2023

Final Evaluation of the RICE Operation

CIOTEK LIMITED

CIOTEK
Helping your business grow.

01792 874777| Fifth Floor Business Centre, ILS2 Building, Singleton Park, Swansea, SA2 8PP.

Final Evaluation of the RICE Operation

Submitted by CIOTEK Limited

Revision 1.4

July 2023

Authors:

Mr Christopher James

Mr Michael O'Shea

Miss Laura Smith

RICE final evaluation report prepared by CIOTEK Limited.

Telephone: 01792 874 777

Email: Support@CIOTEK.com

www.CIOTEK.com

Glossary of Terms	
AIR	Annual Implementation Report
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CCUS	Carbon Capture, Utilisation and Storage
CCT	Cross Cutting Themes
ERDF	European Regional Development Fund
ESIF	European Structural and Investment Funds
ESRI	Energy Safety Research Institute
GEECS	George Ewart Evans Centre for Storytelling
GHG	Green House Gas
HEIs	Higher Education Institutions
IPCC	International Panel on Climate Change
ISCF	Industrial Strategy Challenge Fund
M&E	Monitoring and Evaluation
MoU	Memorandum of Understanding
MVT	Management Verification Team
NDA	Non-Disclosure Agreement
NDC	Nationally Determined Contributions
PI	Principal Investigator
PMC	Programme Monitoring Committee
PSA	Pressure Swing Absorption
R&D	Research and Development
RICE	Reducing Industrial Carbon Emissions
ROI	Return on Investment
RSC	Royal Society of Chemistry
SERC	Sustainable Environment Research Centre
S2E	Stairway to Excellence
SPF	Shared Prosperity Fund
SWIC	South Wales Industrial Cluster
TRL	Technology Readiness Level
UKRI	UK Research and Innovation
UNFCCC	United Nations Framework Convention on Climate Change
USW	University of South Wales

WEFO	Welsh European Funding Office
WES	Women's Engineering Society
WWV	West Wales and the Valleys

Independent External Evaluation of the RICE Operation

Final Evaluation Report

Synopsis

Reducing Industrial Carbon Emissions (RICE) is a £9.2 million operation funded through the European Regional Development Fund (ERDF) to test and drive forward next-generation technologies to help reduce carbon emissions from Welsh industry. The RICE operation is led by the Energy Safety Research Institute (ESRI) at Swansea University, in partnership with the Sustainable Environment Research Centre (SERC) and the George Ewart Evans Centre for Storytelling (GEECS) at the University of South Wales. RICE is funded under the ERDF Priority Axis 1: Promoting Research and Innovation, Specific Objective 1.2: "to increase the successful translation of research and innovation processes into commercial products, processes and services, in particular through improved technology transfer from Higher Education Institutions (HEIs)". RICE contributes to the Result Indicator of "average share of total turnover from product innovation and novel innovation: new to market, new to business and significantly improved". This is achieved through measuring 9 specific results indicators.

The RICE operation had an original start date of 1st March 2018. The operation was successful in being granted a reprofile extension in 2020, extending the operation from the original end date of 28th February 2021 to 30th June 2023. This was accompanied with an additional £1.5 million in funding to support the research. This included a reprofile of the budget which allowed for the reallocation of funding to other areas of the operation that would be of more benefit and align with operational activities.

The aim of this evaluation report is to provide the following organisations with information on the sector context in Wales.

- RICE Management team (delivery partner)
- Swansea University (beneficiary and part sponsor),
- European Union (ERDF funding body)
- Welsh European Funding Office (managing authority)

The evaluation will define the theory of change logic model and will verify that the delivery has aligned with the business plan, achieving the anticipated outcomes and impacts. The final evaluation also draws conclusions and makes recommendations on potential future strategy and sustainability of the initiative and operation.

To achieve this aim, CIOTEK undertook a comprehensive desk research study and primary research at the inception, mid-term, and final stages of the RICE operation. This included 32 in-depth virtual or face-to-face discussions with a combination of the project management and operational team, principal and co-investigators of the project, key industrial collaborators, and external stakeholders.

Further Information

Enquiries relating to this document should be directed to:

CIOTEK Limited
Fifth Floor Business Centre
ILS2 Building, Singleton Park
Swansea, SA2 8PP

www.ciotek.com

Telephone: +44 (0) 1792 874777

Email: chris@ciotek.com

Executive Summary

Evaluation Summary of Findings

Throughout its delivery, the RICE operation has been an exemplar of both academia-industry collaboration and the embedding of cross cutting themes (CCTs) into its delivery. The demonstrator-based research being driven forward by the RICE operation is allowing researchers to develop processes and technologies which large companies will be able to deploy in order to make their day-to-day operations more efficient and less harmful to the environment. In respect of CCTs, RICE was featured in the Welsh European Funding Office (WEFO) Annual Implementation Report (AIR) at the Programme Monitoring Committee (PMC) dated November 2020 as a result of their achievements in CCTs. The RICE Project is proud to have been recognised by the Welsh Government, as a CCT exemplar organisation achieving a total of 71 CCT case studies and 110 interventions during the project.

The RICE project has remained directly aligned with the Welsh and UK government's economic and energy priorities, evidenced in a number of government strategy documents, cabinet statements, policies, and legislation. RICE is particularly relevant due to the recent and ongoing commitment of the UK to the United Nations Framework Agreement on climate change (The Paris Agreement[1]) where Wales play a key role in reducing emissions for the region.

It is evidenced that the project has retained a strong management, monitoring and evaluation activity that has been proactive in managing the framework for the operation, and ensuring that CCTs are embedded at all stages, from project management to technical work packages. Key milestones set out within the monitoring and evaluation plan have been met, and several wider impact metrics have been addressed to ensure the impact of the project is effectively captured throughout the course of the operation.

Context

Wales has established a target to reduce Green House Gas (GHG) emissions by 80% by 2050[2]. It is recognised that this will require development and investment into new systems incorporating diverse technology. Both the mid-term and final evaluations of RICE have evidenced that the collaborations are aligned directly to and have the potential to make a significant contribution towards these targets. They are additionally delivering working models for GHG emissions.

The Energy Sector in Wales is the largest single source of national CO_2 emissions and is responsible for 42.5% of all CO_2 emissions.[3] In comparison to the other UK nations,

[1] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[2] https://gov.wales/wales-accepts-committee-climate-change-95-emissions-reduction-target
[3] https://naturalresources.wales/media/679462/national-assembly-for-wales-research-note-greenhouse-gas-emissions.pdf

Wales has reduced its emissions by 8.5 percentage points less than the UK average since the base year.

Consequently, technologies and systems developed by the RICE operation that enable the reduction of industrial emissions will have a direct and ongoing contribution to the overall reduction of GHG emissions in Wales.

Additionally, the technology readiness levels (TRL) collaborations and demonstrators delivered by RICE have notable commercial potential and have consistently been working toward scaling up and commercial realisation. Positioning Wales as an early adopter and leader in GHG emission reduction brings a number of significant benefits:

- A strong and proven output in Wales would encourage future collaborations with major international companies.
- It would increase the potential to secure inward investment.
- Larger (existing) organisations in Wales will benefit from the track record of successful carbon reduction research.
- Universities will be positioned to optimise greater funding opportunities and to attract and retain high calibre staff.
- There will be increased opportunities for partnership with industrial sector organisations.

Feedback

Discussions with each of the principal and co-investigators of each work package were notably positive and investigators were clear in terms of their technical role within the project as well as the impacts the project is likely to achieve. COVID-19 has emerged as a significant factor and has impacted the delivery timescales of a number of collaborative projects.

Collaborative partner discussions were equally positive and industry partners indicated a desire to maintain and develop the collaboration. Discussions also confirmed that the collaboration was seen as a long-term engagement and that the introduction of operation changing technology was seen as a long-term investment and ongoing development. Accordingly, collaborative partners indicated that many of the impacts, such as investment and jobs created are going to arise over the next three to five years as the technology becomes embedded and forms part of the mainstream process.

The RICE operation was making very good progress in the period reviewed through to March 2020. This was despite a setback in the summer of 2019 resulting from the restructuring of TATA Steel in the UK and the subsequent withdrawal of committed supports. This unforeseen change led initially to delays and added costs which were triggered by a change of senior management at TATA Steel UK. As a result of the retirement of the Chief Executive Officer (and leading advocate of the collaboration),

and the disbanding of TATA Steel Consulting; it became clear that RICE no longer had their support and were not in a position to continue with their contracted in-kind match contribution of £570k to the RICE operation.

The second more recent impact and setback was caused by COVID-19, the subsequent lockdown of industrial sites and the University laboratories as well as the ongoing concern of the unknown future impact on the developed demonstrators.

On a positive note, the disruption and delays caused by COVID-19 were largely mitigated through the RICE operation being granted a no-cost 18-month extension of its timescales by WEFO through a reprofile of the operation delivery.

This latter phase of research has enabled refinements and development of the demonstrators and further impacts against the operation metrics. It should be noted that the nature of the work being undertaken by RICE is not a simple short-term intervention, but a foundation and platform on which to build, develop and grow expertise, applications, and commercial opportunities in Wales. As such, and in common with other operations of this nature, many of the impacts will arise in the medium and long-term and will occur outside the funding timeframe for this intervention.

RICE Achievements against Indicators

Indicator	Achieved to Date	Total Target	Discussion
Number of partners cooperating in a research project	430	550	As has been seen with many other operations of this nature, the indicators will be achieved post operation rather than during the timescale of the funded element. The 550 target will be achieved post operation. Although the funding for RICE will have ended, the Energy Safety Research Institute (ESRI) at Swansea University plan to follow up with partners after 12 months to review progress.
Number of enterprises receiving non-financial support	9	10	RICE will achieve the target of 10 following additional documentation that has been requested by the WEFO Management Verification Team (MVT).
Number of new enterprises supported	7	10	The indicator target of 10 will be achieved post operation.
Private investment	£7.77m	£13m	It is projected that, over the next 3 years, the investment will exceed the

matching public support to enterprises			£13 million indicator target. Please note that over £5.38m of the private investment achieved jointly with other ERDF projects (during the project lifetime) has been claimed (100%) by the collaborating project and could therefore not also be claimed by RICE.
Employment increase in supported enterprises	10	93	Delays due to COVID and SU Finance and Legal Department issues significantly reduced the employment increase since the new and existing Enterprises have not had sufficient time to expand adoption of the pilot technology arising. Over the next 3 years, the employment increase will be achieved with the new enterprises recently formed – RICE anticipate the number of employees to be greater than 100+
Number of enterprises supported to introduce new to market products	10	60	The delays discussed above also impacted this indicator. RICE has established a platform and foundation for the figure of 60 to be realised in future years. This will be achieved through the development of the multiple algae products planned for production and commercialisation as well as the H2 units and PSA units The number of new to market products continues to rise with 30 new and a further projection of 50 being reported whilst the final report was being drafted.
Number of enterprises support to introduce new to firm products	35	100	The delays discussed above also impacted this indicator. Similarly, it is projected that this will be achieved post operation as a range of new products are being planned by collaborative partners
Number of patents registered for products	20	25	RICE management reported that this target has been achieved, however, due to issues raised by MVT, multiple patents were removed from the database and not accepted by WEFO as they were preliminary patent applications and therefore did not fall within ERDF indicator definitions. It is

			noted that once they complete the patent process, which could take up to 2 years, they will be accepted and accordingly, this target will also be achieved
Number of pilot projects completed	11	7	Overachievement on this indicator due to the additional collaborations achieved from multiple industries requesting demonstrators on their sites.

Table 1: RICE Achievements against Indicators – July 2023

Recommendations

Based on the final evaluation of RICE, the following recommendations are proposed for consideration for the future

Recommendation (1) – Maintain ongoing engagement with collaborative partners.

Given the understanding by both parties in the collaboration that the work to date has established a foundation for the future, it is recommended that longer-term contractual agreements are put in place clearly outlining the obligations and commitments of the parties involved.

Recommendation (2) – Explore additional opportunities with collaborative partners.

This, following on from the mid-term recommendations and, given that the funding model has changed due to Brexit and that future funding will be from different sources, it is recommended that in-depth discussions are held with each of the collaborative partners at the earliest stage to determine whether ongoing commitment and resource to support further opportunities for additional projects exists. The Welsh Government 2019 document titled “Prosperity for All: A Low Carbon Wales”[4] defines one of the key actions as “Collaborate with business to further decarbonise their activities whilst at the same time improve their competitiveness and productivity to take advantage of the opportunities arising from the transition to a low-carbon economy” It is recommended that future collaborations explore funding or a funding contribution by the collaborative partners. In particular, this should be achievable for multi-million-pound operations that have both the desire and the obligation to reduce carbon emissions within their own organisations.

[4] https://gov.wales/sites/default/files/publications/2019-06/low-carbon-delivery-plan_1.pdf

Recommendation (3) – Plan for continuation and future sustainability

The targets for carbon reduction in Wales and the UK are long term and it is recommended that the RICE operation seek support from the Welsh government for a continuation of funding beyond the current ERDF project. The ambition of the UK and Welsh governments have been clearly outlined in publications such as **Energy Wales**[5] and the **Climate Change Strategy for Wales**[6].

It now needs to be recognised that there is a requirement for both a strong driver and appropriate levels of funding to realise the ambitions within these documents. RICE has established both a track record and a team of highly skilled individuals and it is critical that the momentum that has been achieved is not allowed to slow down or falter due to political indecision. This in particular applies to some of the smaller, indigenous Welsh businesses who may need some form of funding support to achieve their carbon reduction ambitions.

Recommendation (4) – Future monitoring of achievements

Recognising that many of the benefits and impacts from the intervention are expected to arise beyond the ERDF funding for RICE. It is recommended that a review is undertaken after 12 months and then again after 3 years to evaluate the post funding impacts achieved as a result of the RICE support and intervention. Given that RICE will no longer exist, it is recommended that this should be undertaken by either ESRI or an external organisation. It is recognised that there will need to be funding made available to facilitate this process from whomever wishes to see these results in the future.

[5] https://gov.wales/topics/environmentcountryside/energy/energywales/?lang=en
[6] https://gov.wales/topics/environmentcountryside/climatechange/emissions/climate-change-strategy-for-wales/?lang=en

1

Report Sections
Executive Summary
Section 1: Introduction
Section 2: Mid-Term Report Outcomes
Section 3: Operational Review
Section 4: Evaluation Findings
Section 5: Logic Model
Section 6: Conclusion and Recommendations
Appendix

1 Introduction

The final evaluation report details the findings of an independent assessment of the RICE operation. The RICE operation aims to test and drive forward next-generation technologies to help reduce carbon emissions from Welsh industry.

The report summarises the key outcomes, recommendations and actions taken as a result of the mid-term evaluation undertaken by CIOTEK Ltd in August 2020. Following this, the findings from an evaluation of the operation conducted at its final stage will be presented including an assessment of its progress against targets and feedback provided by the RICE team and participating companies.

1.1 Evaluation Aims and Objectives

The final evaluation of the RICE operation has the following objectives:

- Assess the actions taken against the mid-term recommendations.
- Review the management structure and monitoring and evaluation (M&E) processes.
- Evaluate the extent to which RICE has delivered against targets.
- Assess the progress against CCT objectives and the Well-Being of Future Generations Act.
- Summarise challenges faced and lessons learned.
- Assess the overall impact of RICE and make recommendations beyond the lifecycle of the funded operation.

1.2 Evaluation Methodology

CIOTEK Ltd developed the evaluation methodology in collaboration with the RICE management team. A summary of the evaluation methodology is outlined below:

1.2.1 Desk Research

The desk research conducted included an extensive review of secondary research, publications, and operation documentation. This was completed in order to:

- Understand the progress of the operation by reading key documents such as the Welsh European Funding Office (WEFO) progress reports, CCT activities and other relevant update documents.
- Review M&E processes to understand whether any changes have been introduced throughout the operation.
- Review and update the logic model.

1.2.2 Fieldwork

CIOTEK held meetings with the management team of RICE to confirm the status of the operation and discuss any specific operational or strategic changes that may impact the ongoing or future objectives. Regular updates have been provided and published by RICE through newsletters and website updates.

Additionally, in preparation for the final evaluation, CIOTEK consultants prepared questionnaires that were approved by the RICE management team. CIOTEK consultants undertook 18 (mid) and 14 final online and/or face-to-face interviews with the RICE management, Principal Investigators (PIs), team members, collaborative partners, and external stakeholders. The scope of the interviews is outlined below:

- Semi-structured interview questionnaires were designed to cover the different internal roles at Swansea University and the University of South Wales. These were used as the framework for remote and face-to-face discussion.
- Questionnaires were designed to interview RICE collaborative partners and external stakeholders.

The research sought to identify:

- The implementation of the mid-term recommendations
- Delivery of key outputs and indicators
- M&E processes
- Challenges faced.
- Lessons learned.
- Contribution to CCT activities
- SWOT analysis
- Impact of RICE

1.2.3 Data Analysis

- **Data Collation and Analysis** – Qualitative and quantitative data have been collected anonymously and presented in subsections. The deliverables achieved and their impacts and benefits have been assessed and reported.

Conclusions and Recommendations

- **Conclusions** – Drawn from fieldwork and desk research phases.
- **Recommendations** – Which may be used to further the operation beyond its lifecycle.

1.2.4 Primary Research Scope

The names and details of the individuals (internal and external) that were interviewed as part of this evaluation are confidential under GDPR regulations. All participants have been assured that their input is anonymous, and their feedback will be incorporated as part of a collated response. It is noted that many of the projects are commercially sensitive, and this has been considered during the preparation of this report. Information on organisations, projects and achievements that are in the public domain have been incorporated into the report.

However, information or detail regarding the specific collaborative research and progress reported to WEFO in quarterly reports has not been detailed in this evaluation.

Number of internal interviews 7.

Number of external organisations interviewed and reported on 7.

Total number of organisations engaged in discussions 29.

The RICE Operation had an indicator target of 4 pilot projects against which it has achieved 10. It was agreed with the management team during the planning phase of the final evaluation that the focus should be on in-depth interviews with the key persons and project teams within these pilot projects. Accordingly, specific high-profile organisations were selected by the evaluator where it was felt that there had been notable impact and that the intervention would lead, in the future, to contributions to the economic growth in Wales.

Early discussion with 22 other organisations supported by RICE verified that RICE had helped in guiding them on how to reduce carbon emissions. They would however not make any commitment to how much or what the impact might be. Those selected for the report therefore were those which led to demonstration units and pilot projects with tangible impact and the potential of real impact in the future.

1.2.5 Secondary Research Scope

To supplement the primary research of the RICE final evaluation, the CIOTEK evaluation team has also undertaken a review of the following internal and external documents:

1.2.5.1 Internal Documents

- RICE Business Plan
- RICE M&E Plan
- WEFO progress reports
- WEFO financial claims
- RICE internal meeting minutes
- Project data collection forms

1.2.5.2 External Documents

- The European Regional Development Fund[7]
- Wales Innovates: Creating a stronger, fairer, greener Wales[8]
- Energy Wales
- Scoping the Future of Innovation Policy in Wales[9]
- Climate Change Strategy for Wales[10]
- Climate Change – The Path to Zero Emissions[11]
- Science for Wales[12]
- The Clean Air Plan for Wales[13]
- Prosperity for All: The National Strategy[14]
- Well-being of Future Generations (Wales) Act 2015[15]
- The Environment (Wales) Act 2016[16]
- Achieving our Low Carbon Pathway to 2030[17]
- Advice on the Design of Welsh Carbon Targets[18]
- Building a Low-Carbon Economy in Wales[19]

[7] https://assets.publishing.service.gov.uk/media/5d15e653e5274a065e72179d/PA1_Marches.pdf
[8] https://www.gov.wales/wales-innovates-creating-stronger-fairer-greener-wales-html#117644
[9]https://businesswales.gov.wales/innovation/sites/innovation/files/documents/MASTER%20COPY%20-%20Scoping%20innovation%20policy%20in%20Wales_final%20report_19th%20May%20final.pdf
[10] https://www.gov.wales/sites/default/files/publications/2019-04/climate-change-strategy-summary.pdf
[11] https://research.senedd.wales/research-articles/climate-change-the-path-to-zero-emissions/
[12] https://www.gov.wales/sites/default/files/publications/2019-05/science-for-wales-2017-report.pdf
[13]https://www.gov.wales/sites/default/files/publications/2020-08/clean-air-plan-for-wales-healthy-air-healthy-wales.pdf
[14] https://wcva.cymru/wp-content/uploads/2020/01/Prosperity-for-all.pdf
[15] https://www.futuregenerations.wales/about-us/future-generations-act/
[16] http://www.legislation.gov.uk/anaw/2016/3/contents/enacted
[17] https://gov.wales/sites/default/files/consultations/2019-03/low-carbon-summary-of-responses.pdf
[18]https://www.theccc.org.uk/wp-content/uploads/2017/04/Welsh-Carbon-Targets-Committee-on-Climate-Change-April-2017.pdf
[19]https://www.theccc.org.uk/wp-content/uploads/2017/12/CCC-Building-a-low-carbon-economy-in-Wales-Setting-Welsh-climate-targets.pdf

- British Energy Security Strategy[20]
- Horizon 2020[21]
- Stairway to Excellence[22]
- Europe 2020[23]
- 2030 Climate Target Plan[24]

[20] https://commonslibrary.parliament.uk/research-briefings/cdp-2022-0128
[21] https://ec.europa.eu/programmes/horizon2020/h2020-sections
[22] https://ec.europa.eu/jrc/en/research-topic/stairway-excellence-s2e
[23] http://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf
[24] https://climate.ec.europa.eu/eu-action/european-green-deal/2030-climate-target-plan_en

2

Report Sections
Executive Summary
Section 1: Introduction
Section 2: Mid-Term Report Outcomes
Section 3: Operational Review
Section 4: Evaluation Findings
Section 5: Logic Model
Section 6: Conclusion and Recommendations
Appendix

2 Mid-Term Report Outcomes

Section 2 outlines the findings of the mid-term evaluation report conducted by CIOTEK Ltd in August 2020. This includes the recommendations made and the actions taken by RICE, against these recommendations, following the mid-term evaluation.

