Large scale energy storage

CryoHub

Developing Cryogenic Energy Storage at Refrigerated Warehouses as an Interactive Hub to Integrate Renewable Energy in Industrial Food Refrigeration and to Enhance Power Grid Sustainability

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1. Executive summary

The purpose of this report was to report on the investigation of alternative business strategies, models and concepts aimed at overcoming contextual barriers and increasing CryoHub market uptake and diffusion and review the market testing of alternative business strategies.
The report reviews the results of the face-to-face individual interviews, interactive discussions and workshops and desk research undertaken to explore the key market barriers drawing on some key analytical methodologies drawn from earlier research.

The refrigerated warehouse and food manufacturer interviews undertaken earlier in the project established existing attitudes and approaches to low carbon working and garnered initial responses to the opportunities presented by CryoHub technology. Later detailed, high level interviews, undertaken with University of Birmingham colleagues, tested responses to alternative market strategies. In addition the surveys undertaken with attendees of dissemination events held throughout 2020/21 were able to harvest further responses from a wide range of respondents.

Eleven in-depth interviews were undertaken with eight case study companies, throughout the project. A thematic analysis of the contextual barriers and enablers at play in each of the case study companies interviewed was undertaken revealing some key drivers and enabling conditions for CryoHub including:

- decision making processes and local autonomy;
- influence from customers and/or supply chain;
- the pursuance of environmental credentials;
- current employment of PV and other renewable technologies;
- access to and ease of grid connection;
- specific return on investment expectations;
- organisational energy/low carbon management targets and aims.

In addition to the individual organisational market strategy interviews, three CryoHub dissemination workshops took place between March 2020 and March 2021. Assessing the results from both the market strategy interviews and surveys it can be seen that:

- The most important issues regarding generation and use of energy were:
    - lowering energy bills – identified as most important factor by refrigeration sector interviewees;
    - reducing environmental impact, carbon emissions, pollution etc - identified as the most important factor in webinar surveys (average 74%) and in individual interviews as of key importance;
    - accessing new, additional revenue streams – identified in webinar surveys as the second most important factor (average 34%)
- The most important factors affecting decisions on the deployment of new energy technologies were:
    - Capital expenditure – identified as the most important factor in webinar surveys (average 63%) and joint most important factor by interviewees;
    - Impact on running costs – identified as second most important factor in webinar surveys (average 58%) and second joint most important factor by interviewees.
- Regarding attitudes to testing or demonstrating pre-commercial energy technologies – an average of 66% of survey respondees and 60% of interviewees said they were ‘enthusiastic’.
- An average of 89% of the webinar survey respondees were aware of benefits that may come from energy storage. Similarly, interviewees cited resilience, load shifting, cost reduction and revenue generation as key potential benefits although also noted that any potential benefits

also depended on technical capability, space use, cost and ROI issues.

Looking at the responses to the additional questions posed at the webinar in March 2021:

- 51% of respondees were enthusiastic about 3rd party investment in and/or management of new energy technologies in their businesses.
- The two most common factors that would encourage investment in CryoHub technology were:
  - Proven technology performance
  - Viable business case/ROI
- The two most common factors that would discourage investment in CryoHub technology were:
  - High capital and/or operating costs
  - Weak business case/ROI
- Interest in investing in CryoHub technology, if it were available now increased from 60% to 78% if discouraging factors were removed.

Links were also made between the intelligence gathered from the market interviews and webinar surveys and the key enablers and barriers to decarbonisation as identified by research feeding into the DECC/BIS roadmap report.

This report concludes that although there are hopeful signs for the development of energy storage in general including recent investment commitment for 2GWh of long duration liquid air energy projects in Spain, early adopters of energy storage will not be sufficient to create the magnitude of change that is needed.

By mapping the case study interviewees spoken to onto an organisational responsiveness framework, it can be seen that the organisations are representative of the sector, operating across a range of responsiveness levels.

Those with no specific energy targets, operating within appropriate laws and customer pressures, can be considered to be at the level of compliance. Those with active environmental and energy management systems and energy reduction targets are operating at the efficient management level. Those moving beyond efficiency and towards linking aspirational performance with company strategy are at the breakthrough projects level whilst those who have made the explicit link between decarbonisation and company strategy and who were demonstrating this with an appetite for ongoing experimentation and by seeking partnerships have reached the level of strategic resilience.

Organisations at the higher response levels are more strategically aligned to change, more outward facing and able to form partnerships and less risk adverse, with devolved responsibilities, appropriate expertise and a high degree of agency amongst staff helping to facilitate change. It makes sense for niche actors with novel technological ideas like CryoHub to target these forward looking organisations who, research shows, are open to establishing new types of relationships and joint working.

The question remains that with fossil fuel energy still so cheap it is difficult for renewables and energy storage to compete and until prices increase, few individual organisations have the appetite for the order of magnitude of investment currently indicated for CryoHub technology.

In this context, strategically the best opportunities moving forward may be to explore 3rd party investment in CryoHub technology through generators, aggregators, energy supply and service companies/ other investors. Shown through this research to be of appeal to some sector players (more than half of the respondents at the final webinar for example were enthusiastic about 3rd party investment in and/or management of new energy technologies in their businesses), this market strategy would overcome the key issues raised by the research respondents, in particular around

capital and operating costs, ROI restrictions, lack of requisite skills and the relative newness of the technology.

2. Introduction and context

2.1. CryoHub overview

The original stated aims of the CryoHub project are as follows: the CryoHub innovation project will investigate and extend the potential of large-scale Cryogenic Energy Storage (CES) and will apply the stored energy for both cooling and energy generation. By employing Renewable Energy Sources (RES) to liquefy and store cryogens, CryoHub will balance the power grid, while meeting the cooling demand of a refrigerated food warehouse and recovering the waste heat from its equipment and components.
The variable supply is a major obstacle to the RES power market. In reality, RES are fickle forces, prone to over-producing when demand is low and failing to meet requirements when demand peaks. Europe is about to generate 20% of its required energy from RES by 2020, so that the proper RES integration poses continent-wide challenges.
The CES, and particularly the Liquid Air Energy Storage (LAES), is a promising technology enabling on-site storage of RES energy during periods of high generation and its use at peak grid demand. Thus, CES acts as Grid Energy Storage (GES), where cryogen is boiled to drive a turbine and to restore electricity to the grid. To date, CES applications have been rather limited by the poor round trip efficiency (ratio between energies spent for and retrieved from energy storage) due to unrecovered energy losses.
The CryoHub project is therefore designed to maximise the CES efficiency by recovering energy from cooling and heating in a perfect RES-driven cycle of cryogen liquefaction, storage, distribution and efficient use. Refrigerated warehouses for chilled and frozen food commodities are large electricity consumers, possess powerful installed capacities for cooling and heating and waste substantial amounts of heat. Such facilities provide the ideal industrial environment to advance and demonstrate the LAES benefits.
CryoHub will thus resolve most of the above-mentioned problems at one go, thereby paving the way for broader market prospects for CES-based technologies across Europe.

2.2. Overview of Work Package 8 – Market barriers and strategies

Contextual factors form the basis of the regimes in which we operate and which we seek to change. These fundamentally non-technical aspects need to be recognised and attended to in order to develop and realise the potential of any technological change. Contextual activities typically take place in the individual, interpersonal, social, cultural, organisational, commercial, financial, economic, policy and regulatory spheres.
Previous work with the cold storage industry has demonstrated the important influence that contextual issues such as individual and organisational attitudes and behaviours, as well as cultural and market conditions, can have on the adoption of low carbon technologies and energy efficient practices. Non-technical barriers and enablers to technological change have been identified, which have then informed the development of strategies designed both to remove or overcome the blockages and encourage and diffuse any helpful practices.

Building on this knowledge, this work package has two key objectives:

- to investigate and identify the non-technical, contextual barriers and enablers to the refrigerated warehouse and food processing sector in realising the low carbon potential of

CryoHubs (defined here as cold energy storage systems that integrate renewable energy sources with liquid air energy storage).

- to examine the role that alternative business strategies and models have to play in delivering transformative CryoHub technology and in increasing its market uptake.

2.2.1. Purpose of deliverable

The purpose of this deliverable (8.4) is to:

- report on the investigation of alternative business strategies, models and concepts aimed at overcoming contextual barriers and increasing CryoHub market uptake and diffusion
- review the market testing of alternative business strategies undertaken through discussions and focus groups at dissemination events
- identify optimal means to disseminate outputs and feed into marketing campaigns

3. Scope & methodology

This report reviews the results of the face-to-face individual interviews, interactive discussions and workshops and desk research undertaken to explore the key market barriers and enablers to the uptake of CryoHub technology and to provide some analysis and scrutiny of emerging market strategies. Some of the earlier interviews were undertaken with CryoHub partner, Cranfield University. Later interviews and workshop/webinar research was undertaken with CryoHub colleagues at the University of Birmingham who have incorporated their analysis of the results into their policy reports D10.3 ***Communicating the benefit of, and necessary policy improvements to further support, CryoHub*** and D10.4 ***Updated report on policy***.

