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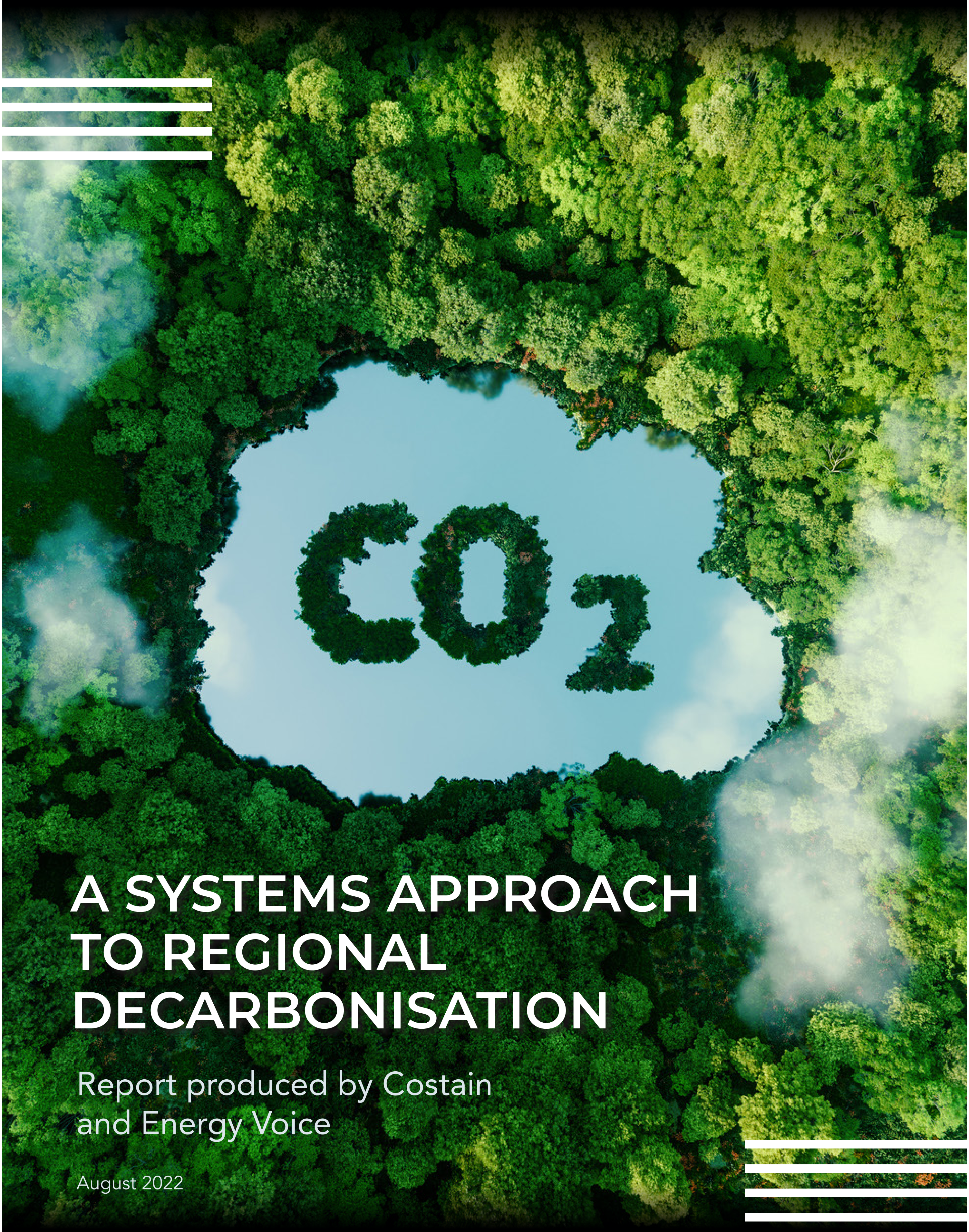

A SYSTEMS APPROACH TO REGIONAL DECARBONISATION

Report produced by Costain and Energy Voice

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CONTENTS

Foreword by Sam White, managing director of the natural resources division at Costain

As challenges go, the race to net zero is a major one. The UK has set the goal of achieving this by 2050, with a major push into renewable energy, hydrogen and carbon capture to deliver this ambitious target. The UK showcased its plans in Glasgow when it hosted COP26 in November 2021. The event saw 197 states involved in discussions on committing to net zero. The International Energy Agency (IEA) predicted that if the pledges can be delivered, the world would be on track for a 1.8 degree Celsius increase.

