GREBE

Generating Renewable Energy Business Enterprise

Northern Periphery and Arctic Programme 2014–2020

Advice Notes on Energy Storage Economics for the NPA Region

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The GREBE Project

What is GREBE?

GREBE (Generating Renewable Energy Business Enterprise) is a €1.77m, 3-year (2015-2018) transnational project to support the renewable energy sector. It is co-funded by the EU's Northern Periphery & Arctic (NPA) Programme. It focuses on the challenges of peripheral and arctic regions as places for doing business, and helps develop renewable energy business opportunities in areas with extreme conditions.

The project partnership includes the eight partners from six countries, Western Development Commission (Ireland), Action Renewables (Northern Ireland), Fermanagh & Omagh District Council (Northern Ireland), Environmental Research Institute (Scotland), LUKE (Finland), Karelia University of Applied Sciences (Finland), Narvik Science Park (Norway) and Innovation Iceland (Iceland).

Why is GREBE happening?

Renewable Energy entrepreneurs working in the NPA area face challenges including a lack of critical mass, dispersed settlements, poor accessibility, vulnerability to climate change effects and limited networking opportunities.

GREBE will equip SMEs and start-ups with the skills and confidence to overcome these challenges and use place based natural assets for RE to best sustainable effect. The renewable energy sector contributes to sustainable regional and rural development and has potential for growth.

What does GREBE do?

GREBE supports renewable energy start-ups and SMEs:

- To grow their business, to provide local jobs, and meet energy demands of local communities.
- By supporting diversification of the technological capacity of SMEs and start-ups so that they can exploit the natural conditions of their locations.
- By providing RE tailored, expert guidance and mentoring to give SMEs and start-ups the knowledge and expertise to grow and expand their businesses.
- By providing a platform for transnational sharing of knowledge to demonstrate the full potential of the RE sector by showcasing innovations on RE technology and strengthening accessibility to expertise and business support available locally and in other NPA regions.
- To connect with other renewable energy businesses to develop new opportunities locally, regionally and transnationally through the Virtual Energy Ideas Hub.

- By conducting research on the processes operating in the sector to improve understanding of the sector's needs and make the case for public policy to support the sector.

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The Advice Note aim to provide introductory material for entrepreneurs, startups and SME's, considering to enter into the renewable energy sphere and based in the NPA regions partners to GREBE. The scope of the Advice Note covers regional, trade and industry, renewable energy (RE), technology information from Ireland, Northern Ireland, Scotland, Iceland and Finland. Different partner regions have different level of deployment of the various RE technologies covered by the Advice Notes. Thus, the level of information will vary depending on the level of deployment for each technology. For example, different types of energy storage are deployed on different scales across the NPA. Electric storage is not deployed on a large scale in Iceland; however, it is deployed to a certain extent in Scotland, Ireland and Northern Ireland. Thermal and chemical storage are in nascent stages of deployment across the partner region; however, show a promising future.

The focus of the Advice notes is to provide regional partner information on some of the main economic characteristics, sited as imperative, when making an informed choice, regarding which RE technology may be the optimal choice for the business:

- Costs and economics associated with the relevant technology
- Support schemes available, relevant to the technology
- Government allowance/exemptions, relevant to the technology
- Funding available for capital costs of the relevant technology
- List of the relevant to the technology suppliers/developers, with focus on local/regional suppliers/developers and the products and services they offer.

The technologies that are covered in the Advice Note are the following:

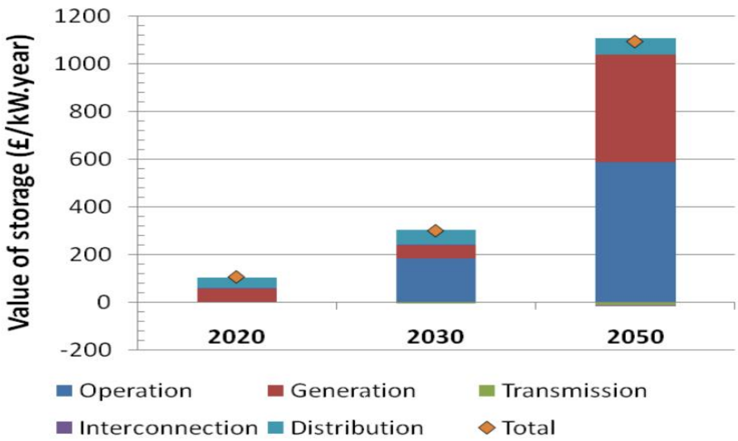
- *Biomass CHP*
- *Wind*
- Solar PV
- *Small – scale Hydro (SHP)*
- *AD*
- *Geothermal*
- *Air source heat pump*
- *Ground source heat pump*
- *Energy storage*
    - ***Electrochemical (batteries)***
    - ***Chemical (hydrogen – fuel cell and electrolysis)***
    - ***Thermal (heat storage)***

The selection of the right RE technology will also be determined by the balance of energy demand of the business, the prospect to exploit local natural resources and the existing supply network. Assessing the energy mix assists in determining which RE technology is apt for your business. Those matters will be discussed in depth in the Renewable Energy Resource Assessment Toolkit.

Energy Storage Economics Across the NPA

Some of the renewable energy resources are classified as intermittent in nature, meaning that the corresponding technologies produce electricity/heat depending on the availability of the resource. Two of the main drawbacks are the short-term variability and low predictability inherent to renewable sources. Thus, when the wind is not blowing and the sun is not shining, the clean technologies cannot match the demand. However, when the resources are available, it is often the case that they produce more energy than required. By storing the energy produced and supplying it on demand, these technologies can continue to power the businesses even when the sun has set and the air is still, creating a continuous, reliable stream of power throughout the day. Furthermore, energy storage systems can shift consumption of electricity from expensive periods of high demand to periods of lower cost electricity during low demand.

This can be over different timescales, from intra-day (when energy is shifted from low value to high value periods within the same 24-hour period) to inter-seasonal, where energy is stored in summer when demand is lower and used in winter when demand is greater. Contingent on elements such as a facility's location, utility rates, and electrical load, energy storage can be an apt solution for facilities to cut energy bills. The use of energy storage can also allow greater returns on investment to be made from deployed renewable energy technologies. Storage technologies could decrease the need to invest in new conventional generation capacity, resulting in financial savings and reduced emissions especially from electricity generation. Utilisation of storage also means fewer and cheaper electricity transmission and distribution system upgrades are required.



Value of storage increases very significantly with the level of penetration of renewable generation

The Advice Notes will focus on different types of energy storage for electricity and heat. Electricity storage technologies can be grouped into three main time categories based on the types of services that they offer.

- Short-term energy storage technologies generally have high life cycles and power densities but lower energy densities. Those technologies are appropriate for delivering short bursts of electricity to aid power systems during the transient period after a system disturbance, such as line switching, load changes and fault clearance. They struggle to compete on the market due to high costs when compared to their market value. A key economic issue is that use of this supply is only occasional – at most a few times per year.
- Long-term energy storage technologies are usually associated with high capital costs. They have the ability to supply or store electrical energy during hours and their application is mainly related with energy management, frequency regulation or grid congestion management. These, most often larger scale systems, are usually for high energy use and thus on the scale of MWh of storage.
- Distributed battery storage -Batteries use chemical reactions with two or more electrochemical cells to enable the flow of electrons. This storage technology can be used for both short and long-term applications (both power and energy services) and benefits from being highly scalable and efficient. However, widespread deployment is hindered by challenges in energy density, power performance, lifetime, charging capabilities, and costs.

Batteries can be widely used in different applications, such as power quality, energy management, and ride-through power and transportation systems.

- Redox Flow Batteries (RFB) - is a device that can store and supply energy via reversible reduction-oxidation reactions of electrolytes, either in liquid or gaseous form, that are stored in separated storage tanks. e. Redox flow batteries are considered as being able to work at high levels of depth of discharge but have lower energy densities. Various redox couples have been tested but only Zinc Bromine (Zn/Br) and all-vanadium (V/V) redox batteries have presently reached commercialisation level. RFB's design flexibility allows for separation of power and energy. Power can be tailored to the load/ generating asset (from 10kW to 10MW), while storage can be individually tailored to the energy storage requirement (500kWh to hundreds of MWh) Thus, RFBs offer a tailored, economical, optimised storage systems. Advantages of RFB's are that they have high cycle lifetime, flexible economical (especially vanadium can be re-used) and vanadium, zinc and bromine

are relatively abundant and sustainable material. One key disadvantage f RFB's is that they have low energy density.

