Queensland Decarbonisation Hub

Policy Report

Defining and mapping Queensland's decarbonisation technology landscape

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Executive summary

This Policy Report provides an overview of the approach and status update for the Queensland Decarbonisation Hub's Decarb Technology Capability and Innovation Ecosystem theme.

The theme is providing a dynamic map of Queensland's capability and innovation landscape to show the scope and nature of decarbonisation activities underway and identify gaps and opportunities in the process. The visual data tool will enable industries, community groups and governments to connect and collaborate with researchers, innovators and support organisations and to understand what technologies, finance and other enablers exist to support their decarbonisation goals. The tool is designed to support the other hub themes including community and regional transformation and identify and assess nature-based solutions and environmental integrity.

An initial release of the platform located at https://www.decarb-hub.org/innovation has been developed and represents a growing list of 62 enabling support institutions, 191 technology providers, and 45 policies related to decarbonisation technology in Queensland. The platform is being shared and expanded through a regular series of webinars focusing on each technology area with an emphasis on Queensland applications and projects.

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Towards a taxonomy of decarbonisation technologies

"Technologies and solutions are available today to immediately reduce emissions, while emerging technologies will be required to achieve the longer-term goal of reaching net zero emissions. While the emissions reductions to 2030 can be delivered with existing technologies, about half of the emissions reductions in 2050 will come from technologies at prototype or demonstration stages today." (Climate Change Authority, 2023, p. 106)

Technology contribution to decarbonisation

Decarbonisation - the removal and reduction of human-induced carbon dioxide (CO2) emissions - is essential to realising climate targets. **Technology** is key in the overall portfolio of decarbonisation strategies, which also include carbon markets, voluntary agreements, research and development, research translation and deployment, compulsory command and control regulations and standards, infrastructure programs, and procurement (OECD, 2021). Under a broad definition, **'decarbonisation technologies'** include methods, processes and activities that reduce or eliminate carbon dioxide emissions from process associated with human activities such as production of energy and industrial sectors (Rissman et al., 2020; Wang et al., 2021).

The application of decarbonisation technologies varies by sector. For example, the energy sector focus on energy generation, including processes or practices that aim to reduce or eliminate the use of fossil fuels for energy production (Papadis & Tsatsaronis, 2020; Voitko et al., 2021). Health care decarbonisation pathways include health care delivery, facilities, operations, supply chains, and the wider economy and society (Karliner et al., 2021; Kayak & Burch, 2021). Agriculture strategies focus on carbon sequestration, bioenergy production, agriculture emission intensity, and shifting diets (Svensson et al., 2021). Similar sector-specific research identifies strategies and technology applications for transportation (Akujor et al., 2022; Christodoulou & Cullinane, 2021; Rohith et al., 2023), construction (Arogundade et al., 2023; Mercader-Moyano & Roldán-Porras, 2020), and tourism (Becken, 2019, 2024).

The diversity of sectors necessitates sector-specific solutions, while the scale of the challenge and application of similar technologies across sectors requires integrated cross-sector approaches that go beyond traditional clustering and collaborative frameworks (Lamb et al., 2021; Rattle et al., 2024). It is essential then that there be a common language and shared knowledge for efficient and effective implementation of decarbonisation technologies.

Technology is also only one part of the overall decarbonisation strategy. It is essential to acknowledge the place-based context in which the technology is applied and its role in each region's decarbonisation transition. Technology application also needs to consider the environmental impact, both positive in its role in realising decarbonisation as well as negative in its disruptive capacity and potential for unintended consequences.

This policy paper highlights the approach of the Queensland Decarbonisation Hub's Technology and Innovation Theme to address these challenges. First, a review of approaches to representing decarbonisation technologies is provided, developing a common taxonomy from a review of literature and existing global and Australian categorisations. Second, considerations are provided for technology taxonomy mapping and governance, a framework for considering technology in place and environmental impact, and visualisation for effective access and usefulness in decision making. Finally, the approach to a public map is provided and an update on the mapping process to date. The review is framed within the context of application for Queensland within the Australian context.

Taxonomies for mapping decarbonisation technologies

A review of decarbonisation technology literature and frameworks needs to consider a few key points:

1. **Decarbonisation technologies are interrelated and integrated.** For example, electricity production and its storage are relevant to all sectors. Technology supporting agriculture efficiency can have application in mining and manufacturing sectors. A given technology may appear in one or area.
2. **Decarbonisation technologies require a support system.** Technology alone is not sufficient to realise decarbonisation goals. Technology requires an ecosystem of ICT infrastructure, enabling policy, sufficient risk capital, viable customer markets, and available skilled workforce and service providers. The taxonomy can be used to map the supporting ecosystem, relevant policies, and place-based applications.
3. **Technologies can apply to a broad category.** A technology can apply across a category, such as across energy storage, as well as to an individual technology, such as solar energy storage.

Similar approaches to the development of taxonomies can be seen in other fields. For example, New Zealand developed a standard definition for agriculture technology informed by other global frameworks (Ministry of Business, Innovation & Employment, 2021). This standard is being tested in Australia with the Australian Ausagritech Association (Renando & Simpson, 2023). Other reviews have focused on the taxonomy of roles in the innovation ecosystem, which will also be used to inform the innovation ecosystem mapping aspects of this project (Renando, 2020).

A review of literature identified five approaches to decarbonisation taxonomies. These include functional-based, sectoral-based, maturity and deployment based, economic viability, and impact and effectiveness based. **Functional-based categorisation** of decarbonisation technologies refers to the primary function of these technologies in reducing carbon emission. For instance, renewable energy technologies are classified together as it relates to generating of power from renewable sources. Storage technologies refer to those technologies which have the capability of storing electricity.

A **sectoral-based taxonomy** groups technologies by industry sector, such as agriculture, mining and energy, tourism, constructions, health, and so on. **Maturity and deployment-based technology categorisation** creates groups according to existing implementation status or technology readiness level. This type of categorisation is often considered together with a technology's **economic viability** and its **impact and effectiveness**. Table 1 provides examples of taxonomies from different countries.

Table 1 Taxonomies for decarbonisation technologies

Decarb Technologies Taxonomies	Country	References
Functional based	China	(Luo et al., 2021)
	Europe	(Carmona-Martínez et al., 2022; European Commission. Directorate General for Energy. et al., 2020)
	Sweden	(Nurdiawati & Urban, 2021)
	Italy	(Borasio & Moret, 2022)

Decarb Technologies Taxonomies	Country	References
	United Kingdom	(Element Energy, 2020)
	Germany	(Fleiter et al., 2020)
	Global	(Fernández & Spencer, 2023; Wang et al., 2021)
Sectoral based	Sweden, USA	(Cresko et al., 2022; Nurdiawati & Urban, 2021)
	Australia	(Brinsmead et al., 2023; Butler et al., 2020)
	United Kingdom	(Element Energy, 2020)
	Canada	(Bailie et al., 2023)
Maturity and Deployment based	Australia	(ClimateWorks, 2020) (Butler et al., 2020)
	Global	(Fan & Friedmann, 2021)
Economic viability based	Australia	(Murugesan et al., 2023)

Most taxonomies focus on functional and sectoral categorisations of decarbonisation technologies. This is used as a basis for the aggregated initial categorisation of decarbonisations technologies for the technology mapping work with the Queensland Decarbonisation Hub (Table 2).

