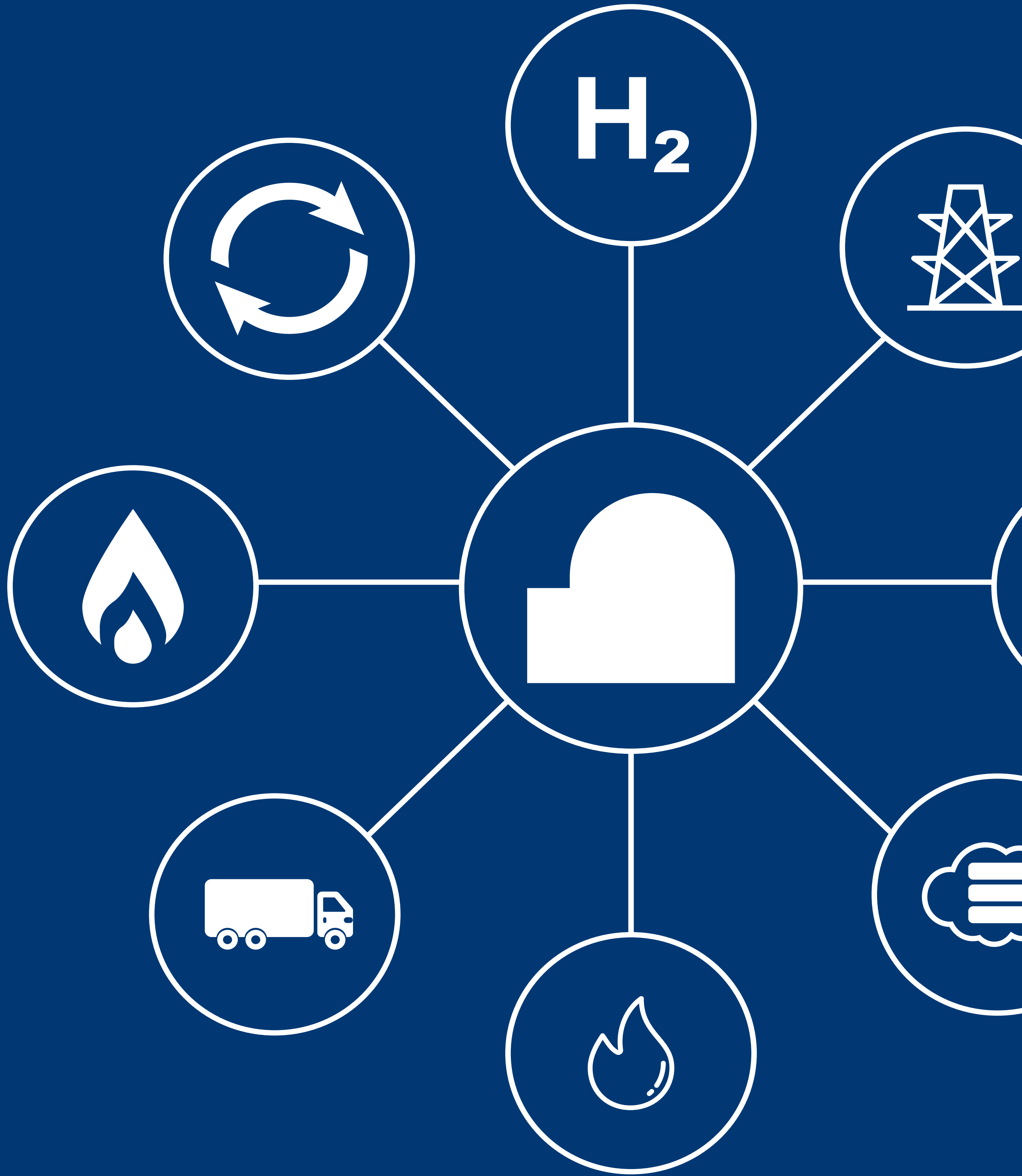
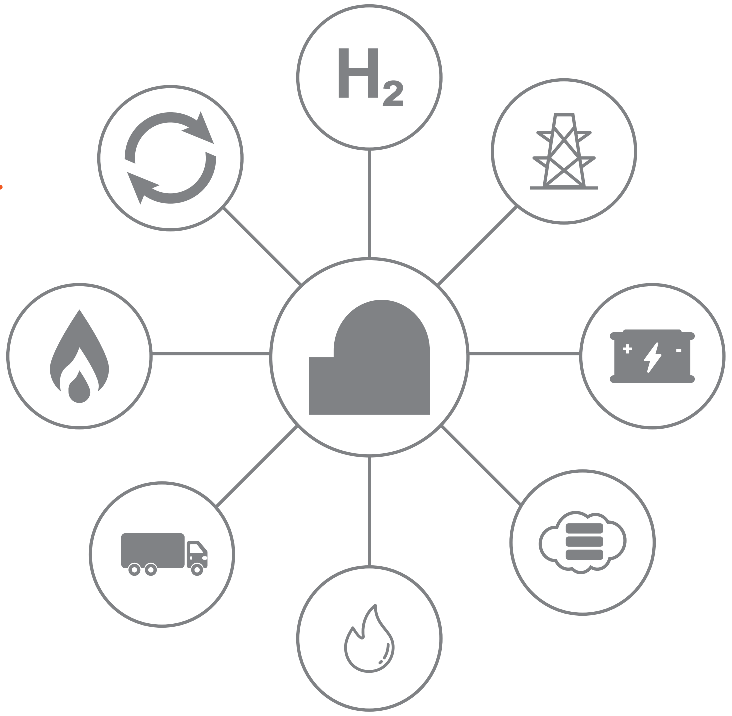
Clean Energy Hub

Moorside, Cumbria



A complete transition of the GB energy system is needed to deliver the UK's net zero target for greenhouse gas emissions by 2050.