- Lithium-based batteries - Li-ion batteries have been used in a wide-ranging energy-storage applications, a few kWh batteries in residential systems, coupled with rooftop solar PV, to multi MWh batteries for the provision of grid ancillary services. Advantages of lithium based batteries include high power density and efficiency, reasonable cycle life only if they are not operated over a wide state of charge range. Disadvantages are high production cost, it requires special charging circuit and there's no established set-up for recycling of lithium.
- Lead-Acid batteries - this is the most established rechargeable battery technology but considerably poorer in terms of power density to lithium-ion. Lead – acid batteries are used for large scale energy storage, but due to short life cycle they have limited application in energy management. Advantages of lead acid batteries are the low capital cost, maturity of technology and established recycling infrastructure. Disadvantages are the limited life cycle when discharged and use of unstainable, short of supply materials as lead.
- Nickel-based batteries – They might not exceed in typical measures such as energy density or cost, but nickel based batteries continue to be important because of their simplicity of implementation devoid of complex management systems. They are still the preferred option for telecom or off-grid renewable energy applications, as they offer almost maintenance-free operation with respect to the electrolyte. Advantages of nickel- based batteries are high power, energy densities and efficiency, coupled with, long lifetime. On the other hand, disadvantages associated with them are high capital cost, since nickel and cadmium have diminishing reserves, as well as, environmental considerations.

Irrespective of which battery is chosen, a complete energy storage system (operate in stand-alone mode/connected to the grid) – has four major components: the storage medium, the control system, the power conversion system and the balance of plant. The design of these components is contingent on the energy storage application and the power rating required. For higher power requirements, several power converter systems can be connected in parallel to provide dynamic control of active and reactive power flow in both directions. Furthermore, monitoring and control systems that allow manual and automatic operation of all components must complement the energy storage system. Communication protocols support remote control and monitoring and may provide load and weather forecasts. In addition to the system components, BOP equipment such as transformers, protection equipment and switchgear are needed to ensure a safe and reliable grid connection and operation of the system. The broad range of available electricity storage

technologies differ with respect to capacity, duty cycle, response time to full power, and load following capability.

Hydrogen is a chemical form of storage of electricity and can be used for long term applications. Electricity is converted into hydrogen by electrolysis, stored, and then re-converted into the desired form (electricity, heat, synthetic natural gas, pure hydrogen or liquid fuel). Hydrogen has substantial potential due to the high energy density, quick response times, and potential for use in large-scale energy storage applications. The round trip efficiency of the process at present is low (30–40%) but could increase up to 50% as more efficient technologies are developed. Even with this low efficiency, the attentiveness of hydrogen as energy storage is growing due to the higher storage capacity compared to batteries (small scale) or pumped hydro (large scale). For example, a storage facility of 500,000 metres cubed could store up to 167GWh of hydrogen, equivalent to 100GWh of electricity. Nevertheless, hydrogen production and re-electrification is currently faced with high upfront costs, low overall efficiencies and safety concerns, as well as a lack of existing infrastructure for large-scale applications.

A fuel cell is an energy conversion device that is closely related to a battery, as it is an electrochemical device that converts chemical to electrical energy. In a battery the chemical energy is stored within, whereas in a fuel cell the chemical energy (fuel and oxidant) is provided externally and can be constantly refilled. The overall reaction in a fuel cell is the spontaneous reaction of hydrogen and oxygen to produce electricity in water. Today, several fuel cell types are in existence and can be categorized by the use of electrolyte and its operational temperature. Hydrogen is the fuel required for all low and medium temperature fuel cells such as:

- Renewable Hydrogen Production Alkaline electrolysis is a mature technology for large systems.
- PEM (Proton Exchange Membrane) electrolysers are more flexible and can be used for small decentralised solutions.

The conversion efficiency for both technologies is about 65–70% (lower heating value). High temperature electrolysers are currently under development and could represent a very efficient alternative to PEM and alkaline systems, with efficiencies up to 90%.

Below is a table of the current performance of key hydrogen technologies.[1]

[1] Technology Roadmap Hydrogen and Fuel Cells. IEA

Table 9: Current performance of key hydrogen generation technologies

Application	Power or capacity	Efficiency*	Initial investment cost	Life time	Maturity
Steam methane reformer, large scale	150-300 MW	70-85%	400-600 USD/kW	30 years	Mature
Steam methane reformer, small scale	0.15-15 MW	~51%	3 000-5 000 USD/kW	15 years	Demon-stration
Alkaline electrolyser	Up to 150 MW	65-82% (HHV)	850-1 500 USD/kW	60 000-90 000 hours	Mature
PEM electrolyser	Up to 150 kW (stacks) Up to 1 MW (systems)	65-78% (HHV)	1 500-3 800 USD/kW	20 000-60 000 hours	Early market
SO electrolyser	Lab scale	85-90% (HHV)	-	~1 000 h	R&D

* = Unless otherwise stated efficiencies are based on LHV.
** = All investment costs refer to the energy output.
Notes: PEM = proton exchange membrane; SO = solid oxide.

Hydrogen Re-Electrification options

- Combined cycle gas turbine (CCGT) power plants (efficiencies as high as 60%)
- Power-to-Power - store hydrogen, and then use for power generation with internal combustion engines (ICEs), gas turbines and fuel cells.
- Power-to-Gas - inject hydrogen into the natural gas networks, this gas can then go into either heat or power
- Power-to-Transport - use hydrogen for road transport, either IC engines or fuel cells
- Power-to-Chemicals - use hydrogen in sustainable chemicals manufacture (ammonia or methanol).

Main advantage of hydrogen is that it is a flexible energy carrier; it can be produced from any regionally prevalent primary energy source and effectively transformed into any form of energy for diverse end-use applications - electricity, heat and transport. However, despite the potential environmental and energy security benefits of hydrogen and fuel cells in end-use applications, the development of hydrogen generation, T&D and retail infrastructure is challenging.

The table below shows a comparison of technical characteristics between electrochemical and chemical energy storage technologies.[2]

[2] World Energy Resources E-Storage | 2016, World energy Council

Technologies	Power rating (MW)	Discharge time	Cycles, or lifetime	Self-discharge	Energy density (Wh/l)	Power density (W/l)	Efficiency	Response time
Li-ion battery	0.05 – 100	1 min – 8h	1000 – 10000	0.1 – 0.3%	200 – 400	1300 – 10000	85 – 95%	< sec
Lead-acid battery	0.001-100	1 min – 8h	6 – 40 years	0.1 – 0.3%	50 – 80	90 - 700	80 – 90%	< sec
Flow battery	0.1 – 100	hours	12000 – 14000	0.2%	20 – 70	0.5 – 2	60 – 85%	< sec
Hydrogen	0.01 – 100	min – week	5 – 30 years	0 – 4%	600 (200bar)	0.2 – 20	25 – 45%	sec - min

Thermal Energy Storage (TES) store energy for later use as heating or cooling capacity. Their applications can be on both the demand and the supply side of the energy system. As heating and cooling necessities characterize 45% of the total energy use in buildings, the demand-side applications of TES can be of substantial value to the management of the energy system equation TES can be used to help balance differences in demand requirements with respect to both disparities that occur in time and magnitude. TES has several advantages such as storing and using solar thermal energy, generating and storing heat at periods of low demand and regenerating at periods of high demand, improving energy efficiency by utilising heat that would have been wasted.TES can be categorized as follows:

- Sensible heat storage - is the most mature form of heat storage system presently with most working major thermal energy storage installations based on this approach. Sensible heat storage relies on the storage of heat in a solid or liquid with no change of phase or chemical reactions taking place. Materials like, water, concrete, granite, molten salts, heat transfer oils, rock, earth, with high density and specific heat capacity can store larger amounts of heat. Sensible thermal storage materials store thermal energy by raising (heat storage) or reducing (cold storage) their temperature. The volume of stored thermal energy in a mass of material is equal to the product of its specific heat capacity and the temperature change. Insulation layer is essential to preserve the storage material and prevent losses of thermal energy. Accordingly,

material is required to have high heat capacity, compatibility with the insulation, long term stability under thermal cycling and, low cost. Hot water tanks are one of the best-known thermal energy storage technologies and are fully commercialised. Large scale low temperature (<100 degrees) thermal energy storage systems have been designed to either provide a short term balancing function when used with Combined Heat and Power and district heating systems with time shifting of heat for periods covering a few hours. There are four main categories of large scale low temperature thermal energy stores that have been successfully developed over a number of different sites[3]

  - Tank thermal energy stores - water is the heat storage medium
  - Pit thermal energy stores
  - Borehole thermal energy stores
  - Aquifer thermal energy stores

- Latent Heat Storage – materials go through a change of phase (from solid to liquid) with the energy storage material carefully chosen contingent on the temperature of application. Due to the change of phase from solid to liquid, the phase change material (PCM) is different from the heat transfer fluid. Energy released or captured during the phase change is called latent heat. Latent heat storage can have substantial advantages of sensible heat storage in terms of the potential energy storage density and required volume for the store, can be realised if the temperature range of the application is close to the phase change temperature. Conversely if a broader temperature range is likely then sensible heat storage will be more cost effective.
- Thermochemical Heat Storage – uses reversible chemical reactions to store large quantities of heat in small volumes. On applying heat to a material it breaks down into two components that are then stored separately, when the components are brought back together they recombine and release heat. The frequently used thermo-chemical materials are metal chlorides, metal hydrides, and metal oxides. The advantages of thermo-chemical storage are the high storage energy densities, small heat loss and long storage duration at near ambient temperature, coupled with, heat-pumping capability. At the same time they are novel and complicated system with a very high capital cost.

