**-5**
Scenario 3: Steam supply, Electrification & CC	2.5	3.3	-7.7	**-5.3**
Scenario 4: Green hydrogen & CC	2.9	3.3	-7.7	**-4.8**
Scenario 5: Blue hydrogen & CC	3.2	3.3	-7.7	**-4.5**
Scenario 6: Electrification & CC	2.9	3.3	-7.7	**-4.8**

Note to reader: column Total Fossil shows the potential for offsetting fossil emissions elsewhere and is calculated by the sum of Fossil Carbon emissions and Greenhouse gas removal.

The current baseline shows 550,000 tonnes of fossil carbon emissions per annum. The implementation of carbon capture not only decarbonises the cluster but also presents the opportunity for the cluster to achieve carbon negativity. This is accomplished through the annual 550,000 tonnes of carbon removal from the atmosphere via Bioenergy with Carbon Capture and Storage (BECCS). With the assumption that carbon capture service commencement takes place in mid of 2035, 7.7 million tonnes of greenhouse gas removal can be realised by 2050.

4

MODELLING & SIMULATION

4 MODELLING AND SIMULATION

4.1 Overview of modelling and simulation

Modelling approaches from Operational Research and Systems Thinking are used to explore the future potential for Industrial Symbiosis and the impact of decarbonisation technologies on the North Kent cluster. The modelling and simulation described in this chapter relates to WP2, although content from WP2 is also embedded in other chapters.

The modelling and simulation approaches used in this study are as follows:

Rich Pictures from Soft Systems Methodology (Checkland and Poulter, 2020), a static modelling approach, have been used to verify and map the current Industrial Symbiosis among the members of the cluster. This approach has also been used to explore current and future energy and material exchanges that enhance sustainability and lead to decarbonisation.

System Dynamics Causal Loop diagramming captures the behavioural relationships around sustainability and resilience. The aim of this model is to enable a greater understanding of the dynamic relationships that are not captured by the quantitative Monte Carlo simulation. Findings from this modelling approach has been embedded in other chapters as this approach refines the inputs into other modelling work developed.

Simulation modelling is a method for mimicking the behaviour of a system over a period of time. It allows us to explore the impact of different scenarios and understand the potential outcomes without needing to implement all the scenarios in a real-world setting. Monte Carlo simulation, specifically, is a type of simulation that uses randomness and probability to account for the inherent uncertainty and variability in complex systems. Developing the simulation models of the different scenarios of interest to the cluster, has meant taking the broad scenarios outlined in chapter 3, and working closely with the individual companies and partners in the cluster to detail the timings for the implementation of the decarbonisation technologies at each site as well as detailing how these future changes might potentially impact on their processes. The simulation models of each scenario provide a detailed account of each scenario as well as capture the variability of inputs. The model created for this project simulates the patterns of production/consumption of the energy and other materials for each of the sites in the North Kent LIDP cluster (Figure 8). The model produces a number of outputs for each scenario which include emissions and the energy balance across a number of years. The model has been developed in Excel with Visual Basic for Applications (VBA) and makes use of forecasting and machine learning.

The development of both the quantitative and qualitative models from this work package involved engagement from both internal and external stakeholders. The participatory nature of the study outlined in chapter 2.

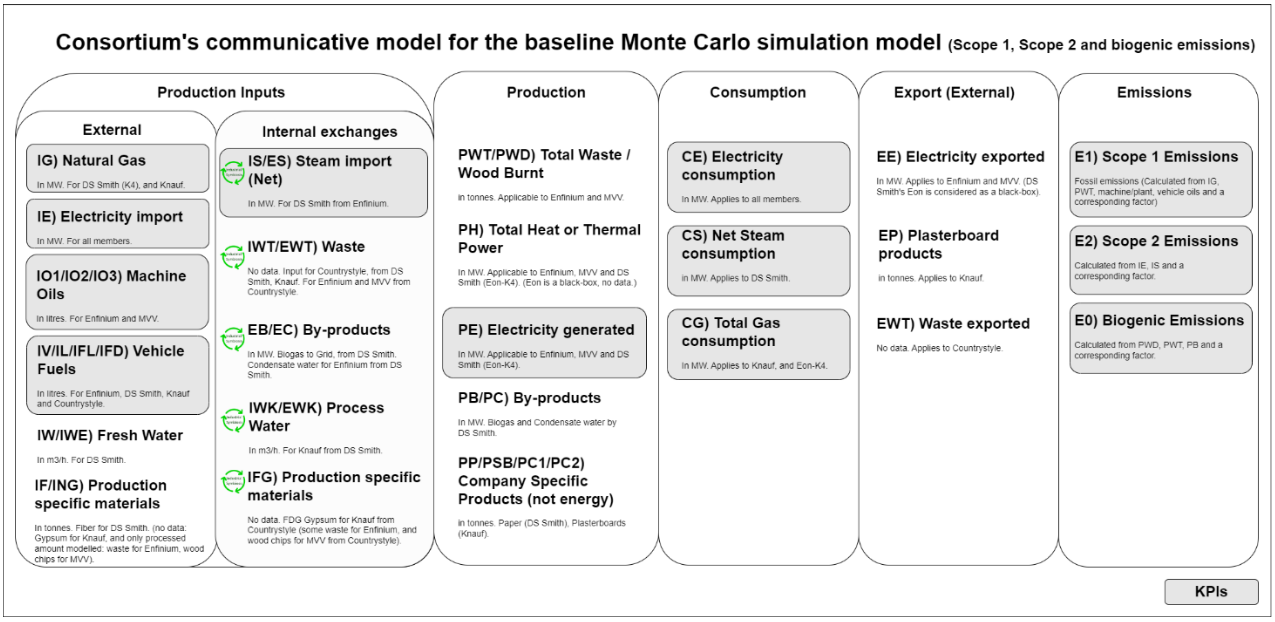

Figure 8 – The conceptual communication diagram for the Monte Carlo model of the North Kent cluster. The green symbols indicate the current Industrial Symbiosis in the cluster.

4.2 Findings and recommendations

Key findings from Systems Thinking

One of our key findings from the participative development of rich pictures is that the North Kent cluster has already established what is arguably an outstanding British example of Industrial Symbiosis (Figure 9) where current exchanges in energy, materials, waste and information have been identified. These examples are expected to have lowered carbon emissions because of the reuse of material or waste as inputs to processes and lower transportation emissions due to the proximity of the companies to each other as they are located within 1.5mi of each other. Sustainability is the precursor to decarbonisation because it provides the framework and guiding principles needed to achieve a low-carbon or carbon-neutral future. In the sense that the more you reuse and repurpose the less you produce. This symbiosis has a potential to grow, where new materials are exchanged with other entities (business or the public sector) joining this Industrial Symbiosis leading to new sustainability opportunities and further decarbonisation. This symbiosis has the potential to become a living lab like the Kalundborg Symbiosis (European Circular Economy Stakeholder Platform, 2018) and promote Industrial Symbiosis in the UK.

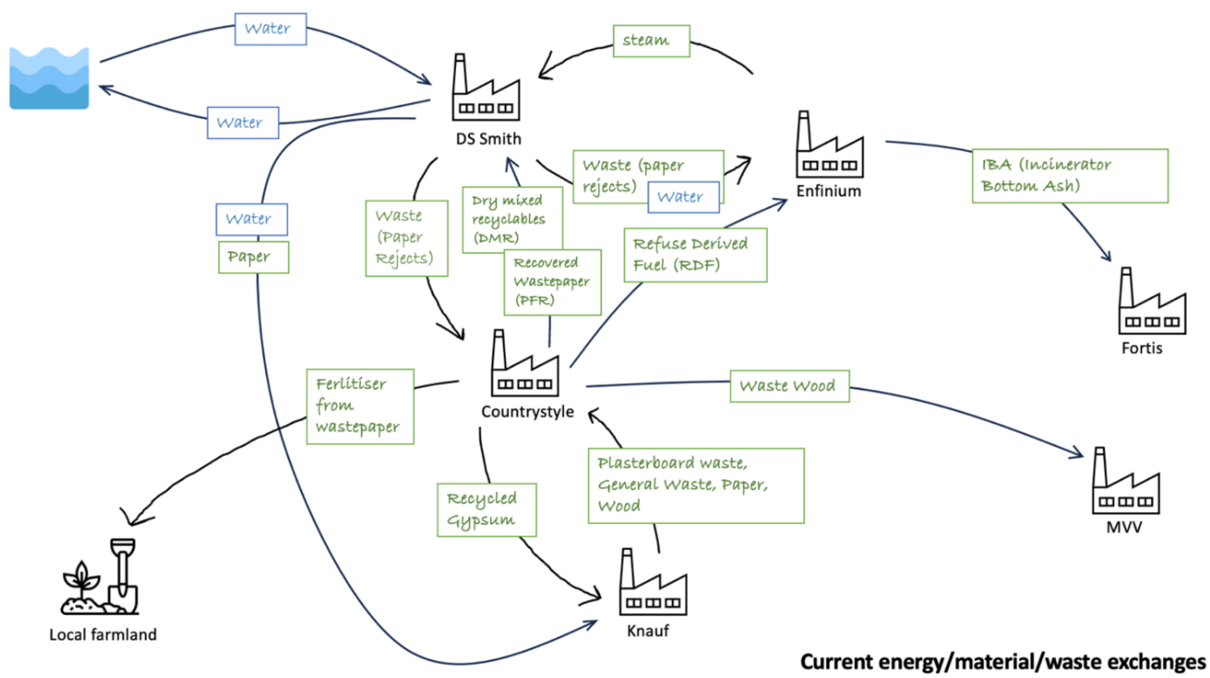

Figure 9 – Rich picture of current Industrial Symbiosis in North Kent

Key findings from Monte Carlo simulation

We present the findings in this section as follows. We initially consider the results of all scenarios for: emissions; hydrogen demand; and the potential for a private wire in meeting the electricity demand of the cluster. While we initially provide comprehensive results for each scenario, we subsequently discuss Scenario 1 in more detail, as this is the preferred scenario by members of the cluster based on technological feasibility.

Figure 10 provides an overall summary of the six scenarios from 2025 to 2050 identified and shortlisted in WP1. The baseline, shown by the blue line at the top, represents the case if the cluster members do nothing. As can be observed, all scenarios are viable and better than “do nothing”. The most significant reduction occurs for all scenarios in 2035 when carbon capture (CC) is expected to be operational, leading the cluster to become carbon negative. Before CC, Scenarios 1 (in red) and 3 (in purple), which include a steam symbiosis by MVV to DS Smith, show significantly lower emissions than Scenarios 4 (in orange) and 6 (in pink), which don’t include this symbiosis. After CC, we observe that Scenario 2 (in green), which is the third scenario that includes this particular steam symbiosis, performs as second best until 2042.

Since none of the decarbonisation solutions, including CC, are 100% efficient (in our model CC is assumed to have a capturing efficiency of 95%), there will always be some residual emissions unless we utilise the offset biogenic emissions that will be captured. This offers a carbon removal potential for the cluster. Additionally, not all emissions are being captured, only those from power generating facilities where CC plants are established, which are enfinium and MVV. Enfinium burns a mix of fossil and biogenic waste, while MVV is considered as fully biogenic, burning waste wood chips. We assume that 95% of these fossil and biogenic emissions will be captured. For scenarios 2 and 5 that include blue hydrogen, we model the blue hydrogen plant with a 96% efficiency of carbon capture, and the remaining 4% fossil emissions would add to the overall residual emissions that are being released.

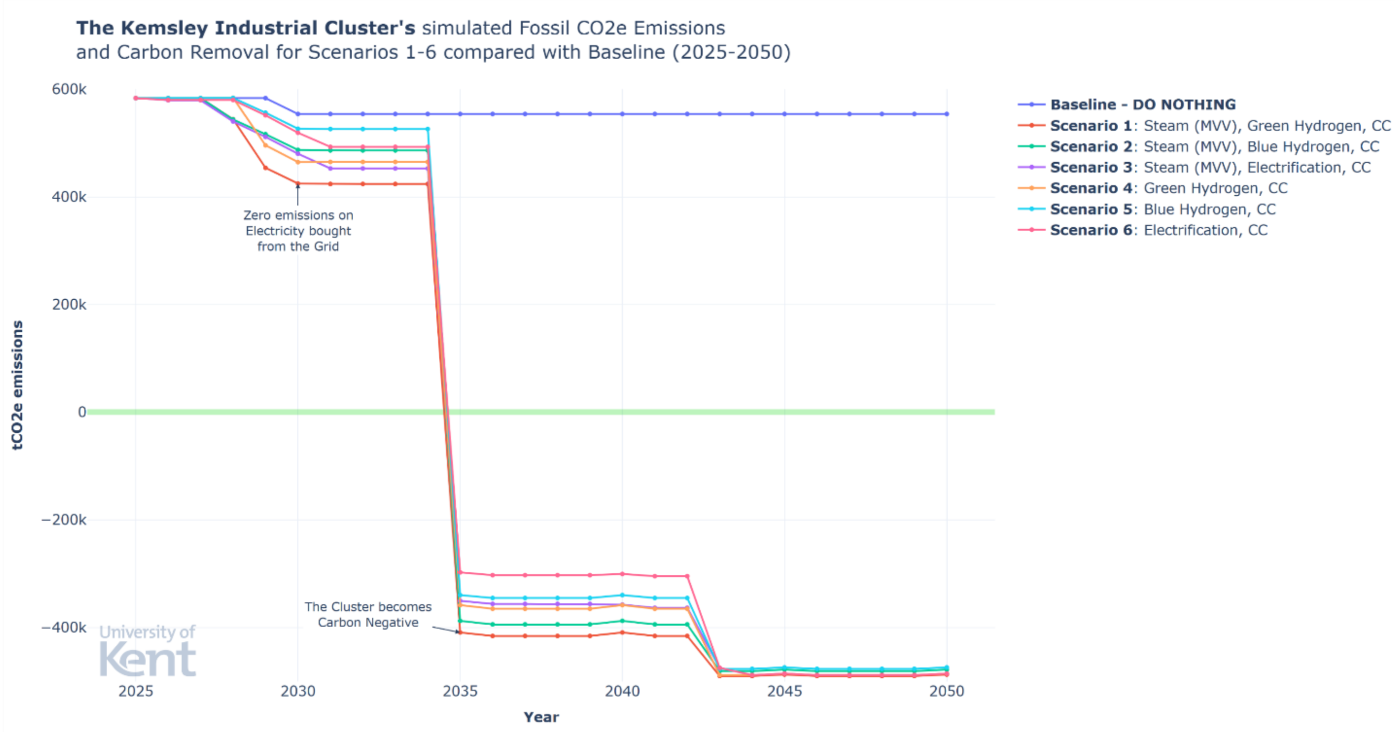

Figure 10 – The Cluster Carbon Removal Potential in the various Scenarios

Table 6 provides the simulation output related to the cluster's emissions for all 6 scenarios. The first three columns are related to fossil (Scope 1 and 2) emissions, their percentage change compared to the baseline (do nothing), and the amount of fossil carbon expected to be captured. The next three columns follow suit but are now comprised of the total fossil and biogenic emissions. This cluster has the unique potential to also remove biogenic emissions unlike many other clusters, enabling carbon offsetting potential for hard-to-eliminate emissions within the cluster and the area. Therefore, it is important to consider biogenic removals in addition to fossil removals. Finally, the last column shows the Carbon Removal Potential of each scenario, which is calculated as the sum of available carbon negative emissions from 2035 to 2050.