Low carbon electricity is a critical component of this transition. In December 2017, the Government published a Written Statement on Energy Infrastructure which asserted that 'new nuclear power generation remains key to meeting our 2050 obligations'. The UK Government's Committee on Climate Change anticipates that the need for electricity will double by 2050, while the need for low carbon electricity will quadruple. This need is exacerbated as over 60% of current UK generating capacity (c. 64GWe) is anticipated to be lost due to plant retirements by 2035. Delivering this massive expansion of low carbon energy will require contributions from wind, solar and nuclear generation, as well as from flexible low carbon technologies.

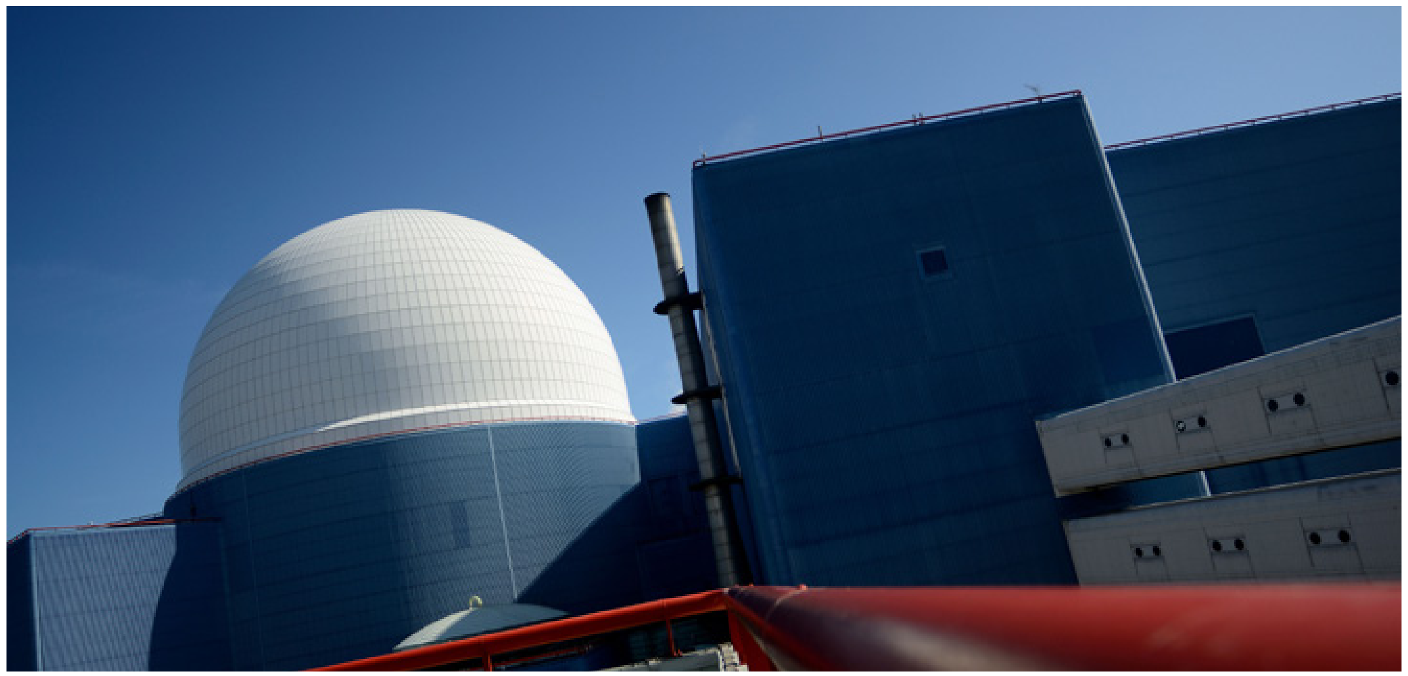
However, thinking about the decarbonisation of electricity alone is not enough. The UK also needs to decarbonise its heat, transport and industrial processes. This decarbonisation will be enabled, in part, by converting processes that are currently powered by fossil fuels to run on low-carbon electricity and/or hydrogen.

Considering the energy system across all sectors means it is possible to imagine an even greater value contribution from nuclear in delivering our challenging net zero goals. As well as producing valuable continuous power, nuclear stations also produce vast quantities of heat.

Integrating this production with storage, hydrogen production and local energy use can provide synergies in terms of using and managing the electrical grid and enable the greater decarbonisation of heat, transport and industrial processes.

Co-location of these different technologies – in a low carbon energy hub – creates flexibility, where the by-products from one process can be used to increase the efficiency of another optimised in real-time to deliver the most value to the energy system as a whole. This concept has the potential to bring further jobs and economic benefit to the region, at a time when the reprocessing operations at Sellafield cease, resulting in the loss of a number of job roles.

A variety of consents would be required for the components of the energy hub to be realised, including planning permission for the physical infrastructure. The location of all elements would need to be subject to careful consideration and discussion with local stakeholders, including the local planning authority, and subject to standard planning application processes.



Moorside can be a location for a low carbon energy hub

Moorside (figure 1) has the potential to offer more to the UK than 3.2GW of reliable low carbon electrical power output.

Like all nuclear stations, Moorside would produce heat (~8GWe) in the form of clean hot water. As illustrated in the figure 2, it is possible to extract high grade heat from the generation process or to simply use the low grade waste heat at the back end of the process.