In undertaking the analysis for this deliverable, this report draws on some methodologies first explored in CryoHub D8.1 *2017* ***Report on the barriers to uptake of renewable and low carbon technologies***, specifically the *complementarities matrix* and *eco-sociotechnical regimes,* which are described briefly below.

3.1. Complementarities matrix

The interviews used the complementarities matrix as a framework to gather information and experience and also to promote further discussions and actions. It provided a template on which to map and understand the contexts for the cold store operators

Person	Position
Individual subjective factors	*Individual objective factors*
Personal values, worldview, assumptions	Role, skills, knowledge, experience, relationships
Company	**External**
Collective subjective factors	*Collective objective factors*
Group cultures, shared mindsets, shared norms	Political, economic, social, technological, legal, environmental

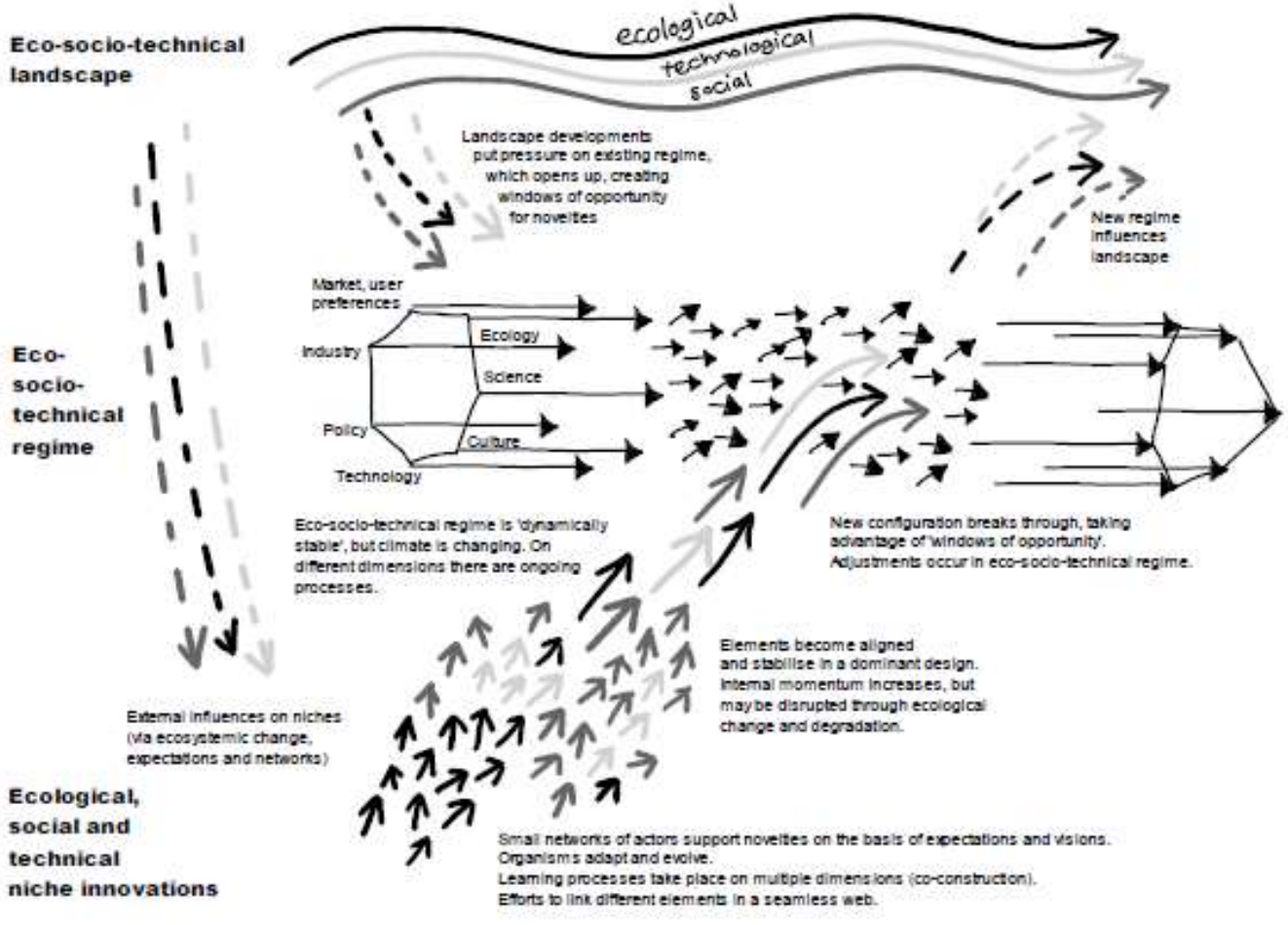
A thematic analysis of the key findings from all the interviews can be undertaken to identify the enabling conditions under each quadrant of the matrix that could contribute to a virtuous circle of performance in carbon reduction and the development of sustainable practices and strategies. This complemented the results and outcomes from the technical strands of the project, with the aim of helping to inform, motivate and enable cold store operators to attend to non-technical issues and develop appropriate market strategies.

3.2. Eco-sociotechnical regimes

The social process of shaping technology - the theories aim to go beyond what is sometimes seen as a technological determinist worldview, where technology is introduced in a linear fashion, with technological change being an exogenous factor introduced into social situations which are then affected by it.

Socio technical regimes are the relatively enduring and stable pattern of interactions: cognitive routines, regulations and standards, adaptations of lifestyle to technical systems, sunk investments in machines, infrastructures, and competencies. They take place at the level of organisational fields and create a lock-in to existing patterns. Recent work emphasises in addition the importance of the co-evolution of institutions with sociotechnical regimes

Technological niche - the "micro-level where radical novelties emerge. These novelties are initially unstable sociotechnical configurations with low performance, [they] act as 'incubation rooms'. Niche-innovations are carried and developed by small networks of dedicated actors, often outsiders or fringe actors; both niches and regimes have the character of organisational fields (community of interacting groups).



For regimes, the communities are large and stable, while for niches they are small and unstable. Both niche and regime communities share certain rules that coordinate action. For regimes, these rules are stable and well-articulated; for niche innovations, they are unstable and 'in the making'. In addition, the social dimensions of what Geels et al usually refer to as technological niches: issues of capacities for collaboration, cohesions, agency, purpose are also important aspects of the model.

Sociotechnical landscape - an exogenous environment beyond the direct influence of niche and regime actors (macro-economics, deep cultural patterns, macro-political developments). Changes at this level take place slowly (decades)", although have a dynamic quality. However this notion of landscape is limited because it is described as a human construct or paradigm. In reality, the landscape must include the 'real' planetary landscape particularly when the planetary ecology is under considerable damaging stress. As such, changes in the landscape may at times be discontinuous and therefore sudden rather than taking place slowly as Geels suggests.
The multi-level perspective argues that transitions come about through interactions between processes at three levels:

a) niche-innovations build up internal momentum, through learning processes, price-performance improvements, and support from powerful groups,
b) changes in the landscape level create pressures on the regime and
c) destabilisation of the regime creates windows of opportunity for niche-innovations.
The alignment of these processes enables the breakthrough of novelties in mainstream markets where they compete with the existing regime.

3.3. Organisational responsiveness

In addition to the complementarities matrix and the eco-sociotechnical regime models, the analysis draws on the 'organisational change for corporate sustainability' work of Dunphy, Griffiths & Benn (2003) and the development of this work by Alexander Ballard Ltd (2008) into the 'organisational responsiveness' model, which describes the transformational journey of organisations as they progress through a number of stages in response to the issues posed by climate change.
The organisational responsiveness model is a useful way to demonstrate how organisations can improve their sustainability and, specifically in the context of this work, their decarbonisation responses in six predictable stages, becoming able to handle issues of increasing complexity as they understand the issues better and build their own capacity. Table 1a below highlights the key characteristics of each response level.

The change process that supports an organisation's progression throughout the response levels is dependent on the development of capacity across nine of complementary and interactive developmental 'pathways', all necessary for improvement. These are set out in table 1b.

Table 1a: Levels of organisational responsiveness

Response level		Description	Characteristics
1	Business as usual	Non-responsive	Reluctant action, if any. No resources will be allocated. Most businesses have moved beyond this stage
2		Compliant	Respond to pressure from legislation or customers but won't be proactive
3		Efficient management	Recognise need for systematic management, but delegated to further down the organisation. Will be measurement systems and targets, ISO 14001 etc.
4	Transformational business	Breakthrough projects	Set targets for performance breakthroughs beyond status quo. Focusing on areas where win-wins with the organisation's other priorities are possible, such projects offer multiple benefits eg costs, revenues, reputation, relationships with stakeholders etc
5		Strategic resilience	Top management team recognise strategic importance. Active on the issues as a key part of strategic management of every part of organisation. Serious decarbonisation need an ability to work at this level.
6		Champion organisation	Still rare. Focus on influencing the political, social, legal and technological environments in which it operates in order to promote decarbonisation rather than just respond to it.

Not all organisations have an equally compelling business case to reach the higher response levels although those who take big, long term investment decisions, those who have a strategic role or who hold significant assets, usually have a business need to achieve response level 5, alone or with others.