Table 6 – Emission results (simplified: without reporting Confidence Intervals)

Scenarios	Fossil emissions released from 2026-2050 (in tCO2)	% change in released Fossil emissions from Baseline	Total CC from 2035-2050 (Fossil) (in tCO2)	Fossil & Biogenic emissions released from 2026-2050 (in tCO2)	% change in released Fossil & Biogenic emissions from Baseline	Total CC from 2035-2050 (Fossil + Biogenic) (in tCO2)	Expected Total Carbon Removal Potential (Residual Fossil emissions minus Captured Biogenic emissions) between 2035-2050 (in tCO2)
Baseline – DO NOTHING	13,979,549	0	-	26,687,437	0	-	-
Scenario 1: Steam supply, green hydrogen and CC	**5,278,070**	**-62.23%**	4,367,425	**10,346,092**	**-61.55%**	12,584,216	**-7,226,022**
Scenario 2: Steam supply, blue hydrogen and CC	5,897,206	-57.80%	5,537,200	10,965,240	-59.24%	13,752,554	-6,979,459
Scenario 3: Steam supply, electrification and CC	5,974,820	-57.24%	4,360,516	11,045,075	-58.95%	12,569,281	-6,737,450
Scenario 4: Green hydrogen and CC	5,982,180	-57.19%	4,361,306	11,041,648	-58.96%	12,571,623	-6,801,252
Scenario 5: Blue hydrogen and CC	6,598,902	-52.77%	5,917,580	11,666,765	-56.64%	14,132,503	-6,555,543

Scenarios	Fossil emissions released from 2026-2050 (in tCO2)	% change in released Fossil emissions from Baseline	Total CC from 2035-2050 (Fossil) (in tCO2)	Fossil & Biogenic emissions released from 2026-2050 (in tCO2)	% change in released Fossil & Biogenic emissions from Baseline	Total CC from 2035-2050 (Fossil + Biogenic) (in tCO2)	Expected Total Carbon Removal Potential (Residual Fossil emissions minus Captured Biogenic emissions) between 2035-2050 (in tCO2)
Scenario 6: Electrification and CC	6,696,470	-52.08%	4,366,326	11,769,462	-56.25%	12,582,357	-6,303,527

A key finding from the simulations is that all scenarios are expected to reduce more than half of the total emissions compared to the baseline The greatest reduction is expected from Scenario 1, with a decrease of 62.23% in fossil emissions and 61.55% in combined fossil and biogenic emissions (total emissions), showing that it performs equally well in fossil removals as well as combined fossil and biogenic removals.

We note that if MVV provides steam to DS Smith (Scenarios 1, 2, and 3), it could result in approximately 700,000 tCO2e fewer fossil emissions until 2050, compared to Scenarios 4, 5, and 6 where they do not provide steam, as can be derived from the second column. Scenario 1 results in about 4.4 MtCO2 fossil emissions captured, and about 12.6 MtCO2 total emissions captured.

The total volume of captured fossil and biogenic emissions could influence decisions regarding the transport and storage of the captured carbon. Indeed, early conversations suggest that the total volume of captured emissions could reduce operational costs due to economies of scale (Chandel et al., 2010). While lower emission volumes are preferred from a sustainability point of view, higher volumes might dictate the adoption of a particular transport solution. There are more emissions being captured in Scenarios 2 and 5, which is due to the blue hydrogen technology.

Next, we consider each scenario's hydrogen and electricity demand, which are met by the private wire. Scenarios 1 and 2, and Scenarios 4 and 5 are very similar in terms of hydrogen demand, as observed in the second column, but different in respect to steam. In Scenarios 1 and 2 MVV and enfinium provide steam to DS Smith, while in Scenario 4 and 5 only enfinium.

Both Scenarios 1 and 2 expected to have about 295k MWh hydrogen demand from the implementation year onwards, increasing to about 455k MWh hydrogen demand from 2043 onwards. This increased hydrogen demand is due to the closure of the CHP plant, which provides steam and electricity to DS Smith until 2042. In Scenarios 4 and 5, these volumes are expected to be 280k MWh and 760k MWh, respectively because of the additional steam demand. The third column shows the anticipated overall hydrogen demand in the scenarios. This could be an important indicator in the discussions with a potential hydrogen provider.

The last three columns in Table 7 indicate the private wire potential when we consider intermittency in the cluster members operations. Carbon Capture (CC) is powered by electricity and steam, and this affects the power generating companies where CC installed (MVV and enfinium). The private wire electricity is supplied by MVV and enfinium, and CC will reduce its power generating output. As observed, the private wire is able to meet the cluster's demand before CC in all scenarios.

After CC, Scenarios 2 and 5 show no significant difference from previous years until 2042. After 2043, we expect that the private wire could meet 48% and 59% of the cluster's electricity demand, respectively. In case of Scenarios 1 and 4, where the technology option is green hydrogen, we considered both excluding and including its electricity need, as seen in the last two columns.

When excluded, we observe that after CC until 2042, the private wire is able to meet 96% and 98.4% of the cluster's demand, while after 2043 this is expected to drop to 56% and 68.1%, respectively. Meanwhile, if the electricity demand for hydrogen production is included (Scenarios 1 and 4), the cluster could still meet a quarter of its electricity needs from 2043 onwards, making it a favourable option for the cluster members.

Table 7 – Hydrogen and electricity demand in the simulated scenarios, counting for intermittency

Scenarios	Hydrogen demand per year by cluster (2029-2050)	Expected Total hydrogen demand by cluster (2029-2050)	% of Electricity demand met annually by private wire before CC	% of Electricity demand met annually by private wire after CC (excluding green hydrogen production electricity need)	% of Electricity demand met annually by private wire after CC (including all technology electricity need)
Scenario 1: Steam supply, green hydrogen and CC	From 2029: 294,500 MWh, from 2043: 455,024 MWh	7,763,800 MWh	99% (or 88% if GHP electricity need is included)	96% (and 56% after 2043)	54% (and 25% after 2043)
Scenario 2: Steam supply, blue hydrogen and CC	from 2035: 294,700 MWh, from 2043: 455,200 MWh	5,999,700 MWh	99%	n/a	96% (and 48% after 2043)
Scenario 3: Steam supply, electrification and CC	0	0	97%	n/a	81% (72% from 2040, 33% from 2043 and 29% from 2044)
Scenario 4: Green hydrogen and CC	From 2029: 279,900 MWh, from 2043: 757,100 MWh	9,974,500 MWh	100% (or 92% if GHP electricity need is included)	98.4% (and 68.1% after 2043)	66% (and 24% after 2043)
Scenario 5: Blue hydrogen and CC	From 2035: 279,700 MWh, from 2043: 760,100 MWh	8,318,700 MWh	100%	n/a	98% (and 59% after 2043)
Scenario 6: Electrification and CC	0	0	99%	n/a	92% (85% from 2040, 31% from 2043, and 28% from 2044)

We now consider Scenario 1 in more detail as this has been identified by the cluster partners as the ideal scenario in terms of technological feasibility and operational implementation. The emissions of Scenario 1 are shown in Figure 11 over our time horizon. The highest emissions can be seen at the start of the simulation with the first visible reduction in 2028 where MVV (energy from biogenic waste) supplies steam to DS Smith. Enfinium (energy from 50% biogenic waste) already supplies some steam to DS Smith, but they will also provide their maximum steam capacity from 2029 onwards, resulting in lower emissions for the cluster. The green hydrogen plant is also expected to become operational in 2029, reducing emissions for members switching to hydrogen from fossil-based fuels. In the following year, 2030, the National Grid is expected to become net zero, which will

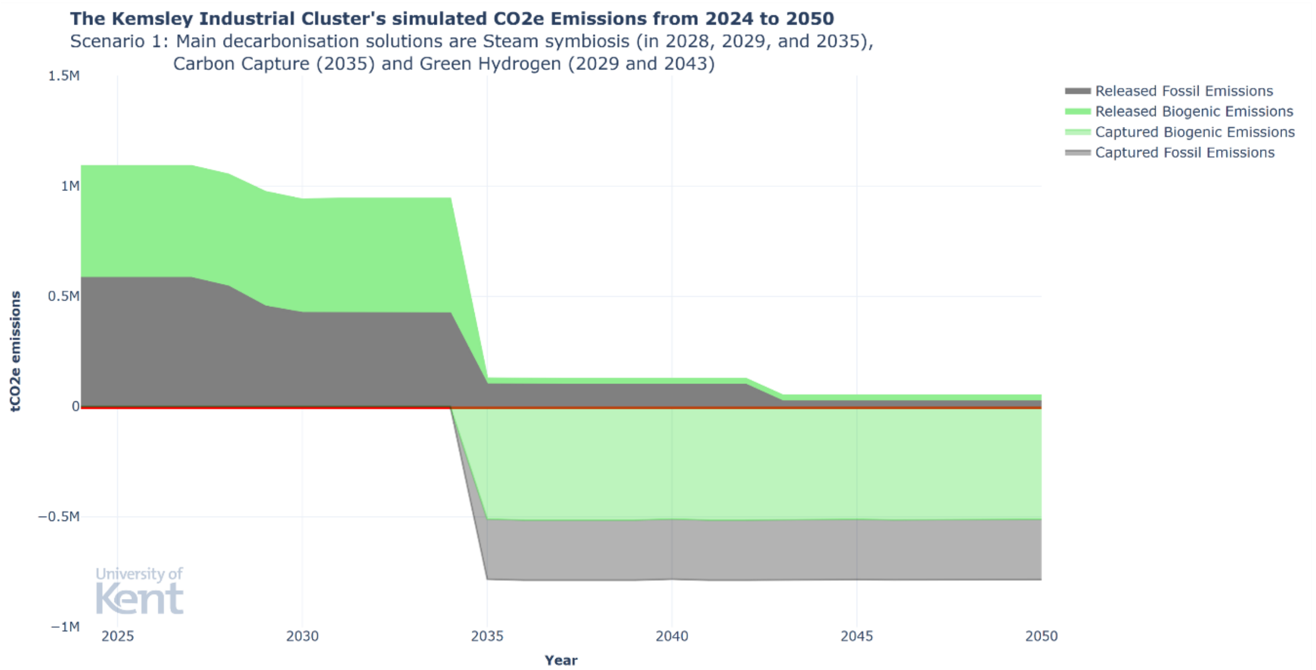

Figure 11 - Scenario 1 emissions 2024-2050

reduce emissions for members using electricity off the grid. The biggest drop in emissions is seen in 2035, when the CC plants become operational. In 2035, due to the modification requirements for implementing carbon capture, MVV is able to provide their maximum steam capacity to DS Smith and DS Smith can potentially use the green electricity from the private wire, resulting in reduced emissions for the cluster. The next drop in emissions is seen in 2042, where K4, the CHP plant which is the primary energy source providing electricity and steam to DS Smith, is expected to close down and be replaced by a (green) hydrogen boiler.

Finally, we present DS Smith's expected steam demand in Figure 12, applicable in Scenarios 1, 2, and 3. As discussed previously, steam is provided to DS Smith by enfinium, the CHP plant, and from 2028 onwards MVV too. The red area named as "Company F" is the CHP plant that burns natural gas to provide steam and electricity to DS Smith and is expected to close down in 2042. Enfinium, named as "Company B", currently providing about a third of DS Smith's demand, and even more from 2029, as shown in green. MVV named as "Company A", is expected to provide substantial amount of steam, currently provided by the CHP plant, shown in turquoise. From 2043 onwards, a steam gap is expected that will need to be filled with an alternative technology solution.

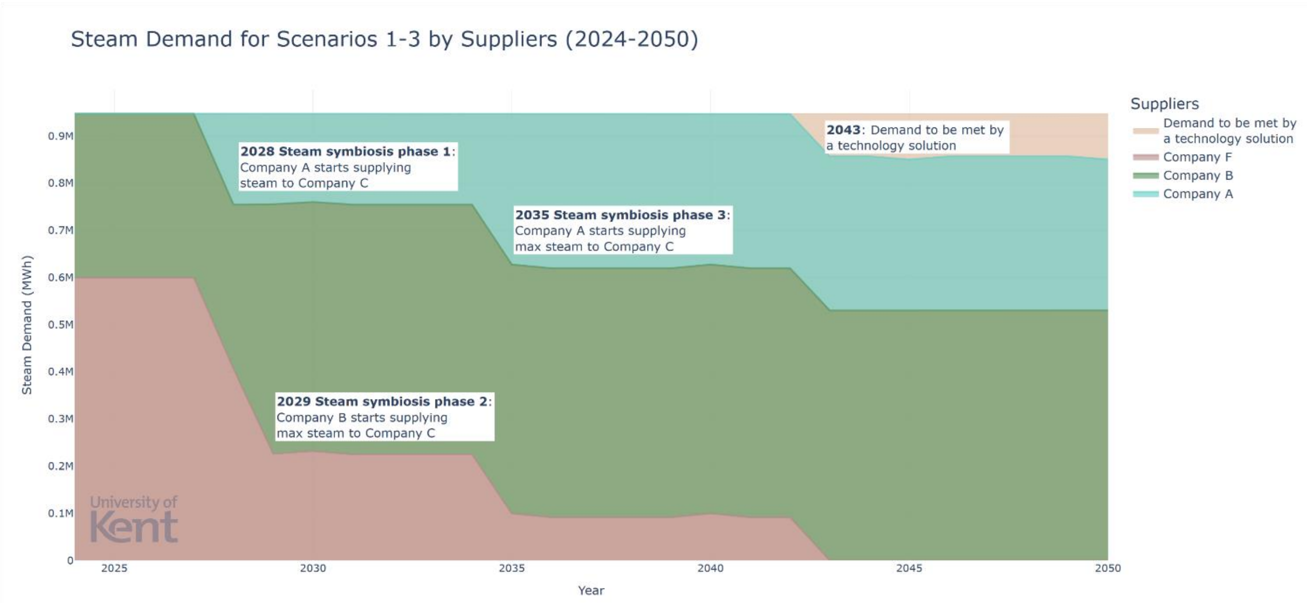

Figure 12 – Scenarios 1-3 steam demand in Industrial Symbiosis

4.3 Conclusion

We have considered the results of all scenarios for: emissions; hydrogen demand; and the potential for a private wire in meeting the electricity demand of the cluster. Across all these performance indicators we found that all scenarios are viable and better than do nothing, however Scenario 1 is the best performing scenario. It also happens to be the preferred scenario for the cluster in terms of technological feasibility and operational implementation.

The Industrial Symbiosis exchanges, originally captured through diagramming in rich pictures, have been simulated and we can see their impact on the cluster’s decarbonisation and sustainability journey. The broader social, economic, and environmental impact of the symbiosis has also been studied using CLDs developed collaboratively with stakeholders. The CLDs consider the point of view of both internal and external stakeholders, analysing issues such as factors impacting the planning permission process, as well as job security and skills requirements and gaps**.**

The steam symbiosis between MVV and DS Smith could lower the cluster's fossil emissions by 700,000 tCO2 in Scenarios 1, 2, and 3, and reduce the demand for hydrogen by 2.2 million MWh for the period between 2026 - 2050. A downside of MVV providing steam to DS Smith is that the private wire will meet a smaller proportion of the cluster’s needs, as increasing steam production reduces electricity generation.

