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Policy Briefing
Energy Storage in Northern Ireland for Efficient Electricity Network Use

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Executive Summary

By 2050, the EU aims to cut its emissions substantially – by 80-95% compared to 1990 levels as part of the efforts required by developed countries as a group. The G7 Summit of June 2015 further indicated that a phase out of fossil fuels will occur by the end of this century. Given the likely technologies of wind and PV leading the way in large scale renewable energy deployment with no doubt other forms of renewable energy supporting regional needs, a number of fundamental questions arise. These address network stability and energy availability. Therefore how much asynchronous renewable energy electricity generation can be placed on the network, how much zero-carbon synchronous generation will be required and how much storage will be needed?

A range of models illustrate typically 40%-80% renewables with the remainder being equally split between Carbon Capture and Storage (CCS) Fossil Fuel Generation and Nuclear Power. Such assertions may contribute to the notion of future “beautiful nuclear energy” cited recently in UK Government circles. Successful CCS based on natural gas may encourage non-conventional fracking gas use with its potential challenges. However is the latter at odds with the G7 proposals? CCS techno-economics needs careful consideration.

However energy storage is more important today than before. It stores electricity and heat from renewable sources (wind, wave, solar) and is key to the electrification of transport. But the current technologies have questionable performance leading to the need to develop new materials for electricity storage, heat storage and mechanical energy storage, new thermodynamic processes have to be optimized, and viable demonstrations need to be initiated to verify promising technologies. These technologies then have to be integrated into robust and cost effective systems. That integration will require a wide range of data interactions and data flows and an increasingly more intelligent energy network that must address renewable energy integration as well as energy network capacity, safety and efficiency. It will also require an increasing involvement from the end-user with a greater potential for influencing behaviour change.

But the questions remain? What capacities of energy storage are required? How will the likely market scenarios be developed that account for energy policy, existing and new energy infrastructure, renewable energy and carbon-zero energy, EU energy union and the complementary energy storage scales and types that give confidence for industry investment in this sector? And of course, how should Northern Ireland react to this agenda?

EU, UK, Ireland and Northern Ireland Context

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 realised. The International Energy Agency (IEA) Technology Roadmap entitled "Energy storage" (2014)[1] demonstrated the level of maturity of technologies (Figure 1).

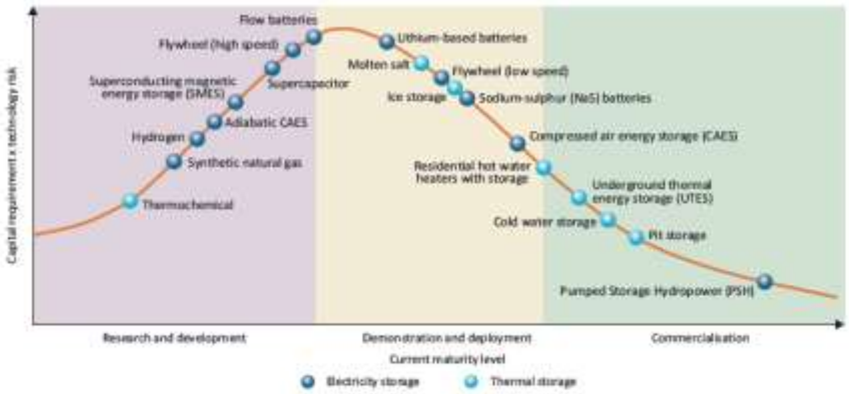

Figure 1: Energy Storage Technology Maturity Level

The cost of energy will increase due to a number of linked but separate issues. Security of energy supply is strategically critical in the face of increasing international prices, supply issues and geopolitical unrest. Energy supply depends on I) the demand for energy services and ii) how that demand is delivered. Energy service demand is driven primarily by economic activity and low energy prices can serve to remove barriers to economic activity.