Table 1b: Nine developmental pathways

Pathway	Description
Awareness	Capacity to grasp what sustainability and decarbonisation means for society, for the organisation and its mission and for particular areas of responsibility.
Agency	The capacity to spot, prioritise and develop opportunities for meaningful and timely action.
Leadership	The capacity of a formal leadership team to develop a strategic vision and to engage with, support, direct and legitimise its implementation.
Agents of change	The capacity to identify, empower and support individuals or groups of change agents to become an effective 'ecosystem' of champions.
Working together	The capacity to involve, respect the needs of, learn from, and act in collaborative partnerships with internal and external groups.

Learning	The capacity to identify and learn from the results of activities and other developments and to use learning to improve procedures, strategies and mission.
Managing operations	The capacity to get to grips with decarbonisation in a systematic way to ensure that intentions and policies turn into action.
Programme scope and coherence	The capacity to develop an overall programme of action suited to the scope of what the organisation is trying to achieve.
Expertise	The capacity to recognise, access and deploy the necessary skills, understanding and technical and change expertise to make the biggest difference.

Each pathway needs to be activated quite differently at each response level. It is not a case of doing more of the same thing but of doing things differently. There is often a double change agenda: both reinforcing the current position and moving ahead to the next response level.

4. Contextual barriers and enablers market research

This section outlines the direct research (supplemented by literature research) undertaken throughout the project both to establish existing practice and market operating conditions and to test alternative market strategies.

The refrigerated warehouse and food manufacturer interviews undertaken earlier in the project were able to establish existing attitudes and approaches to low carbon working and garner initial responses to the opportunities presented by CryoHub technology. Later detailed, high level interviews, undertaken with University of Birmingham colleagues, were additionally able to test responses to alternative market strategies. In addition the surveys undertaken with attendees of dissemination events held virtually (due to COVID restrictions) throughout 2020/21 were able to harvest further responses from a wide range of respondents. The following sections analyse all the research undertaken in more detail.

4.1. Overview of case study interviews

Throughout the duration of the project eleven in-depth interviews were undertaken with eight companies, operating refrigerated warehouses with over 0.5 MW average power input, from Belgium, Bulgaria, France, Hungary, Spain and the UK. Table 2 gives an overview of the case study organisations, outlining the types of company, their storage temperature profiles and key products stored.

Table 2: Overview of case studies

Case study	Type of company	Type of storage	Products
Case A	Dairy producer and manufacturer	Chilled store 3ºC and 5ºC	Dairy
Case B	Vegetable growers, processors and distributors	Chilled store 3ºC and 5ºC Freezer store -25ºC	Vegetables.
Case C	Public refrigerated storage and distribution	Freezer -20ºC and -18ºC Chilled +2ºC and +4ºC	Potato fries, ice-cream
Case D	Vegetable growers and processors	Freezer -18°C	Vegetables
Case E .	Public refrigerated storage and distribution	Cold store – 4 separate rooms Freezer - 20ºC	Mixed
Case F	Food retail	Ambient 11ºC to 19ºC Cold stores 0ºC to +5ºC Freezer - 24ºC to - 28ºC	Mixed
Case G	Food retail	Chilled Frozen	Mixed
Case H	Restaurant chain	Ambient Chilled +4ºC, +7ºC, +9ºC Freezer – 18ºC to -25ºC	Meat, dairy, salad

4.1.1. Complementarities matrix thematic analysis

The following matrices are a thematic analysis of the contextual barriers and enablers at play in each of the case study companies interviewed. They illustrate the key issues that were revealed, which are relevant to the uptake of renewable energy and CryoHub storage within the wider frame of each company's response to the energy efficiency and low carbon agenda. Viewed together a picture starts to emerge of the key drivers and enabling conditions for CryoHub in the refrigerated warehouse sector in terms of the combination of individual attitudes, beliefs, skillsets, company structures and cultural norms and external influences that are required to act together on order to create a 'virtuous circle' of potential change. These key drivers are drawn together in the subsequent section (reference Table 3)

Complementarities matrices

Company A

Personal		Position	
Barriers	**Enablers**	**Barriers**	**Enablers**
		Executive team are non-technical.	Engineering staff enabled to meet environmental objectives. New member of staff in key technical position – more open to change
Company		**External factors**	
Barriers	**Enablers**	**Barriers**	**Enablers**
Capital cost of installation Rate of return on investment Technical difficulties of operation and maintenance Not a desired core competence Lack of willingness to change (risk, cost, inconvenience …..etc).	Good environmental kudos – award winning Reduced electricity consumption Satisfying customer environmental objectives ISO14001 accredited - sets environmental targets and objectives, tracks progress towards carbon reduction targets and measures the carbon footprint related to on-site activities. The owner would like to decarbonise the brand by 2030 or much earlier and has cradle to grave aspirations	No pressure to change from Government	Customer demands

Company B

Personal		Position	
Barriers	**Enablers**	**Barriers**	**Enablers**
		Lack expertise on renewables	Design own energy efficiency equipment
Company culture		**External factors**	
Barriers	**Enablers**	**Barriers**	**Enablers**
	ISO14001 & ISO50001 accreditation	Regional variations in application of limits.	National best practice guides for consumption of

	Ongoing objective to reduce energy costs Trying out solar PV on one site	Grid connection difficult. Government licenses needed for RE and biased to larger installations. No feed-in tariff so less economic. Costs of renewable installations historically high.	energy, water & wastewater. Customer pressure for green credentials Costs of RE installations dropping

Company C

Personal		***Position***	
Barriers	**Enablers**	**Barriers**	**Enablers**
	For owner it's about being green and about independence, cost reduction and competitive advantage. Personal belief in green business.		Staff have requisite skills
Company culture		***External factors***	
Barriers	**Enablers**	**Barriers**	**Enablers**
	Piloting new technology and approaches. Ambition to create a 'virtual power plant'. Aspirations to be low carbon and have energy security. Focus on quality of contracts with customers and partners. Already have renewables on site. Culture of experimentation.		Very close relationship and shared values with key customer. Operations are ahead of regulations.

Company D

Personal		Position	
Barriers	**Enablers**	**Barriers**	**Enablers**
Current CEO prefers to invest the company's money directly into the operations of the business ie new production lines rather than in PV and other renewables			Company has Energy Efficiency R&D network with regional energy managers actively seeking new technologies
Company culture		**External factors**	
Barriers	**Enablers**	**Barriers**	**Enablers**
ROI of RE is still seen as too low	Company has a central sustainable development department and has a strong environmental ethos. The company is potentially interested in RE solutions delivered with an energy partner who would invest and share the benefits eg such as an ESCO. Has biomass plant partnership.		Market for frozen and fresh vegetables growing whilst market for canned vegetables declining.

Company E

Personal		Position	
Barriers	**Enablers**	**Barriers**	**Enablers**
		Problems with recruiting skilled workforce	
Company culture		**External factors**	
Barriers	**Enablers**	**Barriers**	**Enablers**
	Company has space for CryoHub technology. Company target to increase the green energy component of their supply when they next renegotiate their energy contract (as	Reliable energy supply - two alternate network paths for electricity supply so there have never been electricity outages. Number of Government taxes, which create an admin	No government or local regulatory barriers to cryogenic storage adoption. Major customer would like to see 100% renewables employed for their refrigerated

	well as instigating a day/night pricing differential). Company investing in low energy lighting. Company target to reduce energy use by 20% in next 4 years.	burden. Government reporting of energy use but no government targets to reduce consumption. Energy prices decrease as consumption rises. No Government support for larger PV systems in companies Grid feed-in payments are set at 2/3 of the purchase price. The low rate is a barrier to market take up.	product. Energy supplier providing low interest loans to fund energy efficiency improvements

Company F

Personal		***Position***	
Barriers	**Enablers**	**Barriers**	**Enablers**
Reduced agency possible for staff at local level because of tightness of central control.		Decisions about energy systems made at head office in another country. Problems finding and retaining people partly due to skills shortages and partly due to competition in the area (where a number of cold stores operate)	
Company culture		***External factors***	
Barriers	**Enablers**	**Barriers**	**Enablers**
The company manager has a cost reduction agenda with prioritised action on transport as the biggest cost. By comparison, costs for electricity use are in 11th place. The company buys electricity in at 20kV and transforms it using		PV is complicated. Companies are charged a different price for the electricity they buy if they are feeding into the grid. Not aware of any national low carbon policies or drivers for business. As energy is so cheap	Power outages –There are lots of stop/starts with the electricity supply as regular maintenance is carried out. Every 2-3 months the power goes off for 1-2 hours.

an on-site transformer, which is cheaper and makes outages less problematic. PV has not been looked into in detail by the site as it is a policy decision taken centrally. No energy reduction targets exist for this site yet. Energy is far from being the biggest cost for the site. 10 year investment cycle in company.		in the country there is little incentive for solar PV	