2.1 Summary of Findings

The mid-term evaluation reported the RICE operation to be an exemplar of academia-industry collaboration and the embedding of Cross Cutting Themes (CCTs) into its delivery. The demonstrator-based research being driven forward by the RICE operation was seen to allow researchers the opportunity to develop processes and technologies which large companies can deploy in order to make their day-to-day operations more efficient and less harmful to the environment. In respect of CCTs, RICE was featured in WEFOs annual report at their programme meeting as a result of their achievements. Additionally, 46 CCT case studies were developed, which were published on the RICE website.

The RICE operation was directly aligned with the Welsh and UK government's economic and energy priorities, evidenced in a number of government strategy documents, cabinet statements, policies, and legislation. RICE was found to be particularly relevant due to the ongoing commitment of the UK to the United Nations Framework Agreement on climate change (The Paris Agreement[25]) where Wales play a key role in reducing emissions for the region.

The operation retained a strong M&E team that was proactive in managing the framework for the operation, as well as ensuring CCTs were embedded at all stages, from project management to technical work packages. It was evidenced that the data collection and reporting systems had been refined and improved on an ongoing basis to ensure efficiency and fitness for purpose.

The participants and collaborative partners provided positive feedback, praising the operation for having good communication and engagement whenever a problem was encountered.

[25] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

2.2 Mid-Term Recommendations and Actions Taken

Recommendation (1) – Enhanced communication with collaborative partners It is recommended that a more personal, direct, regular, and in-depth communication is introduced for the key collaborative partners in the RICE operation	
Actions Taken	RICE management has implemented advisory board meetings utilising the Zoom online platform. This allowed them to meet more regularly, without the constraint of travelling for the board members who reside outside Wales. Quarterly newsletters have been prepared and the RICE website and social media account has been regularly updated with current progress and RICE events. The delivery team has also been proactive in seeking opportunities to promote RICE by attending, sponsoring, and participating in several Carbon Capture, Utilisation and Storage (CCUS) conferences. These have a local and global networking reach, which has attracted several collaborative partners. The outcome of this is engagement with new key collaborative partners across a wide range of industry sectors within Wales.
Actions Planned	A RICE closing Event titled “What Now” is planned for 20th April 2023. As the ground-breaking Reducing Industrial Carbon Emissions project draws to a close, what next for the research findings and the move towards commercialisation? The purpose of the event is to talk about the next steps, the success of the research and what this means for the ongoing decarbonisation of industry as the technologies are commercialised. The event will include the screening of ***A Wicked Problem***, a 30-minute documentary film, which explores stories at the heart of decarbonisation initiatives and places them within the sublime industrial landscape of South Wales. This has been produced through the innovative collaboration of storytellers and scientists on RICE coming together to find creative ways of communicating climate change solutions. The event will also include panel discussions with those who are tasked with taking forward the research. All advisory board members, key collaborations, along with Welsh Government and local industry partners have been invited to attend.

Recommendation (2) – Explore additional opportunities with collaborative partners. It is recommended that in-depth discussions are held with each of the collaborative partners at the earliest stage to determine whether ongoing commitment and resources support further opportunities for additional projects exist and how likely these might be undertaken through the RICE operation or as an independently funded project. The Welsh Government 2019 document titled "Prosperity for All: A Low Carbon Wales"[26] defines one of the key actions as "Collaborate with business to further decarbonise their activities whilst at the same time improve their competitiveness and productivity to take advantage of the opportunities arising from the transition to a low-carbon economy"	
Actions Taken	RICE has met with several collaborative partners that have approached them after hearing conference talks and following RICE being featured in an IChemE documentary, several BBC news interviews as well as the RICE project being used as a best-in-class example in the House of Commons, demonstrating a project that is making a difference. RICE has made itself available to various industries that want to tour its sites and held in-depth discussions on how RICE can support their business to decarbonise. Demonstration site visits- DeCarb Connect 2023 held in February- RICE had over 40 visitors from various parts of the world touring the demonstrators at Vale Nickel followed by an in-depth round table discussion, offering support and answering questions on how RICE can support them in their business needs to decarbonise- this has resulted in further collaborations and more demonstrators at additional industrial sites as well as smaller scale companies that have a need to lower emissions and cannot wait for the larger heavy industry to adopt the technology.
Actions Planned	RICE has several new collaborations formed and are in communication with several industry partners that want to use RICE technology and have demonstrators on their site and are in negotiations on research sponsorship agreements to carry on the research.

[26] https://gov.wales/sites/default/files/publications/2019-06/low-carbon-delivery-plan_1.pdf

Recommendation (3) – Plan for continuation and future sustainability	
The targets for carbon reduction in Wales and the UK are long term and it is recommended that the RICE operation seek assurance from the Welsh government that there will be a continuation of funding beyond the current ERDF project. The ambition of the UK and Welsh governments have been clearly outlined in publications such as **Energy Wales**[27] and the **Climate Change Strategy for Wales**[28]. It now needs to be recognised that there is a requirement for both a strong driver and appropriate levels of funding to realise the ambitions within these documents. RICE has established both a track record and a team of highly skilled individuals and it is critical that the momentum that has been achieved is not allowed to slow down and stop due to political indecision. In support of this, it is recommended that RICE also seek commitment from the industrial partners with whom they are collaborating to determine if additional private sector funding commitments can be achieved to support the business case going forward.	
Actions Taken	Four of the RICE onsite industry demonstrators have already undergone TRL jumping, by RICE taking a unique approach by de-risking technology adoption and integrating RICE demonstrations within their commercial process taking the TRL to system development. Including 2 that are at TRL 9 and ready for launch and operations.
Actions Planned	RICE has partnered with 3 industry partners where they are committed to taking forward the research of RICE and continuing to support the research toward commercialism.

[27] https://gov.wales/sites/default/files/publications/2019-07/energy-wales-a-low-carbon-transition.pdf
[28] https://gov.wales/sites/default/files/publications/2019-04/climate-change-strategy-summary.pdf

Recommendation (4) – Procurement processes Investigate the procurement processes to determine if these can be streamlined whilst remaining within the strict procurement rules. Seek to establish a fast-track procurement process (prioritised) for critical purchases on high profile collaborations. It is recommended that fast track purchases should be an exception rather than the mainstream and should be approved as a priority purchase by the RICE Project Director.	
Actions Taken	Recommendation has been followed. RICE met with the University's new Finance Chief Officer and discussed its issues and the impact the procurement process has caused. This resulted in a completely new procurement process that was rolled out to the university in late 2021, which streamlined the procurement process and increased the purchasing amount threshold requiring quotes. This has resulted in a faster timeframe and has taken away a lot of the roadblocks RICE was previously experiencing with the previous internal process.
Actions Planned	N/a

Recommendation (5) – Internationalisation Continue to build on the international achievements and the network of interested parties that RICE have engaged with to date. Consider seeking additional funding to develop this network as a platform of excellence in Wales.	
Actions Taken	RICE has always had an international focus, as it collaborates with a lot of industries across the world. This exposure has contributed to putting Wales "on the map", with recognition of the great progress and research and providing an example of excellence in Wales. This has resulted in the funding of 2 additional international projects that have stemmed from RICE.
Actions Planned	RICE will continue to build on its international achievements and develop the network. Funding has been achieved for 2 international projects as an outcome of RICE.

Recommendation (6) – Collaborative partner progress updates Introduce a project progress update communication (monthly) specifically for collaborative partners providing a more personalised and progress-based update (Collaborative partners have indicated they would like more than the social media updates sent to all parties).	
Actions Taken	The RICE newsletter is sent out quarterly, with RICE opting to keep this on a quarterly basis to provide an overview of the operation and the progress of each of the work packages. RICE did, however, send out communications on single work package progress and their success when significant milestones were achieved between the formal quarterly newsletters. RICE also engaged with collaborative partners for these successes and included them in RICE updates by asking the collaborative partners to provide quotes, and oftentimes, to participate in press releases and new stories alongside RICE researchers. RICE sees this involvement as a partnership and the updates and progress are just as much the collaborative partners as they are RICE.
Actions Planned	RICE will have a panel discussion at their closing event in April, where the collaborative partners will be able to share their personal experience working with RICE, the impact it has made on their business and what is next for them taking the research forward. It should be noted that significant interest is being taken in the demonstrators following a March 2023 conference, 4th annual UK CCUS & Hydrogen Decarbonisation Summit (Leeds Football Stadium) which had 400+ attendees. At this event, RICE had involvement in a round table discussion and presentation.

Recommendation (7) – Final evaluation data collection Given the economic uncertainty created by COVID-19 restrictions and the inevitable delay in R&D investment and the associated activities, it is recommended that the final evaluation of the RICE operation should seek to capture both achievements to date and projected data against each of the indicators to provide a fuller picture of the long-term impact of RICE.	

Actions Taken	**Demonstrator 1**.
	RICE has developed a low cost reliable **H2 Electrolyser** that requires no water purification and has been in reliable operation for 3 years. The operation has installed several additional commercial units, ranging from heavy industry to small scale needs.
	• The Return on Investment (ROI)
	  ○ 10kw= 5 years
	  ○ 100kw= 2 years
	• The demonstrator now has over 200 days in operation.
	  ○ Total H2 produced= 85m^3
	  ○ Total carbon dioxide saved by the demonstrator = 199kg
	Demonstrator 2.
	Rice has designed and built an **Integrated Biorefinery**
	• 15,000L photobioreactor (phase 2 = 45,000L) the refinery capacity for food grade processing.
	• Maximised yields by downstream harvesting and recovery using membranes.
	• The microalgae produced as a source for i) feed (algae powder) ii) food (protein rich) iii) food (sugar rich) iv) food (lipid rich) and v) fuel (lipids)
	Demonstrator 3.
	A Carbon Capture Demonstrator
	• Pressure swing adsorption (PSA) unit in an industrial environment to separate CO_2 from industrial emissions. This is a fully automated industry grade PSA SCADA-controlled 4+4 bed unit.

Actions Planned	a) H2 Electrolyser: this is at TRL 9 and ready for commercialising and implementation at various industry sites – RICE is in negotiations with several industry partners who want to purchase the technology and/or sponsor and further fund the research by funding researchers to implement the units at their locations. b) Integrated Biorefinery – This has resulted in the development of a new enterprise that will continue the running of the unit and the commercialisation of the algae. c) Carbon Capture Demonstrator – This will provide a platform for testing novel and advanced carbon capture materials using industrial gas streams. To include: Emitters ▪ Long term testing on industry site, offering a bespoke solution. Adsorbent Manufacturers ▪ Providing real world testing/optimisation.

Recommendation (8) – Ongoing CCT collaborations Following on from the success of the CCT collaboration with Technocamps, it is recommended that RICE target further opportunities to deliver alongside Technocamps prior to the ESF funded element of Technocamps programme end in 2021	
Actions Taken	Equal Opportunities & Gender Mainstreaming – 35 CCT Sustainable Development – 43 CCT Tackling Poverty & Social Exclusion – 166 Welsh Language – 16 71 CCT case studies have been provided to WEFO.
Actions Planned	Dissemination of sustainability information. School visits are ongoing and took place through to end of May 2023 Collaborations with Technocamps to promote STEM amongst girls.

Recommendation (9) – Review against CCT aims and objectives. Ensure the final evaluation specification includes a task to evaluate how the RICE operation has performed against the delivery of CCT aims, objectives and indicators, as well as CCT case (project) related indicators, including what worked well/what didn't work well, problems identified and how these were addressed; how and to what extent has the operation provided opportunities to promote the Welsh language through its activity and how the operation has contributed to the goals of the Well-Being of Future Generations Act?	
Actions Taken	The final evaluation of RICE includes a CCT specific questionnaire that seeks to clarify how the operation has performed against the delivery of CCT aims, objectives and indicators, as well as CCT case (project) related indicators, including what worked well/what did not work well, problems identified and how these were addressed. See Section 3.4 for detail.
Actions Planned	N/A

Recommendation (10) – COVID-19 Reprofile To amortise the impact of the COVID-19 restrictions on the delivery of RICE indicators, it is recommended that RICE should explore the option of extending the timescales of the operation further. This might include evaluating how unused budget (in areas such as travel) might be reallocated to support an extension to the timescales and the associated costs of staff required to deliver.	
Actions Taken	The RICE operation was successful in being granted a reprofile extension in 2020, extending the project from the original end date of 28th February 2021 to 30th June 2023, with an additional £1.5 million in funding to support the research. This included a reprofile of the budget which allowed for the reallocation of some of the funding to other areas that would be of more benefit and align with the project activity.
Actions Planned	A further request for a short (3 month), no-cost extension was made in February 2023 to provide additional time to secure equipment and defray the allowable expenditure. This request was declined by WEFO.

Table 2: Mid-term Recommendation Actions Taken and Actions Planned

3

3 Operational Review

3.1 RICE Context

RICE was originally a three-year, £9.2 million operation under the 2014-2020 WEFO programme and Priority Axis 1: Research and Innovation, Specific Objective 1.2: "*to increase the successful translation of research and innovation processes into commercial products, processes and services, in particular through improved technology transfer from HEIs*". Within this, RICE also contributes to the Result Indicator of "average share of total turnover from product innovation and novel innovation: new to market, new to business and significantly improved".

The RICE operation was initiated in direct response to Welsh Government targets for CO_2 reduction that cannot be met with present technology. It is also recognised that Welsh industry needs to lower energy costs and raw materials consumption to ensure global competitiveness. In order to achieve these objectives, these developments need to be capable of initiating and driving significant additional sustainable world-leading research and the creation of new business for existing SMEs. This will be led through collaboration with global, regional, and local industry stakeholders and world-class academic partners to establish the platform with which to achieve economic growth.

The RICE operation was successful in being granted a reprofile extension in 2020, extending the project from the original end date of 28th February 2021 to 30th June 2023, with an additional £1.5 million in funding to support the research undertaken. This included a reprofile of the budget which allowed for the reallocation of some funding to other areas of the operation that would be of more benefit and align with operation activities.

Led by Swansea University and in partnership with the University of South Wales (USW), the RICE operation draws on world-class expertise to test and drive forward next generation technologies to help reduce carbon emissions in Welsh industry.

Backed with £7.5million of EU funding, RICE works with local supply chain companies within the West Wales and Valleys (WWV) region to test how carbon dioxide produced from heavy industrial processes can be innovatively used and recycled to create high value products and industrially important chemicals.

The project builds on the current energy research expertise in the Welsh higher education sector and dovetails with and adds value to the existing and emerging Smart Specialisation areas in the low carbon energy and environmental sector, contributing to meeting climate change targets and creating world class energy system industrial demonstrators in Wales.

The focus of RICE is to deliver change through the translation of innovative processes to reduce Wales' CO_2 emissions and decrease its heavy industry energy and raw material consumption. This will enable the creation of new businesses and lower the barrier to adoption for existing SMEs leading to the successful translation of research and innovation processes into new and improved commercial products, processes, and services. In turn, this will make a significant contribution to the overall aim of the operation by contributing to the delivery of sustainable economic growth and jobs, as well as supporting transformational change across the Welsh economy.

3.2 Strategic Importance

3.2.1 RICE in a Welsh Context

The final evaluation of RICE verified that the RICE operation remains strongly aligned with Welsh Government policies, legislation, and committee advice. Vision and ambitions highlighted in the operation business plan have remained both key and relevant. RICE is aligned with each of these policies as follows:

- **The European Regional Development Fund**[29] – direct contribution to Priority Axis 1: Promoting Research and Innovation and Specific Objective 1.2 "*to increase the successful translation of research and innovation processes into commercial products, processes and services, in particular through improved technology transfer from HEIs*".
- **Wales Innovates: Creating a stronger, fairer, greener Wales**[30] – Issued in February 2023 and outlines a vision for Wales with specific reference to the use of innovation to improve resource efficiency, reduce carbon emissions and develop the potential for Carbon Capture and Storage (CCS). Specific reference was made to energy and innovation in the power system, stating:

  > "*Our energy system is fundamental to almost every area of life, yet the system in Wales remains reliant on fossil fuels. We are committed to scaling up renewable generation to drive forward the significant change to the carbon intensity of the energy we use. Much of this will be driven by greater electrification of heat and transport, more flexible use of generating technologies, energy demand, storage, and low carbon fuels.*

[29] https://assets.publishing.service.gov.uk/media/5d15e653e5274a065e72179d/PA1_Marches.pdf
[30] https://www.gov.wales/wales-innovates-creating-stronger-fairer-greener-wales-html#117644

Our vision is for a decarbonised energy system providing wider economic and social benefits. Innovation will support a significant increase in the deployment of renewables which drive low-cost and accelerated electrification. The economy will also need to become more resource and energy-efficient with cost effective technologies removing emissions from the atmosphere. Hydrogen will play a significant role, as innovation reduces costs and enables fuel switching".

- **Energy Wales[31] –** The RICE operation has direct alignment with the three stated goals including:
  - To use energy more efficiently
  - To reduce our reliance on energy generated from fossil fuels, and
  - To actively manage the transition to a low carbon economy
- **Scoping the Future of Innovation Policy in Wales**[32] – published in 2021, the report makes specific recommendations directly relevant to the future of RICE.

  Recommendation 2: "*Future innovation policy should do more to encourage universities to develop their translational research activities to bridge the gap between research and innovation in Wales*".
- **Climate Change Strategy for Wales[33]** – contribution to the associated delivery plan which sets targets to reduce greenhouse gas emissions in Wales by 3% every year and achieve at least a 40% reduction by 2020.
- **Climate Change – The Path to Zero Emissions[34]** – This Senedd report highlighted a framework and reported on progress to date. As a result, in February 2021, the Welsh Government laid out four further sets of regulations which:
  - Amend the 2050 emissions target to net-zero.
  - Increase the 2030 target to 63% (from 45%) and the 2040 target to 89% (from 67%), and
  - Set the third carbon budget (2026-2030)
- **Science for Wales[35]** – fit with the priority sector of low carbon energy and environment and one of the key goals is to promote business innovation and exploitation of science.

[31]https://www.gov.wales/sites/default/files/publications/2019-07/energy-wales-a-low-carbon-transition.pdf
[32]https://businesswales.gov.wales/innovation/sites/innovation/files/documents/MASTER%20COPY%20-%20Scoping%20innovation%20policy%20in%20Wales_final%20report_19th%20May%20final.pdf
[33] https://www.gov.wales/sites/default/files/publications/2019-04/climate-change-strategy-summary.pdf
[34] https://research.senedd.wales/research-articles/climate-change-the-path-to-zero-emissions/
[35] https://www.gov.wales/sites/default/files/publications/2019-05/science-for-wales-2017-report.pdf

- **The Clean Air Plan for Wales**[36] – The aim of the Clean Air Plan for Wales is to improve air quality and reduce the impacts of air pollution on human health, biodiversity, the natural environment, and our economy. This plan supports the delivery of commitments under Prosperity for All: the national strategy[37]. In particular, 'reducing emissions and delivering vital improvements in air quality' to support 'healthier communities and better environments.
- **Well-being of Future Generations (Wales) Act 2015**[38] – alignment with the seven key policy goals of a prosperous Wales, a resilient Wales, a healthier Wales, a more equal Wales, a Wales of cohesive communities, a Wales of vibrant culture and thriving Welsh language, and a globally responsible Wales.
- **The Environment (Wales) Act 2016**[39] – RICE is providing solutions to decarbonisation that will support Welsh ministers in their duty of meeting targets to reduce emissions by a minimum of 80% by 2050.
- **Achieving our Low Carbon Pathway to 2030**[40] – A National Assembly for Wales meeting of the Climate Change, Environmental and Rural Affairs Committee on 11th January 2020[41] reported:

  > "*There is a strong belief within the sector that the Welsh Government should be aiming to meet a target of net-zero emissions by 2050, rather than the statutory reduction of at least 80% set out in the Act, particularly in light of the conclusions of the recently published report of the International Panel on Climate Change (IPCC)*".