Sam White, Managing Director - Natural Resources Division

At the heart of the UK's plan for a green industrial revolution is the intent to build on the UK's historic strengths, and adapting industry to embrace the energy transition, paving the way for the UK to meet its carbon commitments – while also creating new opportunities to export expertise.

Shifting from a hydrocarbon-based society to a decarbonised one will not be straightforward. The importance of security of supply was demonstrated in September 2021 when low wind forced coal power plants to be switched on and more recently by the Russian invasion of Ukraine.

> "As well as contributing towards the UK's net zero target, the decarbonisation of major emitters within industrial clusters will act as a catalyst to further decarbonisation throughout the regions in which the clusters are based."

Although good progress has been made in reducing emissions (in 2018, UK carbon emissions stood at 57% of their 1990 levels) this has largely been achieved by offshoring of manufacturing and moving away from coal. There is still much more to be done, particularly for the harder to decarbonise sectors of heating, transport and industry. The next steps will be more challenging.

Regional industrial decarbonisation

The next major change will come through the decarbonisation of six industrial clusters, based in areas of the UK that contribute the most industrial emissions. Industry accounts for around a quarter of all UK greenhouse gas emissions with more than two thirds coming from a small number of energy intensive industries[1]. Tackling industries such as steel and cement production, power generation and oil refining will offer the UK its next big step towards its target; to establish the world's first net zero carbon industrial cluster by 2040 or at least one low carbon cluster by 2030.

The six clusters are initially focused on big industrial players, but as low carbon systems are developed, their scope will broaden beyond their original limits. Once a hydrogen supply is established to power a steel plant, for example, production could be increased to provide zero carbon electricity for supermarkets, houses, hospitals and offices in the surrounding areas.

The South Wales Industrial Cluster (SWIC), along with the other five clusters, will provide an important steppingstone and testing ground for the UK to tackle its wider emissions problem. Costain is a lead partner for the SWIC deployment project, and the focus is on technology agnosticism and bringing together the various strands of technology, energy systems, companies and interests to find a common way forward. This collaborative, cluster approach supports the ultimate ambition of the SWIC project which goes beyond simply identifying how the largest emitters in the region could decarbonise their operations at lowest cost and progress technically feasible projects.

This report looks at the contribution engineers can make to the transition to clean fuels, by using the capital value process – pioneered in the oil and gas industry – to take a structured approach to decision making. It also uses the South Wales Industrial Cluster project to illustrate an integrated, whole systems approach to cluster decarbonisation and how this could be applied at a national level/scale.

[1] *BEIS Industrial Strategy 2019*

CHAPTER 1 - THE ROLE OF ENGINEERING

1

Engineering as we know it had its origins in the Age of Enlightenment that dominated the world of ideas in Europe in the 17th and 18th centuries when science played an important role as pragmatism, logic and rational thinking replaced the authority of tradition and religion.

Combined with enlightenment ideals of advancement and progress, this directly led to the industrial revolution, modernism, and development of the engineering (and underlying scientific) principles which remain foundational to engineering design even to this day.

As we stand on the dawn of a new revolution – the green industrial revolution – once again we need to apply engineering principles and approaches to enable us to make this mammoth shift in the way our society works, plays and progresses.

Politicians, and society at large, tend to present net zero delivery in terms of making strategic choices between rival technologies – whether battery vs hydrogen fuel cell electric vehicles or hydrogen boilers vs heat pumps.

Individual engineers often do this too, but successfully engineering net zero will require looking holistically at all energy systems using measured Systems Thinking, Systems Engineering and a Whole Systems approach. This will involve identifying and managing risks, uncertainties and opportunities to make appropriate, evidence-based decisions as the suite of available solutions is refined and matured to meet the targets and objectives.

The application of engineering to achieve a net zero energy system

Engineering activity is usually applied to the delivery of specific outcomes or products in accordance with a business case or specification. Achieving the goal of a net zero energy system by 2050 is complex and clearly cannot be considered as a single project. The specification here is to achieve net zero emissions, but the way that is achieved will be through a variety of smaller, discrete projects, combining to achieve the end goal.