Table 2 Aggregate list of decarbonisation technologies

Category	Sub-Category	Main Technology	Description	Sub-Technologies
Renewable Energy Sources		Solar Technologies	Technologies related to generation of power from solar energy	Rooftop Solar, Tandem Solar, Utility Solar, Floating Solar
		Advanced Hydropower	Technologies related to generation of power from Water	Pumped Hydro with Solar, Pumped Hydro with Wind
		Advanced Wind Technologies	Pumped Hydro with Solar, Pumped Hydro with Wind	Wind Turbines, Onshore and offshore wind farms, floating wind turbines
		Wave and Tidal Energy	Technologies related to generation of power through waves and tides	Wave and Tidal Energy Converters
		Geothermal Technologies	Technologies related to generation of power from heat underground	Geothermal power plants, enhanced geothermal systems, Closed Cycle Turbines
		Nuclear Technologies	Technologies related to generation of power through nuclear reactions	Small modular reactors, thorium reactors, fusion reactors
		Renewable Hydrogen	Process of generating power from segregating	Electrolysis (Alkaline Electrolysis, Proton

Category	Sub-Category	Main Technology	Description	Sub-Technologies
			oxygen and Hydrogen from water	exchange membrane), Hydrogen Cell technology, Green Hydrogen
		Bioenergy	Electricity derived from organic materials such as plants and animal waste	Biogas, Biomass, Bio-syngas
Advanced Energy Storage Systems		Advanced Batteries- Solar and Wind	Advanced batteries technologies to store electricity generated from different sources	Batteries Technologies, Compressed Air Energy Storage
		Advanced Thermal Storage	Technologies to store heat generated from different process to be used later	
		Pumped Storage	Hydroelectric storage technologies	Pumped Hydro Energy Storage Technologies (PHES)
Energy Transmission Optimisation Technologies		Smart Grids	Grids that utilize modern automated technologies and sensor to efficiently manage flow of electricity	Virtual Power Plants, Grid automation technologies, Inertia control technologies
		Micro Grids	Small scale localized grids that can operate independently or connected to main grid incorporating renewable energy sources and energy storage	
Industry	Sustainable Manufacturing Processes	Fuel Switching Technologies	Technologies involve switching from fossil fuels to cleaner energy sources	Bio-syngas, Bio-Coke, Electrifications, Hydrogen as fuel, Bio-energy solar thermal, Oxy fuel technologies, Direct Injection Carbon Engine, Geothermal Hydrogen
		Renewable Smelting Technologies	Technologies aim to reduce carbon emission from smelting process	Electric arc furnaces, Plasma arc furnaces, Industrial heat pumps, Metal and Plastic recycling technologies, Inert Anodes, Hydrogen reduction technologies,
		Advanced Manufacturing Efficiencies	Technologies related to optimisation of current processes by using sensors, reverse logistics	Optimisation technologies (IoT), Eco-Industrial parks, 3D printing
		By-product recycling and recovery	Technologies related to recycling and recovery of by products from industry	Water Recycling technologies from mines, Acid Mine Drainage
	Carbon Technologies	Carbon monitoring Technologies	Technologies related to measuring and assessing carbon emissions	Carbon Counting Technologies
		Carbon Capture and Utilization Technologies	Technologies related to capturing and utilization of carbon emissions	CCS, CCUS and Bioenergy with carbon

Category	Sub-Category	Main Technology	Description	Sub-Technologies
				capture and storage (BECCS)
	Fugitive emissions reducing technologies	Advanced ventilation technologies	Technologies related to capturing of methane emission from industry processes	Ventilation air methane capture (VAMCAP), Ventilation air methane catalytic turbine (VAMCAT), Ventilation air methane mitigation (VAMMIT)
Buildings	Reduce Energy Use	Advanced Insulation Materials	Technologies to reduce emissions by improving thermal efficiency in buildings	Aerogel insulation, smart insulation, nanomaterials, vacuum insulation panels, optimised design technologies
		Energy Efficient appliances and Technologies	Energy efficient equipment to reduce use of energy	Electrochromic windows, transparent photovoltaic windows, LED lighting, Energy smart systems, Hydrogen appliances, Rooftop solar, inverter refrigerators, High efficiency heating, ventilation and air-conditioning (HVAC) systems
	Sustainable building materials and technologies		Building materials and technologies that can store or reduce carbon emission	Green Cement, Carbon storage materials (Wood products, Bamboo, Recycled materials), Optimisation technologies
Transport	Electrified Vehicles	Passenger Vehicles	Technologies related to reducing emission of passenger vehicles	Battery electric vehicles (BEVs), Hydrogen fuel cell electric vehicles (FCEV), Hybrid Vehicles, mode shift, Autonomous Vehicles
		Heavy Vehicles	Technologies related to reducing emission of heavy vehicles	Hydrogen FCEV for long haul trucks, BEVs,
		Rail transport	Technologies related to reducing emission of rail	Biofuels, Hydrogen FCEV, Battery electric trains, Regenerative breaking technologies
		Shipping Industry	Technologies related to reducing emission of shipping industry	Alternative fuel- Methanol, Ammonia, Hydrogen
		Aviation Industry	Technologies related to reducing emission of aviation industry	Synthetic aviation fuels
		Electric Delivery	Technologies related to delivery of products	Electric drones
	Roads and Infrastructure	Charging facilities	Technologies related to providing charging facilities to electric cars	Smart chargers, Bi-directional electric vehicle charging

Category	Sub-Category	Main Technology	Description	Sub-Technologies
		Ridesharing Technologies	Technologies related to sharing rides to reduce emissions	Smart technologies for sharing electric vehicles
Agriculture	Livestock	Reduced emission livestock feed	Feed technologies reducing low carbon emission	Macroalgae, artificial feed supplements, silvopasture, Alternative feed stock feed-Desmanthus, Soil carbon sequestration and Leucaena
		Vaccinations	Vaccines to reduce emission of Carbon	Anti-methane vaccines
	Alternative Products	Plant-based products	Products produced from plants	Plant-based meat, laboratory grown meat, Gene editing
	Advanced Efficiency and Productivity	IoT and Precision Agriculture	Technologies related to enhance efficiency and reduce wastage of resources	Tags, Sensors, Electronic drones, Robotics, Electric and autonomous tractors
Negative Emissions	Technologies related to absorbing of carbon dioxide from environment			Afforestation, Biochar, Coastal Blue Carbon, Ocean Alkalinisation, Ocean Carbon Capture and Storage, Ocean Fertilisation

A graphical representation of the decarbonisation technology taxonomy is provided in Figure 1.