Fundamental technical issues recognised for consideration when planning a thermal energy storage system are : the store operational temperature regime, the required heat storage capacity, the charge/discharge characteristics, required duration of storage, the energy storage density, round

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[3] Eames, P., Loveday, D., Haines, V. and Romanos, P. (2014) The Future Role of Thermal Energy Storage in the UK Energy System: An Assessment of the Technical Feasibility and Factors Influencing Adoption - Research Report (UKERC: London).

trip efficiency, part load operation characteristics, durability and long term cycle stability, materials availability, cost, and system integration and control. Other significant matters that influence the uptake of thermal storage systems relate to prerequisite installation skills, maintenance requirements, user perception of performance and acceptability and environmental impacts and safety requirements. A key parameter in determining a system's economic viability is the number and frequency of charge/ discharge cycles.

The economic performance of a storage system depends on operating conditions and system costs, which can vary depending on required volume, conversion and generation capacities, and response times.

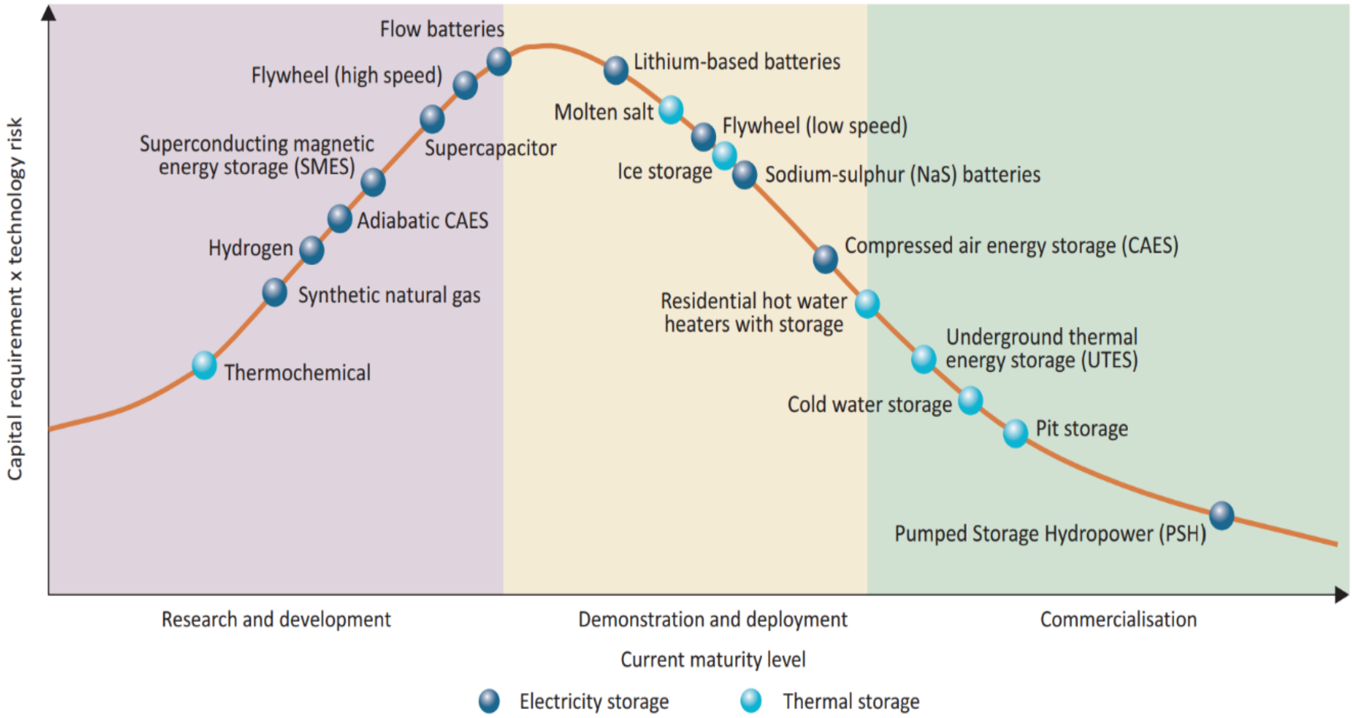


Figure 2. TRL of Energy Storage Technologies.[4]

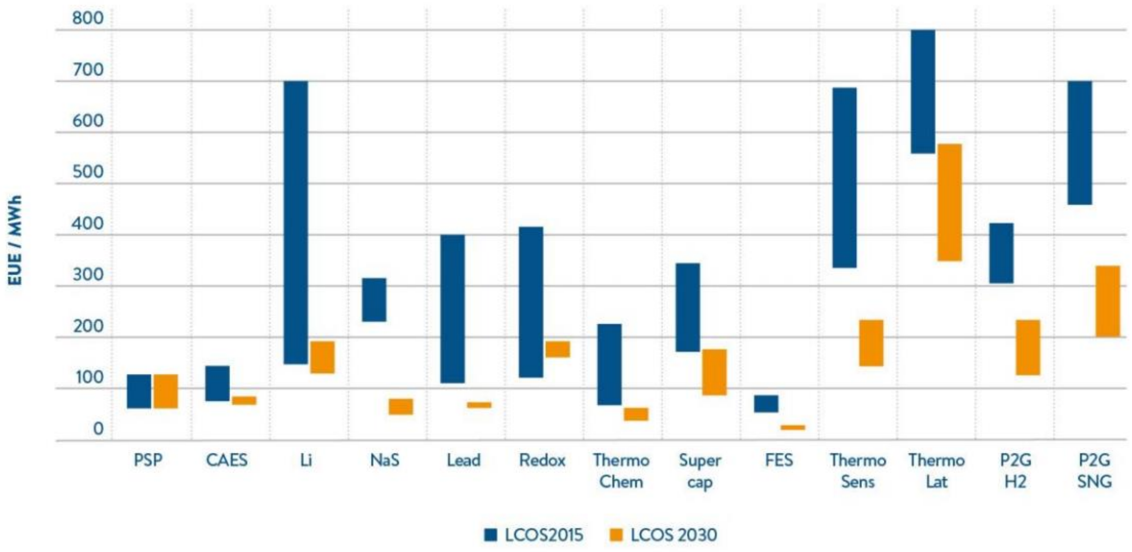
Above some main technologies are exhibited with respect to their related initial capital investment requirements and technology risk versus their current phase of development (i.e. R&D, demonstration and deployment, or commercialisation phases).

Understanding the economics and costs of energy storage is challenging due to the different technologies and applications. In general, energy storage systems are rated by power capacity (kW or MW) and potential energy output (kWh or MWh).

The figure below shows the LCOS in 2015 and the expectation for LCOS for 2030.[5]