The application of engineering is the normal means by which society ensures it achieves desired outcomes. When the challenges we face are as complex and novel as net zero, we need the support and leadership of engineers to take a holistic view of the challenge in a co-ordinated effort of all sections of industry and society.

In engineering terms, all projects follow a life cycle that involve aspects such as concept screening, feasibility, front end engineering design (FEED), detailed design, construction, commissioning, operations & maintenance and finally decommissioning.

While it can be possible to omit some of the interim steps once technology applications have become well established and understood, greater rigour is required for novel and/or bespoke project concepts.

Development of a net zero energy system on the scale required by the UK has never been done before anywhere in the world; while some elements might increasingly be more understood, no-one to date has effectively combined them all together.

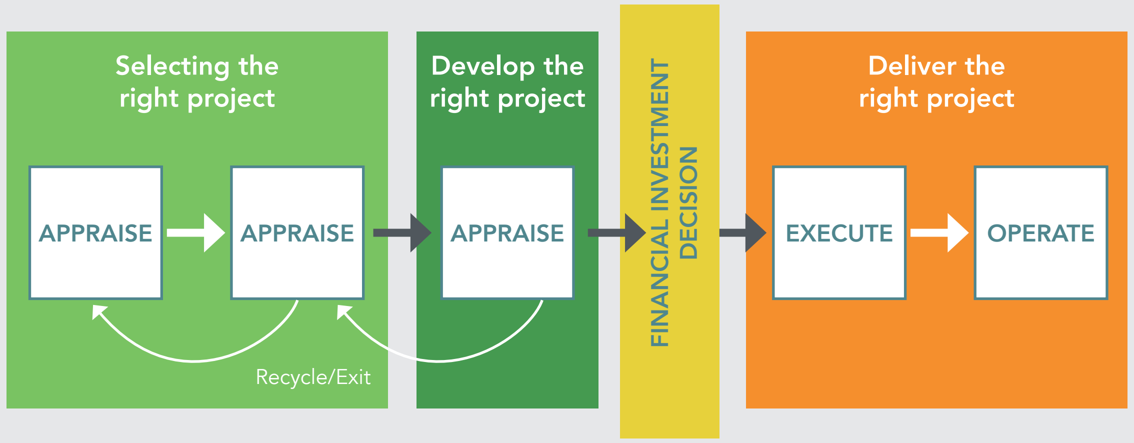
The development of bespoke, novel and safety critical projects and programmes has historically been prevalent in the process, petrochemical and oil and gas sectors. They therefore provide the most appropriate engineering development framework(s) to provide rigour and structure to engineering the delivery of a net zero energy system.

A key example is the capital value process (CVP) which is particularly used in the oil and gas sector to provide a basis for decision making and governance (rather than project management) when developing major capital projects. CVP was developed within bp, with variations on the concept having since been adopted throughout these industries.

A core element of CVP is definition of the proposed project lifecycle development stages: defined by bp as Appraise, Select, Define, Execute and Operate. CVP also defines the main activities and intended outcomes to be achieved to progress through the gateway at the end of each stage onto the next project phase.

While the oil and gas majors have developed their own in-house engineering standards to support CVP delivery, other bodies such as The Association for the Advancement of Cost Engineering provide guidelines for cost estimation and Estimate Class definitions with associated end use, methodology and expected accuracy ranges which are generally used to support project definition and development throughout the industry.

Capital value process (CVP)



Source: bp

Joining the dots across the energy landscape

Despite society's tendency to focus on individual technologies, engineers can take the big picture view required to solve the net zero crisis. They are the very people who understand the current energy systems, the vision of what a viable future energy system would look like, and the technical skills and processes to get us there.

The systems thinking approach will be essential in order to have this macro system view. It will also dictate the expertise needed in the shape of a systems integrator responsible for bringing together the supply chain partners and key stakeholders at the various stages of design, development and deployment.

CHAPTER 2 - WHAT IS SYSTEMS THINKING AND WHY IS IT IMPORTANT?

2

Rather than seeking to simplify complex issues and problems by breaking them down into their component parts, systems thinking focuses more on the development of a holistic understanding as well as the relationships and interactions between elements within a system.