  In addition, it was recommended that:

  > "*The Welsh Government should build on this to encourage more cross-sector collaboration to maximise impact. Stakeholders suggested that one way to achieve this would be through the formation of a cross-industry group to drive collaboration and innovation. The 'South Wales Industrial Cluster' was given as an example of a cross-industry group that could be used as a blueprint for a Wales-wide group*."

[36] https://www.gov.wales/sites/default/files/publications/2020-08/clean-air-plan-for-wales-healthy-air-healthy-wales.pdf
[37] https://wcva.cymru/wp-content/uploads/2020/01/Prosperity-for-all.pdf
[38] https://www.futuregenerations.wales/about-us/future-generations-act/
[39] http://www.legislation.gov.uk/anaw/2016/3/contents/enacted
[40] https://gov.wales/sites/default/files/consultations/2019-03/low-carbon-summary-of-responses.pdf
[41] https://senedd.assembly.wales/documents/s83217/Correspondence%20from%20the%20Chair%20-%2011%20January%202019.pdf

3.2.2 RICE in a UK Context

One of the most pressing environmental policies and one that remains directly aligned with RICE ambitions is the Paris Agreement[42], formed by the United Nations Framework Convention on Climate Change (UNFCCC). This agreement brings all nations together to undertake ambitious efforts to combat climate change and adapt to its effects. This agreement has the overarching aim of holding the increase in global temperature to well below 2°C and pursuing efforts to limit it to 1.5°C. The agreement also aims to achieve zero net emissions – a 100% reduction in net global emissions by 2050 – 2100.

While the UK has set domestic legislation, negotiation of definitive targets and Nationally Determined Contributions (NDCs) toward climate change is ongoing. It is recognised, however, that the UK's contribution toward a long-term reduction in global emissions will be more ambitious and challenging than the current targets. RICE is actively developing solutions for decarbonisation which will ultimately support the reduction of emissions under this agreement.

Linking to the above, RICE collaborations and activities support the advice of the UKCCC[43][44] in terms of building a low-carbon economy in Wales.

Tangible support and the importance of the reduction of carbon emissions in the UK was underlined in February 2020 with an announcement by the UK Government that the UK industry will receive around £350 million[45] to cut down carbon emissions under new plans to step up efforts to tackle climate change.

The package includes:

- £139 million to cut emissions in heavy industry by supporting the transition from natural gas to clean hydrogen power, and scaling up CCS technology which can stop over 90% of emissions being released from industrial plants into the air by storing carbon permanently underground.
- £149 million to drive the use of innovative materials in heavy industry; the 13 initial projects will include proposals to reuse waste ash in the glass and ceramics industry and the development of recyclable steel.
- **British Energy Security Strategy[46]** – On 7th April 2022, the UK Government published its British Energy Security Strategy[47]. The strategy proposes to accelerate the UK towards a low-carbon, energy independent future.

[42] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[43] https://www.theccc.org.uk/wp-content/uploads/2017/04/Welsh-Carbon-Targets-Committee-on-Climate-Change-April-2017.pdf
[44] https://www.theccc.org.uk/wp-content/uploads/2017/12/CCC-Building-a-low-carbon-economy-in-Wales-Setting-Welsh-climate-targets.pdf
[45] https://www.wired-gov.net/wg/news.nsf/articles/PM+commits+350+million+to+fuel+green+recovery

[46] https://commonslibrary.parliament.uk/research-briefings/cdp-2022-0128
[47] https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy

- Finally, RICE is strongly aligned with the priorities under UK Research and Innovation (UKRI)[48]. With a combined budget of more than £6 billion, UKRI works with several organisations and institutions to create the best environment for research and innovation to flourish. The UKRI sees the government's Industrial Strategy Challenge Fund (ISCF)[49], a fund that is part of the UK Government's Industrial Strategy, dedicating £4.7 billion over four years to bring together leading research and business to tackle the big societal and industrial challenges today. RICE can contribute directly to two of the key priorities of this fund namely manufacturing and future materials and prospering from the energy revolution.

3.2.3 RICE in an EU Context

The RICE operation remains closely aligned with the Horizon 2020 programme[50] which supports the three strategic priorities of Open Innovation, Open Science and being Open to the World. RICE particularly supports one of their key priorities which is to create "*a resilient energy union with a forward-looking climate change policy*".

- **European Commission's Cohesion Policy, the Stairway to Excellence (S2E)[51]** – As a funding instrument which includes the European Structural and Investment Funds (ESIF), it aims to assist ESIF beneficiaries to prepare their research and development (R&D) actors in order to participate in better Horizon 2020 calls, ultimately amplifying the innovation potential of these funding sources.
- Embedding the above, the RICE operation is also aligned with the three key priorities of the **Europe 2020 strategy**[52], contributing toward smart, sustainable, and inclusive growth.
- **EU 2030 Climate Target Plan[53]** – The Commission's proposal to cut greenhouse gas emissions by at least 55% by 2030 sets Europe on a responsible path to becoming climate neutral by 2050. Based on a comprehensive impact assessment, the Commission has proposed to increase the EU's ambition on reducing greenhouse gases and set this more ambitious path for the next 10 years. The assessment shows how all sectors of the economy and society can contribute and sets out the policy actions required to achieve this goal.

[48] https://www.ukri.org/
[49] https://www.ukri.org/innovation/industrial-strategy-challenge-fund/
[50] https://ec.europa.eu/programmes/horizon2020/h2020-sections
[51] https://ec.europa.eu/jrc/en/research-topic/stairway-excellence-s2e
[52] http://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf
[53]

3.3 Monitoring and Evaluation

The final evaluation evidenced that RICE has maintained a rigorous and detailed process for monitoring and compliance throughout its delivery. This follows clearly defined and documented processes and procedures for collaboration and ensuring clarity of the responsibilities and obligations of all parties.

The process that has remained throughout is that, at the outset of a potential collaboration, the RICE senior technical managers are involved in discussion with the enterprise to agree on the respective contributions of all parties. This is based on salary costs and overheads for the time projected for the project as well as the cost of consumables, travel, and equipment usage. In addition, outcomes, including intellectual property are defined and an agreement is documented to share the IP by each party in the same proportion as their contribution. Additionally, since the advent of COVID-19, discussions have taken place on the implications and processes for safeguarding participants, and remedial actions to take in the event of a further lockdown or restricted working.

State Aid compliance is monitored and verified during the project approval process. This is followed by a collaborative agreement to confirm the arrangements. The collaborative project is then formally logged by the M&E officer in a monitoring spreadsheet.

Ongoing costs and evidence of contributions are monitored through a gateway system throughout the project lifetime to ensure there is no significant deviation from the costs and/or outputs proposed. In the event of deviation, systems are in place to ensure continued State Aid compliance i.e., reappointment of outcomes in line with evidenced contributions, the enterprise paying for services i.e., contract research.

Prior to the start of the collaboration, all parties will sign a collaboration agreement that will form the basis of all activities and outlines the project plan, and the proposed share and nature of inputs and outputs, including IP.

Since the outset, guidelines have been in place to address instances of a joint/collaborative research project and also to address instances where one or more of the conditions cannot be met.

3.3.1 Monitoring and Compliance for De Minimis Activity

Detailed and robust processes have remained in place throughout delivery to ensure compliance with De Minimis, including a section within the operation's Project Proposal document. This has been devised by the RICE management team and

follows the guidance of the Welsh Government State Aid Unit "How to run a De minimis aid scheme"[54] dated April 2015.

The RICE Project Proposal form has been used as a process to confirm enterprise eligibility, confirm De minimis aid already received by the recipient, and to verify that the De minimis threshold is not breached. In addition, it is used to inform the recipient formally of the estimated value of the aid offered based on the eligible costs of the project. This process is managed by the RICE Senior Technical Manager, with the support of the RICE Operation Manager and the RICE Legal and Contracts Coordinator.

3.3.2 Contract RD&I

The mid-term evaluation identified that the RICE operation had prepared for all instances including exceptional cases where enterprises have initially signed a collaboration agreement under 'RD&I collaborations' but then established during the course of the collaboration that they cannot provide any in-kind input as agreed. The process defined is that the enterprise will have to pay for the activities of the RICE HEI partners, turning the collaboration into 'Contract RD&I'. This process has remained in place through to the operation conclusion.

The final evaluation evidenced that the team have continued to rigorously manage and monitor the activity and assess outcomes at the project completion stage. The team have also maintained project logs and spreadsheets detailing interactions and transactions associated with the activity.

Evidence was presented during the mid-term evaluation which confirmed that the RICE management team has documented and defined detailed processes to cover both State Aid at the level of the University and State Aid at the level of the enterprise.

3.3.3 Document Retention

The evaluation has evidenced that the RICE operation has adhered to the relevant State Aid record-keeping requirements and retained records in accordance with the relevant provisions. The management and retention of documents relating to the RICE operation are governed by the WEFO European Structural Funds Programmes 2014/2020 document: 'Eligibility rules and conditions for support from the European Structural Funds 2014-2020'.

[54] https://gov.wales/sites/default/files/publications/2019-10/how-to-run-a-de-minimis-aid-scheme_0.pdf

3.3.4 Reporting

The final evaluation evidenced that regular and comprehensive quarterly progress reports have been prepared by RICE incorporating:

- Detail of achievements and progress against each of the work packages
- Details on delivery profile variance
- A forward plan of activity planned for the next period.
- Cross Cutting Themes progress and achievements
- Details of Monitoring and Evaluation progress
- A summary of the operation publicity
- A record of procurement and financial commitments
- Information on any Milestones or special conditions
- An Update on State Aid progress
- Payments, Open Matters, Management Verification checks
- An updated Risk Register.

These reports provide high levels of detail and highlight any issues arising at the earliest stage in the RICE operation. In addition to the quarterly reports sent via email to the WEFO PDO, the RICE management team submit each of the CCT Case studies to the WEFO CCT officer. These outline the activity along with highlighting and measuring the impact of the action and the relationship to the relevant CCT.

Interviews with PIs, researchers and staff verified that progress reporting has been ongoing, regular, and consistent, and there is an effective mechanism for the collection and collation of relevant information. It was also verified that there have been no issues in keeping up to date with the reporting and monitoring requirements.

At the start of the RICE operation, a shared document repository was initiated using SharePoint. The process in place is considered to be “best practice” as it provides each team member with access to the quarterly reports and risk register. It is also the portal where each work package has a dedicated workspace to report on and upload information on their progress and thereby share information with all RICE team members.

3.3.5 Projects

RICE has established demonstration units at a wide range of locations which can be found in Appendix A, B, C and D.

3.4 CCT Activities

The RICE operation's approach to CCTs has been both diligent and proactive. CCTs have been embedded in many of the activities and delivery of RICE, and it has only been the disruptions caused by the COVID-19 pandemic that temporarily interrupted its exceptional progress. At the time of the mid-term evaluation, RICE had reported on 46 CCT activities. By the conclusion of the operation, this has risen to 110 interventions and 71 case studies resulting in the RICE operation being identified as a CCT exemplar by the Welsh Government. Examples of the published case studies can be viewed on the RICE website[55].

RICE has made many contributions to the three WEFO[56] CCTs defined for this operation which include:

- Equal Opportunities and Gender Mainstreaming – which aims to reduce injustice and promote social cohesion.
- Sustainable Development – is the central organising principle of the Welsh Government and aims to ensure that programmes and operations meet social, economic, and environmental objectives simultaneously.
- Tackling Poverty and Social Exclusion – is a European Commission and Welsh Government commitment which will focus on actions to create employment and progression opportunities and will help people to access those opportunities.

3.4.1 Equal Opportunities and Gender Mainstreaming

RICE has engaged with school groups and education providers to enable access and engagement with RICE facilities, researchers, and collaborative partners to aid in the provision of insight into career opportunities. RICE has hosted 6 site visits for school and college groups in the past 12 months. This has included personnel discussing how they reach their position in their career, which helped to demonstrate the many different career paths and opportunities. RICE received positive feedback, particularly for the visibility of role models within the community. A RICE researcher secured funding from the Women's Engineering Society (WES) to make a demonstration model of the project to display at a museum interactive event.

3.4.2 Sustainable Development

Due to the nature of the RICE operation, RICE has been able to record 43 contributions to sustainable development including cycling to work, a storytelling symposium on sustainable development, career events, hydrogen refuelling, and sustainable pest control. Within this, a RICE researcher organised a Dragon's Den style event whereby school pupils discussed ideas to tackle climate change. Furthermore, the ESRI planted trees outside of Swansea's Guildhall as part of their

[55] https://www.rice.cymru/en/knowledge-base
[56] https://www.gov.wales/docs/wefo/publications/170213-cct-erdf-key-document-en.pdf

commitment to offset work-related staff travel. A RICE team member participated in the Wales Youth Council Climate Conference as a panel member. This included identification of activities which build skills within the community, mentoring/peer support, & volunteering activities.

3.4.3 Tackling Poverty and Social Exclusion

RICE has undertaken 20 workshops, talks, and events in this area including career workshops, film-making workshops with students of additional educational needs, and community open days. RICE also made educational resources available to teachers to aid lessons including a workshop in partnership with the Royal Society of Chemistry, inviting science teachers on-site to learn about algae, hydrogen, and nickel refining to aid their teaching of the subject in class. 14 RICE staff members took part in the 2019 Mr X Appeal which donates gifts to disadvantaged children across South Wales.

Further to the three WEFO CCTs, RICE also has 6 Case Level indicators as detailed below:

Female Participation in STEM

The RICE operation has worked consistently to promote females in STEM by giving all the RICE female researchers a platform and encouraging them to use their voice both to promote their own work and to also demonstrate to other females and young girls possible career paths. This has included interviews for television, radio, podcasts, and written articles.

RICE has attended or participated in nearly 30 career events, community open days, and conferences and hosted school group visits at demonstration sites where both male and female students have been able to gain first-hand experience of the work being done by the research team.

Activity Supporting Speakers of the Welsh Language

All Rice publicity material has been produced bilingually and promotion of achievements and projects through various Welsh language media.

In support of this CCT, RICE has:

- Established a process to support requests for interviews in Welsh.
- Conducted in the region of 8 interviews in Welsh for television, radio, and video recordings.
- Hosted a school visit to the algae biorefinery demonstration unit, conducted through the medium of Welsh.
- Participated in Gwyddonle at the Eisteddfod, an interactive science pavilion demonstrating RICE research and projects.

Development of an Eco-code

An Eco-Code was developed at the commencement of the RICE operation which was disseminated electronically to all staff and placed on notice boards across the ESRI building. The Eco-Code consists of a series of 5 posters on the themes of waste management, travel, biodiversity, positive procurement, and energy. The eco-code aims to encourage staff members to consider the implications of their actions on the environment to ensure that any negative impact is negated or reduced.

Development of an Organisational Travel Plan and Sustainable Travel

The RICE operation developed a Sustainable Travel Plan which was disseminated to all RICE staff. The Travel Plan consists of a flow chart which forms the decision-making process when staff are required to attend meetings/events/workshops in other locations. The aim of the Travel Plan was to encourage staff members to only travel when absolutely necessary, and if they do need to travel, to use more sustainable modes of transport. It also encouraged staff to share transport wherever possible.

Since the development of the plan, there was a pandemic which significantly changed the way in which business and meetings were conducted. For a considerable time, it was not possible to travel to meetings, but as restrictions eased, staff were encouraged to utilise the plan once again.

Resource Efficiency Measures

RICE has been proactive in making best use of the resources available. On a large scale, many of the RICE demonstration units are housed in shipping containers, which makes them easily transportable and more easily deployed from one site to another. On a small scale, any materials for exhibitions etc, have been produced in a format which can easily be reused. Printing has been reduced to a minimum and, where possible, conference exhibits are sent in advance by courier, thus enabling staff to travel by train to conferences.

Develop / Engage CCT Champions

There have been a number of supportive individuals who have played a major role in helping to develop the CCTs for RICE, through participating in activities and identifying possible CCTs. It is through this proactive work that the achievement of 110 interventions and 71 case studies has been achieved.

RICE has indicated a number of aspects that worked well throughout the operation. Having a group of individuals who understood the need to develop CCTs as part of the RICE operation was beneficial. In addition to the scientific research being conducted, the team were aware of the need for RICE to make a wider contribution within the locality and the wider community. This quickly developed into a good informal network where ideas and opportunities were explored. It involved regular discussions to establish what project activities were planned and to explore which CCT activities could be developed as part of the work.

Opposingly, RICE reported that difficulty occurred when not all members of the operation understood or engaged in the CCT process.

3.4.4 Well-Being of Future Generations Act

The RICE operation has undertaken a range of activities which contribute to the goals of the Well-Being of Future Generations Act as outlined:

A Prosperous Wales

The goal of a prosperous Wales is an innovative, productive, and low carbon society which recognises the limits of the global environment and therefore uses resources efficiently and proportionately. RICE inherently contributes to this goal due to the nature of the work including being initiated in direct response to Welsh Government targets for CO_2 reduction that cannot be met with present technology. RICE collaborates with global, regional, and more importantly, local industry stakeholders which contributes to the goal of a prosperous Wales.

A Resilient Wales

RICE has undertaken a number of activities to contribute to a resilient Wales such as the planting of trees.

A More Equal Wales

RICE has delivered workshops to many schools and colleges, ensuring the visibility of role models to young people in the community.

A Healthier Wales

RICE encourage staff to cycle to work. Furthermore, RICE staff chaired a Well-being Workshop on behalf of the Royal Society of Chemistry (RSC). This workshop was open to all RSC members who have an interest in the subject or would like to have a better understanding of mental health and well-being and was fully funded by the RSC.

A Wales of Cohesive Communities

RICE is active in the community and has delivered a range of events, workshops and undertaken a number of activities.

A Wales of Vibrant Culture & Thriving Welsh Language

All RICE publicity material has been produced bilingually and promotion of achievements and projects through various Welsh language media. RICE has also undertaken a number of activities in Welsh including school visits and participation in the Eisteddfod.

A Globally Responsible Wales

RICE engages with global, regional, and local industry stakeholders and world-class academic partners to establish the platform with which to achieve economic growth and also ensure supply chains are fair, ethical, and sustainable.

4 Evaluation Findings

This section will highlight the primary research findings discovered during interviews undertaken with RICE staff and collaborative partners.

4.1 Progress Against Targets

The RICE operation was successful in being granted a reprofile extension in 2020, extending the operation from the original end date of 28th February 2021 to 30th June 2023. As a part of the reprofiling of the RICE operation, the non-financial support indicator was reduced. Following discussion around the evidence requirements, it was considered best to reduce the target in order to allow RICE to focus on co-operations/collaborations.

The rationale for this reduction is as follows:

- At the outset, when indicator targets were established for RICE, the target for non-financial support was set at 575 on the understanding that this would include workshop attendees. It emerged latterly that workshop attendees would no longer be eligible to contribute toward this indicator which was therefore reduced accordingly.
- RICE is limited to enterprises based in West Wales and the Valleys. Consequently, in the interest of using public resources efficiently and effectively, it was agreed that RICE will focus its monitoring and administration efforts on the “partners cooperating” indicator, and a revised “non-financial support” target of 10 was agreed upon.