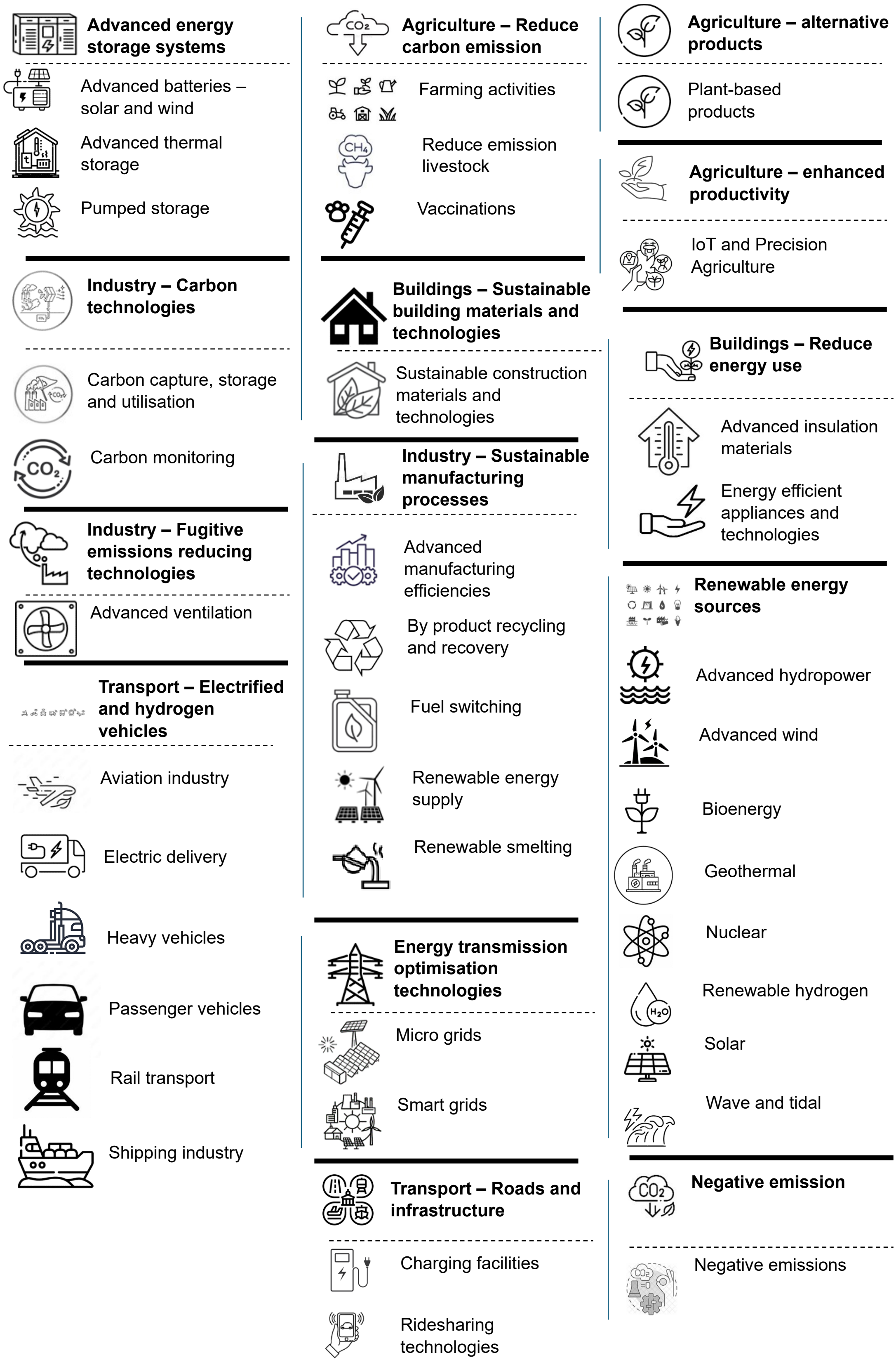

Figure 1 Decarbonisation technology taxonomy

Consideration for governance, application, and presentation

With a decarbonisation taxonomy established, three further points are considered. First is the **governance and maintenance of the taxonomy**. The development of a taxonomy of decarbonisation technologies borrows principles from other contexts such as biological species (Garnett et al., 2020). These principles include:

- The taxonomy is based on science and avoids political or ideological bias.
- The governance and use of the list is community supported and useful for both those making the list and the end users.
- There is transparency in decision-making related to the taxonomy.
- The development of the taxonomy is informed by, but separate to, the process and governance of mapping actors to the taxonomy.
- The establishment of the taxonomy should not limit entrepreneurial and academic freedom to discover and develop new technologies.
- The taxonomy provides clear boundaries while acknowledging cross-over between boundaries.
- The contribution of other's work is recognised.
- Content that informs and adapts the taxonomy is traceable
- The taxonomy is locally relevant, informed, and applied while ensuring global interoperability.

It is not thought that the taxonomy is necessarily the de facto standard. Rather, it provides a starting point to act as a basis to map decarbonisation technology providers, ecosystem enablers, policies, environmental impact, and place-based applications. As soon as it is published, it is expected to be interrogated and integrated with existing and emerging perspectives.

A second consideration relates to **how technologies relate to place and environmental impact**. Technology is central to narratives around place-based net zero transitions to "electrify everything" and create "innovation hot-spots" (Sharp et al., 2024). The application of technology needs to consider local social, economic, and political factors, including tensions around the transition of local industries, which can significantly inhibit or enable decarbonisation technology uptake (Colvin, 2020; Min & Mayfield, 2023). Place-based decarbonisation transition and industrial cluster transformation are systems challenges where technology is part of integrated value chain considerations that touch all aspects of a local community (Balta-Ozkan & Dalkmann, 2024; Devine-Wright, 2022).

Each technology is also considered based on its merit for social and environmental impact. The approach to decarbonisation involving both complimentary and competing options (Davis & Brear, 2022) with trade-offs of risks and opportunities (Sharma et al., 2020), and considerations for those who may benefit and those who might be displaced from technological advancement (Aparisi-Cerdá et al., 2024; Sovacool et al., 2021). The intersection of technology, environment, and place is represented in Figure 2.

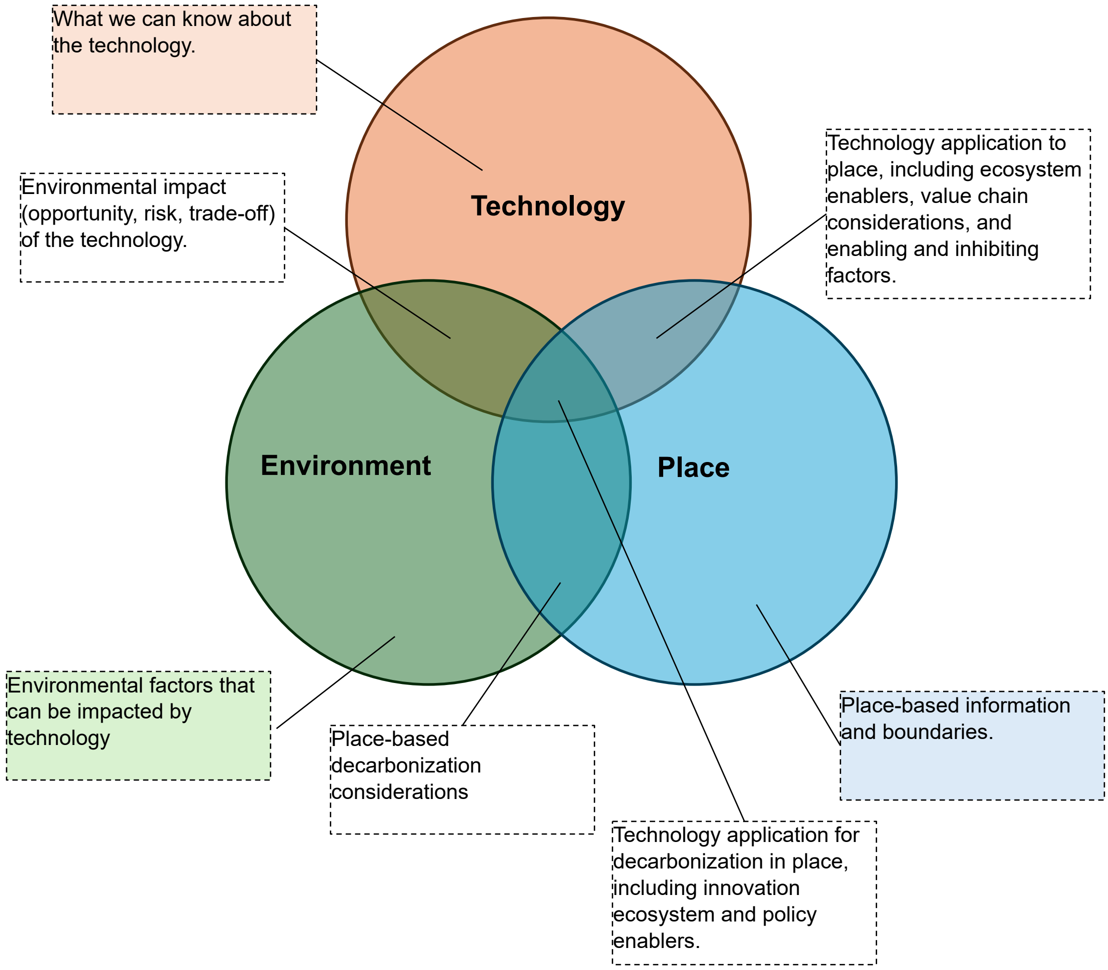

Figure 2 Opportunities at the intersection of technology, environmental impact, and place

A third consideration is **the effective visualisation and access to information about decarbonisation technologies**. Beyond just presenting information, the critical question in presenting decarbonisation technology is “how best to transform the data into something that people can understand for optimal decision making” (Ware, 2020, p. 5). Over 20 interfaces have been reviewed for the structured approach to presenting information related to policy mapping, technology mapping, and climate-specific technology and policy mapping (Appendix).