The heat is key to the energy hub concept, but it is not the only advantage an energy hub can provide. In addition, the energy hub offers:

- Access to a reliable electrical grid connection via Moorside. Moorside is connected to a key point on the grid for current and future offshore wind projects expected off the Cumbrian coast.
- Proximity to ports at Barrow and Workington and transport hubs in the wider North West of England.

Figure 1: Moorside site context

Copeland Local Plan (2013-2028) – Policies Map

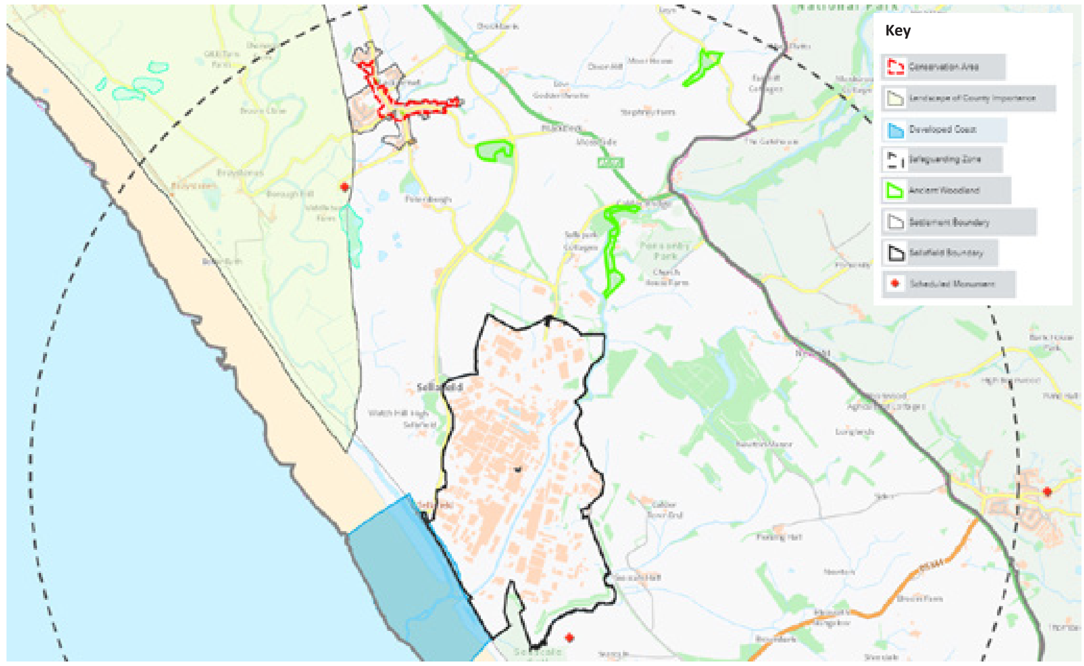


Figure 2: Nuclear Steam Cycle

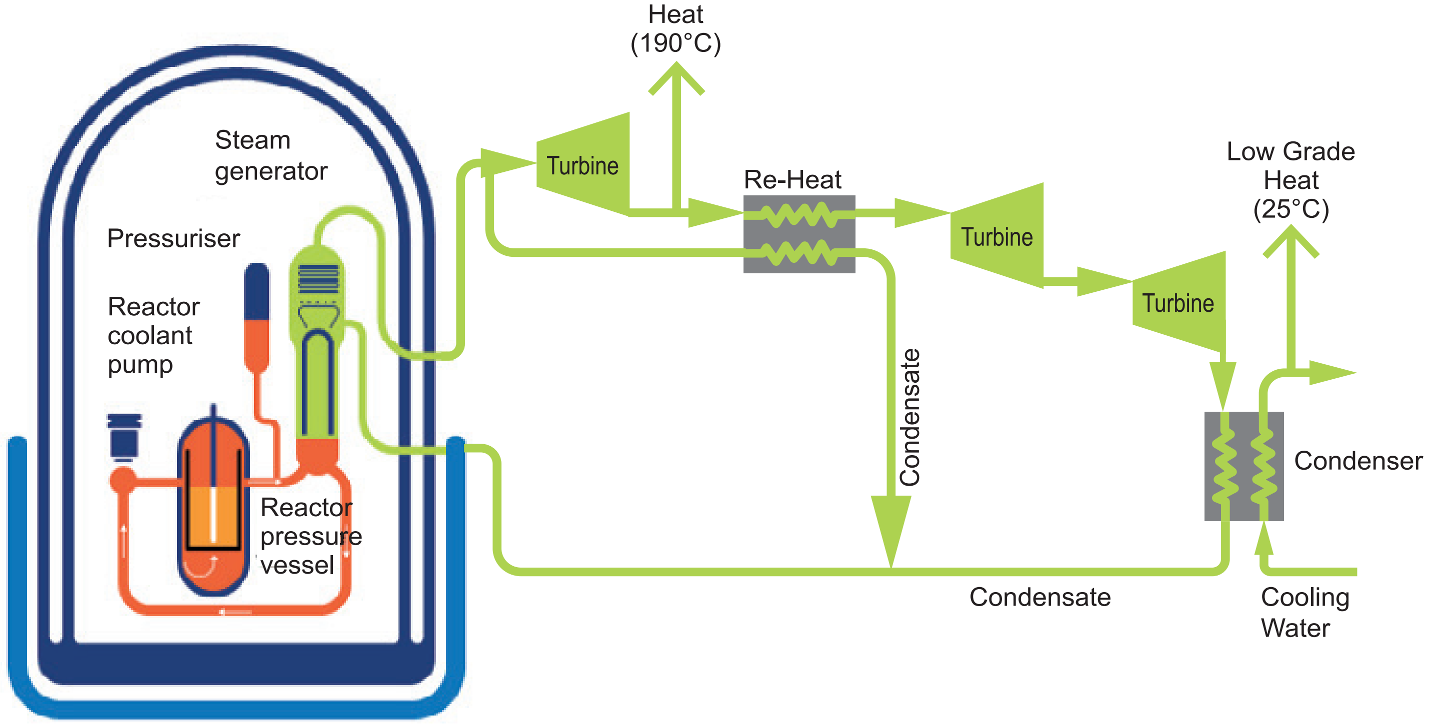


Figure 3: Clean Energy Hub flow diagram

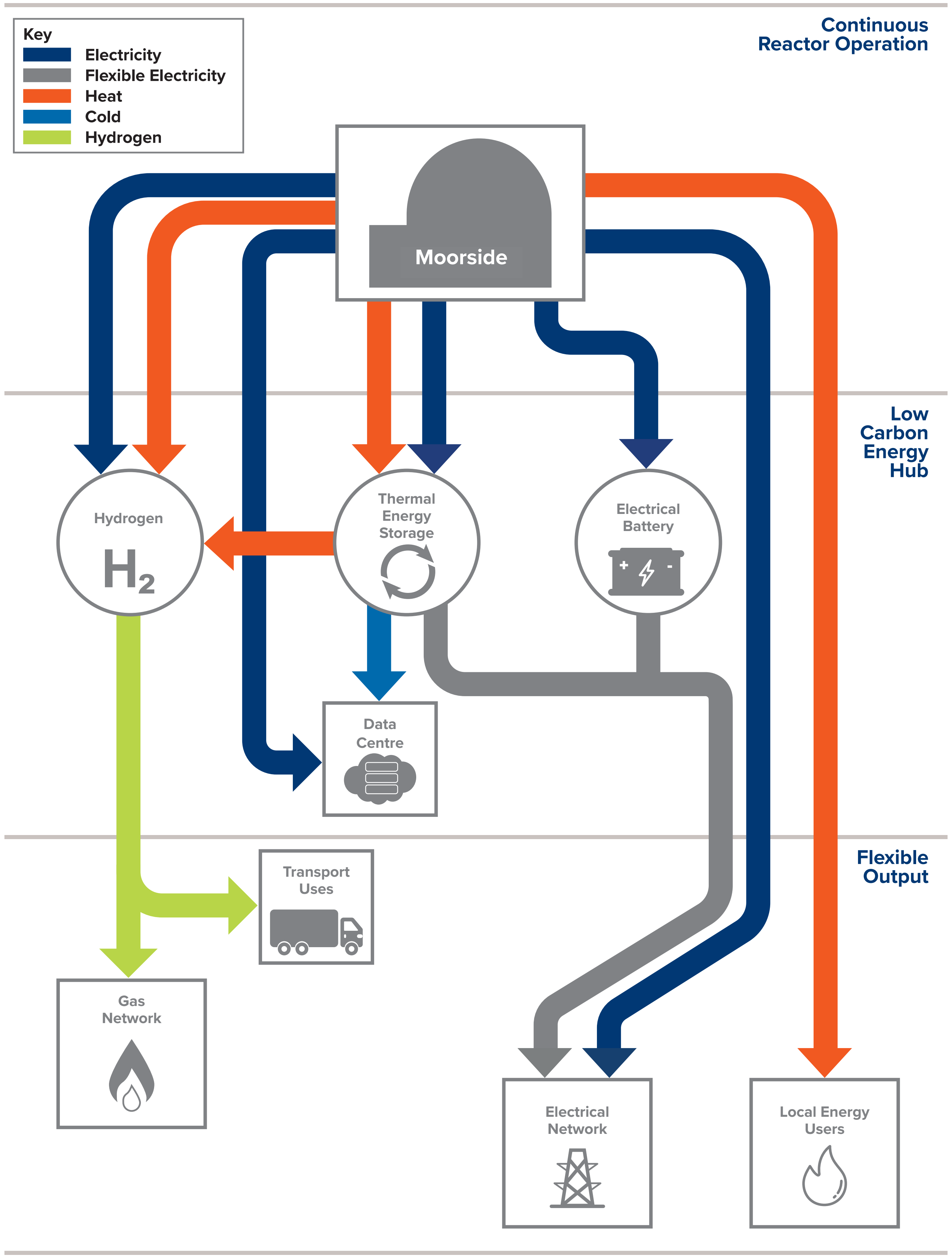


Figure 3 opposite shows how the low carbon energy hub concept could work.

Moorside would have continuous reactor operation producing 3.2GW of low carbon electricity and approximately 8GW of low carbon heat. The energy hub could translate this into 2-4GW of flexible electrical output, green hydrogen and power and heat for local use.

Figure 3 shows the proposed flows of heat (in the form of hot water), electricity, cold (in the form of cold water or liquified air) and hydrogen.

Technologies shown in circles are parts of the energy hub dedicated to storing or transforming energy, while the rectangles denote customers for energy.

Figure 3 shows potential energy flows between the technologies:

- Ability to extract heat from the electricity generation steam cycle to enable flexible energy outputs.
- The high grade heat produced during the charging phase of the cryogenic storage could be used to boost the efficiency of hydrogen production and thermal flow storage.
- The cool stores of air in the cryogenic storage can be used as emergency cooling for the data centre.
- A combination of electric batteries, thermal flow storage and cryogenic storage provides sub-second response, system inertia and long duration response.

As well as offering physical synergies, the energy hub also creates the arbitrage opportunity to flex its outputs to best meet the needs of the system and its customers. The energy hub can be optimised in real time to adapt to conditions depending on the weather, the time of year and the dynamic demand for different products allowing a nuclear generator to offer even better value to the UK energy system.