4.1.1 Achievements Against Indicators

Indicator	Achieved to Date	Total Target	Discussion
Number of partners cooperating in a research project	430	550	As has been seen with many other operations of this nature, the indicators will be achieved post operation rather than during the timescale of the funded element. The 550 target will be achieved post operation. Although the funding for RICE will have ended, the Energy Safety Research Institute (ESRI) at Swansea University plan to follow up with partners after 12 months to review progress.
Number of enterprises receiving non-financial support	9	10	RICE will achieve the target of 10 following additional documentation that has been requested by the WEFO Management Verification Team (MVT).
Number of new enterprises supported	7	10	The indicator target of 10 will be achieved post operation.
Private investment matching public support to enterprises	£4.88m	£13m	It is projected that, over the next 3 years, the investment will exceed the £13 million indicator target. Please note that over £5.38m of the private investment achieved jointly with other ERDF projects (during the project lifetime) has been claimed (100%) by the collaborating project and could therefore not also be claimed by RICE.
Employment increase in supported enterprises	10	93	Delays due to COVID and SU Finance and Legal Department issues significantly reduced the employment increase since the new and existing Enterprises have not had sufficient time to expand adoption of the pilot technology arising. Over the next 3 years, the employment increase will be achieved with the new enterprises recently formed – RICE anticipate the number of employees to be greater than 100+
Number of enterprises	5	60	The delays discussed above also impacted this indicator. RICE has

supported to introduce new to market products			established a platform and foundation for the figure of 60 to be realised in future years. This will be achieved through the development of the multiple algae products planned for production and commercialisation as well as the H2 units and PSA units. The number of new to market products continues to rise with 30 new and a further projection of 50 being reported whilst the final report was being drafted.
Number of enterprises support to introduce new to firm products	5	100	The delays discussed above also impacted this indicator. Similarly, it is projected that this will be achieved post operation as a range of new products are being planned by collaborative partners
Number of patents registered for products	18	25	RICE management reported that this target has been achieved, however, due to issues raised by MVT, multiple patents were removed from the database and not accepted by WEFO as they were preliminary patent applications and therefore did not fall within ERDF indicator definitions. It is noted that once they complete the patent process, which could take up to 2 years, they will be accepted and accordingly, this target will also be achieved
Number of pilot projects completed	10	4	Overachievement on this indicator due to the additional collaborations achieved from multiple industries requesting demonstrators on their sites.

Table 3: RICE Achievements against Indicators – July 2023

Number of Partners Co-operating in a Research Project. More so than almost any other ERDF intervention, the RICE operation impacts will be long term rather than immediate. RICE has established a foundation and critical mass of collaborations that will continue to grow and develop over the next five, ten and twenty years. It is recognised that the concept of carbon reduction is an ongoing and long-term ambition, indeed the Welsh Government themselves have recognised this and set targets stretching forward 25 years[57]. In March 2021, Senedd Cymru approved a net zero

[57] https://www.gov.wales/climate-change-targets-and-carbon-budgets#66856

target for 2050 (net zero means balancing greenhouse gas emissions with the amount of gases we're removing from the atmosphere). Wales also has interim targets for 2030 and 2040 and a series of 5-year carbon budgets.

Additionally, the RICE programme has provided extensive international exposure and business opportunities for its partner enterprises as documented by News coverage on the RICE web site[58]. For example, the alteration of Vale global corporate strategy has been initiated by RICE Work package 2. As an example of a Welsh SME benefiting, H2-NRG is in negotiations with industry partners in Australia and India for licences of the technology from RICE Work package 4.

It has also been evidenced that political, industrial and community interest in decarbonisation is growing swiftly with the recognition that this will impact everyone living in Wales. RICE has been proactive in seeking out and engaging with potential collaboration partners driven by the rising level of interest and demand in the marketplace.

From its inception, RICE has been keen on sharing its achievements using social media and other forms of promotion such as a digital newsletter. This, and a process of diligently following up on potential collaborations will lead to an ongoing and increasing interest and is projected, in time, to exceed the indicator target of 550.

It is apparent that RICE's high-level goal of reducing industrial carbon emissions is very much a 'hot topic' at present and aligns with the global aim of decarbonisation. Many industrial partners are aware of the ambition and objective toward reduced carbon emissions and are accordingly both ready and willing to become involved at an early stage so that they might prepare their businesses appropriately.

Number of Enterprises Receiving Non-Financial Support. Currently reporting 9 enterprises against a target of 10. RICE management has advised that the final enterprise in this indicator is imminent and pending WEFO MVT verification.

Number of New Enterprises Supported. The RICE operation has supported 7 of the target 10 enterprises. It should be noted, however, that the uncertainty created by Brexit and the second COVID-19 wave created an economic climate which was unfavourable for setting up new enterprises. Despite these setbacks, the RICE management projection is that the target of 10 will be achieved in the post funding period.

Private Investment. The RICE operation has fallen short of this target by a large margin. It was noted by the management team that a significant portion of the private investment indicator was achieved through collaboration with other projects. However, the private investment achievements were claimed by other ERDF projects and could therefore not be claimed by RICE. For example, both FLEXIS and SWIC claimed credit for the private investment associated with a demonstration unit that was 100% funded by the RICE programme. This had a value of £5,383,155.70. Despite not being able

[58] https://www.rice.cymru/en/news

to claim this investment, it is expected that, over the next 3 years, the investment achieved by the RICE operation will exceed the target of £13 million.

Employment Increase in Supported Enterprises. RICE has achieved an employment increase of 10 compared to the target of 93. It is expected that this target will be exceeded in the next 3 years, achieving an employment increase of over 100. This is corroborated by collaborative partners with a collated estimate of employment increases of 100 employees.

Number of Enterprises Supported to Introduce New to Market Products. This indicator has been impacted by COVID-19 as businesses take a cautious approach in response to the economic uncertainty and focus on their core activities and as such RICE has currently fallen short of the target of 60. However, RICE has established a platform and foundation for the target of 60 to be realised in the future. This is aimed to be achieved through the development of multiple algae products planned for production and commercialisation as well as the H2 units and PSA units.

Number of Enterprises Supported to Introduce New to Firm Products. This indicator has again been impacted by the COVID-19 pandemic, with businesses focusing on survival rather than development. It is anticipated that this target will be achieved post operation as collaborative partners are in the process of planning and developing a range of new products.

Number of Patents Registered for Products. The RICE operation achieved the target of 25 patents registered. However, the RICE management team reported that due to issues raised by MVT, multiple patents were removed from the database and not accepted by WEFO as they were preliminary patent applications and therefore did not fall within ERDF indicator definitions. . It is noted that once the patent application process is complete, which could take up to 2 years, the patents will be accepted, and the target will be achieved.

Number of Pilot Projects Completed. This RICE operation is unable to report or claim pilot projects until their completion and as such, RICE has currently fallen short of the indicator target of 10. However, this indicator target is expected to be realised over the next 3 years due to the additional collaborations achieved from multiple industries requesting demonstrators on their sites.

4.2 RICE Delivery Team

4.2.1 Work Packages

The RICE operation has 9 work packages as outlined below and detailed on the RICE website[59]:

Work Package	Description
1	Separation and capture of CO_2 from industrial flue gas mixtures
2	Integrated Bio-refinery
3	Integrated Hydrogen Bioprocesses
4	Variable input hydrogen and oxygen production from renewable energy
5	Heat, hydrogen, and their efficient use
6	Heat to hydrogen
7	Systems and techno-economic analysis
8	Engagement and impact
9	Capturing digital stories of energy change

Table 4: RICE Work Packages

The work packages have been delivered as planned and aspirational targets will be achieved over the next 3 months. For one of the work packages, there has been a follow-on extension which allowed technical deliverables to be extended to create new products.

4.2.2 Management Structure

The RICE management and project structures are noted by the RICE staff to be positive, well-managed, collaborative, meaningful, and empowering for staff. The staff also noted that they are well supported and recognised by the RICE management team. Furthermore, the development of a project management board with multiple partners has added value in understanding what others were doing in adopting projects and interacting with the industry. The staff has developed a good team culture, with meetings held regularly. Overall, most of the RICE staff indicated the management structure of the operation to be very effective. It was reported that

[59] https://www.rice.cymru/en/projects

throughout the COVID-19 pandemic, management meetings continued to take place via Zoom and other online communications. Feedback from those interviewed confirmed that the leadership of the RICE operation has been clear, strong, and inspirational. It was noted particularly that the PIs appreciated that there was no micro-management, and they have been allowed the freedom to develop their own work packages using their specific expertise. However, one member of staff believed that the management structure was not effective due to researchers being too focused on their own work packages and targets. It was confirmed by many staff that there has been open sharing of best practices and technology achievements. The RICE team held monthly demonstration update meetings both virtually and in-person, at which, each researcher on a work package provided an update on the present position of their work. Furthermore, the operation held operational management group meetings at which presentations were made regarding the financial position of the operation, achievement of indicators against targets and progress made by individual work packages.

However, the relationship with WEFO was said to be very demanding, bureaucratic, and time-consuming and interactions often related to queries on paperwork procedures or engagement with industrial partners.

4.2.3 Understanding of Objectives

The objectives of RICE have been very clearly explained to the RICE staff. Staff were provided with the business plan at an early stage, with the goals and aspirations of the operation clearly set out. The RICE website outlines further details in an accessible, and easy-to-digest format. Moreover, staff have the opportunity to discuss individual work packages with their respective researchers. This has been noted as being invaluable in providing an insight into the technology being used and created, and its potential applications.

4.2.4 Monitoring and Evaluation

The RICE staff indicated the M&E processes have been very effective and robust and have implemented continuous improvement by adapting and modifying processes with each WEFO MVT audit to meet the compliance rules of the funding. This was reported to be successful and resulted in RICE having near-perfect MVT audits for 4 years with minimal errors.

Staff noted that reporting and monitoring requirements worked well and were kept up to date. There were also good templates used at the outset of the operation which made reporting and monitoring easy.

4.2.5 Impact of RICE on Collaborative Partners

The RICE operation is anticipated to have a wide range of impacts on collaborative partners both during the life of the RICE operation as well as beyond the life of the operation as outlined.

During the Life of the Operation	Beyond the Life of the Operation
➢ Non-financial support ➢ New enterprises supported. ➢ Employment increase ➢ New products and patents ➢ Raised awareness of decarbonisation threats and opportunities ➢ Raised awareness of the availability of collaborative research with HEIs ➢ Provided access to sophisticated R&D facilities and scientific expertise. ➢ Access to RICE's network of contacts, nationally and internationally ➢ Raised awareness of the Welsh Government's SMART Innovation scheme	➢ Employment increase ➢ New products and patents ➢ Raised awareness of the availability of collaborative research with HEIs ➢ Provided access to sophisticated R&D facilities and scientific expertise. ➢ Raised awareness of the Welsh Government's SMART Innovation scheme ➢ Employment in the UK is less attractive to Europeans post Brexit

Table 5: Impacts of RICE during and beyond the life of the operation

4.2.6 RICE's Success in Collaborative Activities

RICE was indicated by the staff to be extremely successful in its collaborative activities. The operation has delivered each of the objectives identified in the original proposal and scope and in addition, delivered extra value through the over-delivery of demonstrators than originally specified, proving that the technology applies to all industry, large scale as well as small scale, coming close to meeting the net zero goals.

The operation has also been noted as having a very positive impact on collaborative partners. RICE has proven that the developed demonstrators have reduced carbon dioxide emissions and produced hydrogen. RICE partners have discussed the savings and benefits received as a result of RICE demonstrators and are open to allowing others in the industry to view the demonstrators.

Please see https://www.youtube.com/watch?v=dpVS2VsHDoY

4.2.7 Market Need

In discussing the ongoing market need for RICE there was an overwhelming view from both internal and external interviewees that the demand and need to reduce carbon emissions has become significantly greater. It is perceived that there is an increased awareness amongst the younger generation of the impact on the environment of CO_2 and other emission gases. Awareness has been accelerated through organisations such as Extinction Rebellion and the awareness raised by activists such as Greta Thunberg[60] and high-profile figures in the UK, such as David Attenborough[61] promoting the need to address issues now to protect the environment for future generations. It was also seen that the collaborative partners are proactively seeking to promote a reduction of their carbon footprint.

RICE has demonstrated its ability to move swiftly to operational activities rather than following slower, more traditional approaches which is important in addressing the needs of the sector.

The net-zero legislation has ensured the RICE operation is at the centre of needs for industry decarbonisation. The acknowledgement by both the Welsh Government and UK Government citing RICE as an exemplar of a carbon capture operation has strengthened this centralisation. Furthermore, the industry has recognised the need for on-site demonstration integrated into commercial processes to evidence benefits, which can be achieved through the RICE operation.

4.2.8 Collaboration with Other EU Funded Projects

Throughout the operation, RICE has collaborated with other EU-funded programmes. These include the FLEXIS[62] initiative, which aims to meet the energy demands of the future, led by Cardiff University and the Technocamps[63] initiative led by Swansea University which focuses on promoting STEM subjects to school-age pupils.

RICE has collaborated with the FLEXIS operation whose remit is aligned to the key 'Science for Wales' priority sector of Low Carbon Energy and Environment. The PI of RICE is one of the PIs on the FLEXIS project and is positioned to align and collaborate with FLEXIS as needed.

In addition, RICE has collaborated with the Technocamps Operation through a USW co-ordinated hydrogen workshop which is delivered to year 7 and 8 students. Along with Technocamps, a programming workshop was developed to demonstrate the potential to produce renewable hydrogen from photovoltaic power. This was developed using Scratch, a visual programming language developed by MIT as a

[60] https://en.wikipedia.org/wiki/Greta_Thunberg
[61] https://www.bbc.co.uk/news/science-environment-47976184
[62] https://www.flexis.wales/
[63] https://www.technocamps.com/en

learning tool. This workshop was seen to address the CCTs of Equal Opportunities and Gender Mainstreaming and Tackling Poverty and Social Exclusion.

It was reported that, during the proposal phase of the South Wales Industrial Cluster (SWIC), RICE was involved and collaborated with SWIC to share research. Subsequently, SWIC is a direct result and branched off of the research of RICE. The SWIC project was successful and has resulted in further funding of projects across South Wales. However, RICE staff indicated that there have been issues that resulted from this collaboration including no public acknowledgement of the collaboration with RICE, despite a signed collaboration agreement. This has resulted in less collaboration than originally intended, as well as other projects focused on achieving their own targets and indicators.

4.2.9 Challenges Faced

The RICE operation faced a number of challenges and implemented a range of strategies to overcome these challenges. Firstly, as with many operations, RICE faced challenges in regard to Brexit and transitional arrangements with the EU, particularly in relation to the creation of financial uncertainty affecting business confidence and willingness to participate in RICE. Procuring equipment and materials has also resulted in challenges for RICE staff resulting in delays in the operation of demo units, particularly Work Package 1.

WEFO's regulatory framework has been identified as a challenge, due to the unclear and changing guidance of criteria and evidential requirements in support of indicator outputs. Further to this, it was found to be difficult to obtain supporting paperwork from collaborative partners as the level of detail required was seen to intimidate some of the collaborative partners. The collection of supporting evidence was particularly difficult for the output indicator private investment as collaborative partners did not want to commit a figure to paper as this might 'bind' them to the figure at a later date. This was found to even be the case when private investment has already been given in-kind through the provision of materials and staff hours.

The RICE operation also found State Aid to be challenging due to its very complicated regulatory framework and it has been agreed that RICE will discuss these issues with WEFO independently. . It was advised that Swansea University have their own REIS team who can advise on these areas, as they will have knowledge and best practice obtained from delivery of the many other ERDF supported operations that Swansea University are involved in. It was also noted that Brexit has now effectively ended ERDF and ESF funding streams although the UK will be bound by State Aid Rules[64] until the end of the Brexit transition period.

[64].https://www.instituteforgovernment.org.uk/article/explainer/state-aid-rules-after-brexit#:~:text=While%20state%20aid%20is%20generally,rules%20therefore%20have%20some%20exemptions.

Finally, it was indicated that there were often very long delays, sometimes in excess of 6 months, between submitting a claim and receiving queries from MVT on the included outputs or financial aspects. This made it very difficult to alter the procedures promptly. There were also inconsistencies between individual auditors regarding the type and level of evidence required. Accordingly, what was sufficient for one auditor might be deemed insufficient by another. It was very difficult for RICE to establish a consistent approach or collect additional evidence months after a claim.

4.2.10 Lessons Learned

RICE staff has reported a range of lessons they have learned throughout the operation. Staff identified the need to de-risk technology and understand safety and economic viability. It was also identified that there is a need to share experiences in order to ensure success. An example of this relates to the design of one of the demonstration units where the technology was evaluated from the outset to assess any safety implications associated with its operation. There has also been a close assessment of the commercial potential of the technology being adopted in order that it may be scaled up from a demonstration unit to a commercial operation. Regular meetings between the PIs and support staff on the projects helped to underline the shared experiences which might be common to all projects.

RICE staff have learned that key contacts in businesses can change commitments and priorities. A change of management with one of the key partners led to significant funding arrangement being withdrawn at a late stage. This was despite the fact that contracts had been signed. This underlined the fragility of relationships when the key contacts are replaced by someone seeking to make their own mark and not inherit projects that their predecessors have initiated, however good they might be. There is also a reluctance of industry to document values which may become public record. Discussion with organisations involved with projects has revealed a resistance to make any projections of impact arising into the future, reporting that such projections are too often taken enthusiastically by government as promises on which they are then challenged. Accordingly, such projections are included on a collated basis and should be accepted purely as projections or plans which may change.

4.2.11 Unanticipated Impacts

The RICE operation has experienced unanticipated impacts including the sharing of achievement of roll-out benefits to a wider audience. Just five of the many unanticipated impacts have been outlined below as examples :-

- The British Ambassador to Qatar visited the RICE algal biorefinery recently to view the technologies being developed and talk to the RICE team.
- RICE being raised in Parliament[65] during questions to Greg Hands, Business Energy, and Industrial Strategy Minister.
- Swansea University working in partnership with Gower College's Department for Independent Living Skills and Leonard Cheshire's Can-Do project have been exploring Swansea: past, present, and future. In considering the copper industrial past of Swansea, the students have also explored the innovations in technology that are creating a greener approach to reducing carbon emissions in existing industry.
- Television coverage with Dr Rhiannon Chalmers Brown was interviewed on BBC Wales Today on her research and the demonstration unit established at Tata Steel in Port Talbot, as part of the RICE project.
- During the COVID-19 pandemic, RICE research was re-purposed for improving PPE mask technology.

These achievements and unanticipated impacts of the RICE initiative have been rolled out to a wider audience at conferences, via newsletters and through the RICE news, updates, events, blogs, and latest developments from the project published in the news section[66] of the website.

The operation has also introduced initiatives to support the scaling up of the outputs from RICE. There is the potential that this will create an opportunity to provide support to spinout companies emerging from academia and from the work of the RICE operation.

Furthermore, the RICE operation has exceeded CCT expectations and has been cited by WEFO as an exemplar.

RICE has actively supported other ERDF operations by providing evidence of carbon capture which they have been able to use to support their indicators. RICE presentations, expertise and models have been shared and utilised as best practice examples by other operations in Wales such as SWIC.

[65] https://www.rice.cymru/en/news.htm?id=201
[66] https://www.rice.cymru/en/news

4.2.12 Impact of COVID-19 and Brexit

The period of lockdown during the pandemic had a negative impact on many projects and for RICE this included losing staff, reduced access to laboratories and the suspension of some work, supply chains impacted the procurement of key materials, and the operation experienced difficulties obtaining working visas for essential overseas employees. However, unlike other ERDF programmes, by ensuring that researchers had contractor status on partner enterprise sites, the installation, and operation of 3 of the demonstration units (2 x Vale & 1 x Hanson) was not significantly impacted.

As with many people, the COVID-19 pandemic required staff to work from home and a sense of team and being part of the wider operation suffered.

A positive view of the COVID-19 pandemic included the use of digital signatures expediting the process of executing documents such as Confidentiality and Non-Disclosure Agreements (NDAs) Agreements and Memoranda of Understanding (MoU). Furthermore, there was an increased focus on paperless administration for the completion and execution of documents including MoUs, NDAs and Collaboration Agreements.

Brexit has also had an impact on the delivery of RICE including long shipment and manufacturing delays plus higher import costs on specialised equipment manufactured in the EU.

4.2.13 Variance in Spend Against Budget

There has been a 13% variance in spend against budget, which is within the allotted 15% threshold set by WEFO. The variance that has occurred is reportedly due to the impact of COVID-19 and Brexit, resulting in extremely long delays with procurement timelines and high costs associated with materials manufactured in the EU.

4.2.14 Sustainability of RICE

It was indicated by RICE staff that the long-term goal is to utilise the developed units to be the basis of ongoing commercial units that will create jobs and revenue for the Welsh economy. All units are noted to have plans for future utilisation resulting in continued contribution towards meeting the net zero goals. For example, hydrogen electrolysers are remaining at Hanson and Lark Hill locations with ongoing operation, while the algae biorefinery is being expanded and brought up to full commercial scale by Algae Products Limited.