Our specification for the complex, first of a kind (FOAK) future net zero energy system is that it must be operable and reliable from the outset, as well as being implemented at lowest cost. Success of the individual elements alone will not necessarily lead to a successful system; success is only achieved if the individual elements when acting in combination deliver the desired outcome. Therefore, the performance metrics used to evaluate the staged process of engineering an outcome from an initial concept through to implementation (whether using CVP or another a similar method) must focus on the way the various elements being proposed are anticipated to behave when combined as a system.

In practice, the process of delivering a net zero energy system will be even more challenging. In addition to engineering a FOAK net zero energy system, our energy systems are Critical National Infrastructure, so we need to ensure that the operability and reliability of the legacy energy systems being converted to low carbon operations will be maintained throughout the transition process. Successful delivery is complicated even further because over the same time period, the maturation and implementation of individual solutions and projects will be taking place over different timescales and at different rates.

The necessity of an engineering plan

Increased complexity adds difficulty – resulting in increased risk, frequency of cost and/or schedule overruns and/or benefit shortfalls. As does introduction of bespoke, novel and/or FOAK requirements.

The Government's Ten Point Plan for a Green Industrial Revolution, published in November 2020, identifies the anticipated key components of the UK's future net zero energy system. The plan includes targets such as producing 40GW of offshore wind by 2030, but does not provide a blueprint which describes how such a future energy system might be realised. It is no use implementing the Ten Point Plan to the letter if we get to 2050 and find that we haven't achieved our primary objective - which is net zero.

It is perhaps more useful to consider the Ten Point Plan as being closer to a shopping list of ingredients. To turn that list of ingredients into a desired outcome, we need to understand how to select the correct quantities of ingredients as well as the process to be used in combining them. Of course, the analogy can only stretch so far: in practice we not only need to deliver an operable, reliable, lowest cost energy system which is also net zero by 2050, as has already been highlighted we must also maintain existing energy systems which are operable, reliable, and ideally lowest cost throughout the transition period to 2050 as well!

Applying the systems approach to the UK's energy systems

If we are to be successful, systems thinking must play an essential part in the energy transition and decarbonisation process which the UK faces. This requires taking a designers' perspective – prioritising the long term view to evaluate the process of solution development within the context of our ability to deliver against our stated objectives.

Debate across the industry is becoming increasingly polarised as the urgent need to take action to address climate change becomes ever clearer. We must employ an engineering framework which provides a means of evaluating the relative merits of technology solutions and end use applications both individually and collectively. A combination of CVP and systems thinking will provide this; without it we lack a proven method which can be resolve the debate.

It is important to remember that all energy systems operate is different ways. Identifying the most efficacious way to meet the various types and characteristics of energy demand, within the context of achieving emissions reduction, will need a system designer to perform analysis of the types and characteristics of energy production solutions. This energy system designer will also need to consider the energy system infrastructure which will act as the conduit to connect these two aspects and make the system function as a whole.

If we don't have sufficient understanding of how a net zero energy system might be achieved in terms of activities within an engineering plan, and in sufficient detail, then the risk of failing to achieve net zero by 2050 at lowest cost is high (if not almost certain). Much simpler projects can, and often do, go wrong. Even if they are relatively well defined and have a clearly understood critical path. However, when considering the pathways we might need to employ to deliver a net zero energy system in the UK, we do not presently have anything approaching an understanding of what our critical path activities might look like.