Blue and green hydrogen differ in their starting date, with green hydrogen being implemented 6 years earlier. In the case of blue hydrogen in Scenarios 2 and 5, there is only a 2% reduction in electricity provided by the private wire until the closure of the CHP plant. After the CHP closure, when DS Smith will utilise hydrogen to produce steam, this could mean an 11% reduction in the private wire electricity potential.

Regardless of the scenario chosen as a preferred option, the symbiosis cannot be considered separately to the decarbonisation solutions as seen from the above. The simulation model is able to capture the dynamic nature of this symbiosis and quantify its impact on the cluster.

5

BUSINESS CASE, ROADMAP AND INVESTMENT PLANNING

5. BUSINESS CASE, ROADMAP AND INVESTMENT PLANNING

5. 1 Overview of work package

The purpose of WP4 is to develop a strategic outline business case (SOC) to support future funding into the LIDP. This also provides a roadmap for the preferred way forward to decarbonisation and identifies funding sources to support investment planning.

The SOC has been created by consolidating some of the outputs from the other work packages into a resulting business case that can be used to support further public and private sector investment in the LIDP. The SOC has been developed in alignment with the HM Treasury Green Book guidance for developing business cases (HM Treasury, 2022).

At SOC stage, there is a greater emphasis on the strategic, financial and economic cases as the appraisal of the proposed options, from a longlist down to a shortlist, is still relatively high level. The purpose of this stage is to identify a “preferred way forward” from the short-list of options, and to demonstrate that the LIDP is worth investing into the next stage of its development. As the business case develops over time, more detailed appraisal can be undertaken on the short-list of options to better understand and compare the potential costs and benefits of each option and ultimately identify a “preferred option” for delivery.

In addition to the SOC, the purpose of work package 4 is to develop a roadmap to decarbonisation for the preferred way forward from the business case / study to help communicate how the LIDP will be delivered over time. It also identifies different funding sources to support investment planning in the LIDP.

5.2 Findings and recommendations

5.2.1 Strategic Case

The strategic case demonstrates that there is a case for change and strategic fit for the cluster to invest in the LIDP. The LIDP aligns strategically with the cluster organisations individual policies and strategies in relation to sustainability and decarbonisation, including:

- **MVV** to become climate positive by 2035 (MVV, 2024)
- **Enfinium** to achieve net zero by 2033 (enfinium, 2024)
- **DS Smith** to reach net zero emissions by 2050 (DS Smith, 2024)
- **Knauf** to achieve net zero carbon emissions by 2045 (Knauf, 2023)
- **Countrystyle Recycling,** to investigate and start implementation of fleet transition to HVO biofuels for 2025 to 2029 (Projected 89% reduction to fleet CO_2 emissions by 2029). (Countrystyle Environmental Policy Statement, 2024)

Furthermore, there is strategic alignment with national, regional and local policy, including:

- The **UK** to achieve net zero greenhouse gas emissions by 2050 (Department for Energy Security and Net Zero, 2022)
- By 2050 the county of **Kent** has reduced emissions to net-zero and is benefiting from a competitive, innovative and resilient low carbon economy, where no deaths are associated with poor air quality (Kent County Council, 2021)
- **Medway** to achieve net zero carbon emissions by 2050 (Medway Council, 2022)
- **Swale Borough** to become net zero by 2030 (Swale Borough Council, 2020)

The LIDP is also in alignment with the UK's 10 Point Plan for Green Industrial Revolution (2020) that includes objectives related to:

- driving the growth of low carbon hydrogen
- accelerating the shift to zero emission vehicles
- investing in carbon capture, usage and storage
- green finance and innovation

Overall, the LIDP demonstrates a strong strategic fit at organisational level and across a broad range of national, regional and local policies reviewed in more detail in the Strategic Case of the SOC and work package 3.

The case for change is demonstrated by assessment of the current CO_2 emissions for the cluster in Table 8.

Table 8 – Total "current state" annual CO_2 emissions for the cluster based on 2023 figures using WP1 output

Fuel Source	Annual CO_2 Emissions for the Cluster (tpa)
Fossil	540,097
Biogenic	524,266
TOTAL	**1,064,363**

This shows a strong case for change for the cluster to decarbonise when considering partner's corporate policies and national, regional and local policies for reducing carbon emissions.

5.2.2 Economic Case

The process for establishing the longlist and consolidating this down to the shortlist is described in WP1.

The benefits associated with the six scenarios identified in WP1 are described in WP2 (CO2 emissions reduction) and WP3 (job creation and economic impact).

A key finding of our study worth mentioning here is that increasing the volume of captured carbon can lower the costs of CO_2 transport and storage (Chandel et al., 2010). This has been verified in workshop discussions with the stakeholders who also provided insights into the potential economic impacts of implementing the decarbonisation solutions. This reduction in operating expenses of carbon capture and storage (CCS) through economies of scale, would make it more feasible for companies to adopt CCS. As more companies implement CCS, the volume of captured carbon is likely to increase further, as is illustrated in the causal loop diagram from WP2 in Figure 13. We are not considering the increase of the cluster membership at this stage of the study but there is support by cluster members to increase membership where there are economic opportunities that would bring down the costs of decarbonisation.

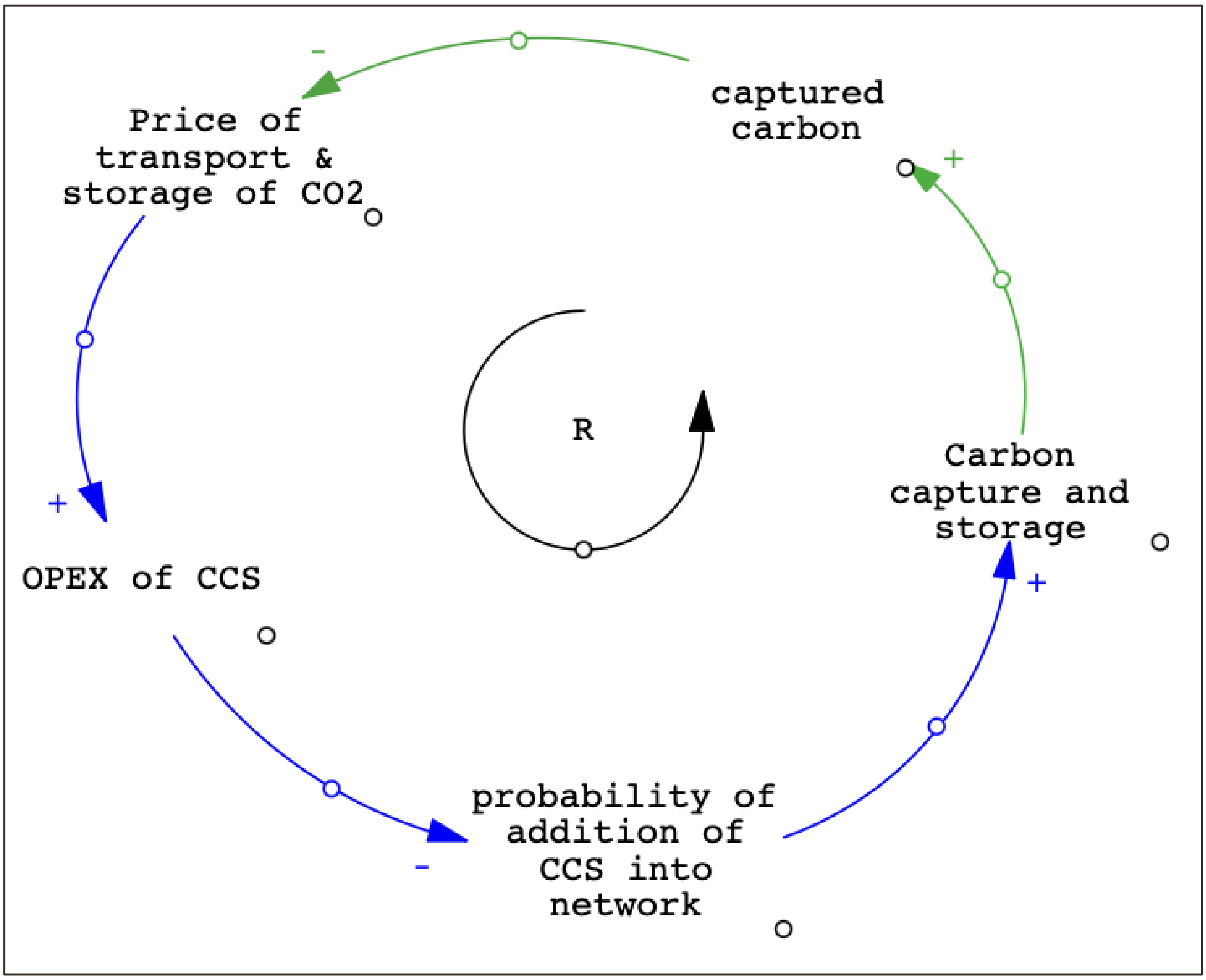

Figure 13 – Causal loop diagram extract from WP2 modelling and simulation

5.2.3 Financial Case

A financial model was developed using the outputs from WP1 to assess cash outflows (present costs) for the cluster associated to:

- Capital expenditure (Capex) for implementing decarbonisation solutions within the cluster only
- Operating expenditure (OpEx) for any additional labour and maintenance costs associated with decarbonisation in comparison with the current baseline for the cluster
- OpEx for energy usage
- Cost of traded carbon associated to CO2 emissions (Assumed will be implemented through UK ETS by 2028)

Furthermore, it looked at cash inflow (present revenues) for the cluster associated with:

- Captured biogenic carbon credits (assumed will be available through UK ETS by 2035)
- Energy production

The table below (Table 9) shows a breakdown of these costs and revenues for each option:

Table 9 – Total cash outflows (costs) and cash inflows (revenues) for the cluster, for each option over a 26-year time period (2025-2050)

	Baseline A - Do Nothing w/o PW	**Baseline B - Do Nothing w/ PW**	**Scenario 1 - ST, H(G), CC**	**Scenario 2 - ST, H(B), CC**	**Scenario 3 – ST, E, CC**	**Scenario 4 - H(G), CC**	**Scenario 5 - H(B), CC**	**Scenario 6 - E, CC**
Cash Outflows								
Capex	£-	£-	-£562	-£562	-£566	-£534	-£534	-£568
OpEx (Labour + Maintenance)	£-	£-	-£237	-£237	-£237	-£237	-£237	-£237
OpEx (Energy Usage)	£-	£-	-£1,182	-£1,182	-£1,182	-£1,182	-£1,182	-£1,182
CO2 Emissions	-£2,444	-£2,341	-£2,841	-£3,007	-£3,232	-£2,839	-£3,149	-£3,109
Present Cost (PC)	-£1,569	-£1,569	-£340	-£367	-£329	-£390	-£417	-£380
Cash Inflows								
Biogenic Carbon Credits	£-	£-	£1,125	£1,125	£1,125	£1,125	£1,125	£1,125
Energy Production	£1,590	£1,694	£1,439	£1,439	£1,511	£1,365	£1,365	£1,395
Present Revenue (PR)	£1,590	£1,694	£2,564	£2,564	£2,637	£2,490	£2,490	£2,520

Note: figures are in million £s

Table 9 shows that Scenario 3 has the highest present cost (PC) for the 26-year time-period of the project (2025-2050). This can be attributed to the higher cost of electricity as an energy source and higher capex associated to electrification in comparison to hydrogen for Knauf.

The Baseline 2 – "do nothing with private wire" case has the lowest PC as there is no additional capex related to new technology installation or opex related to carbon capture, transport and storage. The addition of the private wire also reduces the cost of electricity for the cluster. However, it is important to note that the baseline scenarios would not be considered viable options as they do not align with government or corporate policy for achieving net zero.

Scenario 1 has the lowest PC of the decarbonisation scenarios, due to the lower energy costs of green hydrogen and steam, and lower emissions costs.

Scenario 3 has the lowest CO2 emissions costs, but only if Knauf is able to bring electrification online sooner than green hydrogen, thus decarbonising faster.

Scenario 3 has the highest PR which can be attributed to the higher revenues achieved by MVV and Enfinium from the sale of electricity and steam to the cluster – noting that there is an assumption that electricity sold through the private wire will be higher than the wholesale price achieved through selling to the grid.

Scenarios 4 and 5 have the lowest PR of the decarbonisation options as these do not include steam from MVV to DS Smith and there is lower electricity demand through the private wire, due to hydrogen being the chosen decarbonisation solution in these scenarios.

The revenue from biogenic carbon credits is the same in all decarbonisation scenarios because the amount of carbon capture is assumed to be the same.

The PC and PR for all the decarbonisation scenarios are relatively similar, with a difference of £384m in cost between the lowest and highest costing scenarios, and a difference of £147m in revenue between the lowest and highest revenue scenarios. This shows that at this stage of the project development there is little to separate the solutions from a cost perspective, however as the project progresses considerations like planning approvals, required infrastructure and sensitivity to potential changes in energy prices will need to be considered.

The table below (Table 10) shows the Net Present Value (NPV) for each option where:

NPV = PR – PC

The NPV is shown relative to Baseline A (do nothing without private wire) and the options are shown in rank order, from highest NPV to lowest NPV, relative to Baseline A – indicated by the colour formatting from green (highest NPV) to red (lowest NPV).

Table 10 – Net present cost (NPC), net present revenue (NPR) and net present value (NPV), for the cluster, for all cash inflows and outflows for each option, relative to Baseline A, over a 26-year time period (2025-2050)

Cluster				
Rank	**Option**	**PC (£2023m)**	**PR (£2023m)**	**NPV (£2023m)**
1	Baseline 2 - Do Nothing w/ PW	£103	£103	£207
2	Baseline 1 - Do Nothing w/o PW	£-	£-	£-
3	Scenario 1 - CC, ST, H(G)	-£1,148	£974	-£175
4	Scenario 4 - CC, H(G)	-£1,169	£900	-£269
5	Scenario 2 - CC, ST, H(B)	-£1,342	£974	-£368
6	Scenario 3 - CC, ST, E	-£1,533	£1,046	-£487
7	Scenario 6 - CC, E	-£1,462	£929	-£532
8	Scenario 5 - CC, H(B)	-£1,506	£900	-£607

The results in Table 10 show Scenario 1 has the highest NPV of the decarbonisation scenarios due to its lower costs, particularly associated to energy costs for steam and green hydrogen, but comparable revenues to the other scenarios.

Scenario 5 has the lowest NPV of the decarbonisation scenarios due to its higher costs associated to energy usage and emissions as all the partners do not decarbonise until 2035 in this scenario whereas in other scenarios some partners decarbonise sooner. It also has a lower revenue compared with the other scenarios as it uses hydrogen to decarbonise, rather than electricity or steam which can be provided by the cluster.

With the exception of scenario 5, the electrification scenarios perform more poorly than the hydrogen scenarios due to the higher capex costs for installing electrification and higher energy costs for electricity as an energy source.

Figure 14 shows the annual NPV of each scenario over the 26-year timescale of the financial model – 2025-2050. For all decarbonisation scenarios there is a big drop NPV from 2030-2035 when carbon capture is being installed, after which the annual NPV's for the decarbonisation scenarios recover and begin to overtake the baseline scenarios – in 2037 scenarios 1 and 4 overtake baseline 1, and in 2038 scenarios 1, 4 and 6 overtake baseline 2, although scenario 6 then begins to decline again due to higher operational costs. By 2050 Scenario's 1, 4, 2 and 3 (in order from highest to lowest) have a higher annual NPV than both baseline scenarios.