In planning for the future, RICE has been proactive in engaging with external bodies and organisations outside Wales. In February 2023 RICE was represented at the 2023 Decarb Catalyst event in London titled "*How can we maintain momentum of industry decarbonisation to 2025 amid an energy crisis"?*- at which the RICE PI presented and then chaired a roundtable discussion on decarbonisation. The outcome of this event, for RICE, is a number of potential international collaborations.

The event was followed by a site visit to the RICE demonstrator at Vale. In total, as a result of this event 35 people from around the world, all from different industry sectors have booked to visit the RICE demonstrators.

RICE was also present at the 4th CCUS & Hydrogen Decarbonisation Summit in Leeds in March 2023 which assessed and reviewed the opportunities within the UK Energy Sector. The event explored how hydrogen can help the UK develop its own green energy source. In addition, it considered how CCUS might decarbonise the energy intensive sectors whilst producing a carbon circular economy.

The CCUS & Hydrogen Decarbonisation Summit focused on the projects and innovation around CCS and Carbon Capture and Utilisation (CCU)[67] within industrial operations as well as explored how hydrogen can decarbonise industry and transport. The summit brought together 500+ government officials, regulators, key industry stakeholders, leading academia, and service companies.

4.3 Collaborative Partners

In-depth interviews were completed with senior persons within 7 of the key collaborative partners. In this process, specific questions were asked in relation to the interaction with RICE, the quality of support from RICE, the impact of RICE and the challenges faced. The following section outlines the collated responses of these collaborative partners.

4.3.1 First Contact with RICE

The collaborative partners discussed how they first heard about RICE.

Referral from Third Party	3
Direct contact from RICE	2
Third-party event	1
Other Website (e.g. University website)	1

Table 6: First Heard About RICE

Each of the 7 collaborative partners first contacted RICE using these methods more than 2 years ago. Furthermore, all 7 of the collaborative partners dealt primarily with Swansea University, with one of the collaborative partners also working with the USW.

[67] CCU offers novel solutions to utilise carbon dioxide as a raw material, which helps to replace fossil fuels and chemicals and even produce entirely new products like “food without fields”. CCS technologies on the other hand help create net negative greenhouse gas emissions.

4.3.2 Progress of Projects

The collaborative partners are each at different stages of their project with RICE. This includes 5 projects in progress at the time of interviews and 2 projects complete.

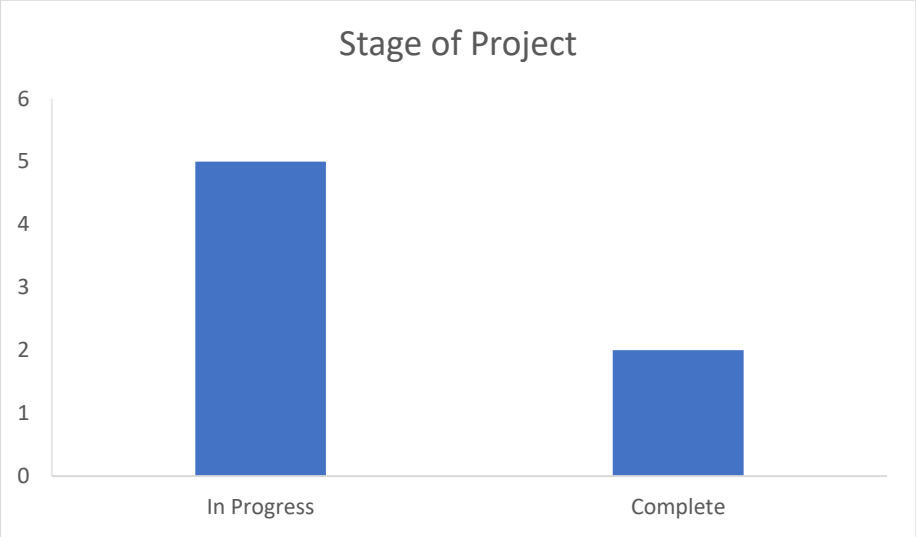


Figure 1: Stage of Project

4.3.3 Interaction with RICE

The collaborative partners have a differing level of project related contact with RICE. This includes most frequently for 4 of the collaborative partners at more than once a month, and less frequently, with 2 of the collaborative partners in contact with RICE 2 to 3 times per year.

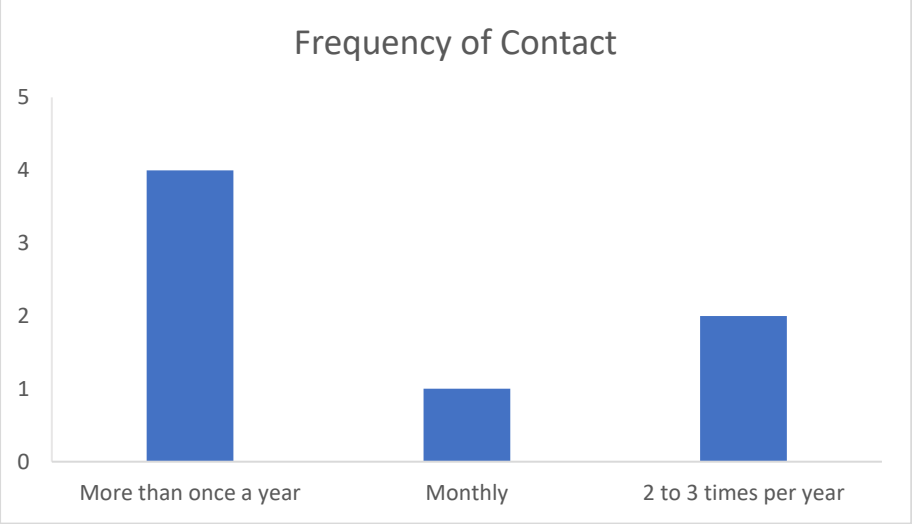


Figure 2: Frequency of Contact

The collaborative partners engaged with the RICE operation for a number of reasons as indicated:

To understand more	2	To collect information	1
Networking	3	To access funded research expertise and facilities	5
Collaboration	4	Product and/or process development	3
Advisory capacity	1	External view on existing project relating to carbon emissions	1

Table 7: Reasons for Engaging with RICE Operation

The majority of collaborative partners engaged with the RICE operation to access funded research expertise and facilities as well as collaboration.

4.3.4 Business Development Needs

The collaborative partners have business development needs, with 5 of the 7 collaborators focused on new products and process development, 3 needing technical expertise and 2 needing access to support and investment in research and development.

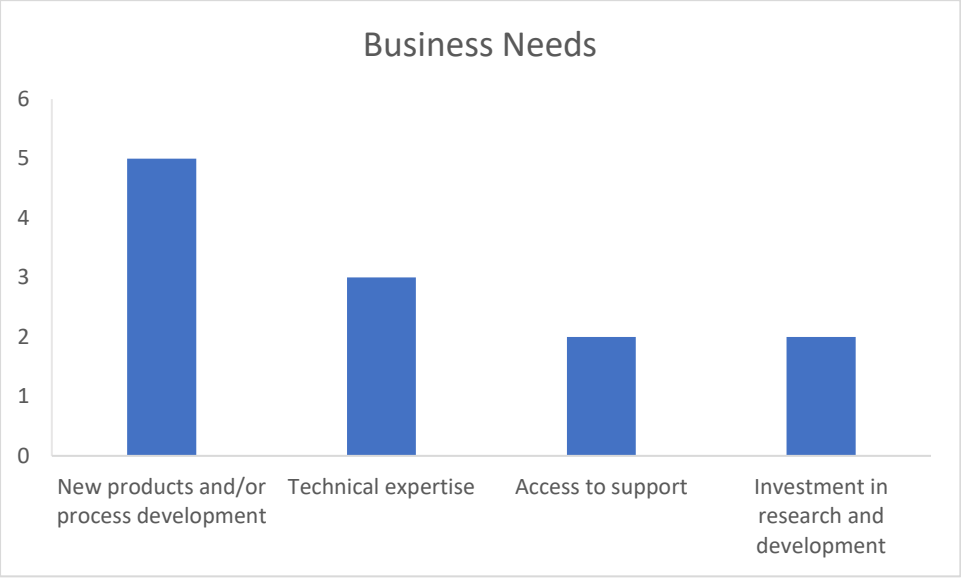


Figure 3: Business Needs

4.3.5 Quality of Support

The quality of support was ranked by the collaborative partners from 1 (poor), 2 (acceptable), 3 (good), and 4 (excellent). The collated responses are outlined below:

Ease of making initial contact	3.4
Speed of initial response	3.4
Quality of ongoing support or communication	3.4
Overall experience with RICE	3.2
How well the RICE programme and support available was explained to you	3
Setting a realistic expectation at the outset of what could be achieved	3.2
RICE understanding of your requirements	3
Ease of dealing with the paperwork	3
Quality of the support you have received	3.4
Amount of support you have received	3.4
Knowledge and expertise of RICE project staff	3.6
Overall value of the project to the business	3.2

Table 8: Quality of Support

The collated opinions of the collaborative partners have resulted in RICE being given a rating of good or above for each of the areas outlined above. Specifically, knowledge and expertise of RICE staff, ease of making initial contact, speed of response, quality of ongoing support and communication, and the quality and amount of support received were all rated highly by the collaborative partners.

It should be noted that 1 collaborative partner indicated that RICE is not good at building industrial relationships due to only holding one advisory group meeting. More regular communication would have been appreciated by the collaborative partner to drive priority needs and to ensure any research outcomes could be implemented.

Another collaborative partner identified paperwork processes acted as a deterrent to collaboration.

4.3.6 Barriers Faced

The collaborative partners indicated the extent to which their business faces the following challenges on a scale where 1 is low and 4 is high.

Financial constraints	2.4	Speed of technical change	2.3
Finding skilled people	1.8	Retaining skilled people	2
Time Pressures	2.2	Technical challenges	1.8
Cultural pressures	2.5	Winning new business	1.6
Retaining existing customers	1.8	Import of overseas products	2
Competition	1.8	Continuous R & D investment	2.4
Onerous legislation	2.3	Knowing where to go to get assistance	1.6

Table 9: Barriers to Business

As indicated, the collaborative partners currently face limited barriers to business. The greatest of these barriers include cultural pressures, continuous R&D development, and financial constraints.

The 7 collaborative partners responding to the question below also indicated the barriers they faced in their collaboration with RICE .

Finding match funding	1	Finding suitable technical expertise	1
Availability of your own time	1	Limitation of RICE resources	1
Availability of your own staff	1	Overcoming technical challenges	1
Your own technical resource	2	Paperwork processes	1
Project timescales	1		

Table 10: Barriers to Collaboration with RICE

Please note that some of the respondents faced more than one challenge and this table is to indicate challenges being faced by businesses in Wales and the breadth of the challenges being faced. It is not an analysis of individual businesses specific challenges, nor does it assess the depth or impact of the challenge. The collaborative partners indicated few barriers to collaboration with RICE, with 2 collaborative partners indicating their own technical resources as a barrier.

4.3.7 Impact of RICE

The RICE operation has had a positive impact on 5 of the 7 collaborative partner's perceptions of academia/industry collaboration.

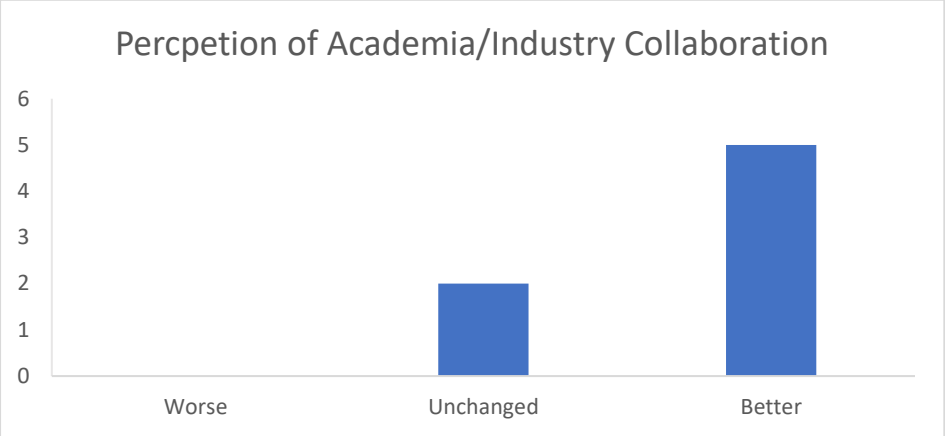


Figure 4: Perception of Academia/Industry Collaboration

The collaborative partners that indicated their collaboration with RICE did not change their perspective of academic/industry collaboration indicated that academia needs to have a better understanding of the industry, and universities need to change their approach to improve commercialisation prospects.

For the collaborative partners that indicated RICE had bettered their perspective of academia/industry collaboration, RICE was able to take a different approach that has not been seen in other universities. This includes making the transition from the laboratory to the real world.

As a result, 3 collaborative partners are more likely to engage in an industry/academic collaboration and 4 collaborative partners are equally likely.

Further to this, the collaborative partners were asked to discuss any improvements or impacts RICE had on their organisation.

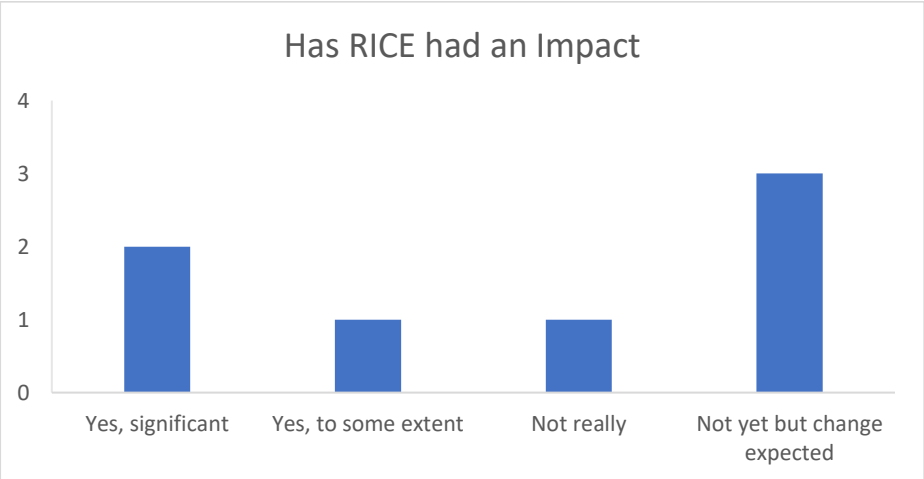


Figure 5: Has RICE had an Impact.

For all but 1 collaborative partner, RICE is expected to have a positive impact. The impacts expected include:

New in-house skills gained	2	Improved competitiveness	1
Improved quality	1	New Intellectual Property created	1
Improved processes	2	Accelerated research & development	2
New products developed	2	Reduced carbon footprint	3
Social benefits	1	Improved environmental processes	3
Cultural change	3	Wider understanding of carbon reduction	1
Improved efficiency	2	Improved growth prospects	2
New external contacts	3	Improved employment opportunities	1

Table 11: Impact Expected

The specific impacts the collaborative partners expected to experience or are currently experiencing are outlined below:

	YES Currently	YES Future	Projected Future Values
Increased level of business	1	1	£30 million
Increased employment		3	100
Increased Investment	1	4	£6 million
Promotion of Equal Opportunities		1	25
Promotion of Environmental sustainability	3	3	£100,000
Launch of new products or services	1	1	2 £100,000
Introduction of new processes or procedures	2	2	5 £650,000
Links to other business in West Wales and the Valleys	1	2	4 £50,000

Table 12: Value of Impacts

The RICE operation has had positive impact on many of the collaborative partners including:

- Increased level of business – 2 collaborative partners expect to increase their level of business by £30 million.
- Increased employment – 3 collaborative partners expect to increase employment by 100 employees in the near future.
- Increased investment – 4 collaborative partners expect to collectively increase investment by £6 million.
- Promotion of equal opportunities – 1 collaborative partner will increase policies relating to the promotion of equal opportunities by 25 beyond the life of RICE's current funding.
- Promotion of environmental sustainability – 4 collaborative partners expect to increase the promotion of environmental sustainability which will equate to an increase of £100,000.
- Launch of new products or services – 2 collaborative partners expect to or have launched 2 new products, equating to £100,000.
- Introduction of new processes or procedures – 2 collaborative partners expect to introduce 5 new processes or procedures equating to £650,000.
- Links to other business in convergence area – 3 collaborative partners will develop 4 new links to other business in the convergence area as a result of RICE, equalling an increase of £50,000.

As shown, many of the benefits the collaborative partners will experience as a result of their collaboration with RICE will result in the future, particularly in the longer term. In this section, some businesses indicated impacts in more than one time period. For example benefits may be realised by a business in both the medium term and long term.

Long Term (More than 3 years)	**4**	Medium-term (1 - 3 years)	**4**	Short Term (Less than 1 year)	**1**	No Benefits	**0**

Table 13: Timescale of Benefits

The collaborative partners will achieve benefits mainly in the medium (1 to 3 years) and long-term (3+ years).

Over the short term, collaborative partners will experience credentialization.

Over the medium-term, collaborative partners will experience:

- Investment in new technology
- Increased knowledge and understanding of green technology and work packages.
- Links to other clients
- New opportunities and contracts
- New processes

Over the long-term, collaborative partners will experience:

- Increased reputation
- Cost benefits
- Improved knowledge base
- Improved decision making
- New income stream

4.3.8 Future Prospects

Collaborative partners indicated a range of reasons for wanting to maintain contact with RICE in the future.

Advisory capacity	1	To be kept informed of developments	2
Networking	2	To access research expertise and facilities	2
Collaboration	4	Product and/or process development	3
Developing skills	1	To continue with an existing project	4
Strategic support	1	To work on a new or additional project	3

Table 14: Reason for Maintaining Contact

4 of the 7 collaborative partners interviewed would like to maintain contact with RICE for collaboration purposes, with 4 of the existing businesses interviewed wishing to maintain contact to continue with an existing project.

Although all the collaborative partners indicated they would continue to maintain contact with RICE, there were a few reasons given by collaborative partners that would encourage them to make **greater** use of the infrastructure or resources of RICE.

Access to technology	2	**Access to subsidised support**	1
Learning experience	3	**Access to expertise**	2

Table 15: Reasons for Making Greater Use of RICE

3 collaborative partners would make greater use of RICE for the increased learning experience, 2 collaborative partners would make use of RICE for access to technology and expertise, and 1 collaborative partner would make greater use of RICE for access to subsidised support.

4.3.9 Expectations

The collaborative partners were asked to discuss whether the RICE operation had met their expectations. The responses are outlined.

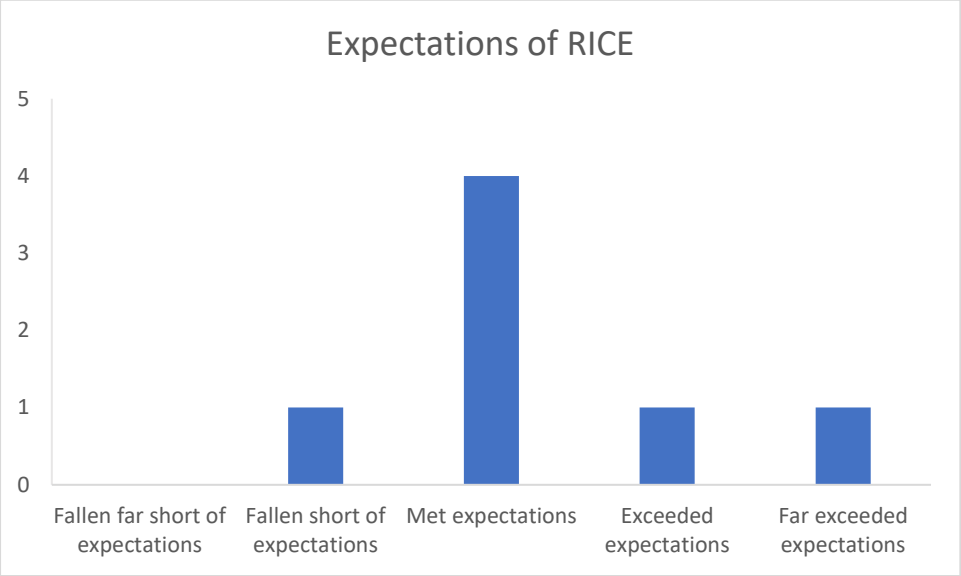


Figure 6: Expectations

4 of the collaborative partners believe RICE had met their expectations, 2 perceived RICE to have exceeded or far exceeded their expectations and 1 collaborative partner believed the operation had fallen short of expectations. The reasons given for these ratings are as follows:

Fallen Short of Expectations

- Insufficient communication and demonstration of technologies that can reduce carbon emissions. The real technical challenges were noted to not be communicated or updated enough.