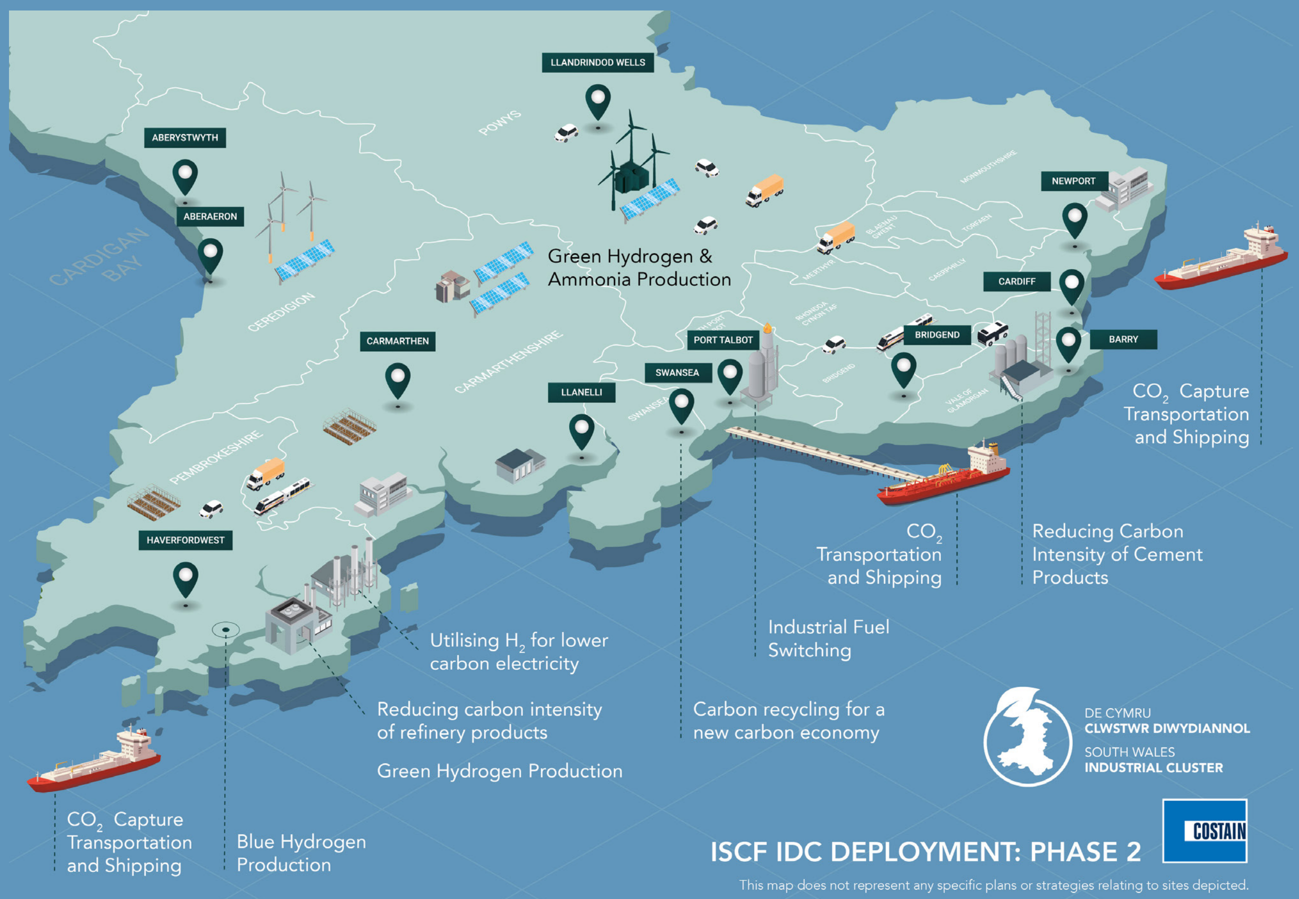
An energy system integrator will be critical, in linking together the disparate parts of the puzzle and presenting an overall, UK-wide schematic. Costain has taken on the de facto role of energy system designer in south Wales, but this is only a part of the broader picture. A national systems integrator must take a view on the broader macro picture; assimilating the clusters, the sources of new energy and everything in between.

CHAPTER 3 - ENGINEERING NET ZERO IN THE SOUTH WALES INDUSTRIAL CLUSTER (SWIC)

3

The Deployment Project being implemented in South Wales is unlike those being proposed by the other UK industrial clusters. The Merseyside, Grangemouth, Teesside and Humberside industrial clusters have all provided much clearer definition on the specific technology solution they intend to implement from the outset and have already progressed further along the project development process. SWIC focuses on technology agnosticism with Costain acting as the integrator, bringing together the various strands of technology, companies and interests to find a common way forward.

The ultimate ambition of the SWIC Deployment Project goes beyond simply identifying how the largest emitters in the region could decarbonise their operations at lowest cost and progress technically feasible projects. It is also to consider how the system works as a whole: how new hydrogen and CO_2 energy system infrastructure, as well as use of existing electricity and gas network infrastructure, could facilitate emissions reduction across the whole region.