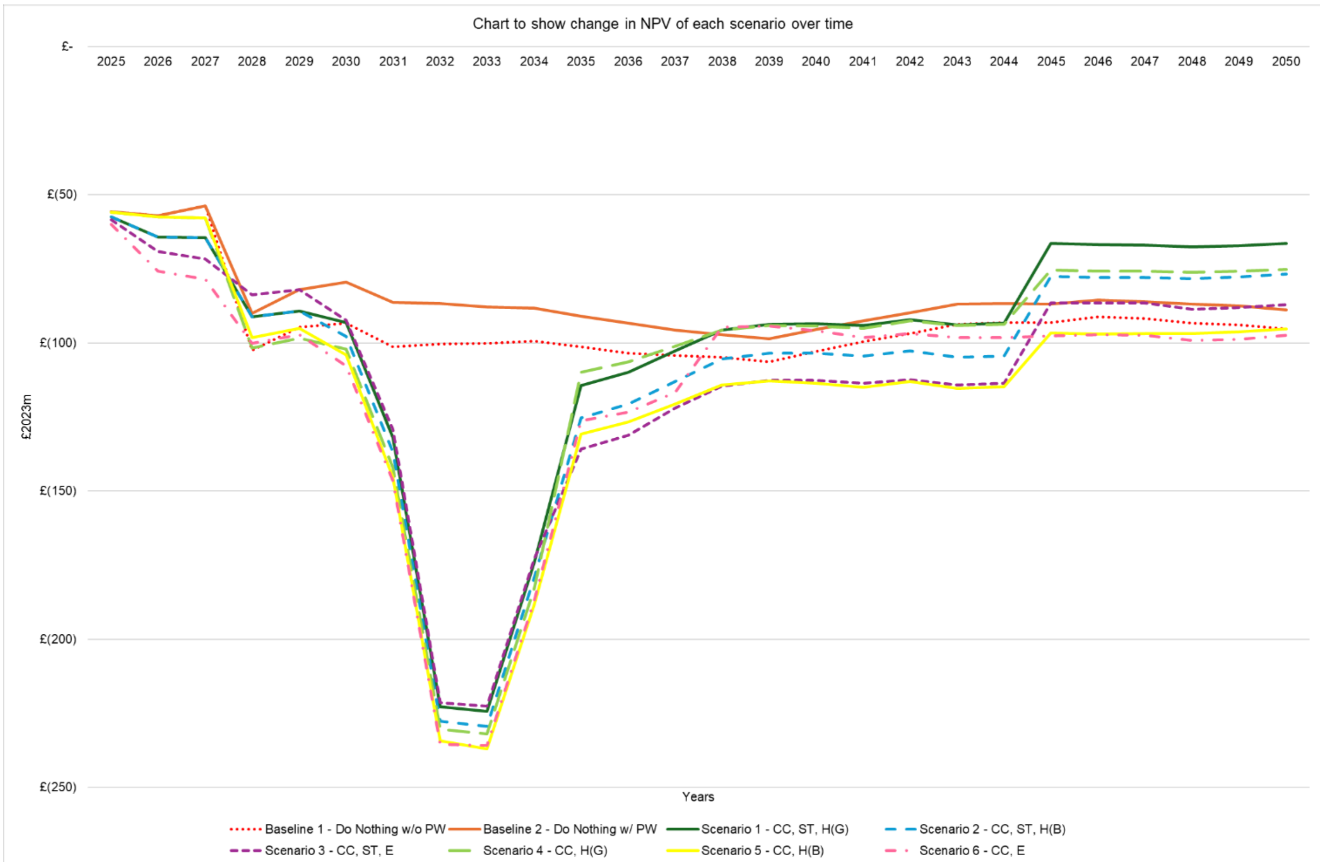

Figure 14 – Chart to show change in NPV for each scenario over time

5.2.4 Sensitivity Analysis – Green Hydrogen Price

Table 11 – Rank order of scenarios based on total net present value (NPV) from 2025-2050 in £2023m - where it is assumed green hydrogen price will not include any government subsidies and is based off the DESNZ green hydrogen production costs

Cluster				
Rank	Option	PC CO2 (£m2023)	PR CO2 (£m2023)	NPV CO2 (£m2023)
1	Baseline 2 - Do Nothing w/ PW	-£3,910	£1,694	-£2,216
2	Baseline 1 - Do Nothing w/o PW	-£4,013	£1,590	-£2,423
3	Scenario 2 - CC, ST, H(B)	-£5,356	£2,564	-£2,791
4	Scenario 3 - CC, ST, E	-£5,546	£2,637	-£2,910
5	Scenario 6 - CC, E	-£5,475	£2,520	-£2,955
6	Scenario 5 - CC, H(B)	-£5,520	£2,490	-£3,030
7	Scenario 1 - CC, ST, H(G)	-£6,208	£2,564	-£3,644
8	Scenario 4 - CC, H(G)	-£6,993	£2,490	-£4,503

Table 11 shows the rank order of scenarios based on total NPV for the cluster, where it is assumed that green hydrogen price will not include any government subsidies and is based off the DESNZ green hydrogen production costs. This shows that when the green hydrogen price is not subsidised, scenarios 1 and 4 go from being the best two decarbonisation scenarios, in terms of NPV, to the worst two decarbonisation scenarios.

This will be an important consideration at the next stage of the business case when deciding between hydrogen or electrification as a decarbonisation option as it is still unclear what subsidies will be offered from the government in relation to green hydrogen. This risk could be mitigated on the basis that selecting hydrogen as a decarbonisation option does allow the flexibility of using green or blue hydrogen as its fuel source, however only providing the infrastructure is in place to access either of these fuels. If there is access to both green and blue hydrogen, and the green hydrogen price becomes prohibitive, then it would be possible to switch to using blue hydrogen which is currently a cheaper alternative – although scope 2 emissions associated with blue hydrogen could be greater.

5.2.5 Investment Planning

Table 12 shows a number of potential funding sources that will help support investment planning for the next stage of the LIDP. The outputs of this study and the SOC can be used as tools to help demonstrate value in the LIDP and to help secure funding to take it to the next stage of development.

Table 12 – Potential funding sources to support investment planning for the next stage of the LIDP

Source	Fund	Details
Department for Energy Security and Net Zero	Industrial Energy Transformation Fund (IETF)	The Industrial Energy Transformation Fund (IETF) is designed to help businesses with high energy use to cut their energy bills and carbon emissions through investing in energy efficiency and low carbon technologies. The IETF launched in 2020 and is in 3 phases with £500 million of funding available up until 2028. IETF Phase 3 Following a 2023 consultation on the design, Phase 3 launched in January 2024 and will provide up to £185 million in funding up to 2028. Comments: Funding for the second competition window of Phase 3 of the IETF that was announced by the previous Government was not included in the Autumn Budget by the new Labour government. To continue to engage with DESNZ to understand what grant funding opportunities will be made available to support UK industrial decarbonisation.
Department for Energy Security and Net Zero	Net Zero Innovation Portfolio	The Net Zero Innovation Portfolio provides funding for low carbon technologies and systems, to help enable the UK to end its contribution to climate change. The Net Zero Innovation Portfolio is a £1 billion fund, announced in the Ten-point plan for a green industrial revolution, to accelerate the commercialisation of low-carbon technologies, systems and business models in power, buildings, and industry. The Portfolio will decrease the costs of decarbonisation and set the UK on the path to a low carbon future. It will create world-leading industries and new green jobs, invest in our regions, and help make the UK a science and innovation superpower. Duration: 2021-2025 Comments: Includes funding for CCUS and hydrogen, however there are not currently any funding competitions open.
UK Infrastructure Bank	Private Sector Finance	The UK Infrastructure Bank has a commitment to invest across the infrastructure landscape, with a focus on the priority sectors in its mandate, including clean energy, digital, transport, waste and water. It has £22bn of financial capacity, of which £8bn has been allocated to providing equity and debt, and £10bn to providing guarantees. It wants to shape transactions proactively and to engage with the market to find problems it can solve by deploying its own financial resources. Its investment team can identify the financing structure that fits its clients' needs and aligns with the Bank's investment principles. It encourages any eligible project to contact them. Comments: Should probably be engaged further down in the project when the preferred option for delivering decarbonisation has been identified.

5.2.6 Commercial Case

At this stage in the LIDP it is too early to establish a comprehensive procurement strategy as the preferred scenario for decarbonisation has not yet been selected. For the commercial case a review of various procurement strategies was undertaken that included decarbonisation technologies they are best suited to delivering, and associated contract types.

At this stage in the business case, the preferred way forward is Scenario 1 – Steam supply, Green Hydrogen and Carbon Capture.

Furthermore, for MVV and Enfinium to implement carbon capture an engineering procurement and construction (EPC) procurement strategy would be recommended due to the higher complexity and costs associated with this technology. An EPC contract helps reduce the risk to the owner for delivering the solution and provides the owner with a single point of accountability.

For the steam upgrades associated to DS Smith, as well as the hydrogen combustion units for DS Smith and Knauf, a design and build (D&B) procurement strategy would be recommended as these are fewer complex solutions and can be delivered quicker – in comparison to carbon capture. At this stage, a transition from diesel vehicles to hydrogen/electric vehicles has only been considered for Countrystyle and therefore any associated design changes to the facility would need to be explored in the next stage of the business case, in addition to HVO biofuel technologies from 2025 to 2029 and green hydrogen vehicle technologies innovation being explored for suitability.

5.2.7 Management Case

The management case will become more clearly defined as the business case develops over time and a preferred option is selected. When the preferred option has been selected the management case will essentially provide the programme / project management plan for how the scenario will be delivered.

At this stage the most important aspect of the management case to establish is the proposed governance for how the LIDP will move forward, this will underpin how the LIDP is managed and delivered.

It is proposed that the LIDP will be delivered as a programme of works comprising each partner organisations decarbonisation project. Model below (Figure 15) provides an overview of how the programme could be Governed.

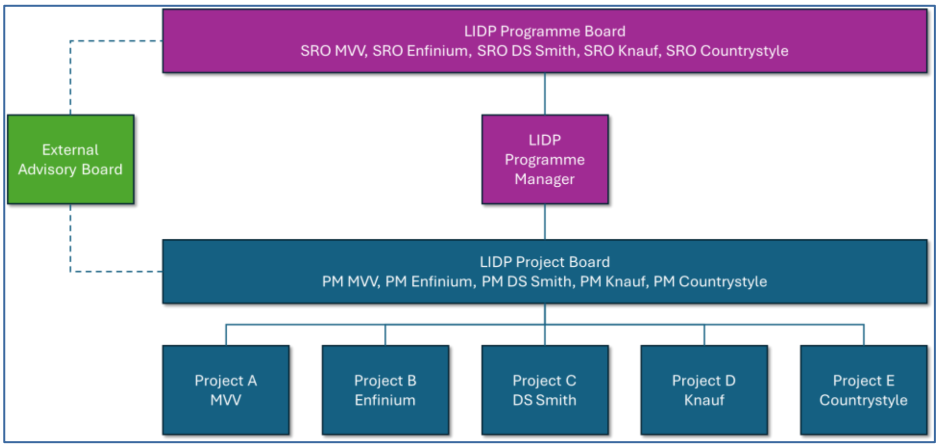

Figure 15 – LIDP proposed Governance structure

Each industrial partner will have a project team responsible for delivering its own decarbonisation solution and each project will have a project manager responsible for leading the delivery of that project. The project managers for each industrial partner will form a project board that will meet monthly to discuss project progress. The project board will also report into the programme manager who will be responsible for overseeing all the cluster projects and ensuring they are progressing against the decarbonisation plan. The project board and programme manager will also report into the programme board on a monthly basis to report progress against the decarbonisation plan. The programme board will have a senior representative from each industrial partner to provide guidance on programme performance and make recommendations on any programme changes. An external advisory board will also provide input on external factors including political, environmental, social, technological and legal matters. The advisory board may include representatives from Kent County Council, Swale Borough Council and Medway Council, and any external funding providers such as DESNZ, UKRI and the UK infrastructure bank, as well as technical, legal and planning experts.

A critical step in establishing the governance for the LIDP will be the cluster partners deciding what entity they will form to take the LIDP forward. The cluster is currently operating under a consortium agreement, which at this stage in the LIDP development provides a sufficient level of protection and flexibility for the partners. As the business case develops over time and gets closer to the final investment decision it may be more beneficial for the partners to enter into an incorporated joint venture that will give them more legal protection and may improve the clusters' chance of securing larger investment. This may also help in appointing a dedicated programme manager with experience in delivering large scale programme of this size. Over time if the cluster grows it may eventually convert into an Industrial Cluster that can deliver an innovation hub and secure greater policy support.

5.2.8 Roadmap to Decarbonisation

The image below (Figure 16) shows the roadmap to decarbonisation for the preferred way forward – Scenario 1 – Steam supply, Green Hydrogen and Carbon Capture. The purpose of the roadmap is to provide a communicable and high-level overview of the LIDP, with critical milestones over the next two years and out to 2050. Over the short-term time horizon (2025-2027) the most critical milestones will be establishing the entity for the cluster moving forward, securing more funding to develop the SOC into a Programme Business Case and carryout pre-FEED and FEED design for the preferred decarbonisation solution and making the final investment decision to move forward into delivery.