Met Expectations

- RICE built the equipment as expected.
- Risks well managed
- Established realistic expectations at the outset of the project.

Exceeded Expectations

- New opportunities arose that were not envisaged at the outset.

Far Exceeded Expectations

- Practical approach taken and injection of new ideas. There was also involvement from all key personnel in manufacturing functions.

It was also noted by the collaborative partners that working with RICE has been a positive experience and supporting local industry and academia in South Wales has been important.

4.4 Ministerial Support and Observations

During the RICE celebration event in April 2023, RICE gave a presentation to the Welsh Government Minister detailing the achievements of the operation.

It was suggested during the presentation that RICE has been set out to be unlike any other WEFO project, as instead of being based on academic research, the goal of RICE is to move forward industrial decarbonisation in Wales. It is recognised that it is too late to talk or research the topic, it is time for action. As a result of this focus, RICE has achieved its goals and more and has developed technology not only for large industry but the smaller industry in Wales.

Some of the work undertaken by RICE (all of which is in the public domain) includes:

Hanson Cement

- RICE has installed a new class of green hydrogen production at Hanson Cement in Port Talbot with 3 years in operation,
- Unlike previous electrolysers for green hydrogen, this technology does not require pre-treatment of the water and is not affected by switching on and off (which is a major drawback for current commercial systems)
- The technology is ideal for Welsh small industry that has to meet Net Zero carbon emissions.
- The technology is being commercialised and exported to Australia and India as well as other possible partners.

Vale

- The UK's largest bio-reactor complex has been operational at Vale for 3 years.
- The technology allows for conversion of GHG (CO_2) to protein for animal and fish feed (and possibly human consumption) as well as a range of high value speciality chemicals.

Tata Steel

- A fermentation pilot unit has been installed at Tata Steel for conversion of blast furnace emissions into acetic acid.

Rockwool

- A unique resource for the UK has been installed at Rockwool that allows for UK industry to determine the optimum process for carbon capture using solid absorbents.
- The system allows absorbent manufacturers to test their products under real-world conditions. It was reported that there is no other system like this.

In response, the Welsh Government Minister for Climate Change indicated that there is a requirement to find a sustainable balance between decarbonisation and retaining

jobs, to which there is no easy solution. It was noted that the next transition must not be at the cost of economic prosperity and must build on the success of universities. The operation needs a credible pathway and solution to the present issues and industrial involvement is required rather than a theoretical plan. Finally, it was stated that businesses do not want any risk, they want proven technology that will work at an affordable price.

4.5 SWOT Analysis

The SWOT analysis illustrated was completed during the final evaluation based on interviews and discussions with RICE team members and collaborative partners.

Strengths	Weaknesses
➢ Delivering real change ➢ Deployed technologies into industry ➢ De-risking opportunities for industry ➢ Strong team building capability and developing internationally recognised expertise. ➢ Proven ability to form successful collaboration between academia and participating industrial companies. ➢ Making a tangible difference in prototype solutions that contribute to overcoming the complexity of industrial decarbonisation in Wales. ➢ CCTs successfully supported. ➢ Placing Wales on the map as a centre of excellence for decarbonisation research and innovation ➢ Involvement of industry in research gives it a tangible and practical element i.e., demonstrating larger scale proof-of-concept at industrial sites. ➢ Multi-faceted but synergistic work packages ➢ Strong leadership and vision	➢ Financial model not compatible with the workings of industrial partners ➢ Subject to too many changes imposed by WEFO in live project situations. ➢ Overestimation of target achievements. ➢ Scope and timescales overambitious, especially when required to meet WEFO output indicators. ➢ COVID-19 created unforeseen challenges and obstacles. ➢ Reliance on collaborative partners who sometimes failed to engage. ➢ Procurement delays ➢ University policy on purchase and procurement slowed development

Opportunities	Threats
➢ Further work with collaborative partners ➢ Utilise expertise and positive gains made in addressing and understanding the whole area of carbon emissions and the objectives for industry to meet the future net zero government targets. ➢ Support companies to develop their specific plans for meeting carbon emissions. ➢ Continue to seek funding to enable the RICE experience and expertise to be further developed and utilised. ➢ First to demonstrate technology in a real-world industrial setting ➢ Ability to demonstrate commercial viability. ➢ Attract further investment and public funding in South Wales ➢ Revenue earning activities to support sustainability	➢ Long term aspirations not fully supported by government funding. ➢ Companies not being able to participate or invest in projects due to other priorities and trading difficulties as a result of Brexit. ➢ Being more difficult to recruit and retain staff in a more competitive environment. ➢ Lack of continuity will result in researchers and staff moving on to alternative work and loss of momentum. ➢ WEFO audit inconsistency ➢ Lack of credit for sharing of research and collaboration activities by other projects

Table 16: SWOT analysis

4.6 Impact Analysis

Primary research conducted with RICE staff and collaborative partners explored the short (completion of the operation), medium (3 years) and long-term (3+ years) impacts the operation has or is likely to have. These responses have been outlined below.

Impacts	
Short-term	➢ Successful collaboration between academia and collaborative partners ➢ Involvement and collaboration with the formation of SWIC to help industrial decarbonisation in Wales and to meet the Welsh Government's future net zero targets. ➢ Prototype and demonstrator developments with collaborative partners have been highly recognised and showcased to build on for other energy related manufacturing plants in Wales. ➢ Small entity industries nearing net zero. Smaller and more agile organisations have adopted new processes more easily than larger and slower moving industries. ➢ Large industry making long term commitments to CCU
Medium-term	➢ New job creation with SMEs taking over one of the RICE industry demonstrators. This is going to be a commercial enterprise creating jobs and attracting investment. ➢ Regional supply of high value protein for Welsh fish farms ➢ Embedded and scaled-up technologies. ➢ Proven decarbonisation technologies and commercial viability ➢ Opportunity for industry funding solutions ➢ Development of a new consortia
Long-term	➢ Continuation of all the hardware and laboratory achievements in developing tests to measure emissions and to contribute to reduction targets. ➢ RICE outputs will feed into future workings of SWIC, and the companies supported. ➢ Act as a springboard to further decarbonisation research ➢ Net zero supply of protein to meet UK Government plans for food supply moving towards net zero. ➢ Provide a significant percentage of CCU for UK industry through adoption by small and medium entities. ➢ Long-term sustainable business based on the RICE demonstrator

Table 17: Impact Analysis

5

Report Sections
Executive Summary
Section 1: Introduction
Section 2: Mid-Term Report Outcomes
Section 3: Operational Review
Section 4: Evaluation Findings
Section 5: Logic Model
Section 6: Conclusion and Recommendations
Appendix

5 Logic Model

The logic model has been reviewed and outlines the operation's context, demand, activities, inputs, outcomes, and impacts.

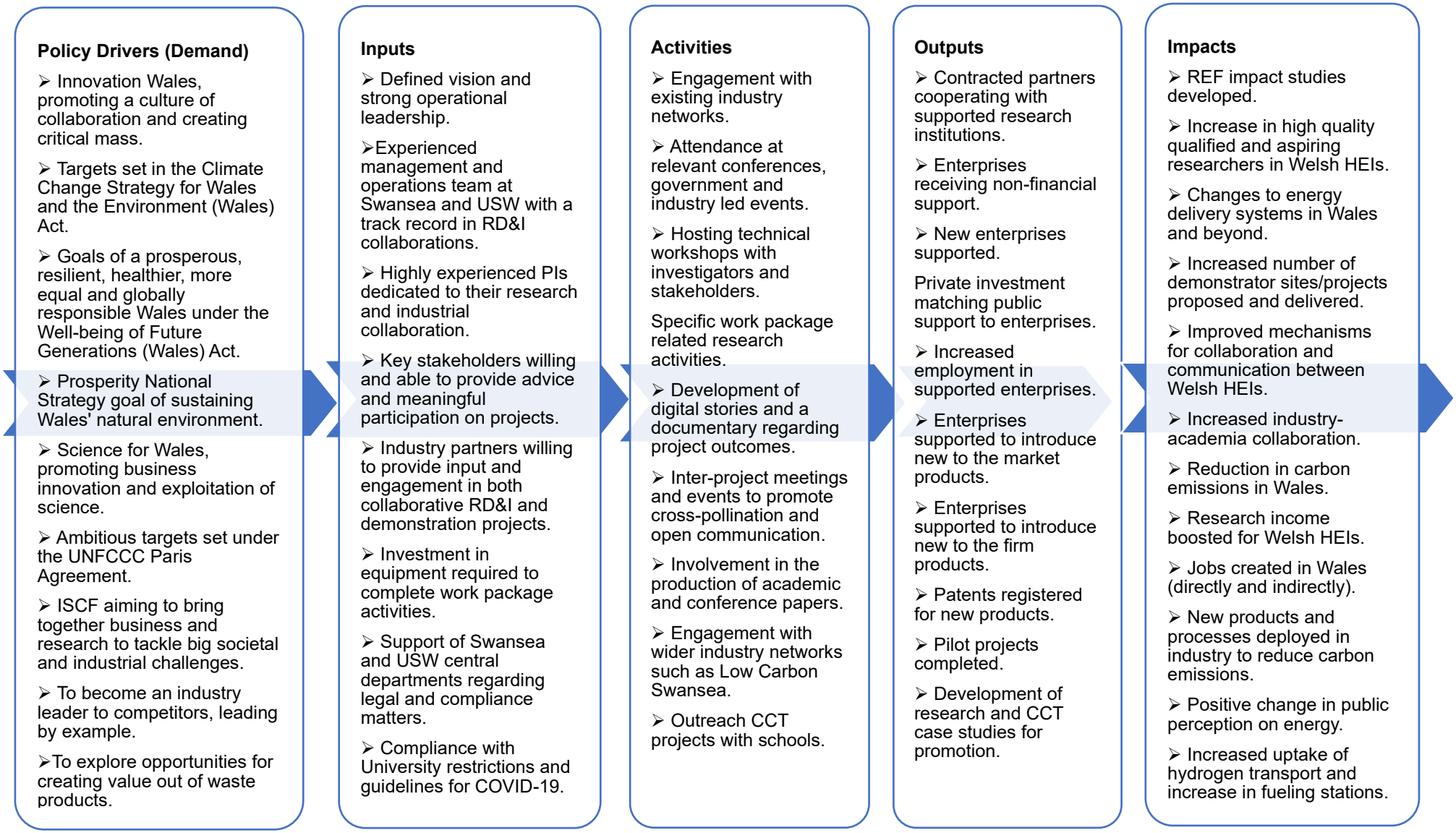


Figure 7: RICE Logic Model

Planned Impact from Logic Model	
REF impact studies developed.	REF Team at Swansea University hold related evidence
Increase in high quality qualified and aspiring researchers in Welsh HEIs.	Whilst no direct link can be attributed to RICE Intervention, it is evidenced that all Welsh HEIs are making significant commitment into energy research. Examples being the Cardiff University Energy Research cluster[68] , the Swansea University ESRI[69] initiative, Aberystwyth University IBERS[70] initiative, USW Sustainable Environment Research Centre[71], which is led by Principal Investigators on the RICE project, Bangor University National Research Network for Low Carbon, Energy and Environment[72].
Changes to energy delivery systems in Wales and beyond.	Since 2010, electricity generation in Wales from renewable sources has trebled. In 2016 renewables generated an amount equivalent to 43% of the electricity consumed in Wales. It is recognised that meeting the 70% target will require significant additional effort, both on energy efficiency and to bring forward additional generation to meet the increased need from the electrification of transport and heat. The Cabinet Secretary for Energy, Planning and Rural Affairs' response to the Welsh Affairs Parliamentary Committee inquiry on renewable energy report[73] proposes that the UK Government should take a broader interpretation of value for money in delivering the Clean Energy strategy. It should require more from industry and business in return for its support. The current auction mechanism only recognises the economic value of electricity and not the wider social and

[68] https://www.cardiff.ac.uk/research/explore/research-units/energy-research-cluster
[69] http://www.esri-swansea.org/en/research.htm
[70] https://www.aber.ac.uk/en/ibers/research-and-enterprise/research/climate-change-adaptation/crops-for-sustainable-energy/
[71] https://serc.research.southwales.ac.uk/
[72] https://www.bangor.ac.uk/energy/
[73] https://committees.parliament.uk/writtenevidence/94565/html/

	economic benefits. Similar mechanisms used in other countries do leverage these wider benefits. For example, South Africa included job creation and community ownership targets within their auction process. In Wales we have seen clear differences in approach between developers. Where developers work with local people and businesses to deliver projects; where people are involved in designing and have the opportunity to buy into projects, the projects can become important and welcome assets. We believe this local ownership is fundamental to the acceptability of future developments and have evidence it can be achieved at an affordable cost.
Increased number of demonstrator sites/projects proposed and delivered.	The RICE operation has generated 10 demonstrator sites in Wales. This significantly exceeds the target of 4 planned at the outset. Details that are available for publication have been outlined on the RICE website.
Improved mechanisms for collaboration and communication between Welsh HEIs.	RICE was a partnership of two HEIs in Wales and has enhanced the mechanisms for communication and collaboration between these two institutes. In addition, RICE has made a notable contribution with the ERDF funded FLEXIS App initiative led by Cardiff University. (As discussed earlier in this report). Vice-Chancellor of Swansea University, Professor Paul Boyle reported[74]: "Following our Queen's Anniversary Prize award in 2021, I am delighted that Swansea is the only university in Wales to have featured in this flagship Net Zero challenge. Our research and campus operations teams have worked together on this exciting project, **alongside other HE and FE institutions**, to develop a framework for carbon reporting. The report demonstrates what is possible with effective collaboration and shared ambition and provides a clear plan for our sector to achieve our critical Net Zero targets."

[74] https://www.swansea.ac.uk/press-office/news-events/news/2023/01/swansea-university-featured-in-flagship-net-zero-report.php

Increased industry-academia collaboration.	The level of collaboration with industry that has taken place would not have happened in the absence of RICE that has been an enabler in increasing industry-academia collaboration, setting a platform for ongoing collaboration and joint initiatives as evidenced in Section 4.4 of this report.
Reduction in carbon emissions in Wales.	The South Wales region is the second largest industrial emitter in the UK, releasing the equivalent of 16 million tonnes of carbon dioxide per year across industry and energy generation. In 2019, the UK became one of the first countries in the world to legislate that it will reach net zero carbon emissions by 2050. Whilst RICE has sought to educate and promote the importance of Carbon Reduction, it was a 63-month operation in a 30-year ambition. The Climate Change Committee Report[75] of 6th June 2023 advised that the First Carbon Budget (2016-2020) was achieved. Welsh greenhouse gas emissions decreased to an average of 28% below 1990 levels during the First Carbon Budget period. Wales has therefore achieved its First Carbon Budget, which required a 23% reduction. The report continues by stating that the Welsh Government has made insufficient progress on emissions reduction with the policy powers available. Action should now be focused on those sectors where Welsh Ministers have the greatest capacity to effect change. This is the best possible basis for deeper co-ordination and influence with the UK Government on those sectors where reserved policy plays a greater role in reducing Welsh emissions. The Second Carbon Budget (2021-2025) - the level of the Second Carbon Budget was set before Wales had a Net Zero target, to an average reduction in emissions of 37% compared to 1990 levels. This is too loose to be on track for Wales's later targets. – In October 2021 the Welsh Government published its plan for emissions reduction over this period. The plan projects to outperform the target

[75] https://www.theccc.org.uk/publication/2023-progress-report-reducing-emissions-in-wales/

	with a reduction of 44%. – A series of targets and milestones for deployment rates in each area of the economy are given in the plan, but the Welsh Government have not published a transparent quantification of how these add up to achieve the plan's sectoral emissions pathways.
Research income boosted for Welsh HEIs.	The ambition at the outset of RICE was to boost income for Welsh HEIs through further EU funded initiatives and operations. Brexit put a very severe stop to the sources of income for HEI projects and there is little evidence that any of the central Government Shared Prosperity Fund (SPF)[76], administered by 22 local authorities in Wales will be directed towards long term initiatives or pan Wales programmes. Whilst the UK Government indicated that the SPF would replace ERDF and ESF funding, this is not the case and Welsh HEIs will have to seek alternative sources of income. Vaughan Gethin, minister for the Economy reported[77] that the entire SPF allocation of £585 million to Wales is **£1.1 billion less compared to EU funds**. This dramatic funding cut has been exacerbated by a series of delays since the SPF was first announced in 2017.
Jobs created in Wales (directly and indirectly).	Evidence collated from key collaborative partners in RICE indicated the impact of COVID-19 and Brexit had delayed employment but projected that as a direct consequence of the RICE intervention, in the region of 100 jobs would be created in the future. Indirectly, the Careers Wales report titled the Green Economy in Wales[78] outlined job opportunities with the caveat that "Statistics are not easily available at Wales, regional and local granularity". The Future Generation Commissioner for Wales report: "Skills through Crisis: Upskilling and (Re)Training for a Green

[76] https://www.gov.uk/government/publications/uk-shared-prosperity-fund-prospectus/uk-shared-prosperity-fund-prospectus
[77] https://www.gov.wales/written-statement-delivery-uk-shared-prosperity-fund
[78] https://careerswales.gov.wales/sites/default/files/images/green-economy-in-wales-november-21_0.pdf

	Recovery in Wales[79] advised that over 60,000 jobs could be created in the green economy by 2022 with infrastructure investment although there is no evidence to show this has been achieved.
New products and processes deployed in industry to reduce carbon emissions	A collaboration between researchers at the Energy Safety Research Institute (ESRI) at Swansea University and insulation producer ROCKWOOL Limited has seen the installation of a new carbon dioxide demonstration unit at the company's manufacturing plant in Bridgend, South Wales. The research, which involves the capture of carbon dioxide gas, is an important technological contribution in enabling Wales and the UK achieve net zero carbon by 2050. The demonstration unit, which will capture carbon dioxide (CO_2) emissions from the manufacturing of insulation products, is being developed as part of the £11.5m Reducing Industrial Carbon Emissions (RICE) project which has been part-funded by the European Regional Development Fund through the Welsh Government and is aimed at the deployment of industrial scale demonstrations of new technology. As a point source of CO_2, the ROCKWOOL plant is a valuable location for RICE researchers to pilot their technology. The researchers have installed a mass spectrometer to analyse gas emission from ROCKWOOL manufacturing facilities, gathering detailed information which inform the separation system. Through utilising different adsorbent materials and varying conditions, researchers will conduct trials to determine the most effective set-up for removing the carbon dioxide. The demonstration unit will include a Pressure Swing Adsorption (PSA) system to separate carbon dioxide from the mixture of emitted gases.

[79] https://www.futuregenerations.wales/resources_posts/skills-through-crisis-upskilling-and-retraining-for-a-green-recovery-in-wales/

Positive change in public perception on energy.	The invasion of Ukraine and the impact on energy sources to Europe have put an immediate focus on the cost of energy and have dramatically increased public awareness and public perception of the need to be self-sustaining in terms of energy production. A UK Government commissioned publication in September 2022 titled BEIS Public Attitudes Tracker: Energy Infrastructure and Energy Sources[80], reported that 85% of people supported the use of renewable energy, such as wind power, solar energy, and biomass to provide electricity, fuel, and heat, with 51% strongly supporting this. Opposition remained very low, with just 1% of people saying they opposed renewable energy. Throughout its operation the RICE project has undertaken extensive engagement with the community to educate and advise the benefits of renewable energy. And whilst there has been no specific report commissioned to measure the change in public perception, the general consensus of the public as shown in the BEIS public tracker report, shows a general positive change in public perception on energy. A Renewable UK[81] news publication[82] in December 2022 on public attitudes towards renewables and tackling climate change shows that 88% of people support using renewable energy - a new record high - and only 2% oppose it. The newest wave of polling in the Public Attitudes Tracker, conducted in the autumn of 2022 and published in December 2022 by the Department for Business, Energy, and Industrial Strategy, beats the previous record of 87% set a year ago. When asked about individual technologies, 85% of people support offshore wind – another new record, beating the previous high of 84% set a year ago - and just 2%

80 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1105383/BEIS_PAT_Summer_2022_Energy_Infrastructure___Energy_Sources.pdf

81 https://www.renewableuk.com/

82.https://www.renewableuk.com/news/626061/

	oppose it. 79% support onshore with only 4% opposing it. 84% support wave and tidal energy while just 1% oppose it. 74% of people say renewable energy provides economic benefits to the UK. The percentage of people in the UK who are concerned about climate change remains high at 83%, and the percentage of people who say they are "very concerned" has risen from 39% to 45%. The poll also shows the percentage of people aware of the concept of Net Zero remains high at 90%
Increased uptake of hydrogen transport and increase in fueling stations	A collaboration between researchers at the Energy Safety Research Institute at Swansea University and cement producer Hanson UK has seen the installation of a new green hydrogen demonstration unit at the company's Regen GGBS plant in Port Talbot, South Wales. The demonstration unit, which generates green hydrogen through renewable energy, has been developed as part of the £9.2m RICE project which has been part-funded by the European Regional Development Fund through the Welsh Government, and is aimed at the deployment of industrial scale demonstrations of new technology. Cement production is energy intensive due to the high temperatures required to produce clinker – the main component of Portland cement. Hanson's Port Talbot plant produces Regen GGBS, ground granulated blast furnace slag, which is used as a replacement for up to 80 per cent of the cement in concrete. Although Regen is also an energy intensive product, using large amounts of natural gas and electricity, its carbon footprint is about one tenth of Portland cement. The aim of the demonstration unit is to replace some of the natural gas used at the plant with green hydrogen, which is considered a clean source of energy as it only emits water when burned, reducing CO_2 emissions from the burner, and reducing the carbon footprint of Regen even further.