The first phase of SWIC Deployment focused on the major emitters in the region working to identify potential energy transition and decarbonisation solutions for their processes and operations. In the second phase of the works, which began in March 2021, the objective is to further investigate project opportunities which would deliver emissions reduction through delivery of feasibility, pre-FEED and FEED study scopes of work.

The number of SWIC Deployment partners involved in these second phase works has been significantly increased. This is to facilitate the development of full chain projects through the involvement of companies interested in developing low carbon hydrogen production facilities, CO_2 terminal hubs and export facilities via shipping and also CO_2 usage – for example with gas fermentation to make low carbon jet fuel.

Hydrogen to support production processes that cannot be electrified

One of the main focuses of the SWIC Deployment Project is the use of hydrogen, which could be produced locally, from gas imports or from local renewable generation.

Solar developer Lightsource bp is participating in SWIC. The company has said it can bring experience to bear from other projects in Australia and Europe. While focused on solar energy, Lightsource bp also has insights into the green hydrogen process, describing this as "one of the fuels of the future"

As an interim step, until green hydrogen can be produced on a scale required to match demand, blue hydrogen could be produced in the cluster, or it could be imported via local terminals South Hook LNG and Dragon LNG. SWIC could be producing hydrogen at scale by 2025, as part of its ambition to decarbonise by 2040.

This plan could make significant inroads into emissions in the next 13 years. Initial volumes of hydrogen would be blended into the National Grid's pipeline network within five years.

The SWIC Deployment Project considers how the system works as a whole: how new hydrogen and CO_2 energy system infrastructure, as well as use of existing electricity and gas network infrastructure, could facilitate emissions reduction across the whole region.

Decarbonising power giving choice to industrial users and consumers

Hydrogen could be used to decarbonise local energy through consumption in RWE's 2.2 GW Pembroke power plant. The power company also has additional clean energy plans, including floating offshore wind in the Celtic Sea and the development of its own electrolyser at the Pembroke site. RWE has investments in both on and offshore wind in Wales including the 576-megawatt (MW) offshore wind farm Gwynt y Môr.

Consumers buying power from a hydrogen-fuelled power plant would cut emissions just as surely as if they are consuming the hydrogen direct. The involvement of decarbonised power as an option broadens the scope of the SWIC plan, allowing offtakers to pick the method that is best suited to their needs.

Whether it makes more sense to generate hydrogen locally or import via ships from regions further afield with lower costs is not yet clear. SWIC can play the role of intermediary, gathering demand to a commercial scale and setting the scene for the most cost effective solution.

Decarbonised fuel supply options do not end with hydrogen. LanzaTech signed up to join SWIC in June 2021. The company is working on the world's first commercial-scale ethanol-based jet fuel facility, which could be installed by 2025 in Port Talbot. The plant will produce 100 million litres per year of synthetic jet fuel, which could be blended with conventional jet to produce Sustainable Aviation Fuel, to drive decarbonisation of the UK's aviation industry. The ethanol feedstock for the Alcohol-to-Jet plant could come from existing waste-based ethanol sources or be produced locally from industrial waste gases using LanzaTech's gas fermentation technology. This approach will offer a further decarbonisation option to SWIC emitters alongside traditional capture and storage solutions.

Could CCUS help to decarbonise and drive economic growth?

Given the scale of the net zero challenge, it is unlikely that all sectors will manage to eliminate emissions in the required timeframe. SWIC includes cement and steel plants, both of which are hard to decarbonise industries.

The UK has a world class carbon storage capacity, with some estimates putting the country's capacity at more than 40% of Europe's total or 78 billion tonnes of CO_2. This capacity is largely located in the North Sea through depleted oil fields and saline aquifers.

Unlike some of the industrial clusters, South Wales has a lack of local storage sites for CO_2 so instead, SWIC has opted to pursue a strategy of CO_2 exports, which would be a first for the UK and marks the creation of a new industry for the region. Welsh industry could benefit from a network of pipelines connecting facilities to port infrastructure, such as at the LNG terminals.

As CCUS develops as an industry, merchant facilities will become more common. For instance, Norway's Northern Lights project covers the construction of infrastructure to receive CO_2 from ships. Emissions will then be piped into a reservoir 2,600 metres under the seabed. The first phase should be ready in 2024, with capacity of up to 1.5mn tonnes per year of CO_2.

