Scotland's centre of expertise connecting climate change research and policy

Energy Storage in Scotland

Summary of reports on thermal and electrical energy storage

1. Introduction

Scotland's energy system is undergoing a major transformation in response to pressures to deliver clean, affordable and secure supplies of energy, in conjunction with wider economic and social benefits, amid rapid changes in global energy markets and technologies. Energy storage is likely to be an increasingly important part of this transition: in particular, there is a need to understand the potential for storage integration across the whole energy system (power, heat and mobility).

In 2014, ClimateXChange commissioned two reports on energy storage in Scotland, on thermal energy storage and on electrical energy storage. Both seek to review the state of technological and market development in the context of Scotland's energy policy ambitions. This short briefing note brings the insights from those two reports, and from other recent reports on energy storage, together to help support thinking on integrated energy policy.

2. The policy context

Secretary of State for Energy and Climate Change Amber Rudd set a new direction for UK energy policy in November 2015, focusing on minimising costs to the consumer whilst securing energy supplies through the use of nuclear and gas-fired power and gas-fired heating. The focus of the UK Government will be to remove regulations that are holding back "smart" market solutions, such as demand-side response or energy storage. This approach aims to enable the market to reveal which is the best model for the UK energy system.

Despite the Scottish Government's limited formal role in energy policy, the collective learning associated with the rapid deployment of renewable electricity since devolution and the fact that heat policy is devolved to Scottish Ministers have led to devolved policies that encourage more localised, integrated energy systems with concomitant social and economic benefits.

3. Scotland's energy challenges

In Scotland, over half of final energy demand is for heat. Over 60% of domestic energy cost is for space and water heating. Scotland's energy needs are highly seasonal: energy consumption for heating is twice that in winter as for summer. At its peak in winter, heating accounts for approximately four times the energy consumption per day as electricity, and over twice that of transport fuels. Heating is provided largely by natural gas (78% of domestic primary heating systems) or by electricity; a majority of households with electric heating are currently in fuel poverty.

From April 2016, Scotland's electricity supply will be delivered by nuclear and largely intermittent renewables, along with reinforced interconnectors to England. By 2020 roughly two thirds of Great Britain's installed renewable electricity capacity will be situated in Scotland. Following anticipated closure of nuclear power plants by 2023, Scotland's electricity supply will consist of local energy systems, intermittent renewables and grid connections to the rest of the GB grid and overseas.

Meeting Scotland's heating, transport and power needs, whilst delivering a decarbonised energy system by 2050 at affordable costs, will require a more holistic approach to energy production and use at different spatial and time scales, including the integration of demand side management and much wider application of energy storage.

4. The role of energy storage

Energy storage enables energy to be provided when it is required, rather than when it is produced. In conventional energy systems in the UK, stocks of fuel or stocks of hot water provide the ability to produce energy on demand (natural gas in the pressurised gas network, transport fuels in bunkers and vehicle fuel tanks, coal stocks at power stations, domestic water tanks). European countries with extensive district heating systems have for many years used the large water storage tanks associated with these networks.

With the move to a much higher proportion of intermittent renewable electricity generation, along with the decarbonisation (and replacement of conventional fuel) of heating and transport, the role of energy storage becomes more important. Better use of energy storage can help Scotland manage peak energy demands and the intermittency of renewables; meet emissions targets; extend infrastructure life; and reduce energy system costs.

Various established and developing energy storage technologies exist, including both electrical and thermal storage. Broadly, energy storage can be provided as:

1. **Electrical energy stored for electricity**
2. **Electrical energy stored for heat**
3. **Thermal energy stored for electricity**
4. **Thermal energy stored for heat**

Energy storage has the potential to contribute to power system operations both qualitatively, by maintaining stability and voltage quality over seconds to minutes, and quantitatively, by load shifting, levelling and peak shaving when output exceeds demand constraints at network or local level over minutes to hours.

Energy storage has the potential to contribute to heat system needs by: storing excess electrical energy generated by renewables at times when demand is low to be provided as heating or cooling at peak times, over periods of hours; balancing co-generation of electricity and heat to provide variable community level heat and power needs, over hours to days; meeting high demand for thermal energy in winter by capturing and storing excess energy in summer, inter-seasonally; integrating variable renewable energy production, on timescales of hours to days; and enabling excess thermal energy from industrial processes or power stations to be converted into useful heat or electricity when needed

5. Key implications for Scotland

Inter-seasonal timescales

- To take a simplistic scenario, any ambition to meet current winter peak heat needs by complete electrification, would require a massive increase in generation capacity across the UK (>40GW), running with low utilisation. This would be a highly costly approach. Massive deployment of building energy efficiency measures will help reduce overall (and peak) heat demands, and reduce both needs for peak generation and energy storage capacity.
- Storage technologies to help reduce the extreme seasonality of heat demand by inter-seasonal storage, such as use of sensible heat stores (e.g. above ground reservoirs, underground aquifers, subsurface rocks), have been demonstrated to date but not deployed at scale in the UK. Further testing at scale is required.