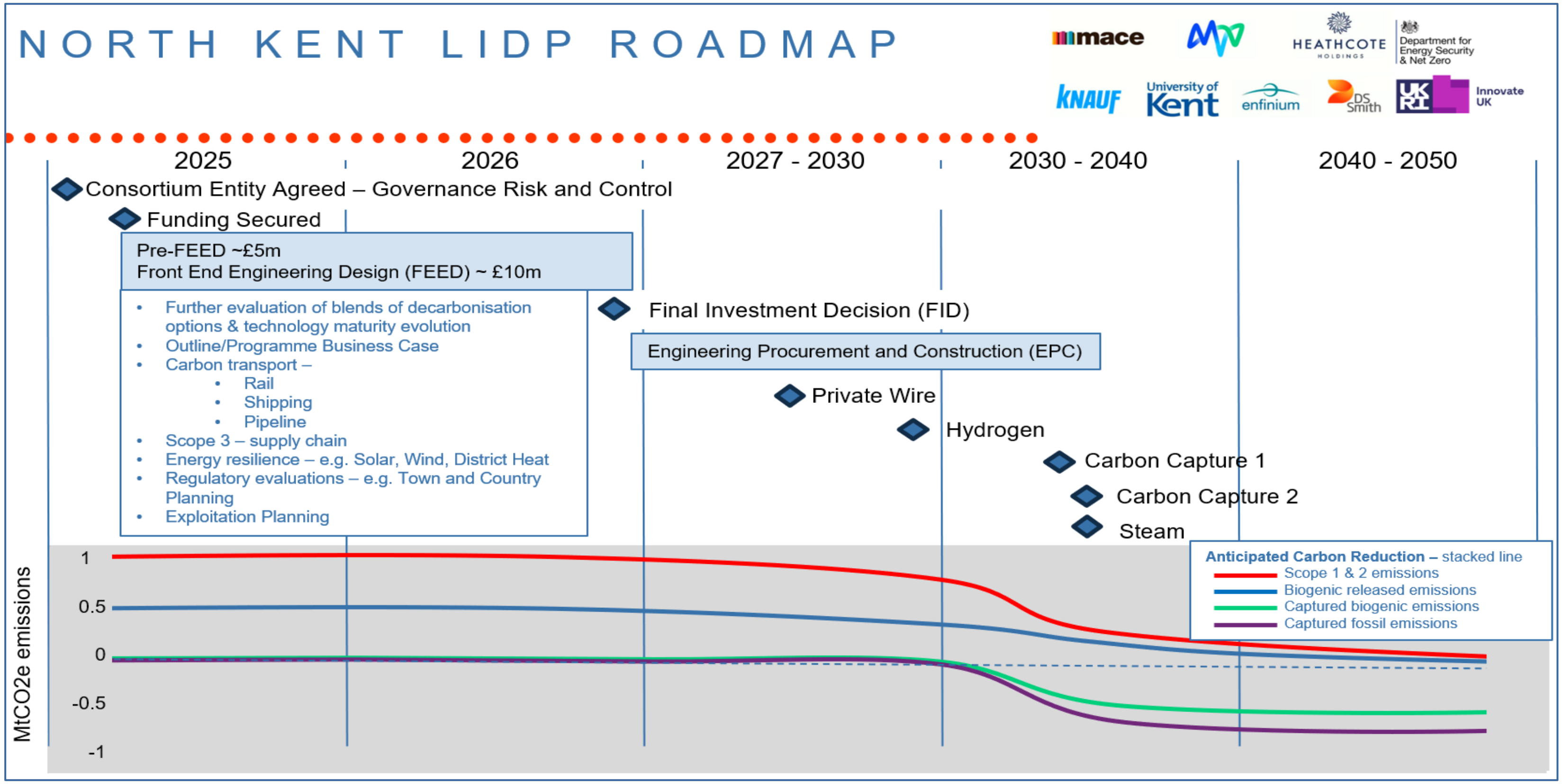

Figure 16 – Roadmap for decarbonisation for the preferred way forward Scenario 1 –ST and H(G), CC

5.2.9 Conclusions

Overall, the following conclusions can be derived:

1. The LIDP shows a strong strategic fit for decarbonisation when reviewed against respective corporate policies for the cluster members, as well as national, regional and local policies. The current total annual CO2 emissions for the cluster also demonstrates a compelling case for change, for reducing overall emissions for the cluster.

With a new government recently elected, the strategic case will need to be reviewed and updated to ensure the project continues to align with any new policies and strategies that are implemented by the government. Any updates to net zero policy may favour some technologies over others and provide faster routes to decarbonisation through improved funding and planning support.

2. Scenario 1 –ST and H(G), CC is currently the best performing decarbonisation option based on net present value (NPV) i.e. overall cash outflows and cash inflows for the cluster over a 26-year time period (2025-2050). This is due to having second lowest present cost (-£340m) and the second highest present revenue (£2,563m) in comparison with the other decarbonisation scenarios modelled. The baseline “do nothing” options are not considered a viable way forward for the cluster as they do not align with corporate or government policy and in the year 2050 have a lower NPV than 4 of the 6 decarbonisation scenarios.

Scenario 1 is currently the preferred way forward and the next stage of the business case will be to identify the preferred option before finalising the design and defining the procurement strategy. At the next stage of the business case it is recommended all decarbonisation scenarios are assessed in more detail i.e. more detailed costings undertaken for each technology and scenario, testing scenarios for sensitivity to changing energy and CO2 prices, and improving understanding of the economic benefits associated to delivering each scenario.

The capital costs for each technology are currently very high level, making it difficult for a realistic comparison i.e. implementing green or blue hydrogen vs electrification. Furthermore, a sensitivity analysis of green hydrogen price without subsidy showed scenarios 1 and 4 drop from the top 2 performing decarbonisation scenarios to the bottom 2 performing scenarios. A sensitivity analysis should be undertaken on all energy prices (blue/green hydrogen, electricity etc.) to understand which scenarios are most resilient to potential increases decreases in these prices over time.

3. Establishing the programme governance for the next stage of the business case is a critical next step that will determine a successful outcome for delivering the LIDP. As part of this process, the industrial partners will need to agree under what entity they wish to continue working together.

It is recommended that a consortium agreement, as per the current setup will be sufficient to move forward at this stage, however in the long-term establishing an incorporated joint venture may improve the overall success of the LIDP when it comes to securing funding, regulatory approvals, and delivering critical infrastructure to support the operation of the selected decarbonisation technologies.

4. The cluster will need to continue to explore and monitor different funding sources and competitions that are made available, to support the delivery of the industrial decarbonisation plan and its associated technologies.

6

SOCIO-ECONOMIC IMPACT ANALYSIS

6. SOCIO-ECONOMIC IMPACT ANALYSIS

6.1 Overview of work package

The aim of this Work Package 3 is to conduct a socio-economic impact analysis to identify and evaluate the potential social and economic effects of the different decarbonisation options presented by the Kemsley Cluster as part of the LIDP. To conduct this assessment the following approaches have been adopted:

6.1.1 Multi-Criteria Decision Analysis (MCDA)

As advocated for within the HMT Green Book guidance for business cases, Multi-Criteria Decision Analysis (MCDA) is a method used to prioritise from a variety of different options based on multiple criteria, using a weighted sum model (HM Treasury, 2024). Each options' performance is assessed and scored against agreed criteria before normalisation, aggregation and weighting to derive an outcome. The high-level process is highlighted in Figure 17.

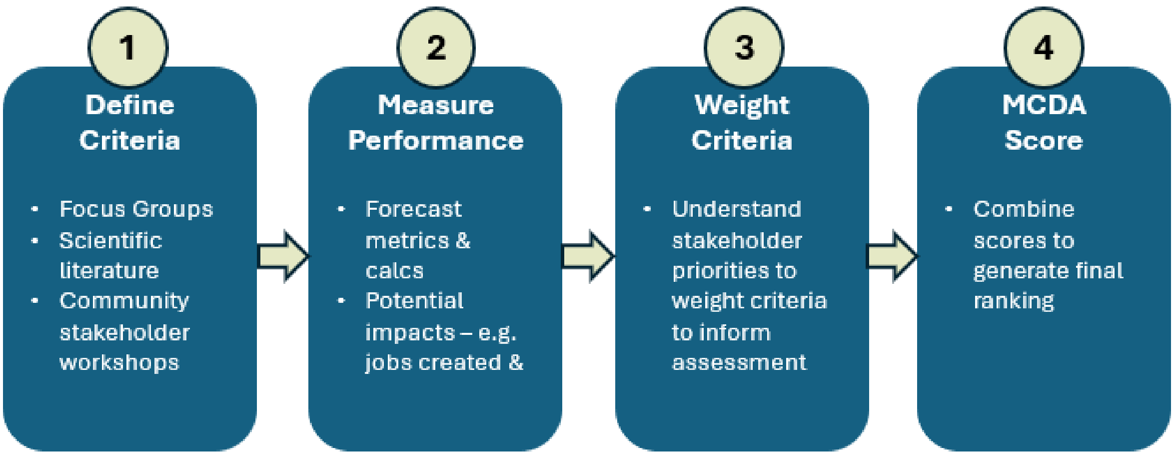

Figure 17 – The process of generating an MCDA score

The criteria and weighting for the MCDA was generated through a series of stakeholder workshops with cluster partners, an analysis of regional demographics and relevant policy, and the generation of the causal loop diagrams conducted by University of Kent academics as part of WP2. The criteria, weighting and accompanying rationale to support the MCDA assessment is included in Table 13. Each criterion is either allocated **a weighting of 1 (least significant), 2 (significant) or 3 (most significant)** as seen in Table 5. Each option is then ranked 1 to 8 against each criterion and assigned points based on this ranking **– 8 for the highest rank, 1 for the lowest rank,** as seen in Table 14.

Table 13 – MCDA Criteria & Weighting

Summary Criteria	Description	Weighting
Emissions	Quantity of total fossil carbon emissions produced (including captured and removed) according to WP1 calculations. The greater the reduction, the higher the score.	2
Net Present Value (NPV)	The value of each option when comparing its expected present cash inflows to the present value of its expected outflows according to WP4 calculations.	2
Economic Growth - Job creation & GVA	The total of Direct, Indirect and Induced jobs and the corresponding local Gross Value Add (GVA), that could be generated by each option. This considers the additive value only (i.e. not the current jobs in the cluster). This was considered to be the most important factor when assessing the decarbonisation options from a socio-economic standpoint.	3
Local socio-economic benefit & policy alignment	Considers the primary benefits of the proposed option against Kent & Medway economic framework ambitions and the UN Sustainable Development Goals. This considers the outcomes of the options in terms of reduced emissions contributing to greater air quality, increased jobs contributing to local growth and placemaking - contributing to the desirability of residing within the region of the cluster.	1
Energy consumption	The delta between the forecast total quantity of power generated versus the power consumed across the cluster (Mwe) according to WP1 calculations.	2
Operational resilience	Considers the impact of each option on the job security of current employees within the cluster and how each option could prevent or contribute to one or all the partners being closed due to non-compliance with local, national and international legislation or help to remove a dependency or reliance on external factors such as national power sources.	2

6.2 Supporting data & analysis

To facilitate the scoring of each option the following research and analysis was undertaken:

Baselining

The partners were consulted to understand their current costs (£), emissions (tpa) and employment figures to establish a working baseline against which the different options could be compared. Figure 18 includes some key figures relating to existing jobs, emissions, exchanges and Net Present Value to support this socio-economic impact assessment.

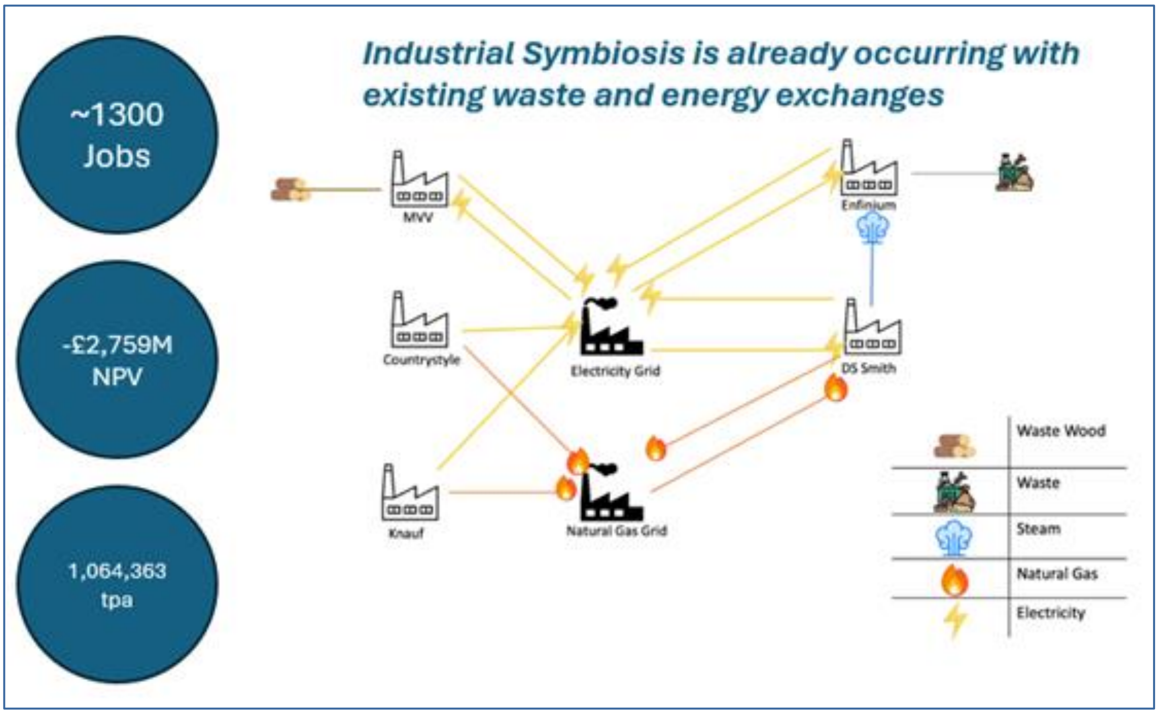

Figure 18 – Baseline figures and energy exchanges (Rich Picture adapted from WP2)

Job Creation & GVA calculations

To assist with the socio-economic assessment of potential decarbonisation technologies, the report also conducts a multi-tier analysis to generate indicative figures for direct, indirect and induced jobs and accompanying Gross Value Added (GVA)[1]. The job values have been calculated using a series of multipliers extracted from a range of literature and research focussed on the low carbon economy (Carbon Capture Coalition, 2020; Hanna et al., 2024; Welsh Government, 2021). Economic Output, measured by Gross Value Added (GVA), has been calculated using data from the ONS Labour Productivity statistics for 2023 (ONS, 2023). These statistics provide values for output per job, broken down by region and industry sector. For direct construction or energy workers the applicable rates have been applied, whilst for indirect and induced workers, the 'General Workers rate' has been used to reflect the range of work involved in the supply chain. Factors for leakage and displacement have then been applied to derive a total estimate for Net local GVA and jobs.

Local Needs Analysis and Policy Review

The work package also includes a Local Needs Analysis (LNA) to determine the economic, social, and environmental needs as well as the demographic trends in Kent and Medway. This analysis is supplemented by a desktop review of local, regional and national strategies and policies, including the Kent & Medway

[1] **Definition:** Direct employment refers to those jobs that that arise directly because of the investment such as in the design, manufacturing, delivery, construction/installation, project management and operation and maintenance of the different components of the technology, or power plant, under consideration. Indirect employment commonly refers to the jobs created within the supply chain supporting a specific project.

Low Emissions Strategy, Economic Framework, Council Strategy and the Medway and Swale Climate Action Plans (Kent County Council, 2024a, 2021; KMEP, n.d.; Medway Council, 2022; Swale Borough Council, n.d.). This analysis supports the MCDA to assess each option's alignment with the local needs and strategic aims, as well as within the context of the evolving national green policy under the new labour government.

6.3 Findings and recommendations

Table 14 ranks the scenarios across the 6 criteria, where 8 is the highest rank and 1 is the lowest. These ranks are then multiplied by the weights as described in section 6.1 to get the Weighted Score. The emissions and energy consumption criteria are based on WP1 calculations, NPV on WP4 calculations, while the rest of the criteria is derived from workshops with the consortium members and the corresponding economic frameworks and policies, as described in the previous section. As Table 6 highlights, at this stage of the project, Scenario 3 – steam supply, electrification, and CC, will derive the most positive combined socio-economic impact, ranking well across Emissions, NPV, Operational Resilience and Job Creation in the MCDA. However, it should be noted that Scenario 3 requires significantly more financial investment than Scenario 1 (second place), emphasizing the requirement to situate this MCDA and socio-economic impact assessment alongside the findings from the other work packages. Steps to mature this analysis are outlined in the 'Recommendations' for this chapter.