	The demonstration unit is producing hydrogen at Hanson's Port Talbot plant through the process of electrolysis. Renewable energy is generated through wind and solar on site and the energy is directed into the electrolyser or water splitting device. The electrolyser can efficiently utilise this energy to split water into hydrogen and oxygen. The hydrogen is then passed into the burner to enrich the combustion mixture, saving carbon emissions from the burning of natural gas. Please also see Section 3.4.7 pf the Welsh Government report Hydrogen development in Wales - Baselining report into hydrogen activities and expertise in Wales [83]

[83] https://www.gov.wales/sites/default/files/consultations/2021-01/baselining-report-hydrogen-development-in-wales.pdf

6

Report Sections
Executive Summary
Section 1: Introduction
Section 2: Mid-Term Report Outcomes
Section 3: Operational Review
Section 4: Evaluation Findings
Section 5: Logic Model
Section 6: Conclusion and Recommendations
Appendix

6 Conclusion and Recommendations

6.1 Conclusion

CIOTEK has undertaken a thorough review of the RICE operation at its final stage, and it is clear that the operation has been consistent in terms of conducting its activities to achieve its goal "*to increase the successful translation of research and innovation processes into commercial products, processes and services, in particular through improved technology transfer from HEIs*".

RICE has made exceptional progress in creating a critical mass of carbon reduction demonstrators in Wales, through collaboration with key industrial partners. Industrial engagement has remained a core focus of the programme alongside the collaborative research and development activities to identify and introduce carbon reduction technologies and alternative fuel sources.

As an operation designed to reduce carbon emissions in Wales, the RICE operation has remained directly aligned with the political context of Wales, the UK and internationally, and is aiming to be a fundamental initiative in supporting the Welsh and UK governments to meet the 2050 targets for carbon reduction.

The operation focus supports the Welsh Government objectives defined in the Future Wales National Plan 2040[84] (Specifically pages 10, 13, 45 and 46). The document asks 7 key questions to help with determining its progress. The first of which is: *Has Wales supported decarbonisation?*

[84] https://www.gov.wales/sites/default/files/publications/2021-02/future-wales-the-national-plan-2040.pdf

Future Wales National Plan 2040

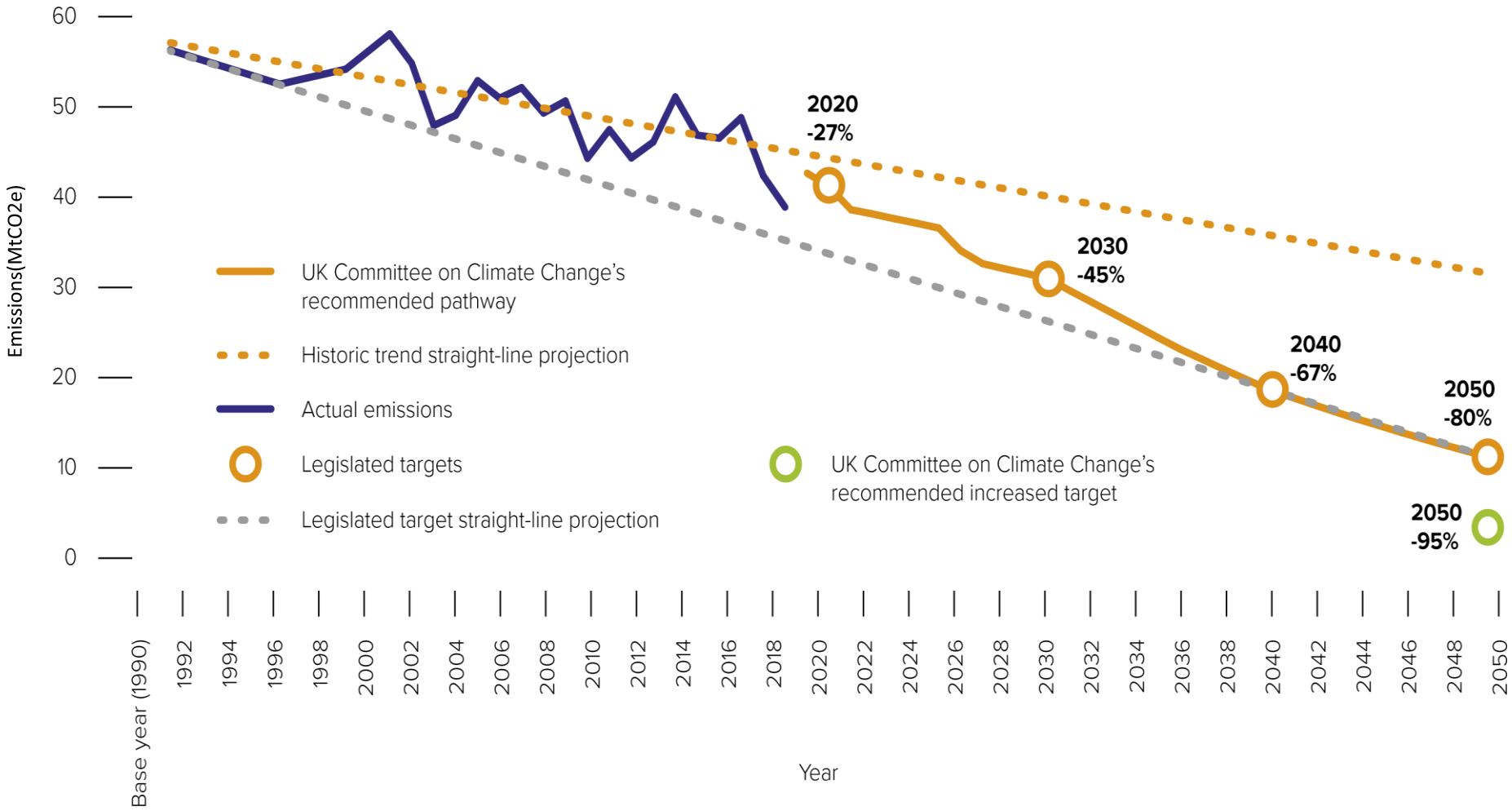


Figure 8. Progress Made in Meeting Greenhouse Gas Emissions Targets in Wales

The final evaluation evidenced that the RICE operation is directly aligned with the Welsh Government's economic priorities under the February 2023 Wales Innovates publication. Specifically, within the manufacturing section of this document the Welsh Government's ambition to address the issues of climate change and the need to decarbonise align with RICE's achievements. The Wales Innovates publication[85] notes that in 2019, the industry and business sector accounted for 38% of Welsh emissions, at 14.83 MtCO2e. Following on, the climate and nature section of the report states:

> *Innovation will support a significant increase in the deployment of renewables which drive low-cost and accelerated electrification. The economy will also need to become more resource and energy-efficient with cost effective technologies removing emissions from the atmosphere. Hydrogen will play a significant role, as innovation reduces costs and enables fuel switching.*

Ambitions which align directly with the ethos and strategy of the RICE operation.

The evaluation also evidenced that the RICE management structure has continued to be a strong backbone of the operational team with regular and frequent meetings keeping the multiskilled team updated and involved. Visionary and effective leadership was cited by a number of contributors as being one of the catalysts that encouraged exploration and innovation.

Stakeholder engagement has been of core importance at all stages of delivery and the operation has been proactive in engaging new key industry partners. In respect of impacts and targets, the reprofile set a new balance and despite the advent of COVID-19, the operation has made significant impact towards these targets, with projections suggesting that all indicators will be achieved (and potentially exceeded) over the next 5 years.

The evaluation verified that the RICE operation's approach to CCTs has been both diligent and proactive. CCTs have been embedded in many of the activities and delivery of RICE and it was only the COVID-19 pandemic which temporarily interrupted its progress. Despite this, RICE has achieved 71 CCT case studies and 110 interventions which resulted in RICE being recognised by the Welsh Government as an exemplar organisation.

Overall, the collaborative partners have benefited greatly from the RICE operation and will continue to receive these benefits over the longer term. RICE met or exceeded many of the collaborative partner's expectations, resulting in a very successful operation.

[85] https://www.gov.wales/wales-innovates-creating-stronger-fairer-greener-wales-html

6.2 Recommendations

Based on the final evaluation of RICE, the following recommendations are proposed for consideration for the future

Recommendation 1. Maintain ongoing engagement with collaborative partners.

Given the understanding by both parties in the collaboration that the work to date has established a foundation for the future, it is recommended that longer-term contractual agreements are put in place clearly outlining the obligations and commitments of the parties involved.

Recommendation 2. Explore additional opportunities with collaborative partners.

This, following on from the mid-term recommendations and, given that the funding model has changed due to Brexit and that future funding will be from different sources, it is recommended that in-depth discussions are held with each of the collaborative partners at the earliest stage to determine whether ongoing commitment and resource to support further opportunities for additional projects exists. The Welsh Government 2019 document titled "Prosperity for All: A Low Carbon Wales"[86] defines one of the key actions as "Collaborate with business to further decarbonise their activities whilst at the same time improve their competitiveness and productivity to take advantage of the opportunities arising from the transition to a low-carbon economy" It is recommended that future collaborations explore funding or a funding contribution by the collaborative partners. In particular, this should be achievable for multi-million-pound operations that have both the desire and the obligation to reduce carbon emissions within their own organisations.

Recommendation 3. Plan for continuation and future sustainability

The targets for carbon reduction in Wales and the UK are long term and it is recommended that the RICE operation seek support from the Welsh government for a continuation of funding beyond the current ERDF project. The ambition of the UK and Welsh governments have been clearly outlined in publications such as **Energy Wales**[87] and the **Climate Change Strategy for Wales**[88].

It now needs to be recognised that there Is a requirement for both a strong driver and appropriate levels of funding to realise the ambitions within these documents. RICE has established both a track record and a team of highly skilled individuals and it is critical that the momentum that has been achieved is not allowed to slow down or falter

[86] https://gov.wales/sites/default/files/publications/2019-06/low-carbon-delivery-plan_1.pdf
[87] https://gov.wales/topics/environmentcountryside/energy/energywales/?lang=en
[88] https://gov.wales/topics/environmentcountryside/climatechange/emissions/climate-change-strategy-for-wales/?lang=en

due to political indecision. This in particular applies to some of the smaller, indigenous Welsh businesses who may need some form of funding support to achieve their carbon reduction ambitions.

Recommendation 4. Future monitoring of achievements

Recognising that many of the benefits and impacts from the intervention are expected to arise beyond the ERDF funding for RICE. It is recommended that a review is undertaken after 12 months and then again after 3 years to evaluate the post funding impacts achieved as a result of the RICE support and intervention. Given that RICE will no longer exist, it is recommended that this should be undertaken by either ESRI or an external organisation. It is recognised that there will need to be funding made available to facilitate this process from whomever wishes to see these results in the future.

A

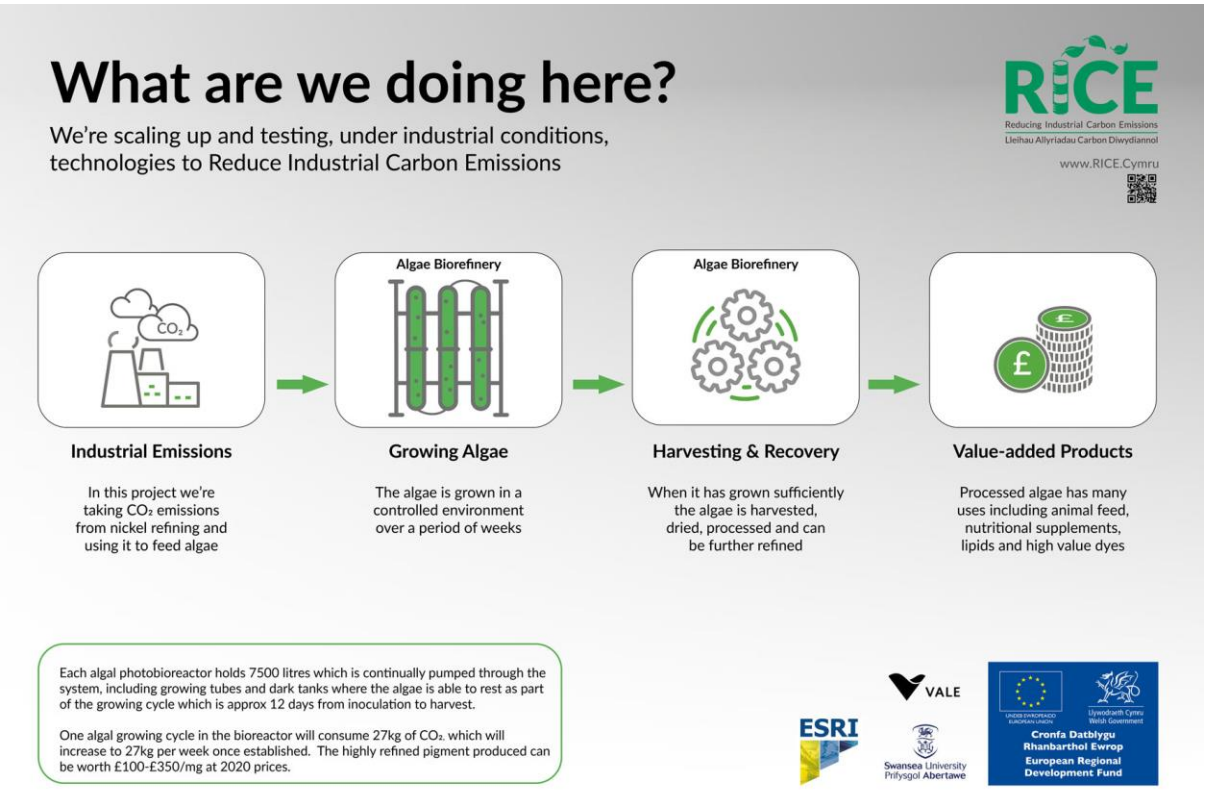
Report Sections
Executive Summary
Section 1: Introduction
Section 2: Mid-Term Report Outcomes
Section 3: Operational Review
Section 4: Evaluation Findings
Section 5: Logic Model
Section 6: Conclusion and Recommendations
Appendix

Appendix A – Algae at Vale[89]

RICE has established a demonstration unit at the Vale Nickel refinery in Clydach, Swansea UK.

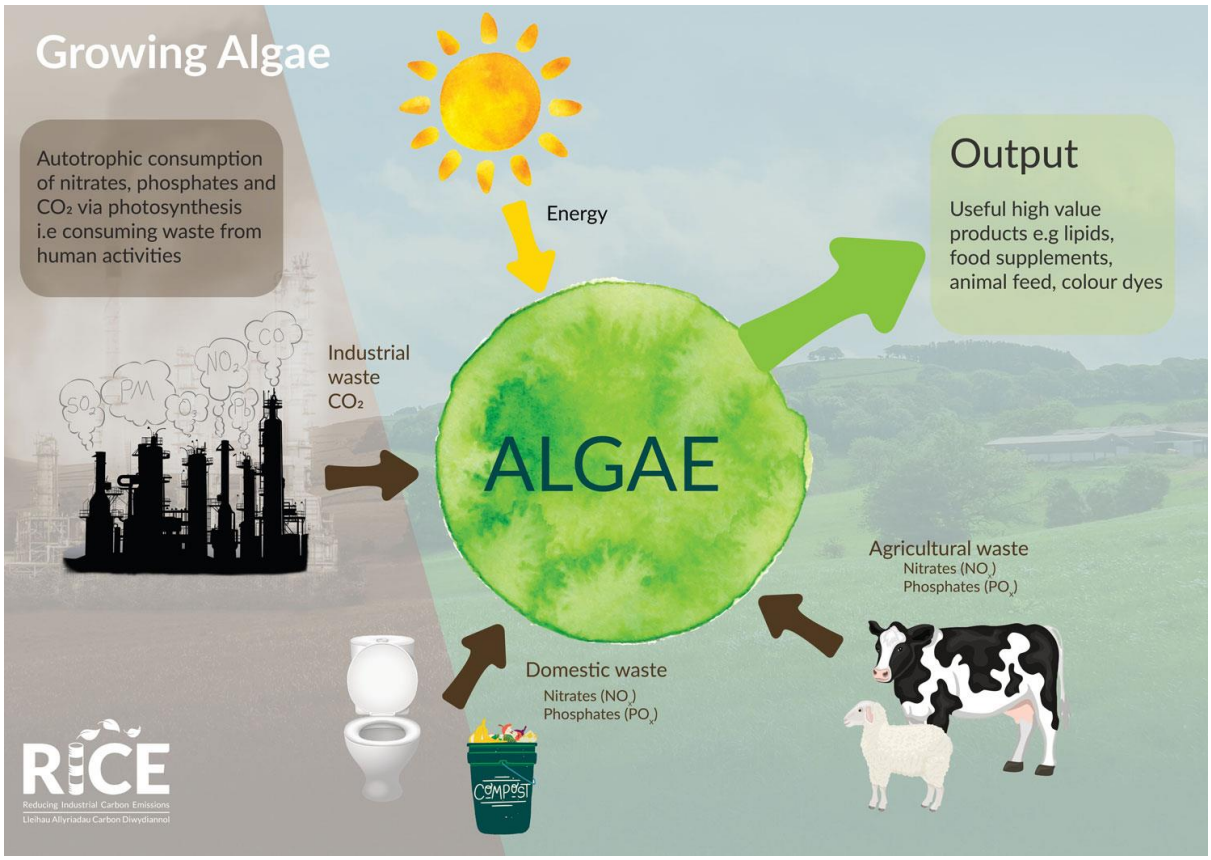
https://youtu.be/yiPlcqFlK1Q

The illustration below explains what we're doing at the demonstration site and the processes we're undertaking.



In order to photosynthesis and grow algae requires energy (from the sun or artificial lighting), nutrients and CO_2. The CO_2 is being taken from the waste emissions of nickel refining and fed into the biorefinery.