Company G

Personal		***Position***	
Barriers	**Enablers**	**Barriers**	**Enablers**
	Great deal of personal agency in engineering team	Difficult to get buy-in from all stakeholders to what is trying to be achieved. Goals are not always aligned.	The engineering team uses a balanced scorecard approach to take into account capital costs/operating costs/carbon agenda/Kilowatts. If this can hit the 'sweet spot' then investment is a 'no-brainer'. It's a comprehensive way of looking at investment. Have staff with role to review, evaluate and trial different innovations in the context of company's net zero declaration
Company culture		***External factors***	
Barriers	**Enablers**	**Barriers**	**Enablers**
In response to the premise of CryoHub to store energy from intermittent renewables 'cold stores are large consumers of energy –	Routine to install renewable energy as part of a new scheme. LAES could be used to create an energy store when energy prices	National policy is a barrier 'From an engineering point of view, national policy and regulation is holding us back because we are ahead	

if you put PV on the roof you wouldn't have anything left to store because of the pure consumption. Excess electrical energy is zero' Lack of green branding 'Need to make wider industry aware of what areas we're investing in – people don't contact us because they don't think we're interested.'	were low for use when energy prices are high. Company always looking for energy saving and consumption reduction in its stores and distribution centres Company encourages anyone working with them to come forward, within company criteria, for initiatives and trials. Have done a lot with load shedding and avoiding peak demands. Has partnerships with other RE companies. Company is investing heavily in achieving net zero by 2040 declaration. The net zero announcement has made stakeholder buy-in easier. Have trial fund – not subject to ROI. If the technology is 'super new' and untested company can employ a *Carbon Step Change* budget.	of it' Carbon pricing '…a realistic value for carbon would make it easier to justify investment in renewables.' To change the standard ROI model in the future carbon will need to be valued more.	

Company H

Personal		***Position***	
Barriers	**Enablers**	**Barriers**	**Enablers**
	Country manager has agency for making improvements.		Local country manager has significant degree of autonomy for site decisions and

			encouraged to share development ideas with owners.
Company culture		***External factors***	
Barriers	**Enablers**	**Barriers**	**Enablers**
	Company projects a green image to customers. PV fitted on roof of store.	Lack of installation and maintenance services in the country to support use of new technology. Potential for selling the building's surplus energy (from PV) is a grey area 'Try and save two hundred Euros and create a two million Euro problem. It takes a year to obtain a permit from local grid operators. Why spend this time for such small money?'	Power supply unreliable in the country.

4.1.2. Key indicators for CryoHub

Table 3 (below) draws together some of the key drivers from the individual thematic analyses in the previous section, which are relevant to the potential diffusion of CryoHub technology. These incorporate organisational attitudes and behaviours around energy efficiency and low carbon working and contextual and operational barriers and enablers to the integration of renewable energy sources and CryoHub systems.

Specific categories compared in the table are :

- decision making processes and local autonomy;
- influence from customers and/or supply chain;
- the pursuance of environmental credentials;
- current employment of PV and other renewable technologies;
- access to and ease of grid connection;
- specific return on investment expectations;
- organisational energy/low carbon management targets and aims.

Table 3: Key drivers for potential diffusion of CryoHub technology

Case study	Local decision making	Customer/supply chain pressure	Green credentials PV fitted	Other RE fitted	Ease of grid connection	ROI expectations in years	Stated targets/aims
Case A	✓✓	✓	✓	✓	x	✓	-	To maximise the use of renewables and innovative technologies.
Case B	✓✓	✓✓	✓	x	x	xxx	5-6	To reduce energy costs by working to an upper limit for consumption of key utilities
Case C	✓✓✓	✓	✓	✓	✓	✓	-	To become a 'virtual power plant' by adding: wind turbine 2.3MWp; gas turbine (gas from grid) 5.2MW. To deliver and optimise energy for themselves and partner site.
Case D	✓✓	x	-	x	✓	✓	5-7	To use biomass technology to generate electricity To reduce 3% of energy consumption on a yearly basis
Case E	✓✓✓	✓✓	x	x	x	xxx	3	Plans to buy cheaper energy at night and overcool -22°C or -23°C avoiding some power use in the daytime. Target to reduce energy use by 20% over 4 years
Case F	✓	x	-	x	x	✓	-	No energy reduction targets and national energy relatively inexpensive and clean
Case G	✓✓	x	✓	✓	-	-	3-4	Net zero commitment made in 2020. £1 billion investment to achieve net zero by 2040.
Case H	✓✓	-	✓	✓	✓	xxx	3-5	No specific energy reduction targets for cold stores

Key:

Local decision making
- ✓ - little or no local investment autonomy or influence on investment decision making process
- ✓✓ - moderate investment autonomy and influence, direct links to investment decision making unit
- ✓✓✓ - full investment autonomy, investment decision making unit based on site

Customer pressure
- x – no direct supply chain pressure for green standards
- ✓ - little direct pressure from customers
- ✓✓ - some customers demanding green targets or standards

Grid connection issues
- ✓ - grid connections possible/not seen as issue

xxx – grid connection conditions complex, administratively difficult and/or expensive

4.2. Interactive workshop research

In addition to the individual organisational market strategy interviews, three CryoHub dissemination workshops took place between March 2020 and March 2021. Due to the restrictions incurred by the pandemic, the events took the form of webinars and an online conference. Attendees were invited to take part in the market strategy research during these events by responding to a set of questions in an online poll.

The summary of responses from the three interactive surveys, showing the percentages of votes cast for each question are set out in table 4 below. The individual results for all three polls can be found in Appendix 1 .

Table 4: Summary of responses from workshop research

Workshop questions	Workshop responses		
	Mar 2020	**Aug 2020**	**Mar 2021**
Attendees	**55**	39	127
Which sector do you represent?			
Private/industry	**83.33**	**45**	**65**
Non-profit organisations	5.56	0	15
Academic	11.11	55	17.5
Government/regulator	-	-	2.5
Which are the two most important issues regarding the generation and use of energy for your business?			
Accessing new, additional revenue streams	30.56	20	**52.5**
Lowering cooling demand	**41.67**	33.33	17.5
Improving reliability of supply	8.33	**40**	20
Reducing environmental impact, carbon emissions, pollution etc	**77.78**	**80**	**65**
Green branding and the promotion of sustainability	36.11	26.67	27.5
Which are the two most important factors that affect decisions on the deployment of new energy technologies in your business?			
Capital expenditure	**58.33**	**73.33**	**57.5**
Impact on running costs	**72.22**	**60**	42.5
Integration with existing technologies/processes	33.33	33.33	**55**
Lack of understanding of the new technology	11.11	-	20
Maturity of the technology	25	20	32.5
What is your attitude to testing or demonstrating pre-commercial energy technologies?			
Enthusiastic	**47.06**	**87.5**	**64.86**
Reluctant	8.82	6.25	10.81
Neutral	44.12	6.25	24.32

Are you aware of any benefits that may come from energy storage?			
Yes	**80**	**94.12**	**92.31**
No	5.71	5.88	7.69
Not sure	14.29	-	-

Five additional questions were added to the survey for the final workshop on March 17th 2021:

The summary of responses to these questions, showing the percentages of votes cast for each question, is shown in table 5 below. The individual results for the additional questions can be found in Appendix 1.

Table 5: Responses from additional questions at workshop on March 17th 2021

Additional questions	%
What is your attitude to 3rd party investment in and /or management of new energy technologies in your business?	
Enthusiastic	**51**
Reluctant	11
Neutral	37
What would encourage you to invest in the CryoHub technology (choose 2)	
Technology performance is proven	**40**
Viable business case ie good ROI, avoiding peak prices etc	**64**
Straightforward integration with other processes	32
Improved carbon reduction ('green') credentials	20
What would discourage you from investing in the CryoHub technology (choose 2)	
Capital cost and/or operational running costs too high	**64**
Unproven technology	32
Weak business case ie poor ROI, limited value from market etc	**68**
Lack of integration with other processes	8
No benefit to the business from potential carbon reduction	20
If it was available now, how interested would you be in investing in CryoHub technology?	
Not interested at all	4
No strong opinion	13
Slightly interested	22

Interested	**43**
Extremely interested	**17**
If the two factors that discouraged you were overcome, how interested would you be in investing in CryoHub technology?	
Not interested	5
No strong opinion	5
Slightly interested	**14**
Interested	**64**
Extremely interested	**14**

4.2.1. Key indicators for CryoHub

Assessing the results from market strategy interviews and surveys it can be seen that:

- The most important issues regarding generation and use of energy were:
  - lowering energy bills – identified as most important factor by refrigeration sector interviewees;
  - reducing environmental impact, carbon emissions, pollution etc - identified as the most important factor in webinar surveys (average 74%) and in individual interviews as of key importance;
  - accessing new, additional revenue streams – identified in webinar surveys as the second most important factor (average 34%)
- The most important factors affecting decisions on the deployment of new energy technologies were:
  - Capital expenditure – identified as the most important factor in webinar surveys (average 63%) and joint most important factor by interviewees;
  - Impact on running costs – identified as second most important factor in webinar surveys (average 58%) and second joint most important factor by interviewees.
- Regarding attitudes to testing or demonstrating pre-commercial energy technologies – an average of 66% of survey respondees and 60% of interviewees said they were 'enthusiastic'.
- An average of 89% of the webinar survey respondees were aware of benefits that may come from energy storage. Similarly, interviewees cited resilience, load shifting, cost reduction and revenue generation as key potential benefits although also noted that any potential benefits also depended on technical capability, space use, cost and ROI issues.