Table 14 – MCDA Combined Scores

Options	Criteria						Score	
	Emissions	NPV	Jobs Created	Energy Consumption	Operational Resilience	Economic / Social Policy alignment	Weighted score	Rank
Baseline A - Do Nothing w/o PW	1	1	1	8	1	1	26	8
Baseline B - Do Nothing w/ PW	1	7	2	8	1	2	42	7
Scenario 1 - ST, H(G), CC	3	8	6	6	8	4	72	2
Scenario 2 - ST, H(B), CC	5	5	6	4	8	5	67	4
Scenario 3 - ST, E , CC	8	3	8	3	8	8	76	1
Scenario 4 - H(G), CC	8	6	4	1	8	6	64	5
Scenario 5 - H(B), CC	5	4	4	5	8	4	60	6
Scenario 6 - E, CC	8	2	7	2	8	7	68	3

LNA & Policy review

With a population of ~1.87 million and generating annual gross value added of ~£44 billion, Kent and Medway is a large and complex economy (Kent County Council, 2024a). With its proximity to London, many residents commute to London and other parts of the Southeast, benefitting from high incomes, contributing to higher-than-average house prices and cost of living within the region. Swale, where the cluster is based, performs above the national median for unemployment, gross weekly resident earnings and business survival rate, with 8.8% of the population (2.8% above the average for the Southeast) relying on manufacturing for their livelihood. However, the area performs below the national average for percentage qualified to RQF level 4 and above; percentage qualified to RQF level 2 and above; GVA per head; and percentage of employees in the knowledge economy (Kent County Council, 2024b).

The Kent & Medway Economic Framework published in March 2024, cites the climate emergency and achieving net zero as the "central change factor" driving long-term economic adjustment. Sustainability is featured at the heart of the framework as represented by the extract of the objectives featured in Figure 19. All local authorities in county have set out detailed climate change strategies and both Medway Council and Kent County Council declared a climate emergency in 2019, with KCC committed to reducing greenhouse gas emissions from its own estate and activities to Net Zero by 2034. The cluster's proposed activities across the range of decarbonisation technologies therefore complement all five of the 2030 ambitions withing the economic framework.

Figure 19 –Extract of 3 core objectives from the Kent & Medway Economic Framework (Kent County Council, 2024a)

Jobs & the 'Green Skill's shortage

In addition to preserving the ~1300 jobs across the cluster by decarbonising, the investment in different decarbonisation technologies and the construction works associated with each, will result in the generation of a substantial number of direct, indirect, and induced jobs as highlighted in Figure 20.

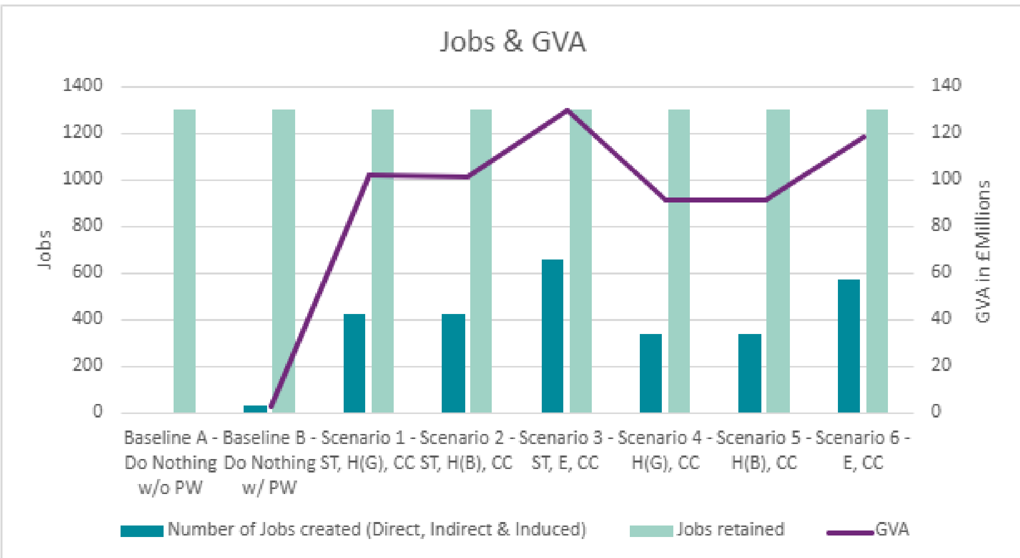

Figure 20 – Forecast Jobs & GVA for each scenario

With the highest investment in infrastructure, **Scenario 3, Electrification is likely to generate the most jobs, totalling 658 against the 424 to be generated under Scenario 1**, the preferred way forward. Of these total jobs generated, approximately 70% will be indirect or induced jobs across the supply chain. Whilst the value chain for each technology option is outside the scope of this study, it is important to acknowledge this potential for wider GVA and job creation when conducting the MCDA. The ratio of 70:30 aligns with other literature and research regarding energy jobs and Figure 21 presents an overview of a potential value chain for Green Hydrogen to illustrate where such indirect or induced jobs may reside (Carbon Capture Coalition, 2020; UKERC, 2014).

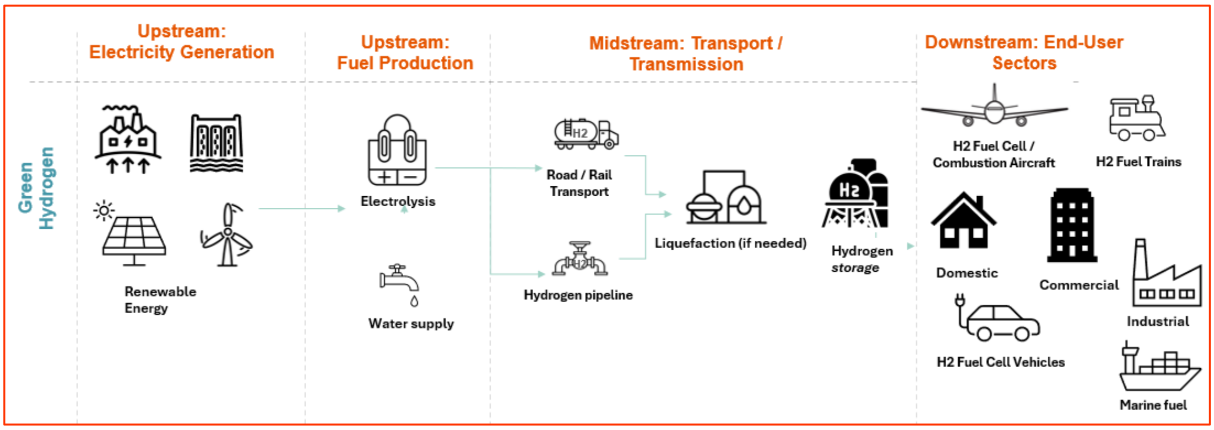

Figure 21 – Indicative Value Chain: Green Hydrogen

Noting the widely acknowledged skills shortage across STEM and 'Green Skills' and the relatively low employment in the 'knowledge economy' within Swale, a primary concern is having sufficiently trained and skilled labour force for the planned decarbonisation technologies (City & Guilds, 2023; IEA, 2023). A challenge further exacerbated by issues with housing and a higher cost of living in the region. Meeting this skills gap will need to be addressed through the provision of upskilling and training for the regional workforce.

This challenge was discussed at the workshop held on 7th November (resulting CLD shown in Figure 22), including representatives from the local councils where it was posed that there was significant potential for the cluster to drive growth in STEM and green skills across the region by providing a clear demand signal and collaborating with local education providers and public funding bodies. A similar approach has been seen within the Humber cluster and the Kalundborg cluster in Denmark (Humber Industrial Cluster, n.d.; Kalundborg Symbiosis, n.d.).

The requirement for enhanced focus and investment in green and digital skills is explicitly outlined within the Kent & Medway Local Skills Improvement Plan (Kent County Council, 2024c) and the region recently received £5.6M of government funding to support the development of Green Engineering, Design and Construction colleges at Ashford, Mid-Kent and Canterbury colleges (EKC Group, 2021).

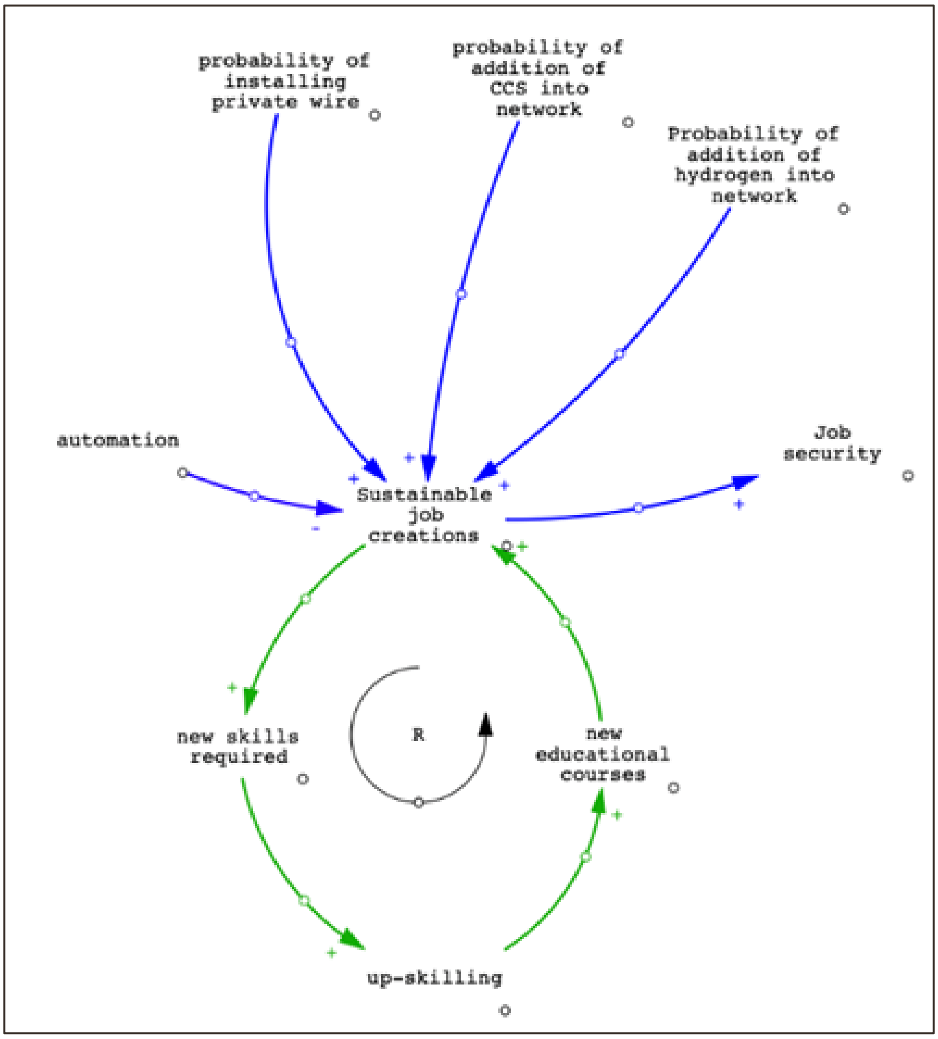

Figure 22 – Sustainable Job Creation Supply & Demand (Causal Loop Diagram extract taken from WP2)

6.4 Key Conclusions & Recommendations

Using the MCDA approach illustrates that at the Strategic Outline Business Case (SOBC) stage, **Scenario 1 - Steam supply, green hydrogen and carbon capture is the preferred route forward**. However, **this is not a clear 'winner'** with a range of significant benefits presented across the other decarbonisation technology options. It is recommended that further analysis is conducted during the Pre-Feed stage to support more granular comparisons. The analysis would be informed by further assessment of the viability of implementing the decarbonisation technologies across the cluster.

This should, as a minimum, include consideration of:

1. Potential options for carbon capture – e.g., re-purposing the old train line or building a pipeline.
2. Opportunities for investing in renewable energy sources to support the increased electricity load required to deliver each technology.
3. An assessment of the planning and regulatory implications of each option, including an analysis of the wider implications of infrastructure projects on the local economy.

Simultaneously, this analysis has demonstrated that whichever option is chosen, there is a skills shortage for achieving delivery. During the pre-feed phase, the cluster should therefore include:

4. Exploring options for building partnerships with local educational institutions, including an assessment of the benefit of establishing an on-site cluster education centre or knowledge hub.
5. A review of potential routes to additional funding investment via the Local Authorities and Local Skills Improvement Plans and Taskforces should be investigated.
6. Accompanying the work on establishing a knowledge or education hub with a local communication campaign to promote awareness of the cluster's activities, ambitions, and plans, with the aim of supporting:
    a. future planning applications and consultations
    b. recruitment of the future workforce
    c. attracting new businesses who may wish to capitalise on green technologies in the local area

7

7

ENGAGEMENT OUTCOMES

7. ENGAGEMENT OUTCOMES

This section provides an overview of the key feedback received from project stakeholders as part of the LIDP activities.

7.1 The importance of Kemsley Industrial Symbiosis as a living lab

One of the insights we have gained from our interaction with external stakeholders is the need to establish Kemsley as a living lab, that is, a space where various stakeholders come together to discuss and solve societal challenges - especially for urban areas (Hossain et al., 2019). The role of living labs in accelerating the paths to decarbonization has been highlighted in the literature (e.g. Devine-Wright, 2022; Fan et al., 2022). Our approach followed and extended the approaches already used in other Clusters, for instance in the North West Industrial Decarbonisation Cluster: tailored communication (for example using Welsh language), engagement and education with the general public, local, regional, and governmental audiences and capturing success stories of regional companies achieving significant carbon reduction have been key (Opergy Group, 2023).

The approach in this project includes creating an awareness of the vital sustainability work that the Kemsley sites undertake as part of the symbiosis. Instead on focusing only on cluster stakeholders early, engaging the public in the planning process was highlighted as crucial for understanding objectives, drivers, and benefits, rather than relegating consultation to the basic introduction of new structures. Kemsley Consortium organisations are already part of the community, organising school visits, local volunteering initiatives and having information centres onsite for visitors. These existing activities can be leveraged to further the messaging of the work done as part of this LIDP and crucial next steps towards planning approvals and decarbonisation, alongside the delivery of a wider Communications and Engagement strategy.

In addition to building relationships with the local community and broader public, stakeholders at the workshop stressed the importance of collaboration between businesses and educational institutions, particularly in the Science, Technology, Engineering and Mathematics (STEM) fields. By engaging local schools and universities, the aim is to ensure that educational outcomes align with the skills required for emerging job opportunities. This proactive approach is essential for addressing any skills gap and preparing students for careers that may not yet exist, thereby fostering a workforce equipped for the demands of new technologies. This is also highlighted in the aforementioned IDRIC report (Hamilton et al., 2023) where decarbonization is viewed as a process that involves ‘re-making’ and deliver benefits to the local community from skills and local jobs to promote pride in place.

The discussion also emphasised the need to showcase the advantages of working in green industries to attract younger generations, illustrating how these sectors can provide fulfilling and meaningful careers. Creating a sustainable environment for businesses not only enhances job opportunities but also contributes to positive community engagement and resilience. Participants noted that an industrial cluster, like Kemsley, can make the region more appealing to new organisations, fostering a sense of collaboration and shared purpose. A report by the Hull and East Yorkshire Local Enterprise Partnership on Humber Industrial Cluster Plan (HICP) highlights that pride in the local area and the rich industrial heritage of the area have contributed to the support of the local stakeholders to the decarbonization plans but should not always be taken for granted (Northall et al., 2023). Our findings support this argument; nevertheless, the relationships between national and local government and industry and local and regional stakeholders need to be improved to ensure transparency and accountability.