[89] https://www.rice.cymru/en/algae-at-vale



Below is a video of the polytunnel, which houses the biorefinery, being built over a period of time.

https://youtu.be/peAgInN6G1M

And here's the bioreactor being inoculated with algae for the first time.

https://youtu.be/bJs3l064vhA

Images of the project as it progresses can be viewed in the RICE gallery

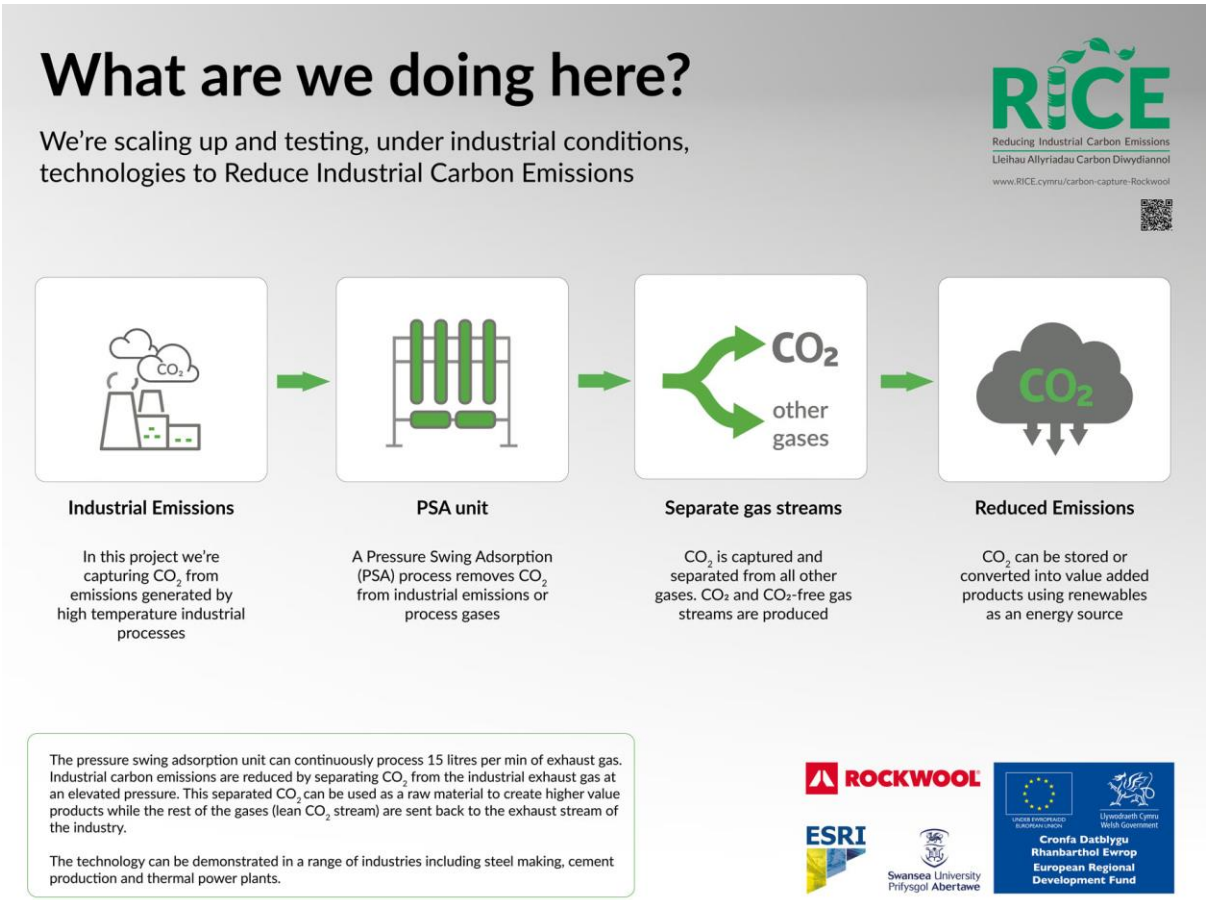
B

Report Sections
Executive Summary
Section 1: Introduction
Section 2: Mid-Term Report Outcomes
Section 3: Operational Review
Section 4: Evaluation Findings
Section 5: Logic Model
Section 6: Conclusion and Recommendations
Appendix

Appendix B – Carbon Capture at ROCKWOOL[90]

RICE has established a demonstration unit at the Bridgend plant of insulation producer ROCKWOOL.

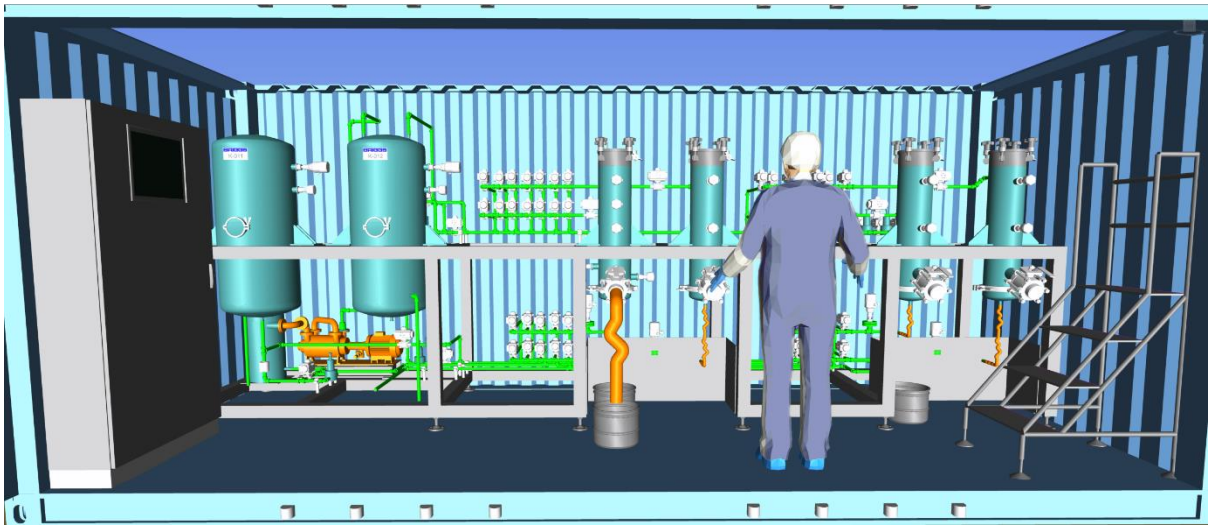
The illustration below explains what we're doing at the demonstration site and the processes we're undertaking.



Carbon Capture and Usage (CCU) is the process of capturing CO_2 to be recycled and is one of the technologies available to reduce greenhouse gas emissions from industrial pollution through separating CO_2 from other gases (N_2, H_2O, and others) present in flue gas.

[90] https://www.rice.cymru/en/carbon-capture-rockwool

WP1 is developing a cost-effective pressure swing adsorption (PSA) unit for post-combustion CO_2 capture from industrial plants. The pilot PSA unit will shortly be deployed at the ESRI Hub and will demonstrate CO_2 separation from simulated flue or exhaust gases using standard adsorbents like zeolites or activated carbon etc. in four packed beds. In addition, the unit will have four bypass microreactors to test novel adsorbents in the range of a few grams as can be synthesised on laboratory scale. Below is a diagram of the PSA unit which is housed within a shipping container.



The PSA unit can continuously process 15 litres per minute of exhaust gas, and carbon emissions are reduced by separating CO_2 from exhaust gas at an elevated pressure. The technology can be utilised in a range of industries including steel making, cement manufacturing industries, thermal power plants and the separated CO_2 can be used as a raw material to create higher value hydrocarbons.

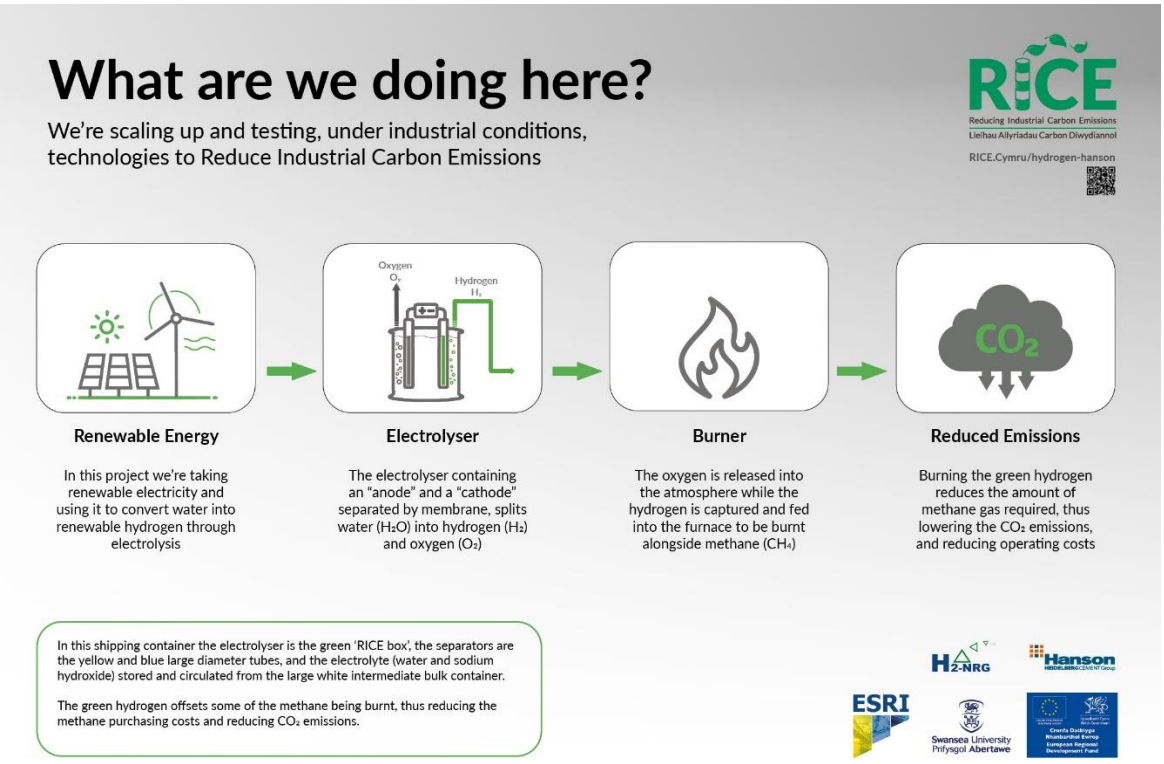
C

Report Sections
Executive Summary
Section 1: Introduction
Section 2: Mid-Term Report Outcomes
Section 3: Operational Review
Section 4: Evaluation Findings
Section 5: Logic Model
Section 6: Conclusion and Recommendations
Appendix

Appendix C – Hydrogen at Hanson[91]

RICE has established a demonstration unit at the Port Talbot plant of cement producers Hanson UK.

The illustration below explains what we're doing at the demonstration site and the processes we're undertaking.



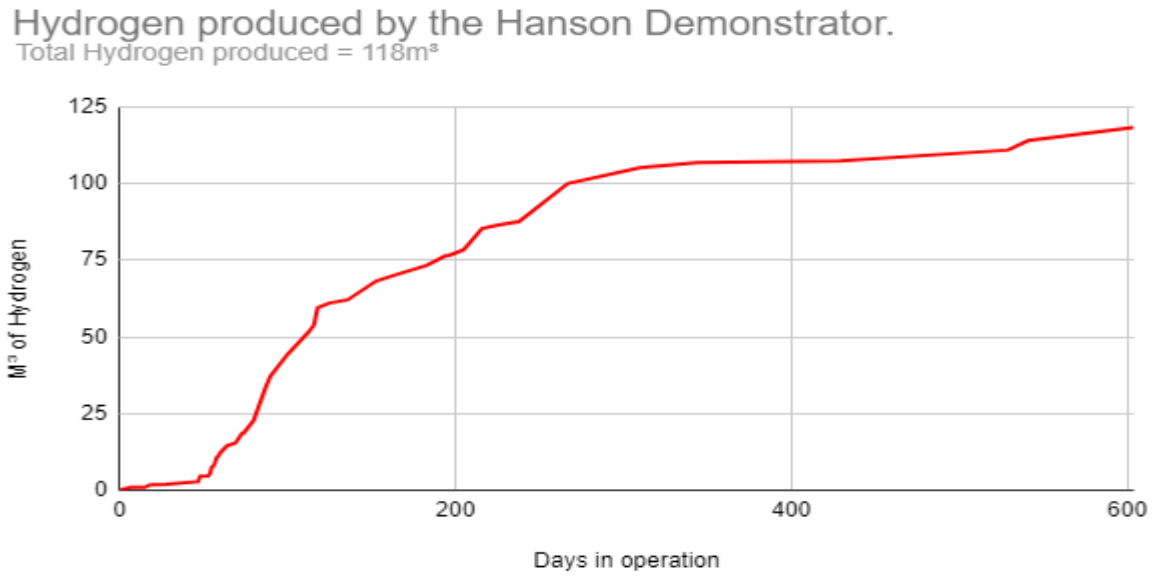
https://youtu.be/rhEjQ-FnGhQ

[91] https://www.rice.cymru/en/hydrogen-hanson

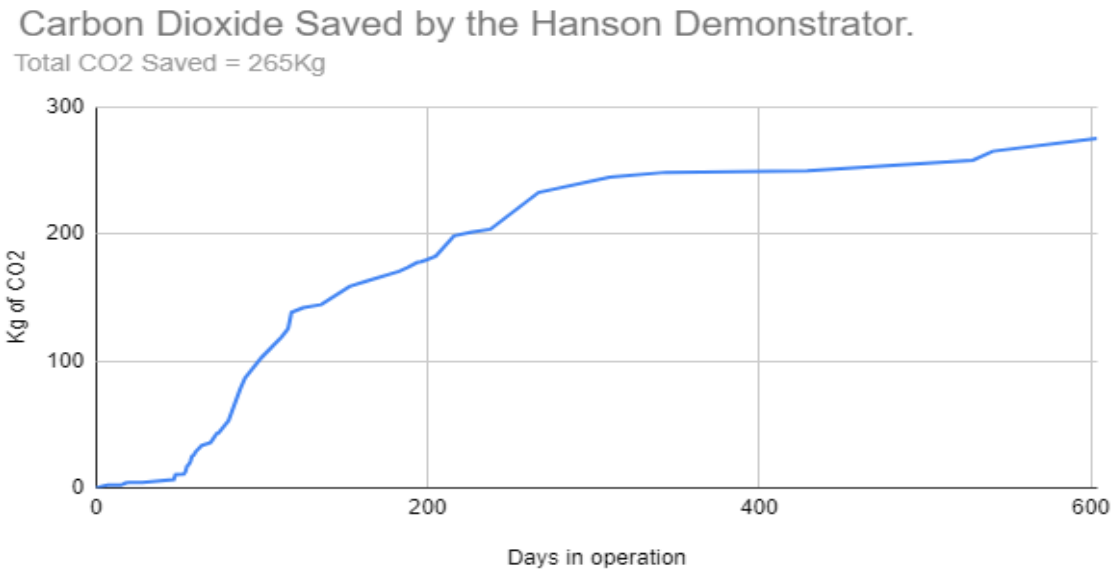
Research

A considerable amount of research activity is taking place at the demonstration unit, and we're gathering vast amounts of data as part of the research.

This chart indicates the amount of hydrogen currently being produced by our demonstrator at the plant.



And this graph illustrates the amount of carbon dioxide being saved.



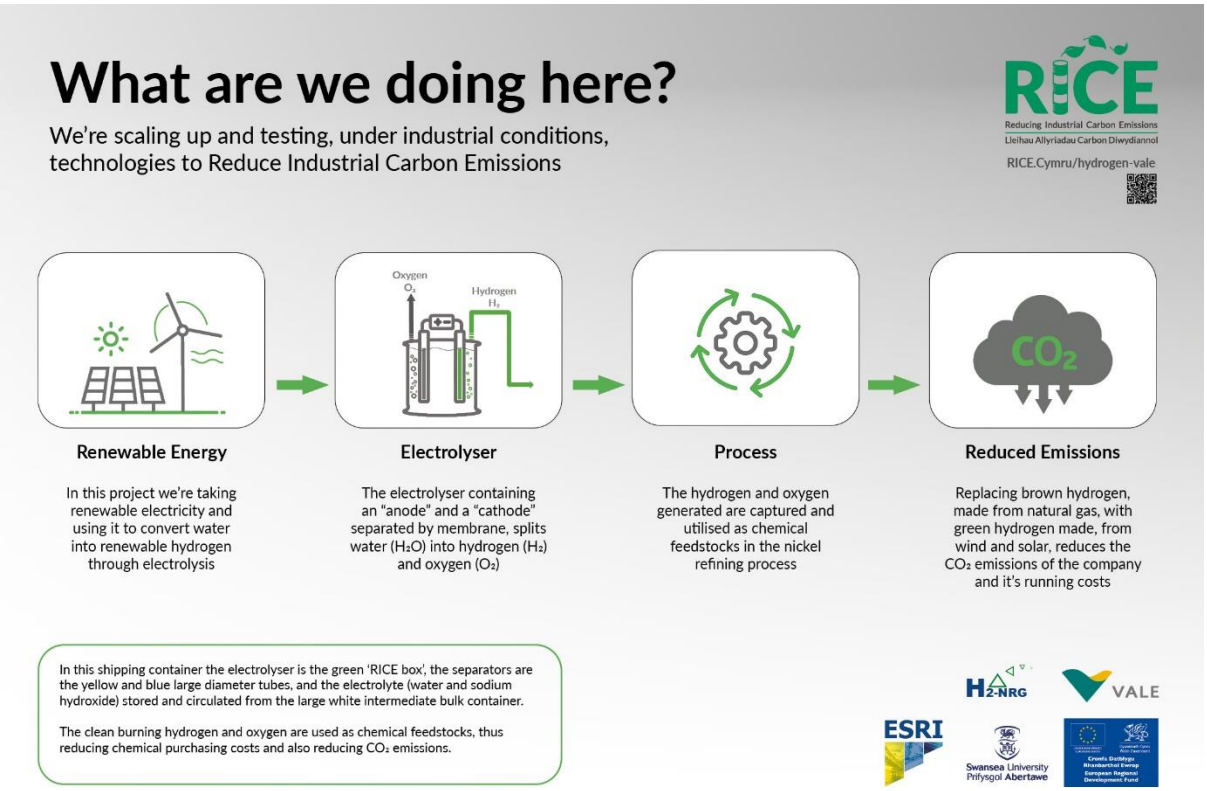
The unit itself is a converted shipping container shown below, and we have more images from the demonstration site available in the Hydrogen Demonstration Unit at Hanson UK in Port Talbot gallery.

https://youtu.be/XsqFpO0FUwA

D

Report Sections
Executive Summary
Section 1: Introduction
Section 2: Mid-Term Report Outcomes
Section 3: Operational Review
Section 4: Evaluation Findings
Section 5: Logic Model
Section 6: Conclusion and Recommendations
Appendix

Appendix D – Hydrogen Vale[92]

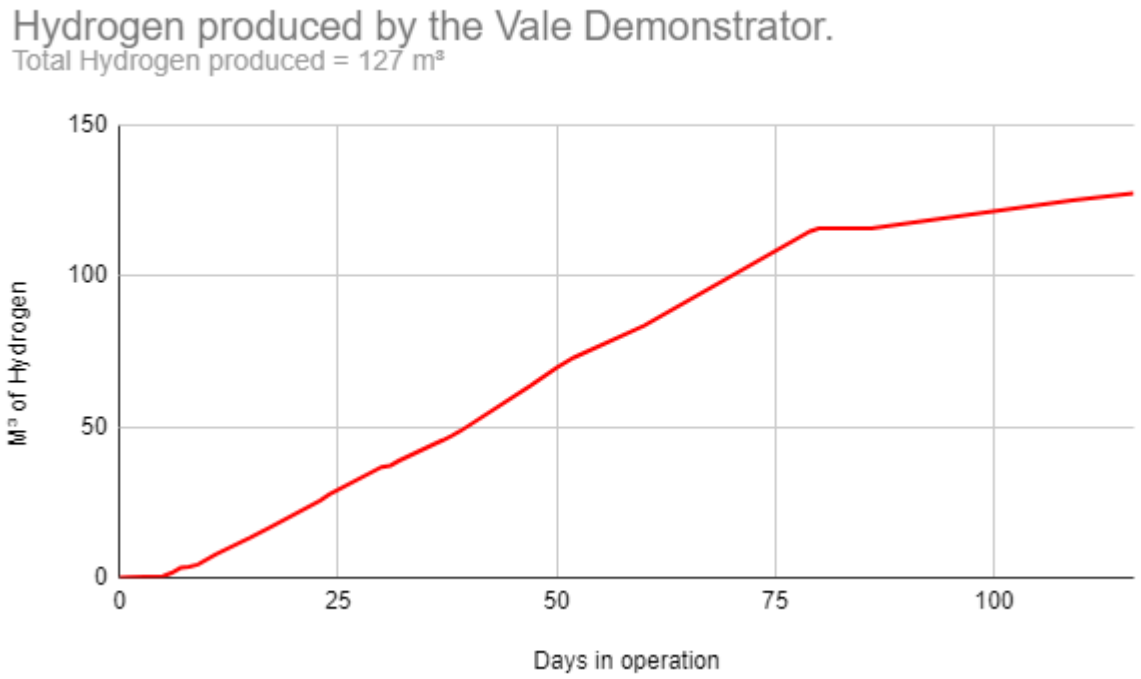


Research

A considerable amount of research activity is taking place at the demonstration unit, and we're gathering vast amounts of data as part of the research.

This chart indicates the amount of hydrogen currently being produced by our demonstrator at the plant.

[92] https://www.rice.cymru/en/hydrogen-vale


Hydrogen produced by the Vale Demonstrator.
Total Hydrogen produced = 127 m³
150
100
50
0
M³ of Hydrogen
0
25
50
75
100
Days in operation