Looking at the responses to the additional questions from the webinar in March 2021:

- 51% of respondees were enthusiastic about 3rd party investment in and/or management of new energy technologies in their businesses.
- The two most common factors that would encourage investment in CryoHub technology were:
  - Proven technology performance
  - Viable business case/ROI
- The two most common factors that would discourage investment in CryoHub technology were:
  - High capital and/or operating costs
  - Weak business case/ROI
- Interest in investing in CryoHub technology, if it were available now increased from 60% to 78% if discouraging factors were removed.

4.3. Sector literature research

The Department of Energy and Climate Change (DECC) and Department for Business, Innovation and Skills (BIS) 2050 roadmap report in the UK highlighted key 'enablers' and 'barriers' for decarbonisation of the food and drink sector. Evidence was collected via a literature review, analysis of publicly available data, interviews, surveys and workshops.

It noted that there is some overlap between barriers and enablers, as they sometimes offer two perspectives on the same issue. Their research showed the main enablers and barriers for decarbonisation of the food and drink sector to include:

Enablers of decarbonisation

Strong, evidence-based business case - identified as having a high impact on implementing decarbonising options. Capturing all costs and financial savings can provide support to obtain executive buy-in and pursue more energy-efficient technologies. Most of the interviewed manufacturers and workshop participants agreed that this enabler is an absolute necessity for senior management to even consider any energy-related projects, more so than for product development or marketing projects. According to the industry, this is mostly driven by increased risk averseness due to the weak economic climate and rising pressure from food and drink retailers to reduce cost***. A robust business case is often difficult to develop for breakthrough technologies as there is a view that there is not sufficient and reliable information about the savings potential and profitability of such technologies***.*

Projects providing multiple benefits - identified as having a high impact on implementing decarbonising options. To cope with the rising pressure from shareholders to reduce production costs and improve profitability margins, managers in the food and drink sector favour projects that can not only help reduce energy and its associated costs, but also increase productivity, reduce labour costs or achieve overall process optimisation. On the other hand, technologies that have the potential to improve product quality are well received by management. As explained by workshop participants, ***this stems from the fact that energy is not perceived as a priority in many businesses due to the low percentage that energy costs contribute to total production costs*** (2-15%).

Leadership commitment to climate change - identified as having a high impact on implementing decarbonising options. ***Senior management buy-in and commitment from top management to make climate change a priority is essential for embedding the company's carbon strategy in the business day-to-day operations.*** This can create a ripple effect across the business and increase the importance of decarbonisation. Unilever's Sustainable Living Plan and Marks & Spencer's 'Plan A' were identified by workshop participants as success stories of such a leadership commitment from the UK food and drink sector.

Effective best practice sharing within the organisation - identified as having a medium to high impact on implementing decarbonising options. One challenge that companies, especially large multinationals, identified is the ***lack of effective exchange of best practice among production facilities and the head office.*** As Lavery (2014) rightfully suggests, this involves not only sharing what is done well at one site but also actively looking for what other plant managers are doing to reduce their carbon emissions and improve energy efficiency. Workshop attendees suggest that case studies work very well to capture best practice and increase awareness.

Realistic commitments - identified as having a medium to high impact on implementing decarbonising options. ***Setting targets and establishing corporate and site-level key performance indicators (KPIs) with regards to reducing carbon emissions and energy***

consumption are perceived as essential to keeping the momentum and mobilising the workforce. When such commitments are made public, companies can exert a certain influence over suppliers and customers and engage them on the journey of achieving these targets. As a result, workshop participants perceive commitments as the first step to embed decarbonisation and energy efficiency in the strategic agenda of the business and ensure everyone in the business – from the production floor to the board – is doing something to achieve those commitments. Targets need to be realistic and time-bound to allow the business to adapt but stretching enough to provide direction and nurture an innovation-driven culture. Several interviewees, responsible for the energy and carbon reduction strategy of their companies, confirmed that long-term corporate-wide targets on reducing carbon emissions drive investment, even if the case is weaker, and influence staff behaviour and engagement.

Collaboration in the value chain - identified as having a high impact on implementing decarbonising options. Close supply chain co-operation is needed to secure resources, improve skills (including resource efficiency management), and to create system solutions with low-impact products, which better meet customer needs (including servicing) and drive improvements in scale. The food and drink sector in the UK is quite diverse in terms of types of products and thus can be characterised by a fairly complex value chain. Retail chains have strong bargaining power over manufacturers and, in turn, manufacturers pass on that pressure to raw material suppliers. Workshop attendees have expressed the concern that for retailers the key focus is reducing costs rather than environmental impacts, including decarbonisation***. A product life-cycle approach has already been considered by the UK food and drink manufacturers and this will require stronger collaboration across the entire value chain in the future.*** This type of opportunity supports the overall need for greater consideration for collaboration across the value chain, to share the risks and speed up innovation. One potential challenge to effective collaboration, expressed by workshop participants, is that due to high competition levels companies are generally not willing to share information about innovation with peers. Therefore, strong incentives and senior-level commitment are crucial to successful collaboration.

Compliance with regulation - identified as having a medium impact on implementing decarbonising options. Compliance with environmental regulation is already a norm in the UK food and drink sector as manufacturers cannot afford to jeopardise their reputation and brand value, or incur unnecessary cost in the form of fines. Several workshop attendees highlighted the fact that their ***commitments with regards to the CCA as well as the EU ETS have been key drivers to reducing CO_2 emissions from manufacturing.*** Many of the subsectors have signed up to climate change agreements that allow certain energy-intensive subsectors to receive up to 90% reduction in the Climate Change Levy (CCL). Volatile energy prices, insecurity of energy supply and the low price of carbon, coupled with the long-term uncertainty around relevant legislative direction, can transform this enabler into a barrier if incentives are reduced or the bureaucratic burden increases.

Barriers to decarbonisation

High capital cost and long investment cycles - identified as having a high impact on implementing decarbonising options. ***The sector investment cycles are to a large extent dictated by the lifespan of manufacturing equipment, usually in the range of 20-30 years but often as long as 40 years. This in itself presents very few opportunities to upgrade the entire production line and achieve major energy and carbon savings until 2050 – as there will only be one or at most two investment cycles, depending on the company and asset type.*** Additionally, the high upfront cost of such investments often limits the financial ability of UK food and drink manufacturers to upgrade multiple production lines at the same time. Rather, companies take a gradual approach to upgrading equipment. SMEs in particular find the upfront cost of advanced technologies such as robotics prohibitively expensive. Interviews with large manufacturers did not identify upfront cost as barrier, however they highlighted the low appetite to invest in major equipment as upgrading existing equipment is often more financially feasible.

Limited financing - identified as having a medium to high impact on implementing decarbonisation options. ***Financing may be available, but improving energy efficiency does not rank highly on the investment hierarchy of companies. Preference is given to growth, acquisitions, marketing, product development and adapting production equipment to changing customer demands*** (FDF, 2014). Lack of resources deployed to identifying available funding, and the reluctance to move to third-party financing are seen as additional barriers to finding financing. Workshop attendees and some of interviewees also indicated that there is a lack of collaboration on financing demonstration projects as this is seen as a competitive advantage and thus sharing the financial burden amongst manufacturers is limited. Large multinational companies expressed concern that energy reduction projects often compete with core business capex; product innovation projects overseas and longer payback times do not help secure that funding as risk is seen as too high. Establishing a long-term regulatory framework is perceived by industry to play an important role in reducing that risk in the future.

Risk of not meeting required product quality or changing character - identified as having a medium to high impact on implementing decarbonising options. It is very unlikely for a UK food and drink manufacturer to invest in and deploy a technology that may diminish product quality or change a product's character and texture. This can be explained by the fact that ***strong brands attract a price premium in the sector and any unwanted change to the product may erode brand and economic value. Thus the sector perceives unproven technologies as an unnecessary business risk***. Subsector-specific regulation maintains the high impact of this barrier. In the spirits subsector, for example, the production of Scotch whisky is set in the law and thus distillers cannot deviate from the prescribed production process. As a result, producers are limited in their choice of opportunities for technology improvement or new build

Risk of production disruption - identified as having a medium to high impact on implementing decarbonising options. ***The potential impact of any changes in operations on machine operability and disruption of production is a barrier to decarbonisation***. Some of the manufacturing in the sector is on a non-stop basis, in particular in the soft drinks and dairy subsectors. Other subsectors such as bakery, frozen food and meat production operate only in a limited time window during the day. Therefore, any downtime in a production line is carefully planned and reduced to an absolute minimum. This is driven by constant and increasing pressure to maintain profitability margins and reduce cost. Thus the sector perceives lines upgrades and retrofits as risky unless equipment is approaching the end of its lifespan. An additional factor that reinforces this barrier is the lack of proven and commercially tested technologies which makes management reluctant to implement, even during downtime, as this may cause disruption and operational challenges in the future.