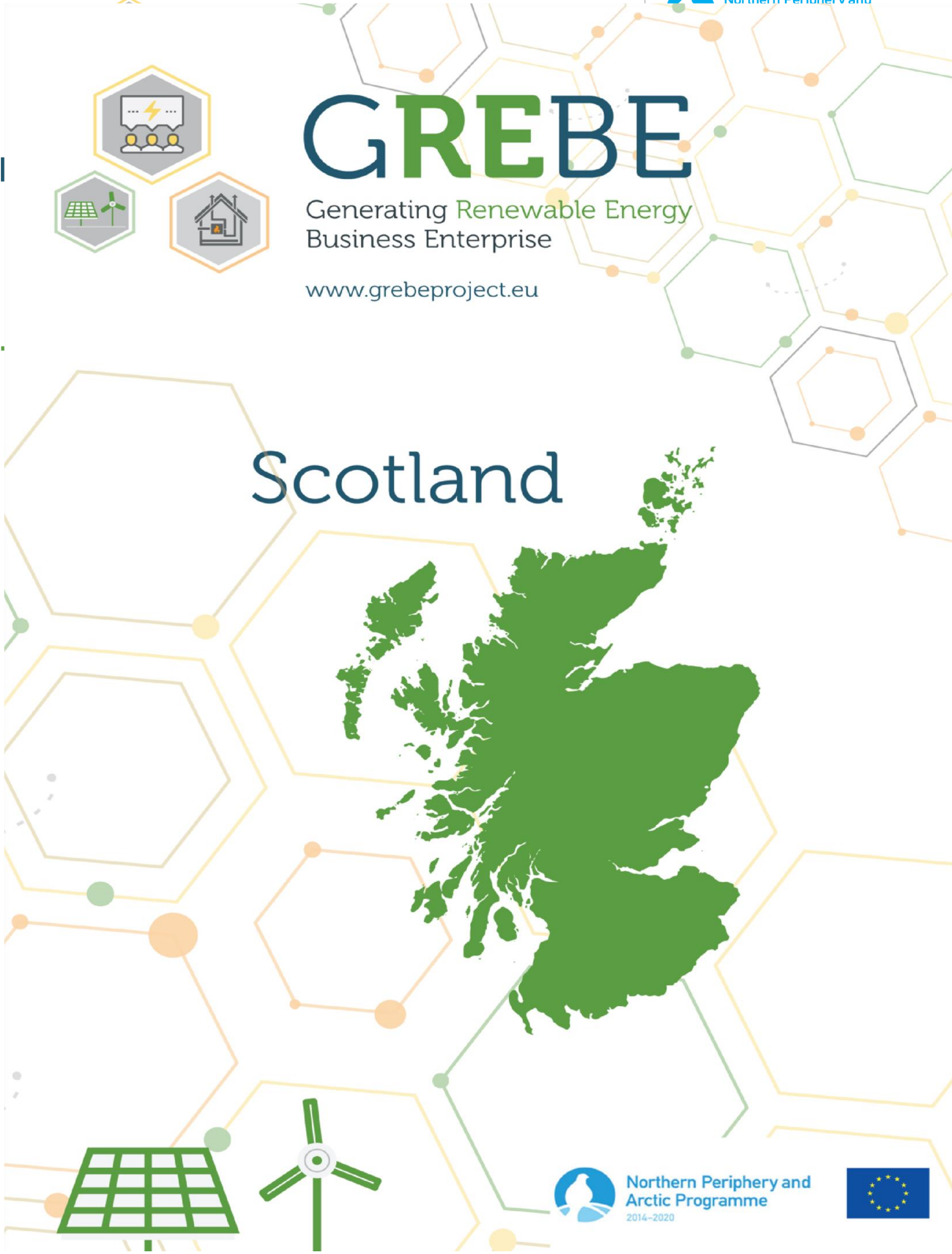
[4] World Energy Resources E-Storage | 2016, World energy Council

FIGURE 7: LEVELISED COST OF STORAGE IN 2015 STUDY PERIOD AND 2030 (€ 2014)



Energy storage is often regarded in terms of high capital costs, but the results of the analyses indicate a clear trend in the cost development. For several storage technologies, there is reason to believe that costs will fall as production volumes increase. This belief is supported by historical cost developments such as the one for Lithium-ion batteries. The so-called experience curve, which can be seen above is based on the observation that for manufactured products the cost decreases as production output increases. This correlation can be credited to economies of scale, as well as manufacturing and engineering progresses.

[5] World Energy Resources E-Storage | 2016, World energy Council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Electrical Storage

Batteries

Costs and economics

Battery systems at the moment still have high costs but are expected to have a sharp price decrease in the near future. Deutsche Bank reported that Lithium-Ion batteries in commercial and utility markets achieved cost reductions of 50% in 2014. Additional substantial cost reductions in a wide range of battery technologies is forecasted, expecting annual cost reduction of upwards of 10% per year over the coming years.[6]It has been argued that for the short time scale, battery technologies are the most cost-efficient technology.

The table below shows the CAPEX, financial lifetime, typical input/output ratio and overall efficiency for li-ion, lead and vanadium redox flow batteries.[7]

Table 6
Specific CAPEX, financial lifetime, typical input/output ratio and overall efficiency for the analyzed technologies.

	Battery Li-ion		Battery Pb		Battery VRF	
Time scale	Today	2030	Today	2030	Today	2030
Specific CAPEX:						
Charging unit [€/kW]						
Storage unit [€/kWh]						
Other fixed cost [€]	660...1050	230...610	240...320	190...270	930...1040	250...350
Discharging unit [€/kW]						
Thermal storage	80	60...70	80	60...70		
Financial lifetime [a]	b	b	b	b	b	b
Typical input/output power ratio	1	1	1	1	1	1
S Overall efficiency[f] [%]	95	95	77	78	80	85

[a] As turbine lifetime.
[b] Lifetime depends on battery o

[6] Deutsche Bank at http://cleantechnica.com/2015/03/04/energy-storage-could-reach-cost-holy-grail-within-5-years/

[7] Comparison of electricity storage options using levelized cost of storage (LCOS) method. Verena Jülch. Applied Energy, 2016, vol. 183, issue C, 1594-1606.

Storage systems larger than 50 kWh, the cost of ready-installed battery systems is (referring to net capacity): Li-ion 1000–1500 €/kWh; Pb 580–1340 €/kWh and VRF 930–1040 €/kWh. The cost for newly built large-scale projects (100 MW/400 MWh) was estimated: Li-ion battery systems at small scale are currently available at 500–800 €/kWh, while lead batteries are much cheaper with a cost of 200–250 €/kWh. Inverters for large scale systems currently cost 80 €/kW], balance-of-system (BOS) is estimated to be about 30% of the price for battery and inverter for Li-ion systems and 20–25% for lead battery systems. If the BOS cost is integrated in the capacity related cost, the CAPEX for Li-ion systems results in 660–1050 €/kWh and 80 €/kW, while the CAPEX for Pb battery systems is 240–320 €/kWh and 80 €/kW. The cost of VRF batteries can be separated into power related and capacity related components. The power related cost is 847– 909 €/kW, capacity related cost is 162–283 €/kWh for state of the art technology, depending on the system configuration.[8]

Future battery CAPEX is 150–400 €/kWh for Li-ion battery systems and 150–200 €/kWh for Pb battery systems, Inverter cost is expected to decrease to 60–70 €/kW. BOS cost is expected to be 50% for Li-ion and 25–30% for Pb battery systems, leading to a CAPEX of 230–610 €/kWh and 60–70 €/kW for Li-ion and 190–270 €/kWh and 60–70 €/kW for Pb battery systems. For VRF batteries optimistic cost projections assume 364–405 €/kW power and 64–120 €/kWh capacity. The LCOS of battery technologies is expected to decrease strongly in the next decade due to technological developments and decreasing CAPEX.[9]

Battery storage technologies vary in Operational and Maintenance costs largely as a function of technology. For instance, flow batteries differ from conventional batteries in the external storage of active materials, affording them an advantage in lifetime and proportional lack of self-discharge. The advantage in terms of maintenance comes from partial replacement of parts and fuel for flow batteries, rather than replacement of the entire unit as seen with lead acid and lithium ion systems.[10]

The table below is from and AEA’s 2010 study which tiered the different energy storage technologies according to a matrix score in the context of application in Scotland reflecting: storage capacity; cost; efficiency; technical maturity; Scottish infrastructure; CO2 emissions; public acceptability;

[8] Comparison of electricity storage options using levelized cost of storage (LCOS) method. Verena Jülch. Applied Energy, 2016, vol. 183, issue C, 1594-1606.
[9] Comparison of electricity storage options using levelized cost of storage (LCOS) method. Verena Jülch. Applied Energy, 2016, vol. 183, issue C, 1594-1606.
[10] Calculation of levelized costs of electricity for various electrical energy storage systems ManassehObi[a]S.M.Jensen[b]Jennifer B.Ferris[c]Robert B.Bass[a]

environmental impact; and future potential advances. The green bars are energy storage technologies, and the pink are power quality technologies.

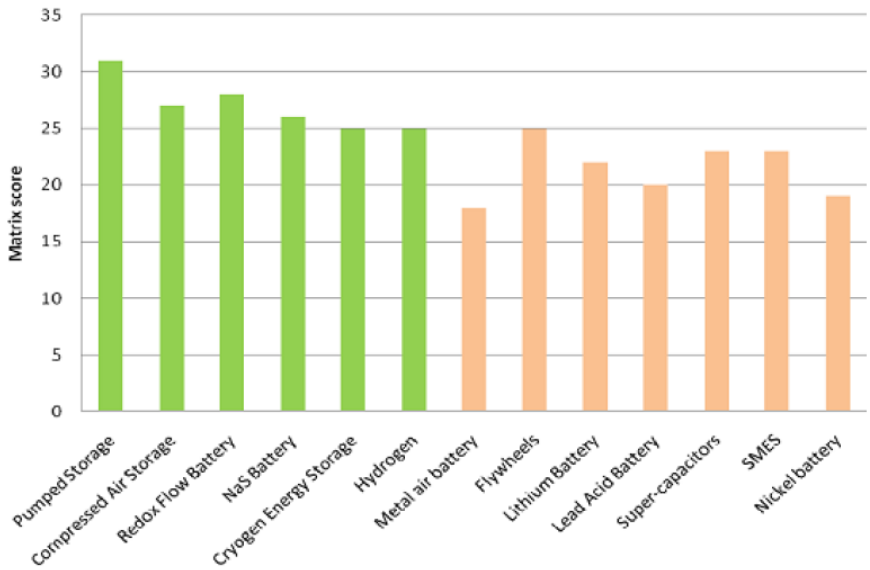


Figure 1. Ranking of energy storage options for Scotland[11]

Benefits and Barriers

Benefits Batteries

- Ability to quickly switch modes of operation to charging and discharging
- Site flexibility
- Maturity of technology - varies from mature technologies such as Lead acid to batteries that are only available in demonstration projects

Barriers Batteries

- Size of battery
- Shorter lifetime (depends on chemistries)
- Significant environmental impact in manufacture
- Location near sub-stations problematic

Benefits Flow Batteries

- Can be scaled up – capacity depends on storage tanks for fluid

[11] Energy Storage and Management Study; AEA 2010, for the Scottish Government.