Initially, it will be larger companies that dominate CCUS export plans in the South Wales area. These tend to have greater commitments in tackling climate change and net zero plans. Having the largest industrial emitters working through the project development Capital Value Process at the same time allows the regional decarbonisation solution to evolve in a way that enables synergies to be identified and a more optimal solution to be developed collaboratively.

Extending regional reach

If demand for CCUS grows, the networks and infrastructure system can then expand. Initial coverage can extend across the two South Wales regions. Cardiff Capital Region is effectively a gateway to the Midlands, Somerset and Gloucester - and as far west as Reading. The South West Wales region, including the Milford Haven, is currently responsible for over 20% of the UK's energy.

Furthermore, the presence of CO_2 pipelines and facilities will attract new investment to the region. Companies taking long-term decisions on constructing facilities will see the benefit of being able to access existing decarbonisation options and move to the region.

CHAPTER 4 - WORKING TOGETHER TO DEVELOP A REGIONAL DECARBONISATION PLAN

4

Implementing the engineering Capital Value Process (CVP) in South Wales means that while the feasibility study work is in progress, it is not possible to present a holistic picture of what the most likely portfolio of SWIC Deployment solutions might look like. However, as project lead, Costain is working to facilitate communication between the partners and enable synergies to be identified.

As the programme progresses, completion of the individual feasibility studies will provide the building blocks needed to develop the overall picture and plan. By taking this approach, SWIC will have greater opportunity to identify and implement the portfolio of solutions which could be combined to reduce the emissions within the entire industrial cluster and beyond.

A key element of the Government's net zero ambition is the creation of economic benefit and the aim of securing 250,000 green jobs. Such a move is critical in ensuring political and public support for net zero.

The disruption of energy markets in late 2021 and into 2022 has shown the complexity of the challenge and the unpredictability of the energy landscape. To tackle this there is a clear incentive to be had in driving positive outcomes from the net zero race. The UK's leading role in practical steps, such as the Ten Point Plan and the subsequent strategies, have made the case that the country could significantly benefit.

The energy transition will rewrite the geopolitics of hydrocarbons. Those countries that can get in early and establish themselves, both in terms of acquiring skills and in the movement of resources, will stand to gain more than latecomers.

Industrial clusters are at the heart of this new drive. They will require new ways of thinking, setting new tests of collaboration between companies and political bodies.

Protecting the future generations

SWIC focuses on building a relationship between industry and two regional city deals. South East Wales includes 10 local authorities, with another four in South West Wales.

SWIC also has links to the devolved government in Cardiff, providing a means of liaising with industry and new partners. Keeping all sides connected and up to date with plans and progress is a critical means of ensuring agreement and collaboration.

The drive for decarbonisation must be balanced with the need for energy security. This applies to both availability and prices. Success would see South Wales taking a lead role in the drive to net zero, with synergies bringing in new companies. Major industries are in a race to decarbonise. Regions that can offer these opportunities are better placed to win new investments over regions that cannot. Wales has taken an important step in this direction through its declaration of a climate emergency which demonstrated early political will and belief in the need to transition.

The country passed the Well-being of Future Generations (Wales) Act 2015, which requires public bodies to consider the long-term impact of decisions. This focuses on various and interlinked issues including poverty and health, in addition to climate change.

> "In this Act, any reference to a public body doing something "in accordance with the sustainable development principle" means that the body must act in a manner which seeks to ensure that the needs of the present are met without compromising the ability of future generations to meet their own needs. - *Quote from the Act*"

Wales also appointed a Future Generations Commissioner in 2016, with Sophie Howe taking the world's first official role working across sectors to deliver change. SWIC and Costain are working closely with Howe on the challenge of synergistic change.

One example of how Wales is working to identify and support future leaders is in the creation of the Future Generations Leadership Academy. The scheme supports young people with opportunities to learn and enhance their leadership skills. Costain decarbonisation consultant Manuel Cortés Moreno is a participant in the 2021-22 cohort.

> "The future of the energy industry is bright yet challenging. Those within the industry will be responsible for delivering the energy transition, as well as meeting the increasing energy demand from a growing global population." - *Manuel Cortés Moreno*

Greening existing jobs and creating new opportunity

For the transition to net zero to succeed, the process must create new jobs and business growth. Clean industries can join legacy players, who are having to adapt and change to be fit for purpose in this new era.