7.2 Stakeholder views on planning consent for decarbonisation technologies

A key concern raised at the stakeholder workshop was that presenting the project as one comprehensive planning application might hinder planning consent due to the varied interests of different stakeholder groups. The participants suggested that submitting a Nationally Significant Infrastructure Project (NSIP) application could be advantageous, particularly if there is common infrastructure involved. This approach would allow for supplementary planning permissions to be obtained later, potentially streamlining the consenting process. The idea of creating a cohesive narrative through a programme of works was discussed, as this would enable individual applications to be framed in a way that highlights the overall benefits of the cluster. However, some participants challenged this view and believed an NSIP could multiply the risks of planning permission rejection.

Planning officers from local borough councils suggested that in order to be successful with obtaining planning permissions, the cluster needs to focus on gaining public support for their decarbonisation journey by presenting the potential benefits of these actions for the local population and involving them with the Cluster through initiatives such as tours of their facilities, creating visitor's centres etc – as suggested above. Emerging government policies related to heat network zones and industrial decarbonisation zones were seen as opportunities to consider wider area and programme implications for planning.

Stakeholders also expressed concerns around the uncertainties related to the policy landscape, emphasising the need for certainty on government funding during the implementation phase of the decarbonisation technologies. Stakeholders highlighted that the project's timeline extends beyond the term of the current government, adding to the uncertainty surrounding the policy landscape. A report by Baltac et al. (2023) argues about the importance of having appropriate policy support because of the high capita costs of infrastructure related to the transitioning to low carbon pathways.

Concerns were also raised about the evolving nature of technology throughout the lifespan of the project, suggesting that while an outline planning application could be beneficial, flexibility must be built into the process to accommodate changes and adjustments in technology that may arise. The discussion acknowledged the importance of clearly articulating the benefits and assumptions from the outset, as this is critical for securing external funding and ensuring all stakeholders are aligned.

7.3 The need for future engagement with external stakeholders

A key lesson reiterated on this project was the importance of early engagement with stakeholders that spans throughout the study. Engaging constructively and directly with stakeholders is important to obtain their diverse opinions, understand future challenges and needs, align interests, and establish trust and legitimacy (World Economic Forum, 2023). Similar approaches have been followed e.g. in a recent report by the Environment Agency sponsored by the Department for Energy Security and Net Zero (DESNZ) to review environmental capacity challenges in the Teesside and HyNet industrial clusters, to understand industry plans at the industrial cluster scale alongside a review of the impacts that deployments may have on the environment (Environmental Agency, 2024).

Furthermore, a report produced by the Department for Energy Security and Net Zero and Department for Business, Energy & Industrial Strategy (2021) also found that public engagement is critical for building trust, promoting fairness, and fostering collective responsibility, all of which are essential for the success of decarbonization projects (Fritz et al., 2024). In most cases, stakeholders were keen to understand how they might be involved or impacted in the project. At the start of the project the cluster had no visible common presence in the region, with most stakeholders unaware of the cluster. Discussions with our internal stakeholders indicated that a project website should be developed that would eventually evolve as part of the North Kent LIDP platform.

With early engagement, Councils and stakeholders can employ tools to support project progress, and include projects within Local Plans to help facilitate the planning process or leveraging groups such as the Kent & Medway Economic Partnership (KMEP, n.d.) Medway economic partnership or Thames Estuary Growth Board (Thames Estuary Growth Board, n.d.) who liaise and can advocate with potential funders (such as Innovate UK and DESNZ).

Stakeholders raised skills, employment, and growth as both a key opportunity and hurdle as part of delivering this project. There was encouragement to build partnerships with educational institutions, particularly regarding Science, Technology, Engineering and Mathematics (STEM), and leverage the opportunities that Kent's multiple universities can offer (especially in relation to the University of Kent's involvement on this project).

7.4 Recommendations

Following delivery and reflection of Work Package 5 within the LIDP project, a number of recommendations relating to communications and engagement are proposed for the Kemsley Cluster moving forward. These recommendations are proposed to further progress the objectives outlined in this workstream (build awareness, evidence decarbonization ambitions, inviting further investment) and to facilitate planning approvals and project delivery as next steps of this initiative.

Most importantly, the Cluster will need to establish joint processes, governance and resourcing for external communications and stakeholder engagement. A dedicated resource representing all organisations within the cluster would be the key point of contact between the cluster and external parties, manage any external facing materials (such as website, press releases, collateral etc.) and streamline review and approval processes. As the project focuses on advocacy, planning, consents, and delivery, having a long-term, overarching stakeholder engagement and communications strategy will be imperative to effective communications and engagement throughout project delivery. The stakeholder engagement and communications strategy would include as a minimum:

- A robust stakeholder map that includes government, technical, representative and community groups, stating their level and areas of interest and influence, key contacts and proposed method and frequency of engagement.
- Outline communication materials to be used on the project, how they will be managed, when they will be developed and who the targeted audience will be for each. This would include collateral (such as factsheets, reports, flyers etc), social media and web channels, contact inbox (and potentially phone number), newsletters (online or hard copy), any third-party channels that can facilitate project messaging (for example, Council e-newsletters) etc.
- Content plan for the project website and any future social media channels, setting out what updates should be done to the website and when, as it relates to project progress. This could include a proposed timeline for delivery (environmental studies, consultation, planning approvals, construction etc), photos or stories from community engagement activities, summarized updates on project progress (eg. Environmental surveys in the area, what the consenting process will include, how people can have their say), and uploads of relevant reports, materials etc.
- Community engagement activities to build profile and relationships with the local community. This could include meeting with Parish Councils, building on existing schools outreach

programmes, participating in community events (such as fair days or volunteering with key community organisations) and establishing a channel for the public to be kept up to date with the project (eg. Social media, e-newsletter.)

- Clear roles, responsibilities and approval requirements for the project team for drafting/reviewing/approval materials, outreach to stakeholders, information management etc.

The next recommendation once the project design has been progressed (likely from 2026) is to determine what consenting and approval process will be used (Development Consent Order (DCO) or Town and Country Planning Act (TCPA)) and begin relevant planning-focused early engagement with statutory bodies to begin that process. Key stakeholders recommended to engage with include the Planning Inspectorate (if appropriate), host authorities (Kent County Council, Swale Borough Council, Medway Council - planning officers and local/committee members), environmental bodies (Natural England, Historic England, Environment Agency) and statutory undertakers (any utility companies with assets in the project area). Having early conversations with stakeholders not only allows for relationship building and early project buy-in but can also raise any key issues early in the process to be mitigated. It also allows statutory consultees to understand project timelines and requirements, understand expectations of engagement and agree an engagement programme (for example, monthly one-to-one meetings with local authorities, quarterly meetings with all local authorities) to plan resourcing accordingly (potentially through establishment of a Planning Performance Agreement). This early engagement with statutory bodies would best be supported by environmental and planning specialists as we move into the pre-FEED phase of delivery (as outlined in work package 4).

In addition to more detailed discussions with these technical stakeholders, and in line with recommendations from Work Package 3, there is benefit in raising awareness of the cluster within the local community to proactively build positive sentiment before any formal consultation begins. Wider community engagement will be included in the Stakeholder engagement and communications plan (outlined above), but should also consider working with local education providers and skills networks to identify any skills gaps in the workforce to deliver decarbonization projects, put in place training programs to ensure the workforce can deliver this work (ideally using local workers), and build partnerships with relevant groups who can facilitate employing local people in the development, construction and operation of the decarbonization project.

Finally, it is recommended the cluster continue to foster and maintain relationships with other industrial clusters who are part of the LIDP cohort. This peer group provides an opportunity to share lessons learnt, and also provides a forum to share common challenges and hurdles, and workshop what potential solutions might be introduced to address them (for example, skills and employment partnerships or initiatives, updated government guidance, funding opportunities etc). These challenges and solutions can then be raised with relevant government stakeholders (i.e. Innovate UK, DESNZ) for consideration and advocacy.

CONSOLIDATED FINDINGS, CONLCUSIONS AND NEXT STEPS

8. CONSOLIDATED FINDINGS, CONCLUSIONS AND NEXT STEPS

This chapter is divided into five parts. We firstly consider the Industrial Symbiosis in the cluster. Then, we present the scenario rankings based on findings from various WPs, we next consider the consolidated analysis from all WPs findings, then we consider next steps and finally we drive conclusions.

8.1 Proof of Industrial Symbiosis in the Cluster

This study has deepened our understanding of the symbiotic relationships within this cluster as well as what contributes to making the cluster more sustainable and resilient. We identified the factors that impact the economic, social, and environmental aspects of the cluster’s sustainability as well as its overall resilience. Notably, increased symbiosis among cluster members yields both environmental and economic benefits. For example, future plans to expand steam exchange between the energy generator plants and the paper mill demonstrate how symbiosis can improve energy efficiency. Directly utilising generated steam in manufacturing processes is more efficient than converting it into electricity, as the latter results in energy losses during generation. Additionally, increased exchanges of materials and by-products among organisations reduce the costs associated with raw material procurement and minimise waste sent to landfill contributing to both environmental and economic benefits for the cluster. For example, in this cluster, a paper mill supplies wastepaper to a waste management plant, which processes it into fertiliser, avoiding waste being sent to landfill and producing a valuable product.

Another benefit of the symbiotic exchanges between the members of the cluster is that by sourcing their raw materials from neighbouring companies, they are able to reduce their transport costs and emissions, as well as providing transparency to their customers regarding the provenance of their products. The geographic proximity of the companies in this cluster is one of its most unique aspects and significant advantages compared to other industrial clusters in the country. Geographic proximity is widely recognised as one of the essential elements of industrial symbiosis, as it facilitates the efficient exchange of resources, energy, and by-products between organisations while minimising logistical complexities and transportation costs and emissions (Chertow, 2000). The proximity between the organisations also enables them to communicate and collaborate more effectively, fostering increased information sharing and visibility among members and ultimately strengthening the cluster’s resilience. The Kemsley cluster is a perfect example of Industrial Symbiosis due to its many existing exchanges of energy, materials, and waste (Figure 23), the proximity of the organisations, and the strong collaborative relationships between the members, with potential to further expand these symbiotic exchanges.

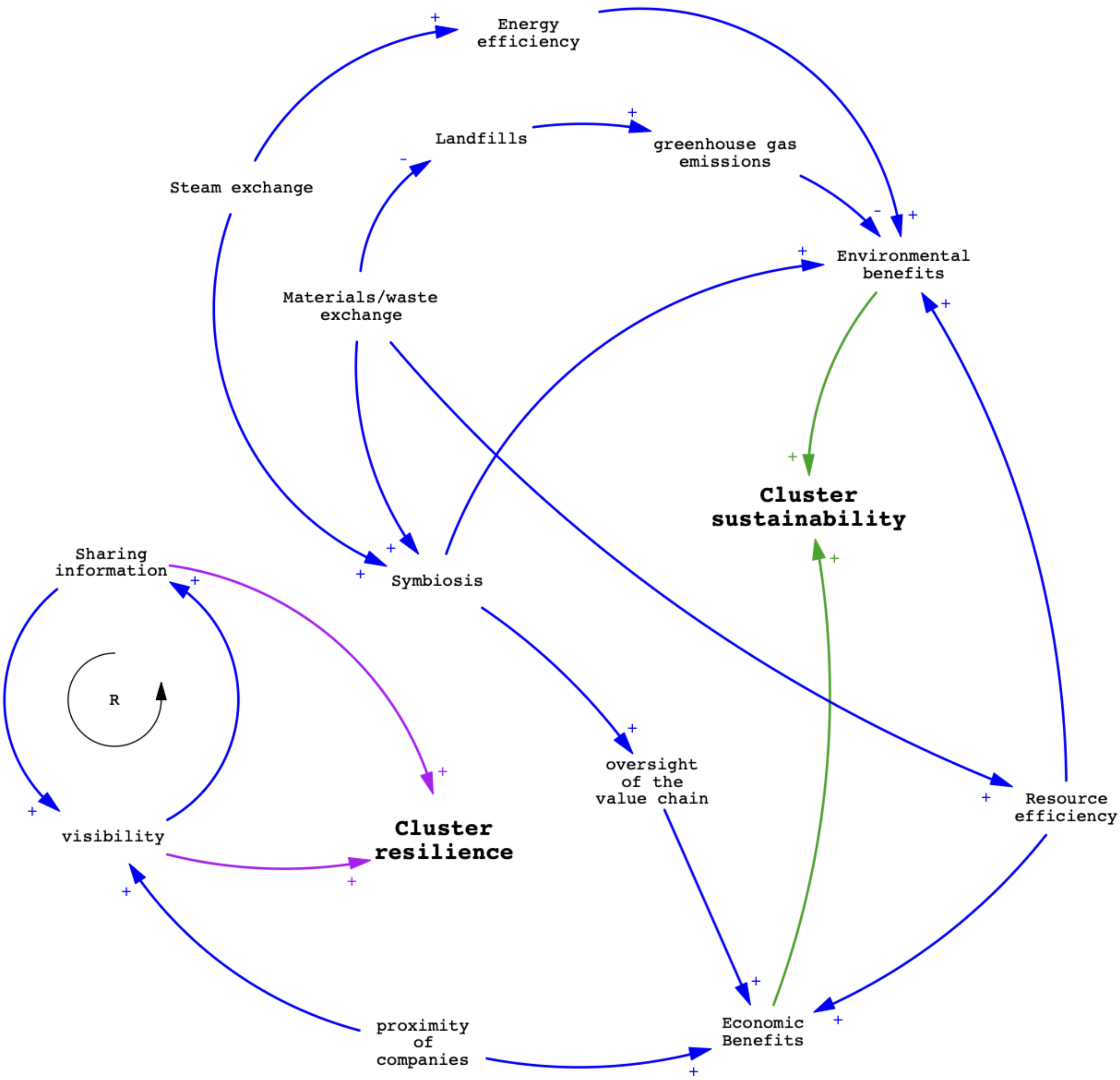

Figure 23 – Causal loop diagram showing variables leading to cluster resilience and sustainability

8.2 Scenario ranking based on findings from WPs

The report so far has considered the analysis from the various analytical approaches in isolation, and we now bring some key performance indicators (KPIs) from each area of analysis in an effort to rank the scenarios from different perspectives. We present the various rankings based on the different KPIs considered throughout the work packages, and refer to them as “Relative Prioritisation based on KPIs” in Table 15:

Technical feasibility and operational implementation: The findings from this indicator are derived from WP1, recommending Scenario 1 as the best option based on factors such as technology readiness levels, practicability in the context of live operations, and initial static model assumptions.

Emissions: this indicator is based on total emissions derived from the Monte Carlo simulations. The simulation model captures the emissions resulting from the consortium’s member-specific process characteristics, such as expected electricity generation and consumption in any hour for the various scenarios. WP2 recommends Scenario 1 as it results in the overall lowest residual emissions including both fossil and biogenic emissions. This is followed by Scenarios 2, 4, 3, and 5, and the scenario with the highest residual emissions after all decarbonisation solutions are implemented is Scenario 6.

Job creation: Based on the analysis from WP3, Scenario 3 is expected to have the highest new jobs created, (exceeding 600 additional jobs). Scenario 6 follows closely behind, while Scenarios 1 and 2 are both expected to add over 400 new jobs. Scenarios 4 and 5 are likely to generate over 300 jobs with Green Hydrogen considered more likely to generate wider economic opportunities within the value chain than a Blue Hydrogen approach.

Net Present Value (NPV): The financial analysis from WP4 included NPV calculations for each scenario, and the calculations were built on WP1 outputs from the Simplified Energy and Mass Balance. Based on NPV values, WP3 recommends Scenarios 1, 4 and 2, followed by scenarios 3, 6, and 5.