Barriers Flow Batteries

- Significant space requirements
- Capacity dependent on volume of electrolyte
- High maintenance requirement
- Can have lower efficiency

Technology suppliers, products and services they offer

Supplier	Products	Services	Contact Information
AGM Batteries Limited	AGM Batteries Limited develops both propriety and client specific cell and battery products: High Energy Density Lithium-ion Cells (LCO, NCA, NMC) High Power Density Lithium-ion Cells Advanced cells incorporating new technologies including Sodium-ion typically being applied to electric vehicle and renewable energy storage applications.	Product development Research Sub-Contract Manufacture	Denchi House, Thurso Business Park, Thurso, Caithness, Scotland, UK KW14 7XW Telephone: +44 (0)1847 808009
Green Hedge	Energy Barn - steel-framed building of approximately 150x65 ft., with a concrete foundation. The electricity storage system housed inside the building consists of racks of lithium-ion batteries, inverters and transformers. The Energy Bar™ is connected to the electricity distribution system at 11, 33, 66 or 132kV with switchgear in a small substation. The batteries store electricity, charging from the grid and then feeding electricity back again when it is needed in the area.	Host an Energy Barn on your land	
redT	Vanadium Redox Flow Battery – a big range of products with power output 5-60 kW), capacity (20 – 300 kWh) and continuous discharge at rated power (4h-15h).	Financing solutions - Warranties Maintenance insurance,	Unit 5, Alderstone Business Park MacMillan, Road Livingston West, Lothian , EH54 7DF

Thermal

Heat Storage

Costs and economics

More than 50% of the energy consumption in Scotland is in the form of heat, largely connected with domestic and commercial heating of buildings, as well as the heating necessities for a wide range of industrial processes. Moreover, with the rising prices of electricity, there are substantial financial impacts for both domestic and industrial customers. Therefore, there is a compelling driver towards the utilisation of renewable heat, and a key enabling technology for renewable heat must be effective heat storage. Store volumes range in size from domestic hot water tanks and electric storage radiators designed to store heat for a few hours to systems with volumes up to 75,000 m3 used for inter seasonal storage. A strong relationship exists between store size and cost, ranging from about £390/m3 for small tank-based systems (volume around 300m3), to about £25/m3 for large pit-based systems (volume around 75,000m3).[12]

Latent heat and thermochemical heat storage systems, although potentially providing greater energy storage for a given volume, are still at lower technology readiness levels. Due to the annual operational cycle, the store cost must be low to provide payback on investment. There is a robust connection between store sizes and costs. A key parameter in determining the adoption of heat networks will relate to the price that heat can be sold for; the payback period of the network must be suitable so that investors obtain a reasonable dividend while heat is priced at a level that is more attractive to potential users than other available options.

[12] Eames, P., Loveday, D., Haines, V. and Romanos, P. (2014) The Future Role of Thermal Energy Storage in the UK Energy System: An Assessment of the Technical Feasibility and Factors Influencing Adoption - Research Report (UKERC: London).

- Small tank storage systems of 300m3 of water costing about £390/m3, whilst for a pit store with a volume of 75,000m3 of water equivalent, costs may reduce to around £25/m3.[13]
- Pit storage, the economy of scale and the additional progress decreases costs significantly. The all-inclusive cost of storage by this method, from summer to winter (one load cycle), is between £15 and £20 per MWh.
- Latent heat storage – Phase change materials (PCMs) temperature range from -5 up to 190°C. PCMs are very effective at heat storage and can store from 5–14 times more heat per unit volume than conventional storage materials such as water, masonry or rock.

Benefits and Barriers

Benefits:

- Energy efficiency can be improved by utilising heat/cool that would have been wasted. The availability of a waste or unutilised heat source, can provide heat at low cost, however the heat generation and heat demand should both be in the local area to keep pumping costs and heat losses low.
- The inclusion of thermal storage as part of the UK energy system provides an opportunity to develop new skills.
- If planned sensitively, a thermal store can have minimal impact, allowing landscaping to hide an installation, or for good design to make it a feature.

Barriers

- Installation costs and inconvenience associated with excavations to install large heat mains in busy urban areas are significant, particularly if the areas are heavily serviced
- Potential economic impact, through the requirements for initial installation and on-going maintenance. There is a potential skills gap in managing and operating complex systems with thermal stores.
- Thermal stores can be very large and, if above ground, can have a significant impact on the built environment.

[13] The Future Role of Thermal Energy Storage in the UK Energy System: An Assessment of the Technical Feasibility and Factors Influencing Adoption, UK ERC, 2014.

Technology suppliers, products and services they offer

Supplier	Products	Services	Contact Information
Sunamp	**Heat &Battery technology**	Installation	1 Satellite Park, Macmerry, East Lothian, EH33 1RY, Scotland info@sunamp.com Telephone: +44 (0)1875 610001

Chemical Storage

Hydrogen

Costs and economics

As with the other energy storage technologies considered, excess electricity can be converted into hydrogen by electrolysis. The hydrogen can then be stored and re-electrified when required. The 'round trip' efficiency is at present as low as 30–40% but could rise up to 50% with the development of technologies. Despite this low efficiency, the interest in hydrogen energy storage is rising due to the much greater storage capability compared to batteries (small scale). Small amounts of hydrogen (up to a few MWh) can be stored in pressurized vessels at 100–300 bar, or liquefied at 20.3K (-253°C). Hydrogen can be re-electrified in fuel cells with efficiencies up to 50%, or alternatively burned in combined cycle gas turbine power plants (efficiencies as high as 60%).

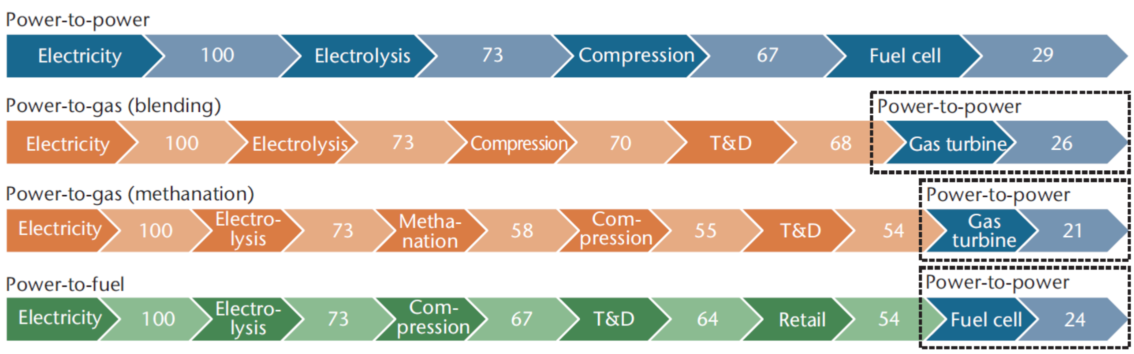
Electricity is converted into hydrogen, stored, and then re-converted into the desired end-use form (e.g. electricity, heat, synthetic natural gas, pure hydrogen or liquid fuel) These storage technologies have substantial prospective due to their high energy density, quick response times, and prospective for use in large-scale energy storage applications. However, they struggle with high upfront costs, low overall efficiencies and safety concerns, as well as a lack of existing infrastructure for large-scale applications.

As an energy carrier, hydrogen can enable new connections between energy supply and demand, in both a centralised or decentralised manner, improving overall energy system flexibility. In remote areas with little access to the power grid, these connections can develop off-grid access to energy services while reducing emissions. Hydrogen-based systems such as power-to-fuel, power-to-power

or power-to-gas can be employed to make use of variable renewable energy (VRE) that would otherwise be curtailed at times when supply outstrips demand. [14]

However, using otherwise-curtailed VRE power to generate hydrogen poses an economic challenge for several reasons. Firstly, electrolysers have a substantial investment cost, which means that they will only be cost effective if they are operated for a sufficient amount of time during the year. As periods of surplus VRE generation will occur only for a limited amount of time, depending exclusively on generation excesses is likely to be deficient to reach appropriate capacity factors. Secondly, each conversion step on the way from electricity to hydrogen and back to electricity entails losses, see the figure below. [15]

Figure 6: Current conversion efficiencies of various hydrogen-based VRE integration pathways



Note: The numbers denote useful energy; except for gas turbines, efficiencies are based on HHV; the conversion efficiency of gas turbines is based on LHV.