Shortage of skilled labour - identified as having a medium to high impact on implementing decarbonising options. A shortage of technically competent staff and a lack of funding for training are still perceived to prevent further advancement of the UK food and drink sector. A further challenge to the sector is attracting new recruits and talent. ***There is an increased demand in the sector for engineers who understand the technical aspects of the industry that support energy efficiency implementation, such as heat engineers.*** This growing need has been recognised by the FDF and its members as a key issue for the sector and initiatives are being rolled out. These include the establishment of 'National Centre of Excellence for Food Engineering' in cooperation with the Sheffield Hallam University and the National Skills Academy, and the 'Apprenticeship Trailblazers' initiative, which aims to build on the success of the apprenticeships programme in 2012 (FDF, 2015).

On the other hand, internally, engineers are currently not appraised adequately and not perceived as a key resource. However, some large manufacturers stated during interviews that their reputable

brands help them secure qualified engineers and that their internal skill development programmes help them train and educate new staff. Other interviewees expressed the concern that there is a need to change outsiders' perceptions of the industry, and to invest in training to make industry more attractive to graduates and other professionals. This is a particular barrier now as the profile of the workforce of the sector is ageing without sufficient succession planning in place.

Shortage of demonstrated technologies - identified as having a medium to high impact on implementing decarbonising options. The UK food and drink manufacturers are risk-averse and are not likely to implement technologies that might lead to production disruptions due to malfunctioning retrofits, or which could compromise product quality or increase production costs. Therefore, ***technologies which have been tried and proven, ideally in the food and drink sector, are more likely to gain traction. As a result, the sector enjoys a slow pace of technological change.*** At the workshop it was suggested that stronger collaboration across the food and drink value chain can strengthen the research base in the UK and help reduce the risk of investment in innovative technologies by sharing it among several players.

Lack of reliable and complete information - identified as having a medium to high impact on implementing decarbonising options. ***There is a need for greater knowledge sharing and R&D collaboration within the sector to accelerate technology advancement along the curve from demonstration to commercialisation.*** The FDF membership also recognised the need for academia, research institutions, the sector and government to agree on a shared vision for innovation in the sector as recognised by the FDF members (FDF, 2015).

Shortage of technical knowledge and capacity within the UK food and drink businesses to identify new technologies and measures is a common challenge. Workshop attendees expressed a concern that managers do not know where to start looking for new options and industry-wide support can be a key to resolve this. Independently verified data on savings potential can further reduce the hesitations of management to consider new technologies. One interviewee, environmental manager of a large multinational, disagreed and stated that the business case is not there for the majority of the technologies compared to other investment projects. This has been identified as a stronger barrier for SMEs in the sector.

4.3.1. Key indicators for CryoHub

Looking at the key enablers and barriers to decarbonisation as identified by the DECC/BIS roadmap report, a number of links can be made with the intelligence gathered from the market interviews and webinar surveys.

Enablers

- Strong business case – identified as a key driver amongst interviewees who stressed the importance of a good ROI and was echoed in the survey results as one of the most important factors in encouraging investment in CryoHub technology.
- Projects provide multiple benefits – accessing new, additional revenue streams was identified in survey results as one of the two most important issues regarding generation and use of energy.
- Leadership commitment to embed strategy – in some case studies ambitious ideas were being not being implemented due to non-technical, risk averse management team. In others, leadership commitment was supporting experimentation for continual improvement.
- Best practice sharing between head office and facilities
- Realistic commitments – KPIs
- Collaboration in value chain –some of the most advanced case study organisations were working in close partnership with their customers for mutual benefit

- Compliance with regulations – front running case study organisations noted that they were sometimes operating ahead of regulations

Barriers

- High capital cost and long investment cycles/Limited financing – commonly identified as a key factor, in surveys and interviews
- Risk of not meeting required product quality or changing character/Risk of production disruption – named as a critical risk factor by interviewees and noted in surveys
- Shortage of skilled labour – identified as a limiting factor by interviewees in some countries
- Shortage of demonstrated technologies/Lack of reliable and complete information - recognised through the need for new technologies to work with existing processes and technologies.

5. Conclusions

Energy storage is set to play an increasingly important role in the decarbonisation of the electricity market and in the delivery of international society's net zero aspirations (although how this is defined precisely is an ongoing key question). To limit global warming to below 2°C, energy storage capacity would need to increase from 140 GW in 2014 to 450 GW in 2050. Early adopters of energy storage will not be enough to create the change that is needed.

Thrive Renewables - moving into storage

In their 2020 company report, UK based generation company Thrive Renewables announced its strategy to focus on diversifying its portfolio of projects. The investments made in the last 18 months reflect this, including both renewable generation which can generate electricity baseload and battery storage projects which can balance the electricity grid as fossil fuel plant retires.

There are hopeful signs (see text boxes), renewable energy generators are diversifying into energy storage investments and the potential for embracing energy storage as a service (EsaaS) is being realised by an increasing number of industries. Recent developments have seen an investment commitment for 2GWh of long duration liquid air energy projects in Spain.

LAES as long duration energy storage

Highview Power, specialist company in long duration energy storage solutions, announced in May 2021 it is developing up to 2 GWh of long duration, liquid air energy storage projects across Spain for an estimated investment of around $1 billion, enabling several Spanish regions to move towards their net zero emissions target. The liquid air storage medium delivers critical grid stability services equivalent in performance to fossil-fuel powered thermal and nuclear baseload power when paired with renewables.

Energy storage as a service (ESaaS)

Energy storage systems provide a range of services to generate revenue create savings, and improve electricity resiliency. ESaaS removes the requirement for capital outlay and the system is controlled and managed by a third party.

In terms of how this relates to market strategies for the cold chain it is useful to revisit the case study research. Mapping the case study interviewees onto the organisational responsiveness levels, it can be seen in table 6 that the organisations spoken to were operating at a range of responsiveness levels. This can be further illustrated through the presence or absence of some of the key drivers indicated in the complementarities analysis.

Those organisations with no specific energy targets who restricted themselves to operating within appropriate laws and might also be responding to customer pressures, can be considered to be at the

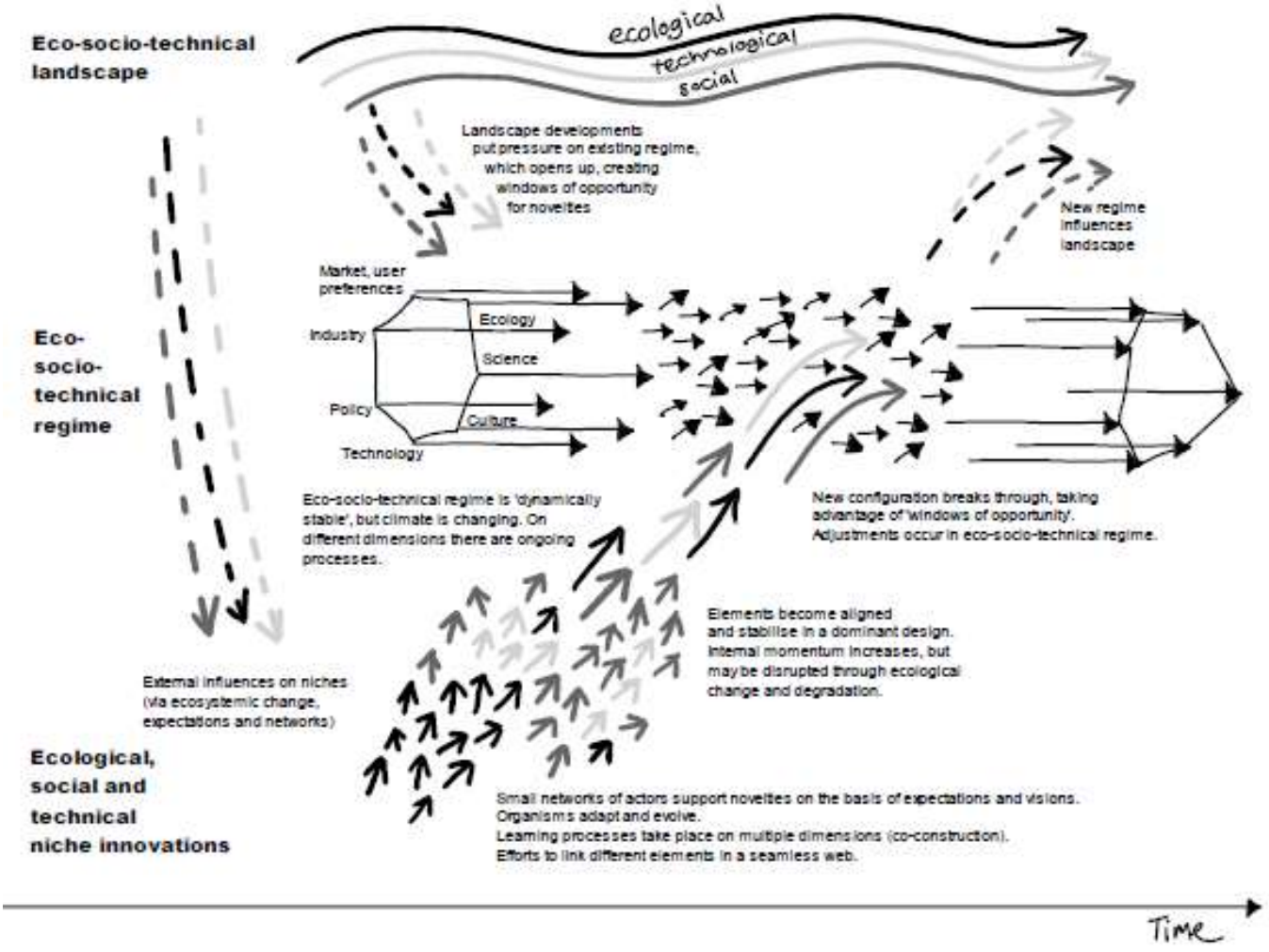
level of compliance. Those who had active environmental and energy management systems and were setting regular energy reduction targets are operating at the efficient management level. Others were already at or beyond the breakthrough projects level – moving beyond efficiency and towards linking aspirational performance with company strategy. Two of the organisations interviewed had made the link between decarbonisation and company strategy explicit and were demonstrating this with an appetite for ongoing experimentation and by seeking partnerships with customers, other company stakeholders and sector players in order to move the agenda forward.