Table 15 highlights the main technology selections by the consortium members. It is also colour coded, CC – Carbon Capture in orange, ST – Steam (from MVV) in purple, H(G) – Green Hydrogen in green, H(B) – Blue Hydrogen in blue, and E – Electrification in yellow. The Relative Prioritisation (RP) does not assume that each KPI is equally important. Therefore, we added weights according to the cluster members’ prioritisation, with 1 representing the highest overall priority (technical feasibility) and 4 the lowest (job creation). However, having the lowest priority does not imply a lack of importance. Rather, it means that technology feasibility, financial viability, and carbon reduction must be ensured first. Only once these factors are addressed the job creation potential can be considered.

Table 15 – Scope 1&2 decarbonisation options with blended relative prioritisation

	Technology Selection						Relative Prioritisation (RP) Based on KPIs								Overall Rank (Business Case)	
	MVV	Enfinium	DS Smith		Knauf	Countrystyle	Technical Feasibility (Weight = 1)		Emissions (Weight = 3)		Job creation (Weight = 4)		NPV (Weight = 2)		Weight Score	Rank Order
							RP	Weighted RP	RP	Weighted RP	RP	Weighted RP	RP	Weighted RP		
Scenario 1 - ST, H(G), CC	CC*	CC*	ST*	H(G)*	H(G)*	H(G)*	1	1	1	3	3	12	1	2	18	1
Scenario 2 - ST, H(B), CC	CC*	CC*	ST*	H(B)*	H(B)*	H(B)*	3	3	2	6	4	16	3	6	31	3
Scenario 3 - ST, E, CC	CC*	CC*	ST*	E*	E*	E*	2	2	4	12	1	4	4	8	26	2
Scenario 4 - H(G), CC	CC*	CC*	H(G)*		H(G)*	H(G)*	4	4	3	9	5	20	2	4	37	4
Scenario 5 - H(B), CC	CC*	CC*	H(B)*		H(B)*	H(B)*	6	6	5	15	6	24	6	12	57	6
Scenario 6 - E, CC	CC*	CC*	E*		E*	E*	5	5	6	18	2	8	5	10	41	5

Based on this combined ranking of a collection of indicators shown in Table 15, Scenario 1 is the preferred option for decarbonisation at the Kemsley cluster, followed by Scenarios 3 and 2. There is little variation between Scenarios 4 and 6, and Scenario 5 is the lowest performing across the various KPIs.

Although the overall recommendations suggest Scenario 1 as the preferred way forward, this is not a clear 'winner' with a range of significant benefits presented across the other decarbonisation technology options. It is recommended that further in-depth analysis is conducted during the Pre-Feed stage to support a more granular comparison.

8.3 Consolidated Analysis of findings from all WPs

This section considers other findings derived from the various areas of analyses detailed in previous chapters. The findings have been grouped and categorised as Strengths, Weaknesses, Opportunities or Threats (SWOT) and are shown in Figure 24. The SWOT analysis highlights the strengths, weaknesses, opportunities, and threats faced by the North Kent cluster as it transitions towards decarbonisation.

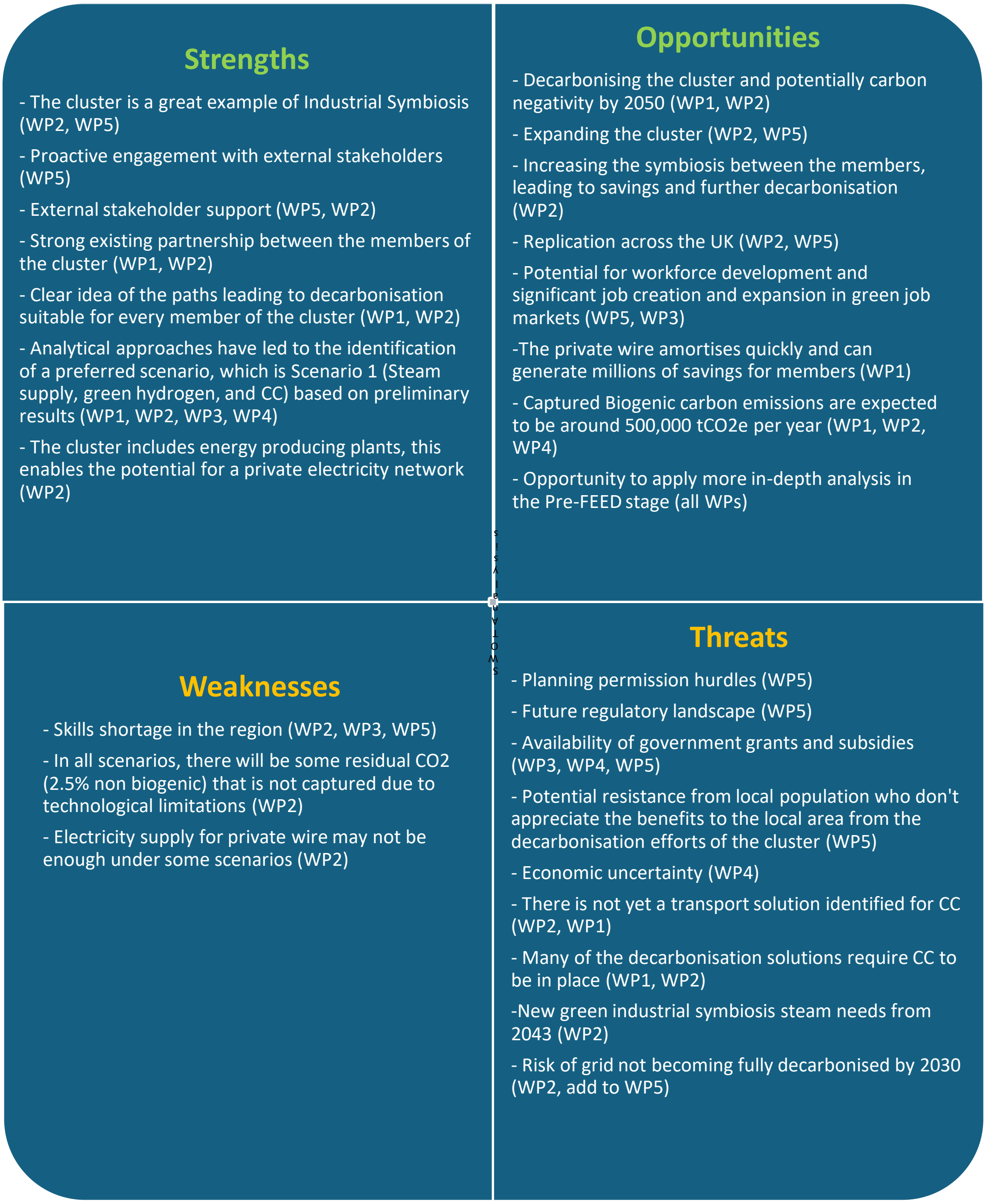

Figure 24 – SWOT analysis of findings from all WPs

The activities and collaborative efforts within the cluster have enabled it to benefit from several key strengths. Due to the existing energy, materials, and waste exchanges between these diverse yet geographically close organisations, **the Kemsley cluster can be considered as a potential leader in industrial symbiosis and a model for replication across the UK**. The cluster also benefits from strong partnerships among its members and proactive stakeholder engagement, as well as a clear roadmap for emissions reduction and decarbonisation. Additionally, the cluster has a clear understanding of its baseline emissions, and the pathways needed for each member to achieve decarbonisation, as well as a currently preferred scenario according to the preliminary results (Scenario 1: Steam Supply, Green Hydrogen, and Carbon Capture) that demonstrates high economic and environmental benefits. Furthermore, the existence of energy generating plants in the cluster enables the potential for a private electricity network, saving costs for the cluster members.

Several opportunities exist to enhance the cluster's sustainability and economic viability. A major opportunity lies in achieving full decarbonisation, with the potential to reach carbon negativity by 2050 through renewable energy integration and carbon capture technologies. The cluster's carbon capture potential—estimated at 500,000 tonnes of CO_2 equivalent per year—further contributes to net-zero goals and creates opportunities in carbon credit markets. The cluster also stands to benefit from further savings and sustainable outcomes by expanding its symbiotic exchanges. This Industrial Symbiosis model could be expanded and replicated across the UK. Growth in the cluster aligns with increasing demand for skilled workers, supporting workforce development and green job creation. Additionally, the deployment of a private wire network offers significant financial savings and energy security for members. Finally, there is the opportunity to apply more in-depth analysis in the Pre-FEED stage.

Despite its strengths, the cluster faces some challenges. We have identified skills shortages in the region, especially green skills necessary for the jobs required in the decarbonisation journey of the cluster, that need to be addressed by collaborating with local educational institutions and schools. Furthermore, due to technological limitations, 2.5% non-biogenic emissions will remain after decarbonisation. Another potential weakness is that there may not be enough electricity supply for the private wire under certain scenarios and the electrification scenarios are economically low-performing compared to the other scenarios.

Additionally, the cluster also faces some risks regarding its planned activities. This includes planning permission hurdles, regulatory uncertainties, and dependence on government grants and subsidies. Economic instability may impact investment and implementation, while potential resistance from local communities could create additional challenges. The absence of a defined transport solution for carbon capture could pose logistical issues and could threaten the decarbonisation strategy of the cluster as many of the solutions depend on CC, making its successful deployment critical to the overall strategy. Additionally, long-term green steam demand beyond 2043 remains uncertain. Moreover, the risk of the national electricity grid not achieving full decarbonisation by 2030 could affect the decarbonisation strategy.

This SWOT analysis underscores the need for careful planning, collaboration, and investment to overcome obstacles and capitalise on the opportunities for sustainable growth and decarbonisation. Targeted actions such as securing funding for further research, enhancing regional green skills through partnerships with local educational institutions, and fostering further industrial symbiosis can help address some of the identified threats and weaknesses.

8.4 Conclusion

This project has made significant strides by bringing together academics, consultants, and companies to tackle a complex challenge of national significance. The analysis highlights the decarbonisation potential of the Kemsley Industrial Cluster through various methods, considering different combinations of the decarbonisation technologies deemed to be suitable for the members of this cluster. This analysis included a preliminary technical feasibility to establish the baseline, followed by a more detailed analysis of the energy balances through a Monte Carlo simulation model. The modelling also included a qualitative aspect in the form of multiple Causal Loop Diagrams that represent the dynamic behavioural relationships around sustainability and resilience. The scenarios were also assessed from both financial and socio-economic impact perspectives, ensuring a holistic approach to evaluating decarbonisation strategies. The socio-economic impact assessment was conducted using the MCDA approach, across a range of criteria including the number of jobs created in each scenario, the NPV, energy consumption, and emissions associated with each scenario derived from other WPs, and the operational resilience of the cluster. The financial analysis was conducted to analyse the financial feasibility and the NPV values associated with all scenarios. All work packages concluded that Scenario 1 (steam supply, green hydrogen, and carbon capture) performs well across a number of KPIs.

The regulatory and public funding landscape needs to provide consistent and long-term support to decarbonisation clusters. Clear and sustained government backing for decarbonisation solutions, such as green hydrogen, will be critical to their success. Decarbonisation of the Kemsley Cluster aligns with the UK government's net zero targets as outlined by the Department for Energy Security and Net Zero (DESNZ) and Innovate UK. If supported, the Kemsley Industrial Cluster's initiative will support these goals by addressing critical areas such as carbon capture and transport, hydrogen production, which are essential for reducing the overall carbon footprint of industrial clusters. Government support is crucial to catalyse private sector investment, drive innovation, and ensure the UK remains a leader in the global green economy. Without such initiatives, the cluster risks falling behind in its climate commitments, missing out on economic opportunities, and failing to achieve its legally binding net zero targets.

Further funding could help transition the cluster from pre-feasibility to the final investment decision stage for decarbonisation. Achieving this requires a coordinated and comprehensive approach, involving a range of professional services and studies, each critical to ensuring the project's success and long-term viability. These services include rigorous modelling and analysis to provide robust data-driven insights, project management to maintain alignment with timelines and budgets, engineering and design to assess the feasibility of the chosen decarbonisation technologies, and environmental consulting to ensure compliance and secure necessary permits. The Kemsley Industrial Cluster is a perfect example of Industrial Symbiosis and benefits from strong relationships and well-established exchanges of energy and materials among its members, creating a solid foundation for further collaboration.

8.5 Next steps and future services needed

The cluster are keen to continue together on this sustainability and decarbonisation journey and plan to apply for follow on funding to enable pre-FEED and FEED stages to be undertaken, ideally with funding that supports these stages to be taken in succession to ensure that momentum is not lost. The following services are recommended to support a robust journey to final investment decisions:

Technology Assessment and Selection including evaluating and pilot testing chosen technologies to ensure they are suitable and scalable. Without thorough technology assessment, the programme risks adopting suboptimal technologies.

Engineering and Design services are needed to create detailed designs and optimise processes for the different decarbonisation technologies under consideration including carbon capture, hydrogen, electrification and the associated infrastructure, such as carbon transport and storage. This includes process, structural, civil, electrical, and mechanical engineering. Without these detailed designs, cost comparison between the options will be less robust and the programme risks technical failures and inefficiencies.

Regulatory and Planning including Environmental Impact Assessments (EIA), biodiversity net gain, obtaining necessary permits, and developing mitigation plans. These steps will ensure compliance with relevant regulations and help mitigate adverse impacts. Failure to address environmental and regulatory concerns could lead to hurdles such as community opposition.

Business Case development, including financial modelling, cost-benefit analysis, and securing funding, are essential to demonstrate the project's economic viability and attract investment. Without robust financial planning, the project may face funding shortfalls and financial instability.

Data Modelling Support and Rigour from the University of Kent is recommended as an additional layer of analytical depth and credibility. The university provides advanced data modelling techniques, rigorous analysis, and access to cutting-edge research. This continued partnership will ensure that the programme's data-driven decisions continue to be robust and scientifically validated. Such an approach gives added assurance that investments are being made with the utmost rigour and confidence.

Stakeholder Engagement and Communication will be vital for gaining support from local communities, government bodies, statutory bodies, local authorities and other stakeholders. A well-developed communication strategy will help manage public relations and maintain a positive programme image. Poor stakeholder engagement could lead to opposition and delays.

Project Management and Delivery Partner to ensure all activities are aligned with timelines, budgets, and regulatory requirements. Effective planning, scheduling, coordination, monitoring, and quality assurance are crucial to maintain momentum and avoid costly delays.

Supply Chain and Logistics planning to ensure the efficient procurement and transportation of materials and equipment. Effective vendor management is also critical. Disruptions in the supply chain could cause significant programme delays and cost overruns.

Legal Services to ensure that all contracts are properly negotiated and that the programme complies with all relevant laws and regulations. Effective risk management is also crucial to mitigate legal risks. Neglecting legal aspects could result in disputes and regulatory penalties.

Health and Safety Consulting to include risk assessments, safety planning, and training to ensure a safe working environment.

Exploring Advanced Tools. Consider digital twinning and private 5G networks for real-time monitoring, predictive maintenance, and data-driven decision-making. This will enhance the cluster's ability to meet decarbonisation goals and maintain a competitive edge in the global market.

Exploring the applicability of these technologies could enhance the Kemsley Cluster's ability to meet decarbonisation goals and remaining at the forefront of sustainable industrial practices, contributing to the UK's net zero targets.

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