Renewable energy sources play a part in avoiding overreliance on imported fossil fuels. Energy diversification has been part of EU law since EU directive 2001/77/EC which was superseded by 2009/28/EC in 2009[2]. This directive is commonly known as the 'Renewables Directive' but covers a number of areas which are interrelated to achieve less dependence on fossil energy as well as renewable alternatives. The aims of this directive are paraphrased to the 20-20-20 targets. Essentially these aim to reduce overall EU greenhouse gas emissions to at least 20% below 1990 levels by the year 2020, achieve a 20% reduction in primary energy use by promoting energy efficiency and to achieve 20% of EU energy consumption to be sourced from renewable resources by 2020. Within the directive Article 16 specifically directs that:

> *Member States shall take the appropriate steps to develop transmission and distribution grid infrastructure, intelligent networks, storage facilities and the electricity system, in order to allow the secure operation of the electricity system as it accommodates the further development of electricity production from renewable energy sources, including interconnection between Member States and between Member States and third countries.*

The onus is on individual Member States to determine the most appropriate implementation of this directive.

Further to this directive, the European Commission coordinates the activities around energy in the 'Energy strategy for Europe' forum. The European Commission communication of the 10 November 2010 entitled "Energy 2020, a strategy for competitive, sustainable and secure energy" set the context for the development of energy policy to 2020 and

[1] International Energy Agency Technology Roadmap – Energy Storage (2014)
[2] EU Directive 2009/28/EC http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:en:PDF retrieved 22/4/2012

beyond to 2050[3]. The Commission recognised that energy was the life blood of society but concurrently is responsible for 80% of the EU's total greenhouse emissions. The Commission identified five priorities to drive the new energy strategy:

1: Achieving and energy efficient Europe
2: Building a truly pan-European integrated energy market
3: Empowering consumers and achieving the highest level of safety and security
4: Extending Europe's leadership in energy technology and innovation
5: Strengthening the external dimension of the EU energy market

Within this strategy outline, energy storage technologies are specifically identified under priority 2, i.e. "Building a pan-European integrated energy market" and the European association of electricity grid operators (ENTSO-E) would undertake to assess the requirements for energy storage on a regional level to report by 2016[4]. Additionally, the Strategic Energy Technology plan sets out a medium term strategy valid across all sectors but the Commission identify the requirement to speed up the development of certain technologies, among which electricity storage is specifically mentioned.

Priority 4 in this plan specifically identifies that Europe must re-establish itself as a technology leader. In 'Extending Europe's leadership in energy technology and innovation' the Commission states that it will be supporting Action 2 which aims to re-establish Europe's leadership in electricity storage and that these developments will prepare the grid at all voltage levels for the massive uptake of small-scale decentralised and large-scale centralised renewable electricity sources. This is a clear indication that energy storage technologies are an integral part of Europe's future energy infrastructure. Furthermore, energy storage technologies are a cornerstone of the European Infrastructure initiative within this plan. On 19 October 2011, the Commission proposed a regulation on "Guidelines for trans-European energy infrastructure". This regulation aims at full integration of the energy market within the EU in order to achieve 20-20-20 targets. The initiative identifies a number of trans-European priority corridors and areas covering gas and electricity networks which will have activities within these areas benefit from accelerated planning processes, facilitation of regulatory procedures and even access to critical funding through the "Connecting Europe Facility" which is subject to a separate legislative proposal. Investment costs for large scale energy storage technologies are given in Table 1[5],[6].

The Energy Roadmap 2050[7] has been structured through a series of scenarios considering possibilities of almost full decarbonisation of the electricity supply by 2050. The UK approach to energy and climate change is based on the Climate Change Act[8] and the UK Climate Change Committee (CCC) recommendations on how to meet the needs of this act. The CCC has advised that the electricity supply be largely decarbonised by 2030, so that heat and transport could then be decarbonised through electrification[9]. In examining a number of information and policy sources namely DUKES[10], UK Renewable Energy Roadmap[11] and the UK National Renewable Energy Action Plan[12]; Radcliffe[13] developed