Table 6. Case study organisational response levels

Case study organisational response levels								
6 Champion org								
5 Strategic resilience								
4 Break-through								
3 Efficient manag't								
2 Compliant								
1 Non response								
Response level ↑ Case study →	F	H	E	B	D	A	C	H
Indicative case study drivers	No specific energy targets No local autonomy Energy cheap	No specific energy targets Active manager with some local autonomy Grid connection opps poor	Energy reduction targets Customer pressure Grid connection opportunity poor	Customer pressure Energy manage-ment systems Energy targets Grid connection opportunity poor	Renewable generation Annual reduction targets Active energy team	Renewable generation Green credentials Strategic energy targets Active energy team Risk averse manage-ment team	Renewable generation Green credentials Strategic energy aspirations Active energy team Local autonomy Active partnership working	Renewable generation Green credentials Net zero carbon declaration & investment funds Active energy team with autonomy Active partnership working

Looked at within the context of the eco-sociotechnical regime change model (following page), the refrigeration sector is an established regime player, historically slow to change with long-term investment cycles. Awareness and agency of the landscape changes that will impact energy security, resilience and pricing are manifesting differently across the sector, depending in part on external factors which differ from country to country and in part on the relative response levels of individual organisations.

Organisations at the higher response levels are more strategically aligned to change, more outward facing and able to form partnerships and less risk adverse, with devolved responsibilities, appropriate expertise and a high degree of agency amongst staff helping to facilitate change. It makes sense for niche actors with novel ideas to target these forward looking organisations who, research shows, are open to establishing new types of relationships and joint working.



The question remains that with fossil fuel energy still so cheap it is difficult for renewables and energy storage to compete and until prices increase, few individual organisations have the appetite for the order of magnitude of investment currently indicated for CryoHub technology.

In this context strategically the best opportunities moving forward may be to explore 3rd party investment in CryoHub technology through generators, aggregators, energy supply and service companies/ other investors. This market strategy would overcome the key issues raised by organisations in this refrigeration sector research, in particular around capital and operating costs, ROI restrictions, lack of requisite skills and the relative newness of the technology.

6. References

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CryoHub D2.3 2017 **Report on Potential Opportunities for CryoHub in Europe**. https://cryohub.eu/en-gb/downloads

CryoHub D3.1 2017 **Report on Current and Future Benefits of CryoHub**. https://cryohub.eu/en-gb/downloads

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CryoHub D8.2 2019 **Energy Profile Report** https://cryohub.eu/en-gb/downloads

CryoHub D8.3 2021 **Report on Alternative Business Strategies and Models** COMMISSION CONFIDENTIAL

CryoHub D10.3 **Communicating the benefit of, and necessary policy improvements to further support, CryoHub** https://cryohub.eu/en-gb/downloads

CryoHub D10.4 2020 **Analysis of National Policies Relevant to the CryoHub Concept** https://cryohub.eu/en-gb/downloads

DECC/Department for Business, Innovation and Skills 2015 **Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050 – Food and Drink**

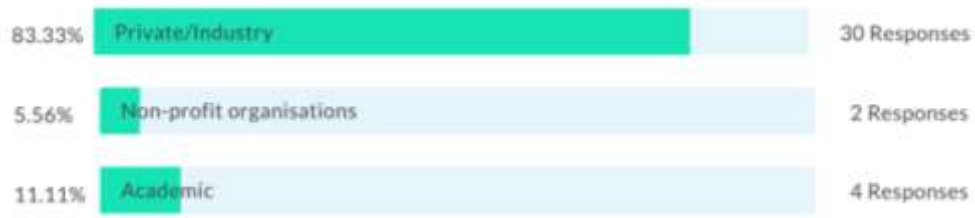
CARPP, University of Bath 2009. **Insider Voices - Human Dimensions of Low carbon Technology**

7. Appendices

7.1. Appendix 1

CryoHub workshop March 19th 2020

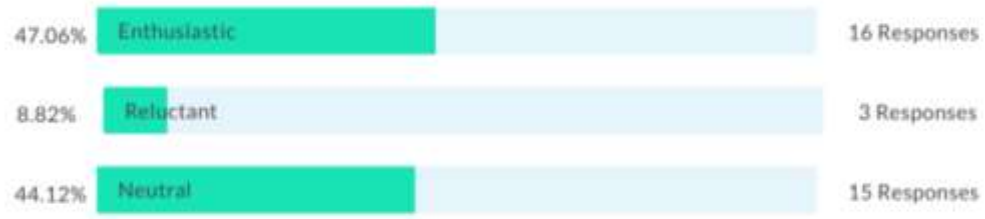
Which sector do you represent? (36 of 55)



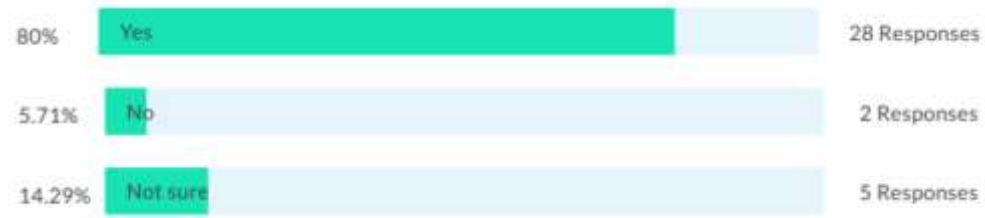
Which are the two most important issues regarding the generation and use of energy for your business? (36 of 55)

Which are the two most important factors that affect decisions on the deployment of new energy technologies in your business? (36 of 55)

What is your attitude to testing or demonstrating pre-commercial energy technologies in your business? (34 of 55)

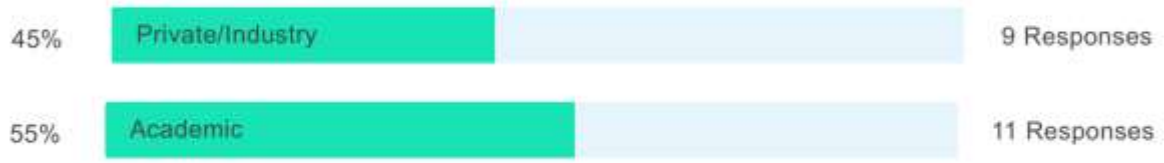


Are you aware of any benefits that can result from energy storage? (35 of 55)



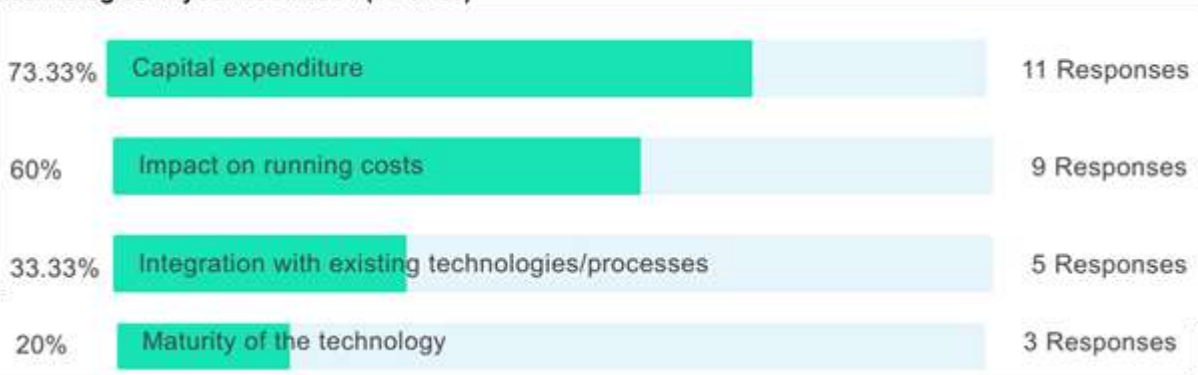
Workshop at ICCC conference August 26th 2020 Nantes