In addition to making the domestic political case, the companies at work in SWIC – and other clusters – are often global in nature. As such, any proposed project must be globally competitive to secure capital allocation from the group level. Part of the cluster challenge, therefore, is to create the right environment to encourage industries to set up in the area and commit to new projects.

The challenge lies in attracting long-term investment. Companies tend to focus on a timeline in the three to five year range. The push to decarbonisation is much longer term, in the 10-20 years, or more. To secure the long-term commitments needed, companies must have faith that policies will continue to support their investments.

SWIC aims to help bridge the gap between industry and policymakers. Often, industry and politicians misunderstand each other, despite a desire from both parties to make progress. Bringing together disparate interests all focused on the same long-term goal provides an important forum for finding a joint way forward.

Companies are also increasingly aware of reputational risks and allegations of greenwashing. A commitment to build new energy transition facilities and create new, well-paying jobs is the best way for investors to navigate the difficulties of the changing landscape.

The role of academia

The University of South Wales provides support to the SWIC project.

This institution is continually scanning new technologies and methods to future proof the project – to secure a technological advantage wherever possible.

Local research centres also have a part to play. The Hydrogen R&D Centre at Port Talbot and Gas Turbine Research Centre at Cardiff University both fall within the SWIC region.

This scientific research and knowledge base can go some way to resolving some of the uncertainties that industry, business leaders and consumers may have around the concept of the cluster. They provide a holistic view of decarbonisation that differentiates what SWIC is doing. Their presence also helps establish a pipeline of new workers, who are enthused about the prospect of both helping decarbonise industry and gaining a well-paid career.

From the outset, SWIC had ambitions to create sustainable skills and highly paid aspirational jobs that could be a catalyst to transform Wales, socially and economically. By taking control of decarbonisation, it is within Wales's power to ensure the outcomes achieve its aims to deliver a lasting legacy for the future generations.

CONCLUSION – SHAPING THE WAY FORWARD

The UK faces a momentous task in meeting its net zero commitments.

It is evident that, to achieve these goals, much must change. At the same time, the essential task of the energy industry – allowing the economy to continue turning, while powering people's lives – must continue.

There are clearly technical challenges that must be overcome, but to allow this to take place requires support from across a variety of sectors and industries.

The capital value process (CVP) offers the best route to achieving this goal. This process sets out a clear vision of steps and periodic assessments. Such a move offers a chance to map progress and assess against the long-term vision of cutting emissions. The engineering mindset can be deployed on a range of scales, from the micro to macro, and considers the system as a whole.

To scale up any of the solutions developed at regional level, there will need to be plans to link together these success stories and drive change at a national level. Some evidence of systems planning is coming together in the clusters but as the UK presses onwards with its plans, there is a clear need for an overarching systems integrator at a national level.

Stitching together the various needs and drivers of the UK's energy transition into one vision will be complex and will require substantial flexibility of outlook. A system design should leave options open in order that it be as inclusive as possible, capable of accepting different inputs and outputs.

Responding to the changes at pace

Demand for change is not just coming from the government, though. Companies are increasingly making net zero pledges – and will have to start showing how they will deliver on them.

Social licence to operate, to ensure communities, stakeholders and political interests understand the process, will be critical in delivering these ambitious goals.

Reaching net zero is the UK – and the world's – best shot at tackling climate change. But the steps towards this solution must be palatable. Providing new employment opportunities and easing the transition from those in hydrocarbon-linked industries will be an essential part of such a shift.

These new technologies and concepts could go to providing employment and commercial opportunities to UK companies. Get it right at home and companies will be able to export knowledge and goods around the world – possibly including new commodities such as low-carbon hydrogen and CO_2.

To get there, the government will have to take some tough decisions and commit political capital to delivering on its ambitions. If it gets it right, though, the UK could seize the opportunity to take a leading role in providing the tools of net zero to the world.

A REGIONAL APPROACH TO INDUSTRIAL DECARBONISATION

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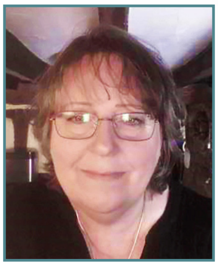

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