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[3] Energy 2020 A strategy for competitive, sustainable and secure energy http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0639:FIN:EN:HTML, retrieved 22/4/2012
[4] Proposal for a Regulation of the European Parliament and of the Council on guidelines for Trans-European energy infrastructure http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0658:FIN:EN:HTML retrieved 22/4/2012
[5] Gatzen, C. (2008). The economics of power storage. Munich: OldenbourgIndustrieverlag.
[6] Dean, P. (2010). Derivation of Robust Intertemporal Targets for Large Scale Pumped Hydro Energy Storage using Plexos. Plexos for Power Systems. European User Conference. London.
[7] COM(2011) 885 final, COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS
Energy Roadmap 2050, Brussels, 15.12.2011
[8] http://www.legislation.gov.uk/ukpga/2008/27/contents
[9] Building a low-carbon economy – the UK's contribution to tackling climate change, Committee on Climate Change, December 2008
[10] http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx (2012)
[11] http://www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/re_roadmap/re_roadmap.aspx (2009)

Figure 2 as an illustration of likely renewable energy integration rates. Furthermore, the UK is committed to reducing its greenhouse gas emissions by at least 80% by 2050, relative to 1990 level with Radcliffe again indicating that offshore wind will reach an installed capacity of 50GW[14]. While this may cause fewer problems on a large interconnected network, the smaller island of Ireland with similar climate change mitigation goals faces a considerable challenge.

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

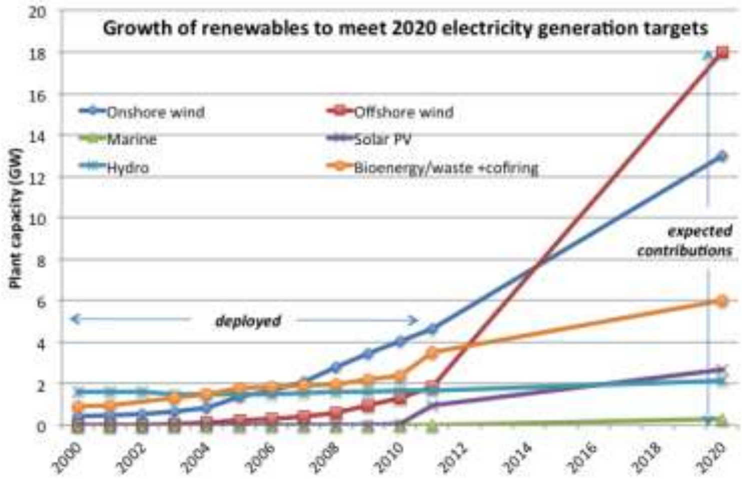

Figure 2: Expected renewables contribution to generation by 2020

The intermittent nature of wind is the biggest problem[15] due to the mismatch between energy supply and demand i.e. wind is non-dispatchable. Increased solar PV has the potential to add to this issue. High levels of wind generation cause technical problems on the whole Irish network. At present these issues are addressed by constraining (turning down) and curtailing (cutting off) wind generators. This will increase as the Republic of Ireland's National Renewable Energy Action Plan driven by Directive 2009/28/EC sets a target 40% of electricity from renewable energy sources by 2020. Thus the Irish grid will have to cope with large amounts of intermittent power.

EU implementation of renewable energy is based on the 20-20-20 commitments i.e. 20% of all energy from renewable sources by 2020. 61% of all new electricity generation capacity in 2009 came from renewables (mainly wind and PV). It is predicted that over 50% of the power generated will be from non-dispatchable sources such as wind. The recent transition to an all-Island grid system, as well as market deregulation, has thrown up further barriers to wind energy, despite evidence that overall renewable energy penetration decreases the wholesale price of electricity.

[12] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47871/25-nat-ren-energy-action-plan.pdf
[13] Radcliffe, J., Energy Research Partnership Technology Report: The future role for energy storage in the UK. Main Report (2011)
[14] ENERGY STORAGE: THE MISSING LINK IN THE UK'S ENERGY COMMITMENTS. Institution of Mechanical Engineers, April 2014
[15] Impact of Intermittency: How wind variably could change the shape of the British and Irish markets. Summary Report, July 2009 Poyry Energy (Oxford) Ltd.