Green Hydrogen

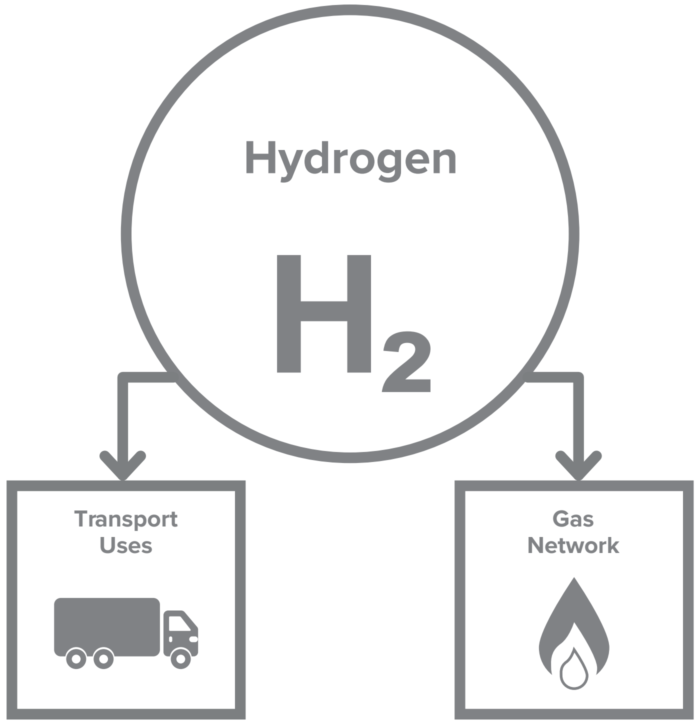
Opportunity
The challenges for decarbonisation in the UK include heat, transport and industry as well as electricity. Green hydrogen is a low carbon product which could help in decarbonising all of these sectors by providing fuel for heavy goods vehicles and replacing natural gas in the gas grid.

Hydrogen also has the potential to act as an energy storage medium. By using low cost energy during periods of high production or low demand to make hydrogen through electrolysis, it can then be stored (for example in caverns or tanks) and re-converted to electricity in a turbine or fuel cell when there is a shortfall in low carbon power available to the system.

Solution
Electrolysis is the process of turning water into hydrogen using electricity. The hydrogen produced is a low carbon fuel essential in many decarbonisation pathways.

The technology for electrolysis is undergoing rapid development. One of the most promising electrolysis technologies is high temperature or steam electrolysis. Steam electrolysis uses input heat to boost efficiency.

This could be integrated into the energy hub by using heat from Moorside to boost the temperature of input water; for example, a temperature of 150°C could reduce the electrical energy requirement for the electrolysis by 10-15% when compared to systems without heat added. Higher grade heat, for example, from cryo-batteries, could boost the efficiency further.



Benefits
A low carbon energy hub has the potential to produce low cost green hydrogen. The low cost will come from maximising efficiency (by using the available heat), low cost electricity (supplied directly from Moorside) and economies of scale in production. The green hydrogen could be used to:

- Replace natural gas in the GB gas grid (either by blending or by completely replacing in future).
- Supply vehicles (HGVs, buses, trains and shipping) with hydrogen fuel - see figure 4.
- Provide a storable carbon-free fuel for when the UK system requires back-up power during wind lulls and peak winter demand - see figure 5.

Figure 4: Hydrogen Bus

Moorside Datahub

Opportunity
Data centres are extremely large power users. The largest centres have demands of hundreds of MWs (equivalent to a small city). Much of this demand (up to 50%) is for cooling.

Data centres have particular requirements for secure continuous electrical supply, and are seeking to reduce their environmental impact by using low carbon power. The combination of requirements makes the low carbon energy hub concept ideal for a large data centre.

Solution
A large data centre could form part of the energy hub. The data centre would need to have a secure connection to the National Grid and the Moorside generator via a private wire connection. Further security of supply could be provided by the energy storage in the energy hub, potentially including interlinking the data centre cooling systems with the liquid air stores of the cryo-batteries to provide emergency cooling. This would reduce/eliminate the requirement for back-up diesel generation.

Counterintuitively, there is also the possibility to use heat from Moorside to cool a data centre. Absorption chilling is a form of cooling that uses heat to circulate a refrigerant in a cooling cycle (providing cooling). Thus, the energy input into the system is heat. If this method of chilling is used with heat from Moorside, it may significantly reduce the electricity demand of a data centre.

Designing contingency in the data centre cooling system would allow the data centre to operate with limited power for short periods of time. This design would allow the data centre to provide reduction in power consumption (demand side response) to assist the electricity network in managing short term disruptions.

Benefits
- Secure carbon-free power directly from Moorside.
- Access to the National Grid – four transmission lines provide a reliable connection to the National Grid to provide power on the rare occasions when Moorside is not generating.
- Potential to use heat from Moorside for cooling the data centre.
- Secure back-up power supplies from co-located storage.
- Access to emergency chilling from cryogenic storage is possible.
- Provide fast demand side response to assist the electricity network in managing short term disruptions.
- Reduced cost of energy for the data centre – supply is via a private wire and no additional grid infrastructure is required.
- Provision of data services to the UK.

Figure 5: Offshore windfarm

Flexible Energy Storage

Opportunity

The UK network requires flexibility to accommodate increasing variable renewable generation. Key challenges include:

- Stabilising the network, since variable renewable generation does not automatically provide inertia to help balance generation and stabilise the system frequency.
- Providing low carbon electricity during extended periods when variable renewable generation output is low. Longer duration storage technologies may help provide this electricity.