KEY POINT: Total round-trip efficiencies of hydrogen-based energy storage applications are low.

Losses are of minor importance if the input electricity cannot be used for other applications, however, hydrogen generation will compete with other possible uses of surplus electricity, such as thermal storage.

While technology components such as electrolysers and fuel cells remain expensive, all possible energy system services or by-products need to be exploited to the fullest extent possible, adopting the benefits stacking principle (Bi-generation (hydrogen and electricity) or even tri-generation systems (hydrogen, electricity and heat) offer the possibility of selling their products at the respective highest price, depending on the market conditions.

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[14] Technology Roadmap Hydrogen and Fuel Cells. IEA
[15] Technology Roadmap Hydrogen and Fuel Cells. IEA

- Power-to-power: electricity is transformed into hydrogen via electrolysis, stored in an underground cavern or a pressurised tank and re-electrified when needed using a fuel cell or a hydrogen gas turbine.
- Power-to-gas: electricity is transformed into hydrogen via electrolysis. It is then blended in the natural gas grid (hydrogen-enriched natural gas – HENG) or transformed to synthetic methane in a subsequent methanation step. For methanation, a low-cost CO2 source is necessary.
- Power-to-fuel: electricity is transformed into hydrogen and then used as a fuel for FCEVs in the transport sector.
- Power-to-feedstock: electricity is transformed into hydrogen and then used as a feedstock, e.g. in the refining industry.

Table 10: Current performance of key hydrogen conversion, T&D and storage technologies

Application	*Power or capacity*	*Efficiency **	*Initial investment cost*	*Life time*	*Maturity*
Alkaline FC	Up to 250 kW	~50% (HHV)	USD 200-700/kW	5 000-8 000 hours	Early market
PEMFC stationary	0.5-400 kW	32%-49% (HHV)	USD 3 000-4 000/kW	~60 000 hours	Early market
PEMFC mobile	80-100 kW	Up to 60% (HHV)	USD ~500/kW	<5 000 hours	Early market
SOFC	Up to 200 kW	50%-70% (HHV)	USD 3 000-4 000/kW	Up to 90 000 hours	Demon-stration
PAFC	Up to 11 MW	30%-40% (HHV)	USD 4 000-5 000/kW	30 000-60 000 hours	Mature
MCFC	KW to several MW	More than 60% (HHV)	USD 4 000-6 000/kW	20 000-30 000 hours	Early market
Compressor, 18 MPa	-	88%-95%	USD ~70 /kWH$_2$	20 years	Mature
Compressor, 70 MPa	-	80%-91%	USD 200-400/kWH$_2$	20 years	Early market
Liquefier	15-80 MW	~70%	USD 900-2 000/kW	30 years	Mature
FCEV on-board storage tank, 70 MPa	5 to 6 kg H_2	Almost 100% (without compression)	USD 33-17/kWh (10 000 and 500 000 units produced per year)	15 years	Early market
Pressurised tank	0.1-10 MWh	Almost 100% (without compression)	USD 6 000-10 000/MWh	20 years	Mature
Liquid storage	0.1-100 GWh	Boil-off stream: 0.3% loss per day	USD 800-10 000/MWh	20 years	Mature
Pipeline	-	95%, incl. compression	Rural: USD 300 000-1.2 million/km Urban: USD 700 000-1.5 million /km (dependent on diameter)	40 years	Mature

The figure above shows current performance and initial investment cost of key hydrogen conversion, T&D and storage.[16]

Examples

Surf 'n' Turf is a collaborative, novel project between Community Energy Scotland, Eday Renewable Energy Ltd, EMEC, Orkney Islands Council and ITM Power. Surf 'n' Turf provides Eday's community-owned wind turbine and EMEC with equipment to convert and store the surplus energy as hydrogen. The hydrogen is compressed by EMEC's electrolyser, stored and transported to Kirkwall for off-site use. Surf 'n' Turf is developing training facilities and arrangements to make use of hydrogen in Kirkwall. In Orkney some RE generators have around 40-60% their potential energy production curtailed, resulting in loss of revenue for investors. There is no need for curtailment of surplus RE when hydrogen storage is available. The electrolyser situated on Eday allows production of hydrogen fuel from the excess energy, which diminishes the dependency on the UK National Grid and increases the probability of further investment in RE. The excess energy is harnessed, stored, compressed by EMEC's electrolyser in Eday and transported to Kirkwall for off-site use. This hydrogen will power a fuel cell at Kirkwall Harbour where it generates electricity for the surrounding buildings and docked ferries. The success led to The BIG HIT targeted at demonstration of a fully cohesive model of hydrogen production, storage, transportation and utilisation for low carbon heat, power and transport. Around 10 electric vans will be deployed in Orkney, with a built-in hydrogen fuel cell range extender, and a construction of a hydrogen refuelling station. BIG HIT will fit two hydrogen-powered boilers at appropriate locations to provide zero carbon heat.

H2 Aberdeen is an initiative working to bring about a hydrogen economy in the Aberdeen City Region. It will help to reinforce the area's position as an energy city, now and in the future. With the transferable oil and gas expertise in the North East of Scotland, as well as a capacity for renewable energy generation, there is an opportunity to further enhance our economic competitiveness by being at the forefront of a hydrogen economy.

The H2 Aberdeen initiative has to date delivered:

- a hydrogen strategy outlining the key actions required by the City Region over the next 10 years;

[16] Technology Roadmap Hydrogen and Fuel Cells. IEA

- a state-of-the-art hydrogen production and bus refuelling station
- 10 hydrogen fuel cell buses, the Europe's largest fleet
- The HyTrEc project (Hydrogen Transport Economy for the North Sea Region) which includes the trial of fleet vehicles - hydrogen hybrid vans and plug in range extended vans.

Just recently the Scottish government has awarded funding for a feasibility study of the idea for a ferry powered by hydrogen manufactured by community-owned wind turbines has been proposed for Scotland's west coast. The feasibility study will look at the manufacture of the hydrogen using local wind power, the challenges of how to handle, transport and store the hydrogen on local piers, and how the design of the ship and its engines needs to be adapted to run on hydrogen fuel. Point and Sandwick Trust, operators of the community-owned Beinn Ghrideag Wind Farm on the Isle of Lewis, is leading the project. The project's partners include CMAL, owners of Caledonian MacBrayne Ferries. Ferguson Marine shipyard in Glasgow and Siemens Gamesa Renewable Energy are among the other partners.

Benefits and Barriers

Benefits

- Versatile – uses include electricity generation, heating, cooking and transport
- Lower environmental Impact
- Potential for generating hydrogen from surplus electricity

Barriers

- Need for hard data
- High cost
- Uncertain performance
- Health & safety concerns

Technology suppliers, products and services they offer

Provider	Product & Services	Contacts
Logan Energy	Design, install, commission and maintain fuel cells and hydrogen technologies ranging in size from kWe to MW We offer a full turnkey service – delivering system design, integration, installation, maintenance and finance.	10 York Place, Edinburgh, EH1 3EP T 0131 523 1414
Pure Centre	Offer a wide range of products: • Hydrogen electrolyser • Hydrogen fuel cell kit • Hydrogen compressor • Hydrogen fuelling station / dispenser • Hydrogen vehicle • Hydrogen storage • Hydrogen boiler • Hydrogen cooker • Hydrogen monitoring system • Hydrogen internal conversion engine	Unit 3, Hagdale Industrial Estate, Baltasound Unst, Shetland ZE2 9TW United Kingdom Telephone: +44 (0) 1957 711 410 Fax: +44 (0) 1957 711 838


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Electrical Storage

Batteries

Costs and economics

The price-level of energy storages/batteries is based on few reference cases in North-Karelia. The CAPEX of Fronius solar batteries varies between 6 000 (4 kW) and 12 000 €'s (12 kW), (VAT 24%), including the delivery but not installing work. Tesla Power wall cost is 7100 € (14 kW), installing 1000-2500 €; according to Tesla, installations in Finland are beginning in 2017.

OPEX is not yet available, as there is only first energy storage cases invested.

Estimated LCOE for solar PV (5.4 kW) and energy storage system with Fronius solar battery (6 kW), 7.24 c/kWh (60% investment support and 30 a), and without LEADER support LCOE is 15.92 c/kWh. The LCOE of battery only, has not yet been calculated.

Benefits and Barriers

Currently, first energy storage cases are in investment phase and based on 60% LEADER support. The economic feasibility without support has not yet been reached. The limited availability of the suppliers and experience of the systems is a still a significant barrier.

The main drivers are flexibility of the system use / adjusting the supply for the demand (battery improved approximately 15 % of the own consumption of the energy in above mentioned reference case located in Nurmes).

Funding available for Capital Costs

Energy storage investments of innovative new technologies can receive up to 40 % energy support. This is based on a case specific consideration. Energy efficiency projects of conventional technologies can receive 30% support. (TEM, Ministry of the Employment and the Economy via TEKES Finnish Funding Agency for Innovation).