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Visualising the interface between technology, environmental impact, and place

The decarbonisation technology taxonomy is being tested through a mapping process which has identified a growing list of 62 enabling support institutions, 191 technology providers, and 45 policies added to an online portal. The mapping borrows on and is informed by an existing dataset of over 4,000 actors in the Australian innovation ecosystem from the Startup Status data platform (Startup Status, n.d.)[1].

Using decarbonisation technology as a connection point between technology organisations, support organisations (hubs), and policy allows for the facilitation of more rapid connections and identification of networks. The network graph in the figure below shows the connections between organisation, hubs, policy, and technology categories in the current dataset.

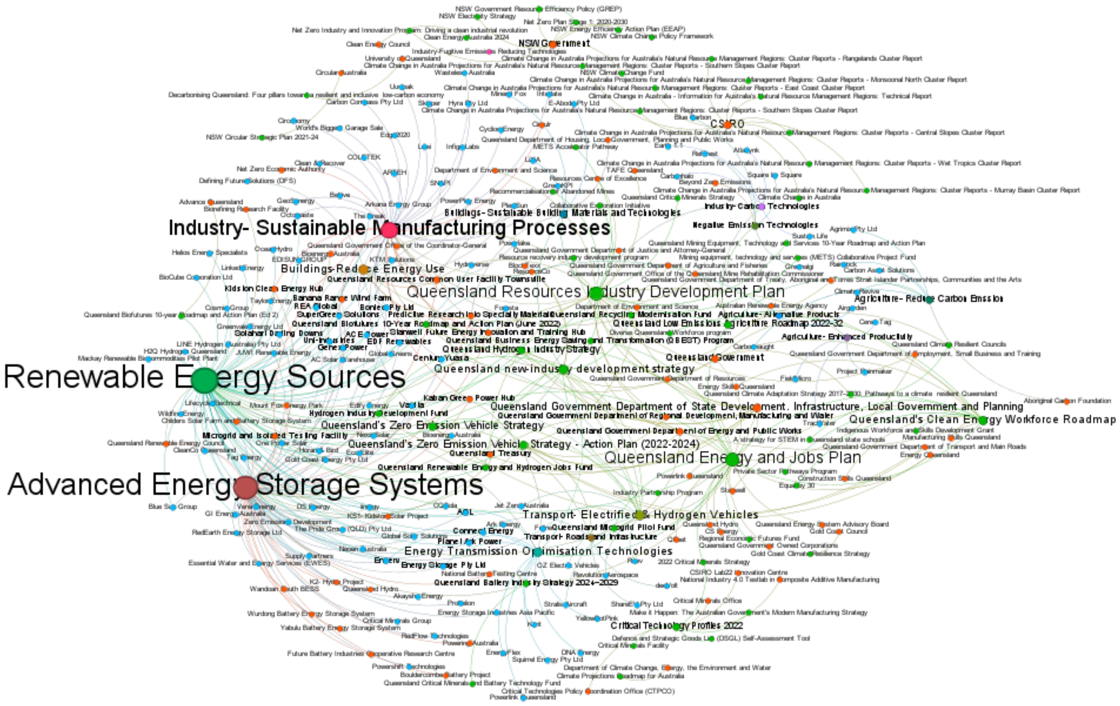

Figure 3 Network graph of current decarbonisation technology mapping dataset

The network can be further refined for a specific area of impact, region, technology, or organisation cohort such as program participants or funding recipients. The network graph below shows the dataset filtered for battery storage. While there are few connections between hubs, policy, and organisation, this will be expected to grow over time as data is updated with publicly available information.

[1] Map of the Australian innovation ecosystem at https://your.startupstatus.co/map/

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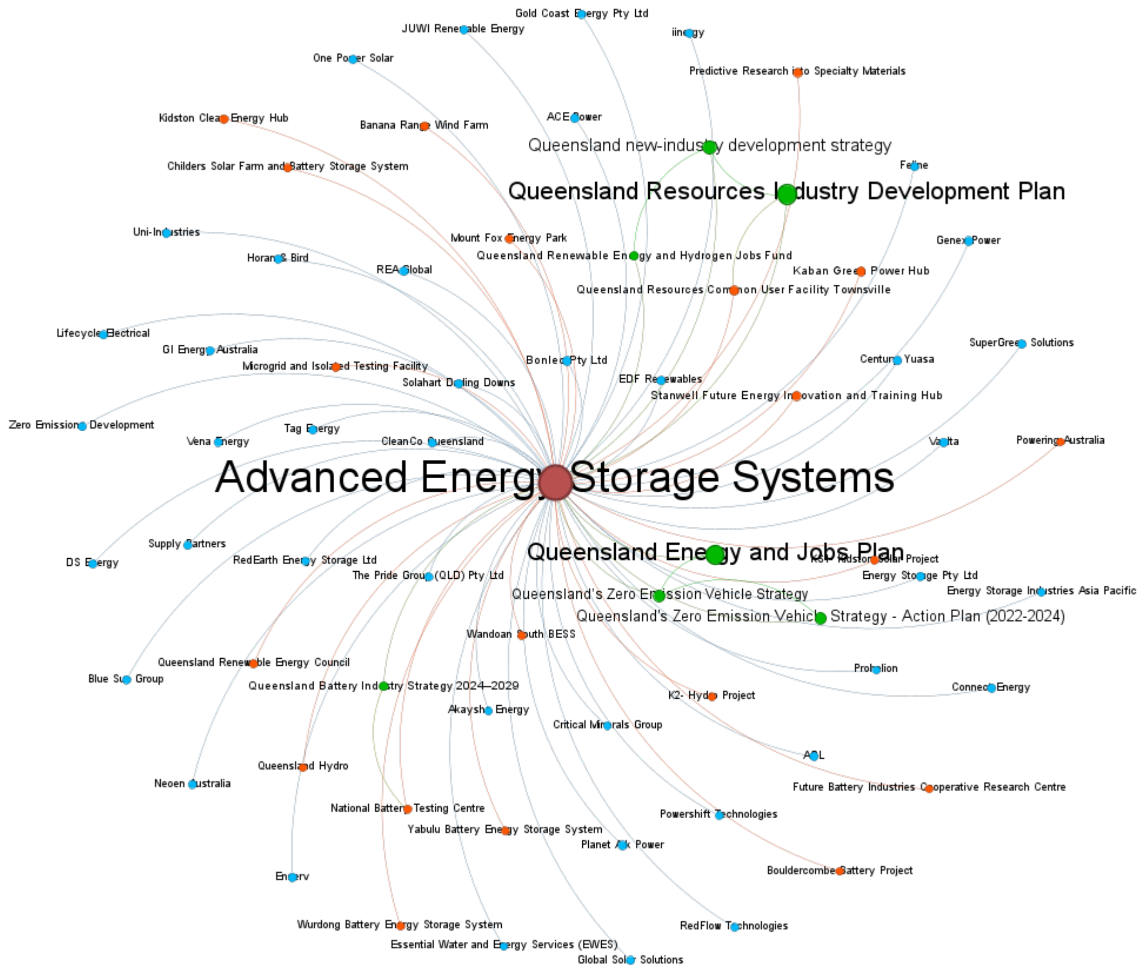

Figure 4 Network graph of current decarbonisation technology mapping dataset filtered for Advanced Battery Storage

The end goal of the mapping process is to have a platform that can be interrogated to reduce barriers to realising commercial, environmental, and social outcomes for Queensland. Such questions might include:

- Who can I connect to for support for agriculture productivity related to decarbonisation?
- Who is involved in battery storage in my region?
- What policies are relevant and what funding is available for advanced manufacturing?
- What organisations can I approach to help inform policy related to hydrogen?