Solution

The low carbon energy hub allows the possibility to combine different storage technologies to provide sub-second response, system inertia and longer duration response. We propose considering Lithium ion batteries for fast (sub-second) response and thermal energy storage for longer duration storage.

There are several thermal energy storage technologies that could be deployed in the energy hub, for example:

- Cryogenic storage (Cryo-batteries) – energy is stored by liquefying air and storing it in cold tanks at approx -200^{0}C (see Figure 6). Energy is discharged by rapid re-gasification causing a massive expansion in volume which is used to drive a turbine. Low grade heat from Moorside could be used as a heat input during the regasification process. This could limit the requirement to store high grade heat, allowing this to be used in other processes (such as hydrogen production). The heat will be produced during times of energy storage. As such, it is likely to be coincident with low carbon energy abundance and hence hydrogen production.
- Pumped heat thermal energy storage – where electricity is used to create hot and cold temperature stores using similar principles as outlined in Figure 6. The temperature difference is used to rotate a generator and produce power when required. Additional hours of storage can be added at low cost by increasing the heat storage capacity. These hot and cold stores could also be used for other processes in the energy hub. High grade heat from Moorside could be used to improve the processes round-trip efficiency.

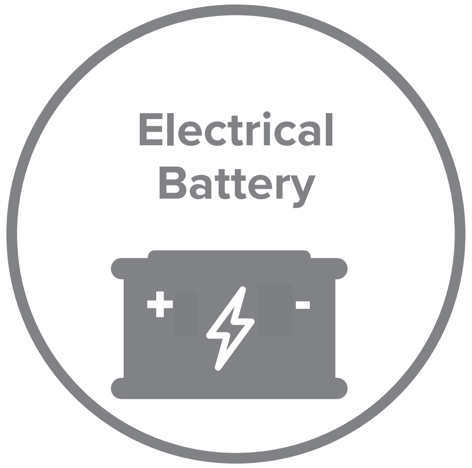
Benefits

The combination of electric batteries, thermal flow storage and cryogenic storage in the energy hub could provide the following benefits:

- Power output flexibility – the energy hub could turn down the power export from Moorside without wasting its energy, and then provide increased electricity export during extended periods of low renewable generation.
- Increase in inertia – Moorside generator (which uses rotating plant) is a crucial source of system inertia. Both thermal flow and cryogenic storage also use rotating plant to discharge power. The rotating plant could be designed to be continuously spinning to provide an additional source of system inertia.
- Security of supply – having on-site energy storage enhances security of supply to key loads in the energy hub, including data centres.

The energy hub is well placed to export additional power during periods of low wind.

There are several major offshore wind farms in operation on the West Cumbrian coast and further offshore wind projects and cable interconnectors are planned or being built in the Irish Sea meaning the scope for integrating Moorside flexible exports could increase in the next decade.



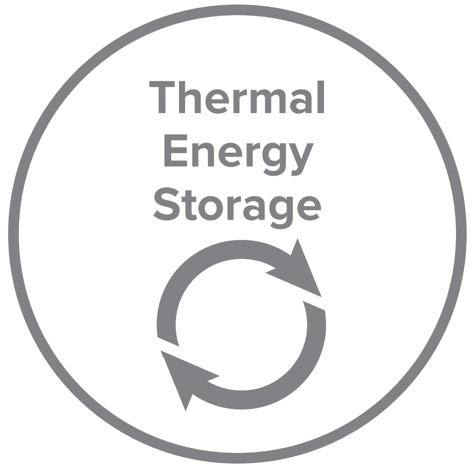
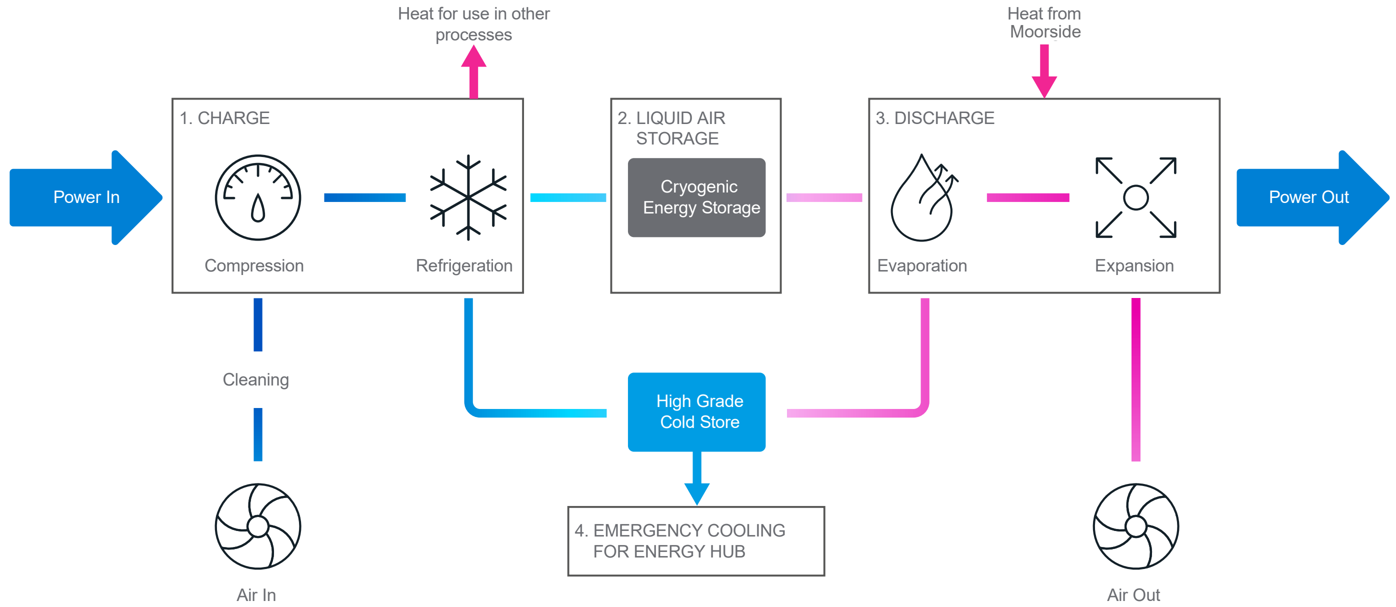