The Single Electricity Market Operator (SEMO) operates the all-island electricity market trading through a 'pool' system where licensed generators sell their electricity to a licensed supplier who sells it onto the 'pool', and receives the system marginal price (SMP). Alternative backup generation (inflexible conventional fossil fuel powered plants e.g. gas etc.) needs to be available to ensure system stability. As the penetration of wind increases this alternative generation plant is increasingly generating electricity inefficiently and this mitigates the benefits of wind power. Storage and demand side management can replace elements of this enabling plant.

A recent NREL study concludes that "Wind curtailment initiatives appear to be increasing, perhaps in part because of the rapid growth of wind power and the lack of development of supporting transmission infrastructure to keep up". In Ireland's Single Electricity Market, scenarios predict up to 16% curtailment with high wind penetration. Wind penetration in Ireland currently is over 40% during holiday times and often exceeds 50%. In Ireland, the curtailment rate has been seen at 63MW in 15 minutes (approximately 12% of capacity at the time), 144MW in 1 hour (29% capacity) and 338MW in 12 h (68% capacity) in order to manage wind generated electricity when electricity demand has been insufficient. At present there is a limit of 50% wind penetration allowed on the network, which has been reached on a large number of occasions. An upper limit of 75% is being developed for known as the 'Delivering a Secure Sustainable Electricity System (DS3)' programme[16]. This manages the change between the present day scenario and the 2020 targets.

Currently there is 2031.25MW of installed wind capacity which may increase to 6500MW by 2020 if the 40% target is to be met. Recent road maps for smart grid and wind for Ireland to 2050 illustrate that onshore wind installed capacity could increase to 15,000MW with 30,000MW of offshore wind. Already wind curtailment is an issue in the wind industry and presents major barriers and uncertainties for future wind project developments and for Ireland to realise the full benefits of wind energy and targets set out above. Thus greater interconnection, energy storage and demand side management must be incorporated in future energy systems to allow decarbonisation with wind in the first instance to have a chance of being a reality.

Northern Ireland's Response

The need for Northern Ireland to contribute to its share of the 20-20-20 commitments and the recently set 2030 targets of a 40% reduction in greenhouse gases and a 27% target for renewable energy and energy efficiency[17] requires the maximum use of non-dispatachable renewable energy. Further the replacement of oil and gas fired space heating will require a significant growth in electrical generation capacity. This growth has to be based around renewables. There is a need for a debate as to the type of storage that suits the economy's need. Storage can be at either the grid or user level. Grid level storages devices are outlined in Table 1. Only pump storage is considered to be a mature technology. A new 600MWh scheme is being developed in at Llyn Padern, North Wales[18]. Wales has both the geology and geography for such an installation and the developers are taking advantage of a former slate quarry for the development in the National Park. 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. Compressed Air is worthy of consideration. It uses conventional mature compressor and turbine technologies. Air is compressed using excess electricity, and when required the air is fed into turbines to generate electricity. The storage of the air requires a large container able to withstand considerable pressure and hence this technology is best buried and the salt bearing beds of east Antrim provide an excellent geological safe base for such caverns. The advantage of east Antrim is the existing electrical network emanating from Ballylumford and Kilroot, reducing the need for expensive connections to a distant site. Redox batteries and hydrogen fuel cells require further research and development. They are likely to be smaller in capacity but could be developed amongst industrial buildings as they can be housed in basic building shells. Ulster University has

[16] The DS3 Programme, Delivering a Secure, Sustainable Electricity System, EirGrid, 2015.
[17] http://ec.europa.eu/clima/policies/2030/index_en.htm
[18] http://www.theengineer.co.uk/energy/in-depth/pumped-storage-a-new-project-for-wales/1020129.article

been working in conjunction with Duhdalk IT and Gaelectric Ltd in the SPIRE project[19] The aims have been to investigate large scale compressed air energy storage in the Larne salt beds, commercial site-scale storage (flow batteries and ice banks) for renewable energy integration into community scale energy management and domestic scale demand response with heat pumps and thermal stores replacing gas boilers. Outputs are technology assessment and developments coupled with an overall market penetration of these technologies in an all-Ireland scenario.