These questions will be asked through a public interface in development to allow efficient access to decarbonisation technologies, ecosystem support, and policies. Additional narratives are being developed to showcase case studies and profile existing policies and progress as it related to place-based transitions and environmental impacts. These will be supported by a series of webinars showcasing the application of specific technologies applied towards environmental impact and place-based transition in Queensland (*Webinar: Decarb Technologies | Queensland Decarbonisation Hub*, n.d.)[2].

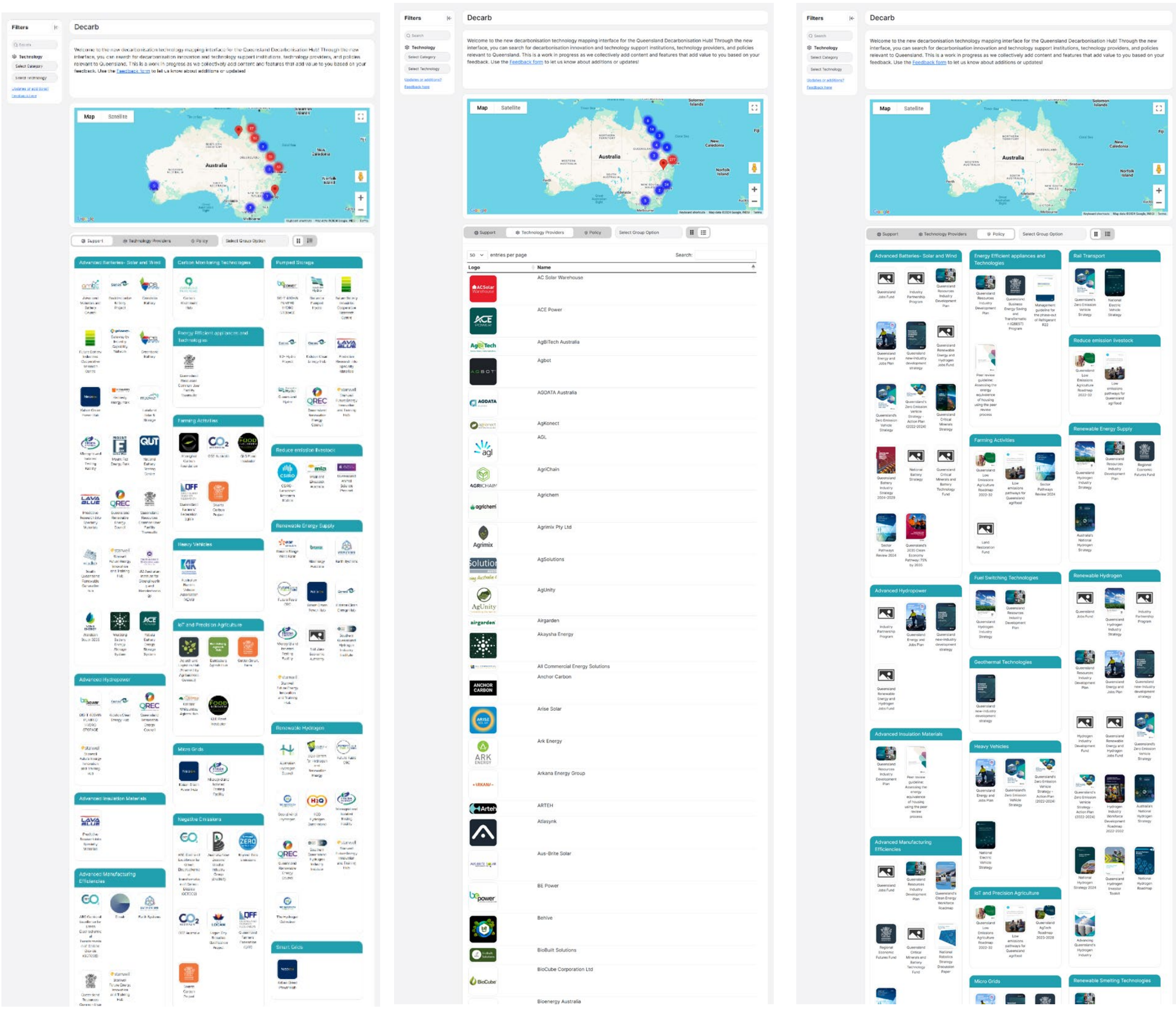

Figure 5 Public interface showing support organisations, technology providers, and policies

[2] Webinar on Decarbonisation Technologies in Queensland https://decarb-hub.org/publication/qld-decarb-hub-webinar

Webinars

The platform will be shared and expanded through a series of webinars focused on specific technologies, projects, and areas of impact. One webinar was held in May 2024 as an initial introduction to support for decarbonisation technologies in Queensland. A second webinar is scheduled in November focused on battery technologies, with subsequent webinars being scheduled four to sic weeks thereafter.

Webinar 1: Support for decarbonisation technologies in Queensland

As the platform was developed, the first webinar on May 31, 2024, focused on existing taxonomies of general decarbonisation technologies with a focus on emerging startups and application. A full webinar write up is posted here: https://www.linkedin.com/pulse/support-decarbonisation-technologies-queensland-chad-renando-deejc/

The webinar attracted over 70 registrations with panellists including:

- **Claudia Vickers:** Director, BioBuilt Solutions Co-Founder, Senseory Plants and Adjunct Professor, QUT
- **Peter Laurie**: New ventures and Innovations Advisor, Director and Founder, Junta Pty Ltd
- **Phillippe Ceulen**: Startup Community Leader, Director, Innovation Architechts, Partner, Mandalay Venture Partners
- **Charlotte Connell**: Climate Innovation and investing, Director of impact for Climate Zeitgeist, Climate Tech Ambassador for Greenhouse, Founder of the Sustainability Collective

The panelists raised challenges related to a lack of understanding and uncertainties around decarbonisation technologies across different sectors.

Peter Laurie highlighted the complexity of navigating these uncertainties stating "*We are operating in uncertainties. It is not enough to have a solution or technology. The real art is how to apply the technology.*".

Charlotte Connell expanded on this point emphasising the fragmented nature of the climate tech sector and a need for greater collaboration "In the climate tech space, it still amazes me that not everybody knows each other. We need co-investments happening to de-risk and do due diligence to help accelerate these solutions". However, Charlotte mentioned that Queensland has shown some uniqueness on climate tech due to political shift and regional advantage, noting that unique to Queensland is *"bipartisan support for emission reduction targets of 75% by 2035 which is a key ingredient to have continuity and confidence that these solutions will be progressed*"

Another critical insight from the webinar is the challenge of transforming decarbonisation technology into an impactful solution. Claudia Vickers spoke from her perspective in academia and research, mentioning "*I didn't feel we did well as in terms of translating technologies and to make a difference in the world*".

The panel explored future trajectories and proposed solutions to existing challenges. A shift towards circular economy was advocated as an immediate action, accompanied by expanded interdisciplinary approaches. The importance of sustained government support and private investment into climate tech startups was highlighted as a solution. The panel highlighted the scale of the challenge and opportunity and the need for multiple and diverse approaches to overcome these challenges.

Webinar 2: Energy storage in Queensland: Mapping opportunities and impacts in research, policy, and technology

The next webinar is scheduled for November 13, 2024 on Energy Storage Technologies and Ecosystem in Queensland With scheduled panelists including Dr Joshua Watts, Associate Professor and Director for the National Battery Testing Centre, Energy Storage Research Group, QUT, and Reagan Parle, Senior Project Manager, Energy Industry Development, Toowoomba and Surat Basin Enterprise, Toowoomba, Queensland.

The aim of these webinars is to commence a regular schedule of technology-focused public conversations to drive traffic and updates to the decarbonisation map.

Engagement strategy

Engagement process

Building on the underlying platform, the innovation and technology engagement strategy is outlined in Figure 6.