Which sector do you represent? (20 of 39)

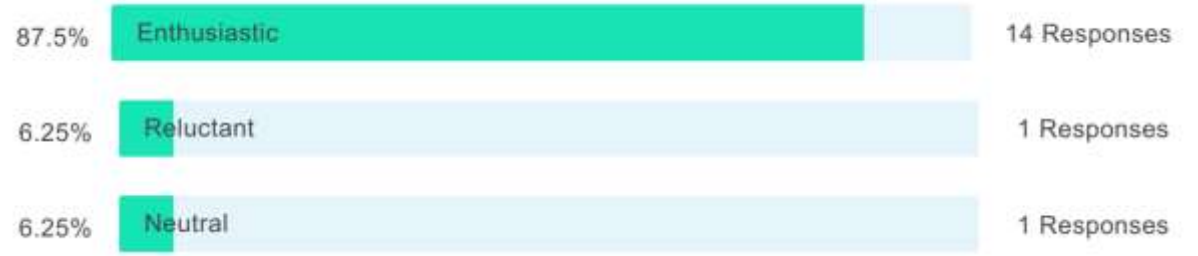


Which are the two most important issues regarding the generation and use of energy for your business? (15 of 39)

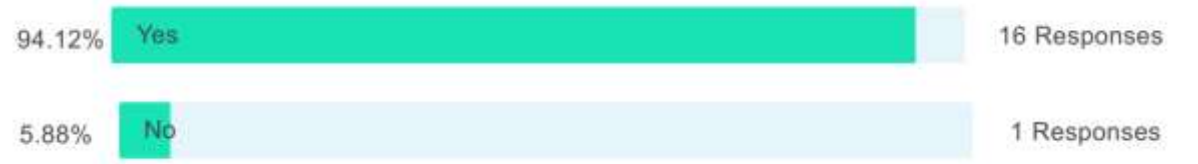
Which are the two most important factors that affect decisions on the deployment of new energy technologies in your business? (15 of 39)



What is your attitude to testing or demonstrating pre-commercial energy technologies in your business? (16 of 39)

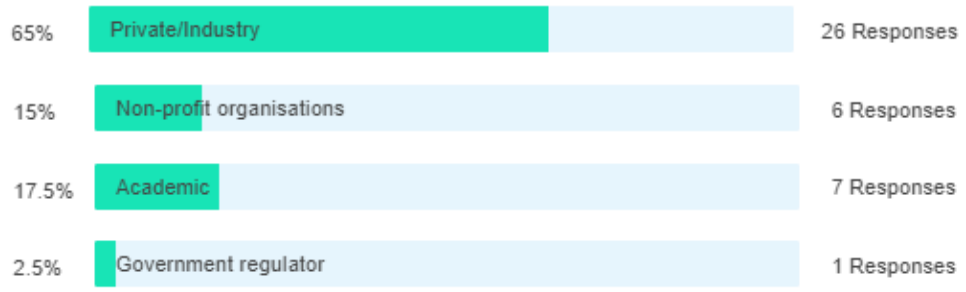


Are you aware of any benefits that can result from energy storage? (17 of 39)



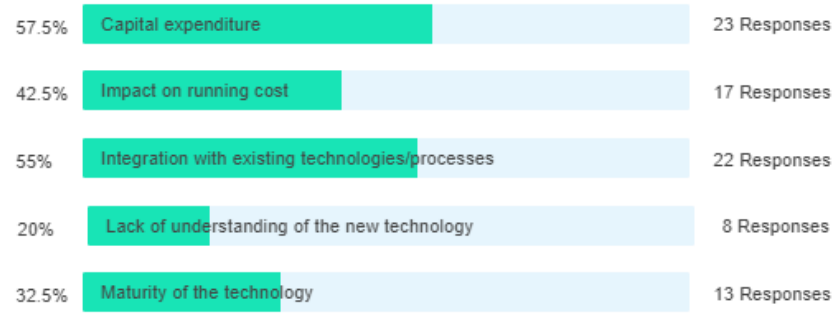
Final CryoHub Workshop March 17th 2021 (127 attendees)

Which sector do you represent?

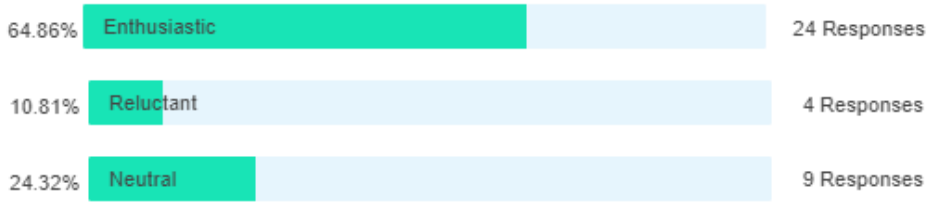


Which are the two most important issues regarding the generation and use of energy for your business?

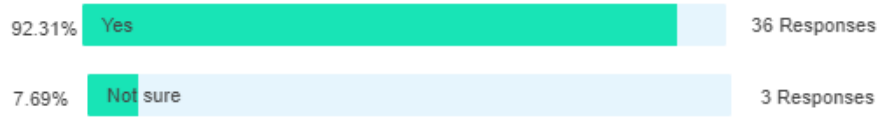
Which are the two most important factors that affect decisions on the deployment of new energy technologies in your business?



What is your attitude to testing or demonstrating pre-commercial energy technologies in your business?

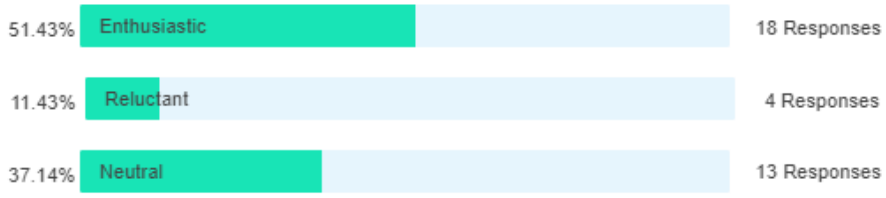


Are you aware of any benefits that can result from energy storage?



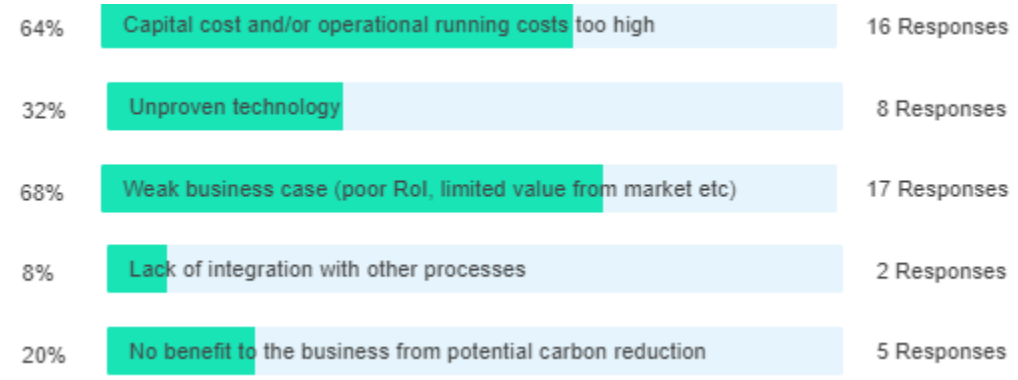
Additional questions:

What is your attitude to 3rd party investment in and /or management of new energy technologies in your business?

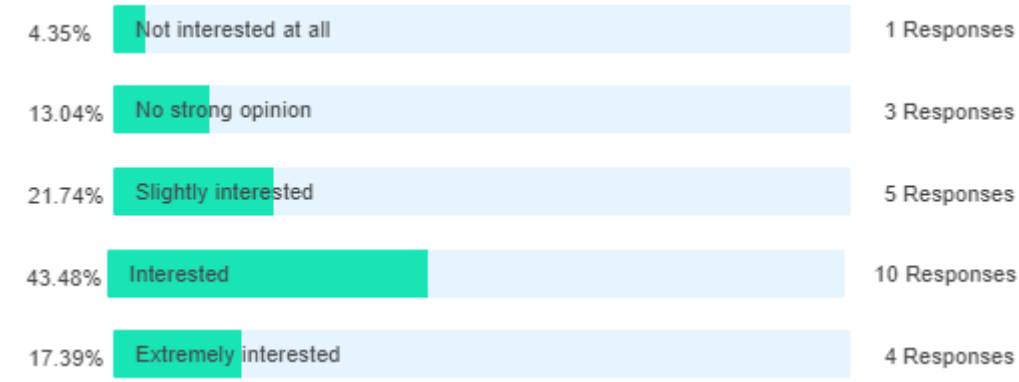


What would encourage you to invest in the CryoHub technology (choose 2)

What would discourage you from investing in the CryoHub technology (choose 2)



If it was available now, how interested would you be in investing in CryoHub technology?



If the two factors that discouraged you were overcome, how interested would you be in investing in CryoHub technology?