ESB Networks Smart Energy Services, in the case of businesses and, subject to certain conditions, will fund the upfront costs and procurement of batteries.

Solo-Energy are in the process of launching a flexi-grid virtual power plant scheme whereby you can avail of cheaper rates of renewably sourced electricity when coupled with battery technology. Aside from this, no other funding models currently available for battery technology.

Technology suppliers, products and services they offer

Provider	Product & Services	Contacts
ABB	ABB offers scalable and flexible energy storage systems to fit every grid application. Energy Storage Modules (ESM)-Single or three phase system in arc-proof enclosures up to 5 MW / 4 hours with output voltage range from 120 V to 40.5 kV. Community Energy Storage (CES) systems Distributed Energy Storage (DES) systems	Tel:+353 1 405 7300 marketing@ie.abb.com
Europa Batteries	Diverse battery specialist with interests in Telecoms, Industrial, Transport, Automotive, Commercial, Marine, Leisure and mobility batteries.	Tel: +353578662397
Tesla	Tesla Powerwall now available in Ireland. Comes in 13.5 kWh usable capacity. Scalable up to ten units.	Tel:+353 1800817354
Solo-Energy	Providers of Tesla Powerwall and operators of flexigrid virtual power plants currently being introduced in Ireland and UK.	Tel: +353 (0)21 237 6054

Kingspan	Kingspan Energy Store Battery Solutions Domestic or industrial battery storage	Tel:+353 (0) 42 9698500 info@kingspanpanels.com
Warikenergy	Residential and Commercial Energy Storage Systems in Ireland and UK. The EMMA SES Residential Series is available in four capacities ranging from 2.5 to 10.0 kWh and can be scaled up to 80kWh.	Tel: +353 1 8948100 info@warikenergy.com
BNRGDistribution	Retailers of Fronius Solar battery (3.6-9.6 KWh usable capacities)	sales@bnrgdistibution.ie T: +353 1 7919 765

Thermal

Heat Storage

Costs and economics

District heating systems already have considerable energy storage potential associated with the large volumes of water in use. This can be increased by adding hot water storage tanks to improve the flexibility of operation and capability to absorb surplus wind energy. Heat storage is easy to accommodate in this way, but Ireland makes very limited use of district heating at present. There is scope for improved electric storage radiators to be deployed and linked to smart grid control systems.

The Glen Dimplex Quantum range of SETS (Smart Electrical Thermal Storage) storage heaters vary in size from 1.56KW -3.3KW and in price from €785-€990.

Other types of thermal storage would include hot water buffer tanks which range in size and cost depending on various factors.

Benefits and Barriers

Barriers:

- Reconversion to electricity requires very high storage temperatures and is unproven.
- Latent heat and thermochemical heat storage systems, although potentially providing greater energy storage for a given volume, are still at lower technology readiness levels.
- The current price of some energy storage technologies is too great to give a business model for deployment, even if the full system value could be extracted.

Benefits

- High power ratings and high energy ratings.
- Relatively simple to add storage capacity.
- Storage in individual properties could require significant heating system upgrades.
- Heat storage is mature and widely used for supplying heat loads.

Funding available for Capital Costs

None in place

Technology suppliers, products and services they offer

Provider	Product	Contacts
Crystalair	One of the leaders in air conditioning installation, design, service & maintenance throughout Ireland. Providers of PCM TES (Phase Change Material Thermal Energy Storage). PCM TES is a more efficient and cost effective way to deliver energy to chill air.	Tel: +35345 893228
Joule	Provide a range of thermal storage solutions for hot water in sizes ranging from 100l -5000l.	Tel: 353 (1) 6237080 info@joule.ie
Glendimplex	Manufacturers of storage heaters that make use of off peak night time electricity. Quantum off peak heaters.	Ph: +353 (0)1 8424833 salesireland@glendimplex.com
Green Heat	Providers of buffer tanks/hot water storage solutions.	t: +353 (0)69 65200 info@greenheat.ie

Chemical Storage

Hydrogen

Costs and economics

Research is under way to investigate the use of renewable energy sources such as wind, solar or biomass for the generation of hydrogen.

Typically hydrogen is produced from steam reforming of natural gas and electrolysis. BOC gases operate an electrolysis plant in Ireland.

Costs vary for the gas from BOC, depending on tank size, with 1.4m^3 costing roughly €32.

Examples

As well as producing & selling a variety of compressed gases, BOC gases also sell the HYMERA® Hydrogen Fuel Cell Generator, a low power providing hydrogen fuel cell being sold as an alternative to small petrol or diesel generators or large battery banks.

BOC are also positioning themselves as installers of hydrogen fueling stations for deployment in the future.

GENCOMM is an EU funded project underway investigating the potential for the generation of hydrogen from renewable sources combined with energy storage for the purpose of providing heat, power and transportation fuels.

Recently launched SEAFUEL project aims to look at potential for production of hydrogen from seawater and renewable energy sources for the purposes of transport on the Aran Islands.

Gas Networks Ireland is also looking into the potential for integration of hydrogen with their natural gas network.

Benefits and Barriers

Barriers

- Need for hard data
- High cost
- Uncertain performance
- Health & safety concerns
- Cost of storage

Benefits

- Versatile – uses include electricity generation, heating, cooking and transport
- Lower environmental Impact
- Potential for generating hydrogen from surplus electricity
- Lifetime - thousands of cycles

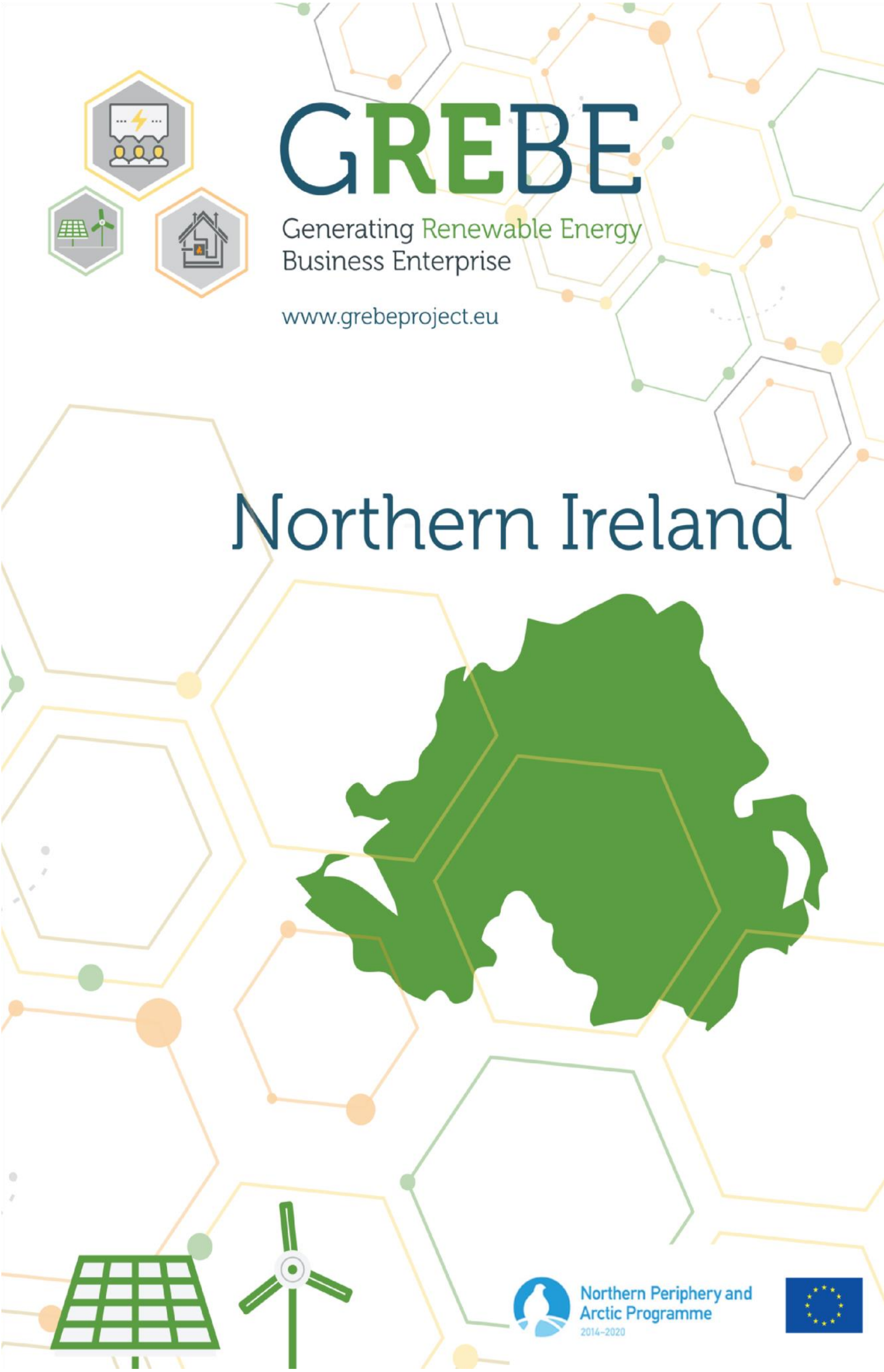
Funding available for Capital Costs

Currently there are a number of funds and grants being made available to R & D elements relating to hydrogen production and storage. These include:

- FREED project
- GENCOMM project
- SEAFUEL project

Technology suppliers, products and services they offer

Provider	Product and Services	Contacts
BOC **A member of the LINDE group**	Bulk Hydrogen in a variety of sizes and purities, typically for industrial use. HYMERA® Hydrogen Fuel Cell Generator(alternate to battery banks or petrol/diesel generators) Providers of gas control equipment. Development of A full turnkey solutions for hydrogen generation fuel stations(none in Ireland yet) Providers of HYDROSS® plants that produce hydrogen onsite by Electrolysis, steam methane reformation or methanol cracking.	T:+353 1 409 1800
Air Products	Air Products supplies liquid and gaseous hydrogen as well as a broad portfolio of fuelling infrastructure solutions. Providers of hydrogen of different purities and under different pressures, hydrogen storage modules, on-site generators, Know how safety training and maintenance services.	T:+353 1800 99 5029 ieinfo@airproducts.com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Electrical Storage

Batteries

Costs and economics

The cost of electricity batteries currently ranges from £4,000 to £5,000 for a fully integrated 3kWh system, but this is expected to fall in the future.

Table 1: Grid scale energy storage devices

Technology	Capital costs, € 000/MW	Efficiency, %	FO&M costs, € 000/MW year	Economic lifetime, years
Pumped Storage	435 – 2,170	70-85	3.8	30
CAES	650 -750	57	1.42	30
CAES vessels	800 – 900	70	3.77	30
Redox batteries	2,300-2,350	70-85	6	5-10
Hydrogen plus fuel cells	2,350 – 2,450	32	6	10 – 20

Benefits and Barriers

Energy storage technologies absorb energy and store it for a period of time before releasing it to supply energy or power services. Through this process, storage technologies can bridge temporal and (when coupled with other energy infrastructure components) geographical gaps between energy supply and demand. Energy storage technologies can be implemented on large and small scales in distributed and centralised manners throughout the energy system. While some technologies are mature or near maturity, most are still in the early stages of development and will require additional attention before their potential can be fully realized.

Only pump storage is considered to be a mature technology. Sites for pump storage in Northern Ireland are limited by the geography, primarily a lack of 'z' or vertical drop required to maximize the potential energy of the falling water that can be converted into electricity. A scheme was investigated at Camlough, County Armagh, but quickly abandoned.

Tesla has recently announced a home batter0. As battery technologies improve these will reduce in price. They have initially priced around $3,000 per 7kWh and have a substantial footprint. This will suit the US middle class home with its basement or large garage, but will be more of a problem in the smaller UK/Irish house. Furthermore 7kWh would only be ½ a day electricity for most people, making this an expensive outlay. Arbarr are a company based in Limavady who develops batteries for demand side storage.

Funding available for Capital Costs

Not available

Technology suppliers, products and services they offer

Provider	Product	Services	Contacts
Henbo Energy Storage	Henbo offers bespoke design, development & support with energy storage systems for the following areas: Domestic, Agricultural and Industrial Energy Storage.		t: 028 7954 9771 info@henboenergystorage.com www.henboenergystorage.com
AES UK & Ireland	Battery based energy storage		**Ballylumford Power Station** +44 (0)28 93 381 100 **Kilroot Power Station** +44 (0)28 93 356 200

Thermal

Heat Storage

Costs and economics

The cost can be around £970 per kWh for a single heat source thermal store including installation, up to £2900 for a multi heat source thermal store.

Benefits and Barriers

The benefits of a thermal store:

- Allows management of the difference in time between when heat is available and when it is needed. For example, hot water produced by a solar water heating system during the day can be stored for use when little or no solar energy is available.
- Enables warm water to be heated up by a secondary heating source such as a conventional boiler or electric immersion heater.
- Enables a renewable heating system to work more efficiently. This is particularly relevant to wood-fuelled heating systems such as log boilers that operate much more efficiently if they are used at maximum output rather than kept ticking over.
- Let's you use a wood burning boiler stove or a stove with a back boiler at maximum efficiency without overheating the room.
- Reduces the need to buy expensive fossil fuels to meet on-demand hot water or space heating.

Examples

Thermal energy for space and water heating comprises 65-75% of total energy demand by householders in Northern Ireland, storing excess energy as heat may be a better solution as it matches demand. Ulster University has been involved in the Einstein project, which has been developing large scale seasonal thermal energy storage. Hot water is collected during the summer using solar collectors on groups of houses. A large tank stores the hot water centrally and is drawn off on demand to provide heat for homes, see figure 3. The store is known as a sensible heat store.

As well as district scale solutions for seasonal storage Ulster University has also been investigating single family dwelling energy storage using a 23m3 thermal store that is charged in the summer by 10m2 of solar thermal collectors. The house is located outside Galway and has a low space energy demand23. During the cold winter of 2010 the store provided all the space heating requirements through November and December. Such a store is suitable for detached houses with underground storage space available near the house in the garden. With the large number of rural detached houses in Northern Ireland such installations may help reduce the dependence of the economy on imported heating oil. Glen Dimplex, Kingspan (both Portadown) and Emersion (Cookstown), are developing demand side response technologies for houses.

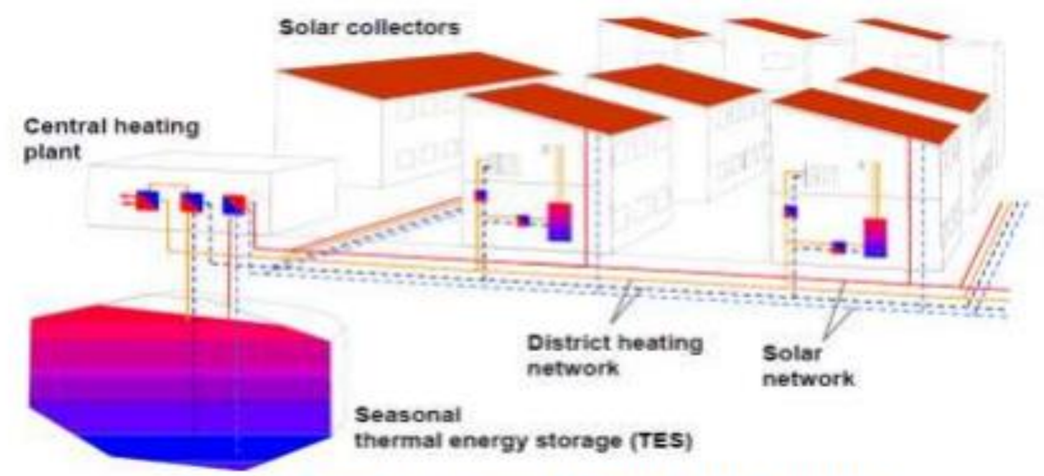

Figure 3: District scale seasonal thermal energy storage

Sensible heat storage, where the energy is stored by raising the temperature of a fluid is the simplest form of thermal energy storage, but requires the most bulk. Other options involving latent energy storage and chemical energy storage require further research but have the potential to store the energy in a much smaller energy volume. Seasonal energy storage requires forethought in planning

and infrastructure development. District heating has a very low take-up in the UK and Ireland, primarily due to low population densities. However it provides the ability to move with one switch of power to a different source for multiple dwellings and provides economies of scale not open to the individual householder.


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Technology suppliers, products and services they offer

Supplier	Product	Services	Contact Information
Akkuhuolto Sinkkonen Oy	AGM batteries (off-grid)	Turn-key solutions, installations, service and maintenance, support, reselling.	http://www.akkusinkkonen.fi
Solarworks Oy, Joensuu,	Fronius solar batteries, on-grid (4-12 kW).	Turn-key solutions, installations, service and maintenance, support, reselling, intelligent controls, optimising.	https://www.solarworks.fi/

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Project Partners
GREBE will be operated by eight partner organisations across six regions:

- WDC – Western Development Commission
- Action Renewables – the future of energy, today
- Luke – Natural Resources Institute Finland
- FPN – Forskningsparken i Narvik
- eri – environmental research institute
- Fermanagh & Omagh District Council – Comhairle Ceantair Fhear Manach agus na hÓmaí
- Innovation Center Iceland
- Karelia

About GREBE
GREBE is a €1.77m, 3-year (2015-2018) transnational project to support the renewable energy sector. It is co-funded by the EU's Northern Periphery & Arctic (NPA) Programme. It will focus on the challenges of peripheral and arctic regions as places for doing business, and help develop renewable energy business opportunities provided by extreme conditions.