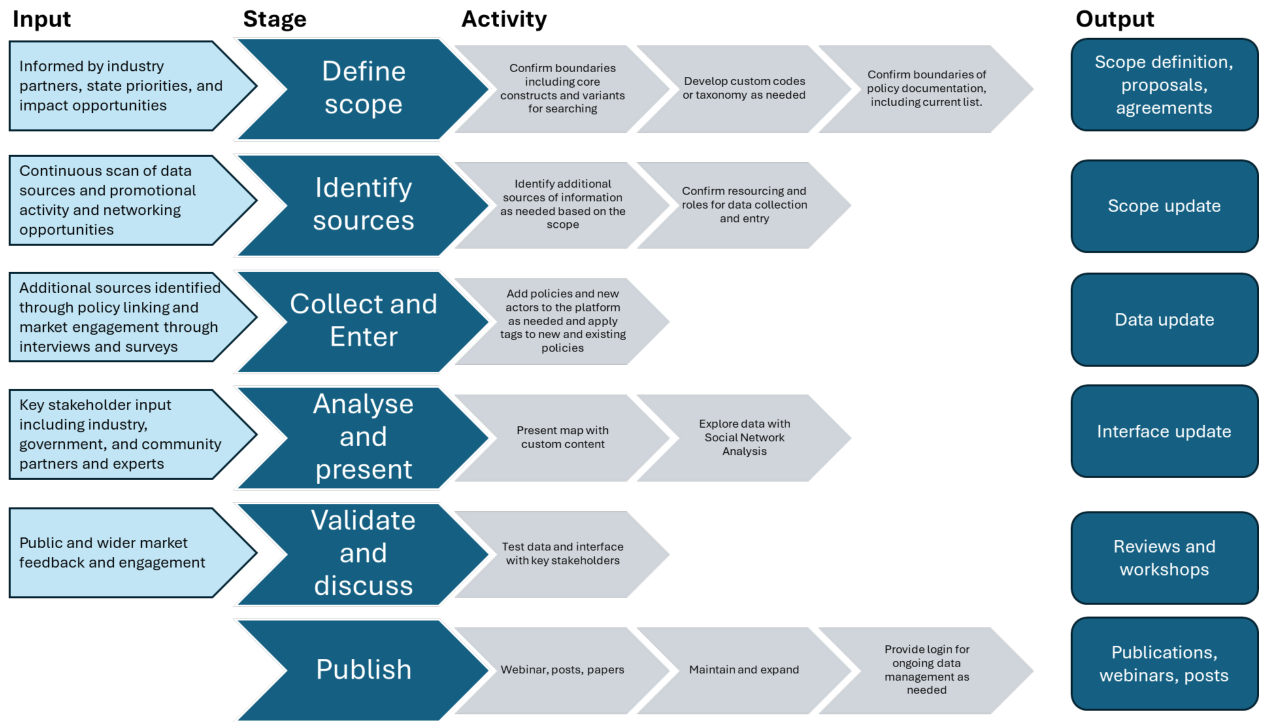

Figure 6 Queensland Decarbonisation Hub Innovcation and Technology Theme Engagement Strategy

Stage 1: Define scope

The scope of each engagement is informed by industry partners, Queensland state priorities, and opportunities for impact. Examples of a scope boundary include a specific technology such as battery storage or quantum, a project such as the use of drones in energy infrastructure, an overall sector focus such as agriculture or tourism, or a context such as related to First Nations or female-founded technology companies or related to a specific region like Goondiwindi or Mt Isa. The scope may inform additional categories to inform the data collection. The scope also considers additional partners and key stakeholders to engage and custom visualisations.

Stage 2: Identify sources

Sources of data include the current data platform, other Australian and global directories such as Crunchbase or Pitchbook or those maintained by industry bodies and research organisations, media and web searches, and key stakeholder interviews. The size of the search, number of sources, and resources required is also determined.

Stage 3: Collect and enter

With the scope and sources identified, data is collected, entered into the online platform, and coded against technology or impact-specific taxonomies. The process is iterative as new sources are identified and the scope is validated and expanded or reduced based on emerging information.

Stage 4: Analyse and present

As the data is entered, the data is shown on the public digital platform. The data is analysed to assess gaps, correlations against geography and shared projects, and alignment with stakeholder expectations.

Stage 5: Validate and discuss

As the project nears completion, the interface is shared with key stakeholders to validate and consider applications and strategies to increase value in Queensland.

Stage 6: Publish

The final publish stage provides a broader public interface through reports, journals, social media and blog posts, and webinars.

Battery storage example

The example below reflects the engagement process applied to battery storage technologies in Queensland.

Scope

Development of renewable energy sources such as solar, wind and hydro are accelerating due to growing concerns over climate change. However, the intermittency of renewable energy has posed significant challenges for its large-scale deployment. Advanced energy storage technologies are essential to addressing this challenge and promoting broader adoption of renewable energy. Advanced energy storage technologies encompass a wide range of systems, applications, initiatives focused on storing energy for later use and can be broadly classified into three types of technologies; batteries, thermal storage technologies and pumped hydro storage technologies.

Batteries are energy storage technology that store and release energy on demand. Lithium-ion batteries are the most common technology for electricity storage. Advance batteries are integrated with other renewable energy sources such as solar and wind to store excess energy and discharge it for later use commonly referred to as a Battery Energy Storage System (BESS).

Pumped Hydro storage technology is a mature technology for storing and generating electricity by utilising renewable resources (wind and solar) to pump water from a lower reservoir to higher one. The water is released from higher reservoir to lower one which spins turbine to generate electricity when in demand.

Thermal storage technology refers to energy storage systems that can hold heat as a means of storing energy. There are three key types of thermal technologies including sensible, latent and thermochemical technologies.

The purpose of mapping the ecosystem of advanced energy storage technologies is to provide a comprehensive overview of existing actors, policies and research. The ultimate goal is to develop a platform that visually presents the ecosystem of advanced storage technologies in Queensland. This platform will highlight technology providers, support hubs, relevant policies and opportunities, while identifying and addressing its barriers for large-scale deployment in Queensland. Specific objectives and intended outcomes of the ecosystem mapping is outlined below.

Objectives and Intended outcomes:

- To create a centralised platform on energy storage system technologies, Queensland government policies, technology providers and relevant research support organisations
- To foster collaboration between industries, researchers, technology providers and government bodies for sharing data, research and advancement in decarbonisation efforts in Queensland
- To identify gaps and areas of improvement in energy storage system technologies for targeted policy development, initiatives and research

Identify sources:

Data mining technique was utilised to systematically identify key sources related to energy storage technologies, relevant policies, technology providers and research and support organisations. Within the category of energy storage systems, three distinct tags were identified on the basis of the scope corresponding to specific types of energy storage technologies. Following process was carried out for identifying sources on energy storage technologies.

- Comprehensive search of Queensland government websites was conducted to identify policies related to decarbonisation efforts with a specific focus on energy storage technologies. Relevant policies were retrieved for adding into the platform for further identification of sources
- Selected policies were reviewed to identify additional related policies, case studies, and technology providers. This involved cross-referencing within the other databases such as gateway by ICN to uncover further sources of information.
- Searching through the university websites for identification of research groups/centres or institutions working within the energy storage technologies

Collect and Enter:

After the information sources were identified, the data related to energy storage technologies were entered into the platform. The tagging system in the platform was utilised to uniquely identify each entry based on specific technology, geographic location and associated policies and funding opportunities. A brief description along with contact details were entered into the platform for further facilitation and engagement for the user. This approach ensured that a comprehensive repository of energy storage technology stakeholders is presented to end user enabling smooth transition to Net Zero by enhancing stakeholders' collaboration.

Analyse and present:

The data in repository is presented through a user-based interface on the basis of specific technologies which is in this case- Advanced energy storage systems and also filtering by a specific technology. Data is presented in three different layouts including support organisations, technology providers and relevant Queensland Government policy framework. The interface is also showing the spectrum of the relevant organisations on the Queensland map to present an overview to the user the saturation and focus of certain areas.