Medium timescales: hours to days

- Reducing heat and electricity peak loads – by load shifting, levelling or shaving – is already possible using bulk storage on the electricity transmission network (with pumped hydro systems or compressed air) or balancing co-generation of heat and electricity, using hot water accumulators.
- Similarly, reducing daily peak demand for thermal energy can be achieved by storing off-peak electricity energy to be discharged as heat at peak times. The roll out of smart meters should enable excess energy from wind power to be stored instantaneously; trials in Scotland have shown this approach to be feasible, whether from modern storage heaters or the use of hot water tanks.
- Maintaining thermal stores close to energy use (e.g. domestic hot water tanks) provides additional options for short to medium scale storage.
- Local heat networks can also act as a heat store at times of surplus electricity production, providing this heat to users on the network at a later time. Extensive waste heat from industrial processes could be stored in this way.
- Managing two-way, intermittent flows of electricity in the distribution network can be managed by use of batteries to support voltage control, rather than expensive reinforcement of the network, so managing local constraints.
- Similarly, intraday storage close to energy generation can ensure daily variability of energy demand is met more easily (e.g. maximum demand for energy in morning and evening, but maximum production of solar power is in the middle of the day).

- The impact of increasing vehicle electricity charging at peak times is poorly understood: there is a theoretical potential for using vehicles to help balance electricity grid needs but substantial development of "smart" systems and cost incentives are required.
- At GB power system scale, bulk electricity storage is most effectively located in Scotland, to facilitate the integration of intermittent wind energy and reduce transmission costs.

Short timescales: seconds to minutes

- Electricity storage can help short-term variability associated with intermittent renewables on a second-to-second and minute-to-minute basis, helping ensure system stability and reducing costs of ramping up and down thermal generation elsewhere on the system.

Cost effectiveness/investment

- The value of storage is affected by investment in other measures, as well as the level of renewables penetration. For example, deployment of CCS-fitted conventional generation would tend to reduce the value of energy storage on the power system, although storage may still be attractive for peak shifting.
- At the level of the whole power system, the expansion of transmission capacity is currently cheaper and more effective in terms of system balancing and security than large-scale electrical storage. This is in part because the existing electricity market does not presently allow the full value of energy storage to be realised.
- Specific regulatory constraints on further deployment of energy storage include: double charging bulk electricity storage operators for both meeting demand and absorbing electricity at times of network overload; not allowing Distribution Network Operators (NDOs) to operate storage facilities at distribution level, because they are prevented from holding generation licences; and not incentivising renewable generation operators from co-locating energy storage to help reduce system fluctuations.
- Energy storage for heat and electricity should go hand-in-hand with demand side management (DSM). However, storage and DSM solutions need to be integrated, as DSM is to some extent an alternative to energy storage and can detract from its value.
- Smaller, distributed technologies such as batteries and hydrogen cells have the potential to contribute to peak load and demand management, particularly within local energy systems. However, such technologies currently remain expensive, suggesting they will need support to reach the point of significant deployment.

Key implications for Scotland

- Energy storage technologies are already available to meet short or medium timescale challenges in the energy system, but are poorly incentivised by the current market framework: the most recent bulk electricity storage system in the UK – pumped hydro – was built over 30 years ago. The loss of thermal power generation means a loss of inertia, making the system more difficult to manage.
- The real value to Scotland of energy storage may be: to integrate its intermittent electricity generation assets to help meet the seasonality and daily fluctuation in heat demand; and to develop

specific heat storage approaches, such as utilising its increasing number of combined heat and power networks or other thermal stores, to the same end.

- Some emergent technologies, such as smart control technologies to allow thermal storage (electricity storage heaters) to respond automatically to system signals, fit well into the Scottish context (reflecting the structure of the power network, topography, patterns of demand, extent of future interconnection). Others fit less well.

The two reports commissioned by ClimateXChange in 2014-15 provide more detail on the appropriateness of storage technologies to the Scottish context.