Demand side storage may be either thermal or electrical. Tesla has recently announced a home battery[20]. As battery technology improves 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. A Limavady company, Arbarr[21] are developing batteries for demand side storage.

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[22], 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 $23m^3$ thermal store that is charged in the summer by $10m^2$ of solar thermal collectors. The house is located outside Galway and has a low space energy demand[23]. 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.

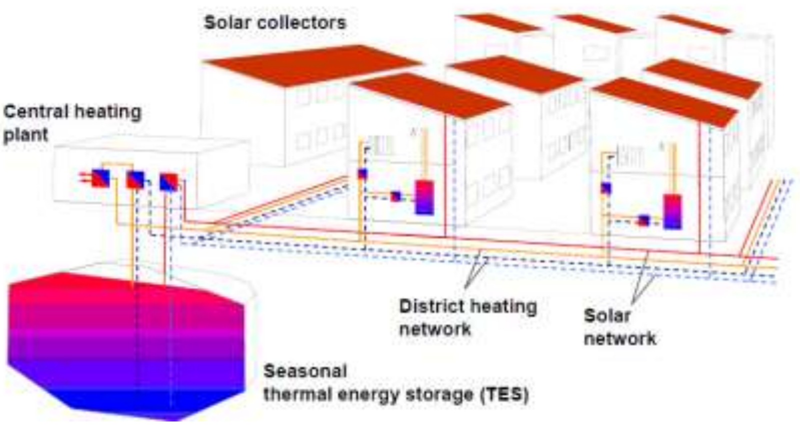

Figure 3: District scale seasonal thermal energy storage

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

[19] http://projectspire.eu/
[20] http://www.teslamotors.com/powerwall
[21] http://www.arbarr.com/
[22] http://www.einstein-project.eu/english
[23] http://www.scanhome.ie/research/solarseasonal.php

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.

Solar thermal is not the only source of renewable energy. Excess wind energy can be used to heat hot water tanks. This requires changes to how electricity is charged, with low rates available at times of excess electricity and a control system that draws down the electricity and switches on the immersion in the hot water tank. With wind energy tending to be in excess at night, this would allow the hot water to be heated before the traditional boiler heat up first thing in the morning, thereby offsetting either gas or oil consumption. Such an approach would require the electricity to be charged at a lower rate than fossil fuels. Smart meters will aid this but again grid infrastructure development is required to run the controls. The growth of the photovoltaics (PV) solar collector installations can also provide a source of energy. Excess energy generated by PV that it is not used in the house is exported. Better and flexible controls could enable that energy to be used to heat water, a far better use for the householder than exporting the electricity and using gas to heat the water later.

Conclusion

The basis of all of this is the electrification of heat. Heat pumps will be the main focus of future domestic heating. Air sourced heat pumps are capable of being retrofitted in place of a traditional boiler. Linked with renewable energy, whose availability is as flexible as fossil fuels when using energy storage, heat pumps provide the main route through to achieving Northern Ireland's contribution to the UK and EU's carbon reduction commitments. Northern Ireland has significant renewable energy resources that can offset the import of fossil fuels. Storage is required to enable renewable energy to be dispatched on demand instead of requiring customers to re-organise their life around energy availability. Such a move would be a backwards step.

Northern Ireland is developing expertise to form an important supply chain in the advancement of these technologies, which have a global appeal as renewable energy penetration increases. If supported correctly the opportunity exists with DS3 for an all-Ireland business opportunity to be filled by indigenous companies which will then have the lead on their European and global counterparts.

About the Authors

Professor Neil J Hewitt (BSc Hons, PhD) is Director of the Centre for Sustainable Technologies (CST) at Ulster University. CST represents energy research at Ulster with over £13m of externally funded research and 30 members of staff and researchers developing energy storage concepts and related renewable energy and energy efficiency technologies.

Professor Philip Griffiths (BSc Hons, MSc, PhD) is Head of the School of the Built Environment in addition to being Ulster's representative International Energy Agency and EU energy storage programs. As Head of School, he is also responsible for ensuring the energy agenda is incorporated in undergraduate and post graduate education curricula to assist in fulfilling engineering skills gaps in this and the wider energy sector.