Figure 6: Cryo-battery flow diagram



Source: Highview Power diagram showing Cryo-batteries processes

Key to Figure 6**.**

1. Charge Stage

The input air is refrigerated until it becomes liquid by a series of compression and cooling stages (powered by electricity). This stage produces waste heat. This heat can be used in other clean energy hub processes including to enhance the efficiency of hydrogen production.

2. Storage Stage

The liquified air is stored in low pressure tanks.

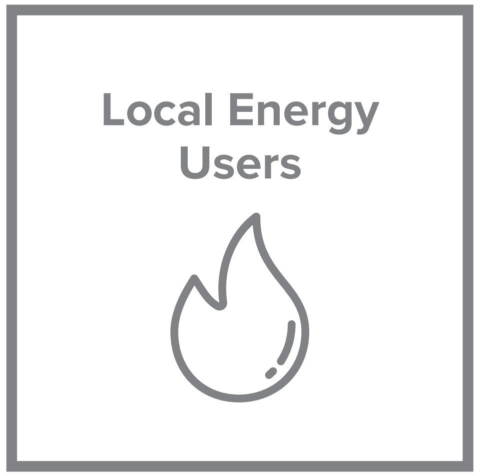
3. Discharge Stage

When electricity is needed, the liquified air is heated (by waste heat from Moorside) and expanded. The resultant high pressure gas is used to turn turbines producing electricity.

4. Cold Store

The discharge stage produces waste cold (from the liquified air). This is captured and stored to be used in the cooling of the charge stage. This improves the efficiency of the process. This cold store could also be used to assist other processes in the clean energy hub such as providing emergency cooling for the data centre.

Local Energy Users



In addition to the core aspects of the low carbon energy hub, Moorside could also provide support to local energy users. A non-exclusive list of such users includes:

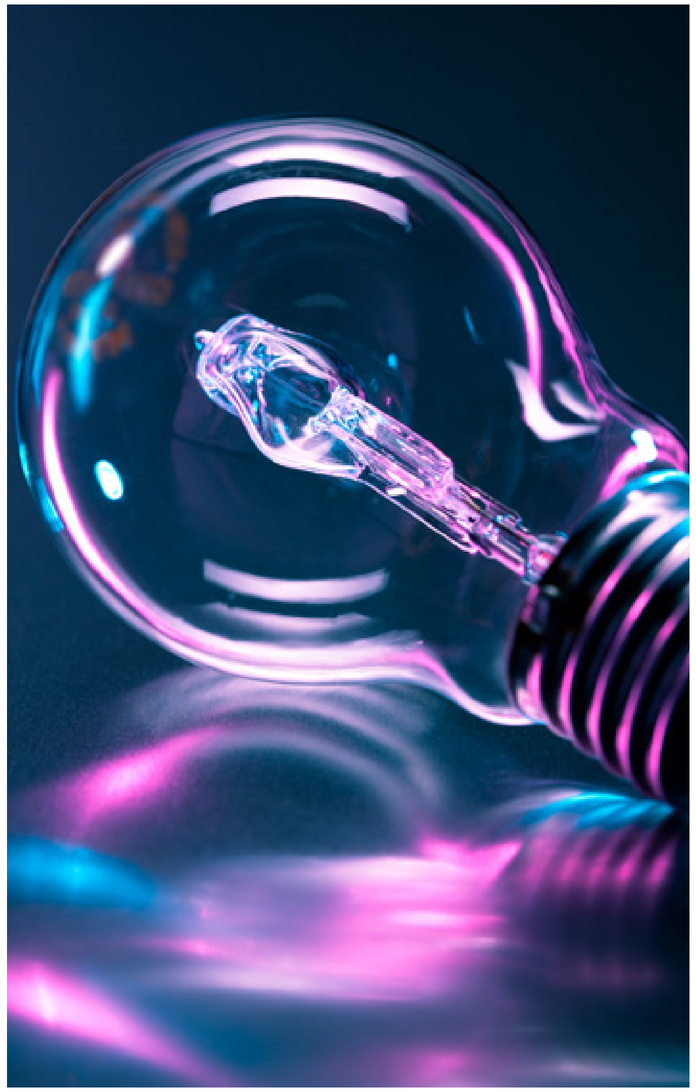
Industry
Local industries which require heat, such as the Fellside CHP plant and proposed coking coal extraction, could benefit from the energy hub. We will engage with local industry to provide support.

Housing
New housing developments built in West Cumbria could source low cost carbon-free heat from Moorside using a district heating scheme. There is a potential for permanent housing to be a legacy project from the Moorside working accommodation sites.

Agriculture
Heat from Moorside could be used to heat greenhouses and polytunnels near Moorside to enable exotic fruit, vegetables and plants to be grown year-round. This would reduce the carbon impact of transport and help local farmers diversify their offering to the market.