Validate and discuss:

The Interface developed will be shared through the hub's website, online posts and webinar by engaging relevant stakeholders to ensure that it effectively captures the evolving landscape including technology providers, hubs and policies. For wider engagement, feedback form on the interface public website will be provided to users for further validation and discussion.

Publish:

To make the interface widely accessible, webinars, social media posts and papers will be utilised to raise further awareness and enhance collaboration across different actors in the ecosystem and users. Furthermore, stakeholders requiring ongoing data management capabilities will be provided with login access to the system to continuously update and refine data entries.

Future updates

With the launch of the entry version of the digital platform, the Technology and Innovation theme is moving to the next phase of public forums and feature development. The regular open forums will allow for feedback into the platform and realise the outcomes and impact of the theme for raising awareness and showcasing projects, connecting providers with opportunities, and facilitating greater collaboration through information sharing. Feedback from these sessions will inform the addition of new data and features.

Planned development includes:

- Expansion of policy details to highlight individual initiatives and actions and inform future policy development
- Public network graphs showing connection between support, providers, and policies
- Segmenting data based on individual topics, feature news stories, and policy platforms.

References

Akujor, C. E., Uzowuru, E. E., Abubakar, S. S., & Amakom, C. M. (2022). Decarbonisation of the Transport Sector in Nigeria. *Environmental Health Insights*, *16*, 117863022211250. https://doi.org/10.1177/11786302221125039

Aparisi-Cerdá, I., Ribó-Pérez, D., Gomar-Pascual, J., Pineda-Soler, J., Poveda-Bautista, R., & García-Melón, M. (2024). Assessing gender and climate objectives interactions in urban decarbonisation policies. *Renewable and Sustainable Energy Reviews*, *189*, 113927. https://doi.org/10.1016/j.rser.2023.113927

Arogundade, S., Dulaimi, M., & Ajayi, S. (2023). Holistic Review of Construction Process Carbon-Reduction Measures: A Systematic Literature Review Approach. *Buildings*, *13*(7), 1780. https://doi.org/10.3390/buildings13071780

Bailie, A., Pied, M., Vaillancourt, K., Bahn, O., Koasidis, K., Gambhir, A., Wachsmuth, J., Warnke, P., McWilliams, B., Doukas, H., & Nikas, A. (2023). Co-creating Canada's path to net-zero: A stakeholder-driven modelling analysis. *Renewable and Sustainable Energy Transition*, *4*, 100061. https://doi.org/10.1016/j.rset.2023.100061

Balta-Ozkan, N., & Dalkmann, H. (2024). Place-based decarbonisation in low and middle income countries: A whole systems view. *Transport Policy*, *150*, 80–83. https://doi.org/10.1016/j.tranpol.2024.02.019

Becken, S. (2019). Decarbonising tourism: Mission impossible? *Tourism Recreation Research*, *44*(4), 419–433. https://doi.org/10.1080/02508281.2019.1598042

Becken, S. (2024). Mapping the mitigation context for sectoral decarbonisation. *Tourism Recreation Research*, 1–8. https://doi.org/10.1080/02508281.2024.2329847

Borasio, M., & Moret, S. (2022). Deep decarbonisation of regional energy systems: A novel modelling approach and its application to the Italian energy transition. *Renewable and Sustainable Energy Reviews*, *153*, 111730. https://doi.org/10.1016/j.rser.2021.111730

Brinsmead, T. S., Verikios, G., Cook, S., Green, D., Khandoker, T., Kember, O., Reedman, L., Rodriguez, S., & Whitten, S. (2023). *Pathways to Net Zero Emissions – An Australian*

Perspective on Rapid Decarbonisation (p. 142). CSIRO. https://www.csiro.au/-/media/Environment/Net-zero/Reports/Technical-Report_Pathways-to-Net-Zero-Emissions.pdf

Butler, C., Denis-Ryan, A., Graham, P., Kelly, R., Reedman, D. L., Stewart, I., & Yankos, T. (2020). *Decarbonisation Futures: Solutions, actions and benchmarks for a net zero emissions Australia* (p. 138). ClimateWorks Australia. https://www.climateworkscentre.org/wp-content/uploads/2020/04/Decarbonisation-Futures-March-2020-full-report-.pdf

Carmona-Martínez, A. A., Fresneda-Cruz, A., Rueda, A., Birgi, O., Khawaja, C., Janssen, R., Davidis, B., Reumerman, P., Vis, M., Karampinis, E., Grammelis, P., & Jarauta-Córdoba, C. (2022). Renewable Power and Heat for the Decarbonisation of Energy-Intensive Industries. *Processes*, *11*(1), 18. https://doi.org/10.3390/pr11010018

Christodoulou, A., & Cullinane, K. (2021). Potential for, and drivers of, private voluntary initiatives for the decarbonisation of short sea shipping: Evidence from a Swedish ferry line. *Maritime Economics & Logistics*, *23*(4), 632–654. https://doi.org/10.1057/s41278-020-00160-9

Climate Change Authority. (2023). *2023 Annual Progress Report* (p. 212). Climate Change Authority. https://www.climatechangeauthority.gov.au/sites/default/files/documents/2023-11/2023%20AnnualProgressReport_0.pdf

Colvin, R. M. (2020). Social identity in the energy transition: An analysis of the “Stop Adani Convoy” to explore social-political conflict in Australia. *Energy Research & Social Science*, *66*, 101492. https://doi.org/10.1016/j.erss.2020.101492

Cresko, J., Rightor, E., Carpenter, A., Peretti, K., Elliott, N., Nimbalkar, S., Morrow Iii, W., Hasanbeigi, A., Hedman, B., Supekar, S., McMillan, C., Hoffmeister, A., Whitlock, A., Igogo, T., Walzberg, J., D’Alessandro, C., Anderson, S., Atnoorkar, S., Upsani, S., … Liddell, H. (2022). *U.S. Department of Energy’s Industrial Decarbonization Roadmap* (DOE/EE--2635, 1961393; p. DOE/EE--2635, 1961393). https://doi.org/10.2172/1961393

Davis, D., & Brear, M. J. (2022). Decarbonising Australia's National Electricity Market and the role of firm, low-carbon technologies. *Journal of Cleaner Production*, *373*, 133757. https://doi.org/10.1016/j.jclepro.2022.133757

Devine-Wright, P. (2022). Decarbonisation of industrial clusters: A place-based research agenda. *Energy Research & Social Science*, *91*, 102725. https://doi.org/10.1016/j.erss.2022.102725

Element Energy. (2020). *Deep-Decarbonisation Pathways for UK Industry* (p. 71). Element Energy. https://www.theccc.org.uk/wp-content/uploads/2020/12/Element-Energy-Deep-Decarbonisation-Pathways-for-UK-Industry.pdf

European Commission. Directorate General for Energy., E3 Modelling., Ecofys., & Tractebel. (2020). *Technology pathways in decarbonisation scenarios.* Publications Office. https://data.europa.eu/doi/10.2833/994817

Fan, Z., & Friedmann, S. J. (2021). Low-carbon production of iron and steel: Technology options, economic assessment, and policy. *Joule*, *5*(4), 829–862. https://doi.org/10.1016/j.joule.2021.02.018

Fernández, A., & Spencer. (2023). *Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach—2023 Update* (p. 226). International Energy Agency. https://iea.blob.core.windows.net/assets/9a698da4-4002-4e53-8ef3-631d8971bf84/NetZeroRoadmap_AGlobalPathwaytoKeepthe1.5CGoalinReach-2023Update.pdf

Fleiter, T., Rehfeldt, M., Neuwirth, M., & Herbst, A. (2020). Deep decarbonisation of the German industry via electricity or gas? A scenariobased comparison of pathways. *Industrial Efficiency 2020 - Decarbonise Industry! Eceee Industrial Summer Study 2020*, 509–519. https://doi.org/10.24406/publica-fhg-409071

Garnett, S. T., Christidis, L., Conix, S., Costello, M. J., Zachos, F. E., Bánki, O. S., Bao, Y., Barik, S. K., Buckeridge, J. S., Hobern, D., Lien, A., Montgomery, N., Nikolaeva, S., Pyle, R. L., Thomson, S. A., Van Dijk, P. P., Whalen, A., Zhang, Z.-Q., & Thiele, K. R. (2020).

Principles for creating a single authoritative list of the world's species. *PLOS Biology*, *18*(7), e3000736. https://doi.org/10.1371/journal.pbio.3000736

Karliner, J., Roschnik, S., Boyd, R., Ashby, B., Steele, K., & Guinto, R. (2021). *Global Road Map for Health Care Decarbonization* (p. 100). Health Care Without Harm. https://healthcareclimateaction.org/sites/default/files/2021-06/Health%20Care%20Without%20Harm_Health%20Care%20Decarbonization_Road%20Map.pdf

Kayak, E., & Burch, H. (2021). Australian health sector leadership and roadmap for healthcare decarbonisation to net zero emissions. *The Journal of Climate Change and Health*, *4*, 100081. https://doi.org/10.1016/j.joclim.2021.100081

Lamb, W. F., Wiedmann, T., Pongratz, J., Andrew, R., Crippa, M., Olivier, J. G. J., Wiedenhofer, D., Mattioli, G., Khourdajie, A. A., House, J., Pachauri, S., Figueroa, M., Saheb, Y., Slade, R., Hubacek, K., Sun, L., Ribeiro, S. K., Khennas, S., De La Rue Du Can, S., … Minx, J. (2021). A review of trends and drivers of greenhouse gas emissions by sector from 1990 to 2018. *Environmental Research Letters*, *16*(7), 073005. https://doi.org/10.1088/1748-9326/abee4e

Luo, S., Hu, W., Liu, W., Xu, X., Huang, Q., Chen, Z., & Lund, H. (2021). Transition pathways towards a deep decarbonization energy system—A case study in Sichuan, China. *Applied Energy*, *302*, 117507. https://doi.org/10.1016/j.apenergy.2021.117507

Mercader-Moyano, P., & Roldán-Porras, J. (2020). Evaluating Environmental Impact in Foundations and Structures through Disaggregated Models: Towards the Decarbonisation of the Construction Sector. *Sustainability*, *12*(12), 5150. https://doi.org/10.3390/su12125150

Min, Y., & Mayfield, E. (2023). Rooftop solar, electric vehicle, and heat pump adoption in rural areas in the United States. *Energy Research & Social Science*, *105*, 103292. https://doi.org/10.1016/j.erss.2023.103292

Ministry of Business, Innovation & Employment. (2021). *A definition and taxonomy for monitoring the Aotearoa New Zealand agritech sector*. https://www.mbie.govt.nz/dmsdocument/15167-a-definition-and-taxonomy-for-monitoring-the-aotearoa-new-zealand-agritech-sector

Murugesan, M., Reedman, L., Brinsmead, T. S., Rifkin, W., Gordon, J., & Megharaj, M. (2023). Modelling least-cost technology pathways to decarbonise the New South Wales energy system by 2050. *Renewable and Sustainable Energy Transition*, *3*, 100041. https://doi.org/10.1016/j.rset.2022.100041

Nurdiawati, A., & Urban, F. (2021). Towards Deep Decarbonisation of Energy-Intensive Industries: A Review of Current Status, Technologies and Policies. *Energies*, *14*(9), 2408. https://doi.org/10.3390/en14092408

OECD. (2021). *Policies for a Carbon-Neutral Industry in the Netherlands*. OECD. https://doi.org/10.1787/6813bf38-en

Papadis, E., & Tsatsaronis, G. (2020). Challenges in the decarbonization of the energy sector. *Energy*, *205*, 118025. https://doi.org/10.1016/j.energy.2020.118025

Rattle, I., Gailani, A., & Taylor, P. G. (2024). Decarbonisation strategies in industry: Going beyond clusters. *Sustainability Science*, *19*(1), 105–123. https://doi.org/10.1007/s11625-023-01313-4

Renando, C. (2020). *The role of innovative hubs in building community resilience*. University of Southern Queensland.

Renando, C., & Simpson, C. (2023). *2023 Australian Agritech Sector Report* (p. 58). Australian Agritech Association. https://ausagritech.org/survey-report/

Rissman, J., Bataille, C., Masanet, E., Aden, N., Morrow, W. R., Zhou, N., Elliott, N., Dell, R., Heeren, N., Huckestein, B., Cresko, J., Miller, S. A., Roy, J., Fennell, P., Cremmins, B., Koch Blank, T., Hone, D., Williams, E. D., De La Rue Du Can, S., … Helseth, J. (2020). Technologies and policies to decarbonize global industry: Review and assessment of mitigation drivers through 2070. *Applied Energy*, *266*, 114848. https://doi.org/10.1016/j.apenergy.2020.114848

Rohith, G., Devika, K. B., Menon, P. P., & Subramanian, S. C. (2023). Sustainable Heavy Goods Vehicle Electrification Strategies for Long-Haul Road Freight Transportation. *IEEE Access*, *11*, 26459–26470. https://doi.org/10.1109/ACCESS.2023.3257431

Sharma, T., Ó Gallachóir, B., & Rogan, F. (2020). A new hybrid approach for evaluating technology risks and opportunities in the energy transition in Ireland. *Environmental Innovation and Societal Transitions*, *35*, 429–444. https://doi.org/10.1016/j.eist.2020.01.012

Sharp, D., Raven, R., & Farrelly, M. (2024). Pluralising place frames in urban transition management: Net-zero transitions at precinct scale. *Environmental Innovation and Societal Transitions*, *50*, 100803. https://doi.org/10.1016/j.eist.2023.100803

Sovacool, B. K., Turnheim, B., Hook, A., Brock, A., & Martiskainen, M. (2021). Dispossessed by decarbonisation: Reducing vulnerability, injustice, and inequality in the lived experience of low-carbon pathways. *World Development*, *137*, 105116. https://doi.org/10.1016/j.worlddev.2020.105116

Startup Status. (n.d.). *Map of the Australian Innovation Ecosystem*. Retrieved 17 July 2024, from https://your.startupstatus.co/map/#All#All#All#All#All#All#All#All#role

Svensson, J., Waisman, H., Vogt-Schilb, A., Bataille, C., Aubert, P.-M., Jaramilo-Gil, M., Angulo-Paniagua, J., Arguello, R., Bravo, G., Buira, D., Collado, M., De La Torre Ugarte, D., Delgado, R., Lallana, F., Quiros-Tortos, J., Soria, R., Tovilla, J., & Villamar, D. (2021). A low GHG development pathway design framework for agriculture, forestry and land use. *Energy Strategy Reviews*, *37*, 100683. https://doi.org/10.1016/j.esr.2021.100683

Voitko, S., Trofymenko, O., & Pavlenco, T. (2021). Decarbonisation of the economy through the introduction of innovative technologies into the energy sector. *E3S Web of Conferences*, *255*, 01016. https://doi.org/10.1051/e3sconf/202125501016

Wang, F., Harindintwali, J. D., Yuan, Z., Wang, M., Wang, F., Li, S., Yin, Z., Huang, L., Fu, Y., Li, L., Chang, S. X., Zhang, L., Rinklebe, J., Yuan, Z., Zhu, Q., Xiang, L., Tsang, D. C. W., Xu, L., Jiang, X., … Chen, J. M. (2021). Technologies and perspectives for achieving carbon neutrality. *The Innovation*, *2*(4), 100180. https://doi.org/10.1016/j.xinn.2021.100180

Ware, C. (2020). *Information Visualization: Perception for Design* (4th edition). Morgan Kaufmann.

Webinar: Decarb Technologies | Queensland Decarbonisation Hub. (n.d.). Retrieved 17 July 2024, from https://decarb-hub.org/publication/qld-decarb-hub-webinar