Transport
The Moorside site is close to the port and shipbuilding centre of expertise at Barrow. The site is also close to other ports at Workington and Whitehaven. Hydrogen may play a key role for the decarbonisation of HGV transport and shipping. Moorside could be a key source in the low carbon fuel, reducing the carbon impact of transport.

Technology Moving to Maturity



Mature technology
Nuclear Energy Providing Heat
Nuclear power stations produce heat as well as electricity. Some stations, including four nuclear power generators in Switzerland, provide heat as a commercial service. The stations have been in operation for 25 years and provide heat to thousands of residential and commercial buildings with a district heating system. This is a mature application.

Developing technologies
Green Hydrogen
With the UK commitment to net zero targets, hydrogen could play a key part to decarbonise heating, transport, electricity and industry. At present, multi-megawatt electrolysers are in the demonstration stage including the 10MW Refhyne demonstrator in Germany. The largest high temperature or steam electrolysis system in operation is a 750kW demonstrator in Germany. There is a high probability that electrolyser technology will become commercially available for large-scale deployment as early as the mid to late 2020s.

Using Heat for Energy Storage
UK companies are some of the leading players driving the development of technologies using heat for energy storage. BEIS is supporting technology developers to implement demonstrators. Project Malta (a former Google X company) and Siemens are also developing pumped heat energy storage technologies. There is a high probability that heat energy storage technologies will become commercially available for large-scale deployment within the next 5 years.

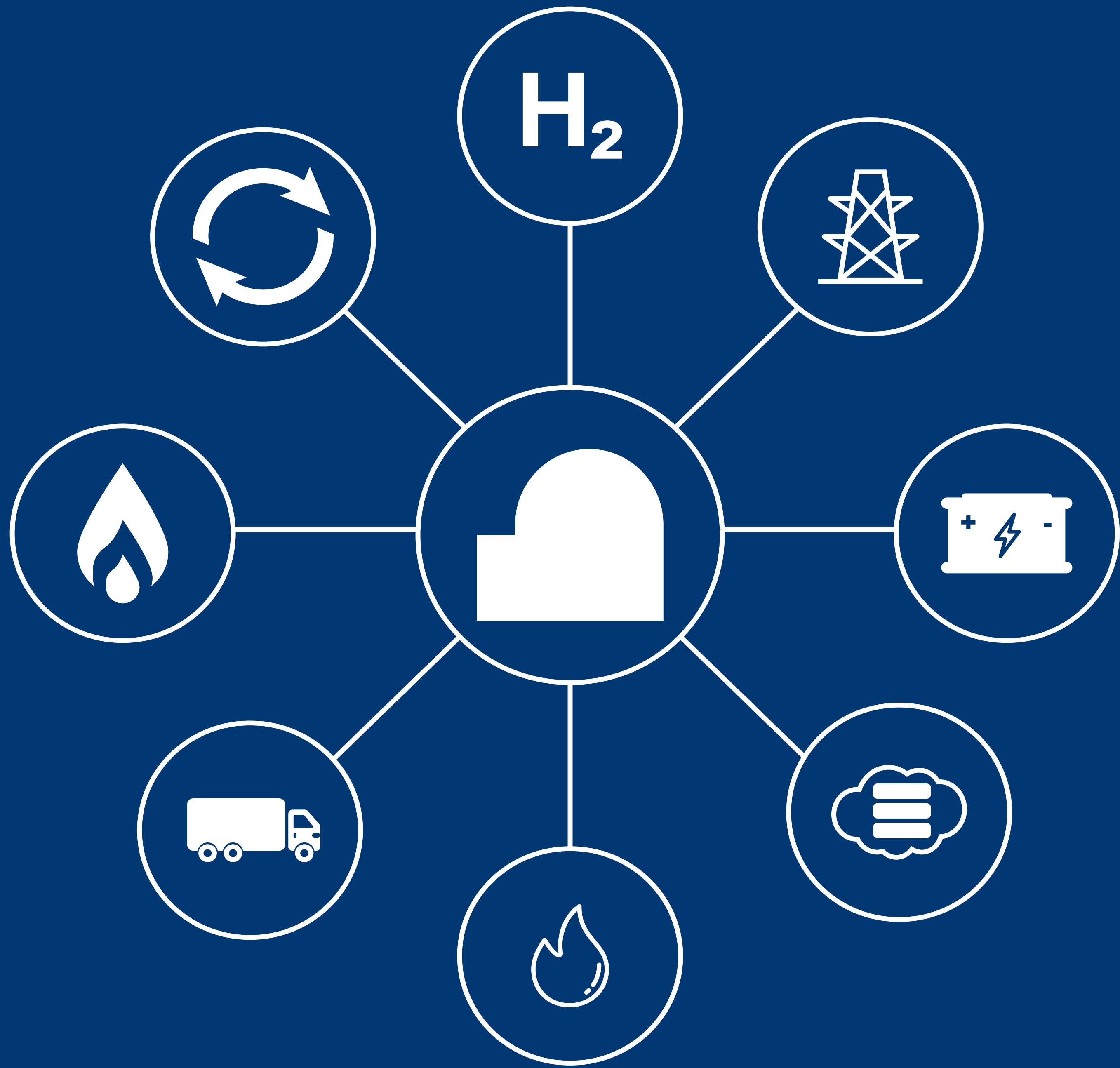
Contact Details

Mark Liddiard
Global Practice Leader Nuclear

Direct: 0121 234 1574
Email: mark.liddiard@mottmac.com

Prem Mahi
Energy Knowledge and Innovation Director

Direct: 01273 365165
Email: prem.mahi@mottmac.com



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This brochure has been prepared by Mott MacDonald for the Moorside Clean Energy Hub.

MOTT MACDONALD

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