ENERGY STORAGE

Report of the ICARB International Energy Storage Workshop

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Workshop Summary

Introduction

ICARB's programme of events is designed to meet two key objectives: to further our core activities in promoting and advancing carbon accounting in line with the GHG Protocols Group's '5 Principles'; and to identify and explore wider and emerging issues related to decarbonising our economy and society where the expertise of carbon accountants can be brought to bear.

Energy has always been a core area of our work, and in 2014 ICARB ran two very successful 'Backcasting' events to generate and explore future visions for Scotland's energy systems in 2030. The question we asked delegates was if Scotland's energy supply could be 100% renewable or low carbon by 2030, and if so what would the most likely energy system and mix to reach this target? The three Visions developed were:

A) *Better Together* – with large super-grids and interconnectors to Europe and Ireland with embedded nuclear generation capacity.

B) *Going It Alone* – allowing some cross border exchange of energy but providing all Scotland's energy from generation capacity within Scotland including some employing Carbon Capture and Storage systems.

C) *Autarky* – locally self-sufficient de-centralised supply and demand systems depending largely on renewable energy generation, demand management, embedded storage and smart controls.

What became clear was that whatever system is developed, which no doubt will be a combination of all three, energy storage will be key to the low carbon, low impact and resilient energy systems we need for the future, and so we realised we needed to understand this field in more detail. The vast scale of the work going on in energy storage is impressive - in the laboratory, in the field trials and in the real world. We brought together top thinkers and practitioners from Europe and the UK to report on progress in their specialist areas, share their experiences and opinions, and to work with us on ways forward for embedding energy storage in the economy, society and landscapes of Scotland.

In what may be a sign of the growing importance of storage in future planning for energy, the workshop attracted around 100 delegates from across Scotland and the UK, with some travelling from as far afield as London and Brighton, and many had high levels of expertise. As is customary for ICARB events, the day was split into a series of plenary sessions followed by parallel workshops, the results of which were reported back to a final panel session. This report summarises the key discussions from the event, with full notes from the workshop sessions included as appendices. Presentations can be found on our website at www.icarb.org.

Plenary Sessions

Emerging Scottish Policy to promote energy storage
Chris Stark, Deputy Director, Energy and Climate Change, Head of Electricity, Scottish Government
The Role of Storage in Smart Energy Systems
Professor Henrik Lund, Aalborg University, Denmark
Storage integration in heating systems at domestic, community and industrial scales
Prof. Klaus Vajen, Kassel University, Germany
Inter-seasonal heat storage systems: Lessons from the Danish Experience
Dr Ebbe Münster, PlanEnergi, Denmark
Energy storage in urban multi-energy systems
Prof. Marco Masoero, Politecnico di Torino
Optimising energy storage within micro-grid systems
Dr Eddie Owens, Heriot Watt University
Why Energy Storage?
Dr Grant Wilson, University of Sheffield

Plenary Session Talks:

The event began with a presentation by **Chris Stark** of the Scottish Government, which highlighted both the range of energy storage options being considered and the need for more and better information on both the practicalities of integrating energy storage into the

National Grid and other energy infrastructure, and on the potential for incorporating different technologies, which comprise a mix of established and emerging storage solutions.

Prof Henrik Lund, one of the most highly cited researchers in the world, presented his work on Energy systems. Denmark has demonstrated a long standing political will to being a globally leading low carbon economy. Lund quoted former Prime Minister Anders Fogh Rasmussen in his opening speech to the Parliament in 2006 when he announced the high level political aim to convert Denmark to 100% Renewable Energy and totally free its economy from fossil fuels like oil, coal and gas. He proposed Smart Energy Systems as being key to cost-efficient 100% Renewable Energy and pointed out that a sole focus on renewable electricity (smart grid) production leads to electricity storage and solutions that can service flexible demand. Looking at renewable electricity as a part smart energy systems including heating, industry, gas and transportation opens the way for cheaper and better solutions. He detailed the potential for using Power to Heat; Power to Gas and Power to Transport systems to provide storage at the grid level. He presented a range of policy and research options and some estimated costed alternatives for related energy storage systems.

Prof Klaus Vajen's talk on thermal storage in buildings highlighted how far we could still go with established storage technologies. Building scientists and engineers have known about and made use of thermal storage and other truly passive ways of saving energy for millennia, and whilst new methods involve some 21st century technology they would still be familiar to an ancient Roman. However in the UK using thermal mass has been dis-incentivised by the Building Regulations and shrinking average house sizes. Retrofitting these homes with external panels that incorporate heat storage technologies is certainly feasible, as is inserting large water storage tanks into multiple occupancy buildings, however some of Klaus's photographs neatly illustrated why it's still preferable to design these in from day one, and this needs to be incentivised by the relevant standards and regulations.

On a similar note but at a much larger scale, **Dr Ebbe Munster**, working with **Morten Vang Jensen** of PlanEnergi in Demark presented two detailed case studies of community scale thermal storage systesm that were up and running in Denmark. He demonstrated hiw they were designed and implementd and was abe to cover ppreliminary measuring results and costs for a) Borehole thermal energy storage in Braedstrup and b) Pit heat storage in Marstal. In his conclusions he compared the size, costs, heat supplied to, and recovered from, these seasonal storage systems. On the basis of this real world evidence he provided conclusions on the commercial and practical viability of the systems coloured by the experience of implementing both schemes.

Professor Marco Masoero presented a general typology of Electrical Energy Storage (EES), and their roles and technical parameters. He also did the same for Thermal Energy Storage (TES) systems including a review of their purpose in energy plants, related technologies and discussing their short-term (daily) versus long-term (seasonal) storage applications in District Heating and Cooling schemes, touching briefly on the issue of adopting Power-to-Fuels technologies.

Dr Eddie Owens described the ongoing European ORIGIN project that is centred on micro-grid communities in Scotland, Portugal and Italy. The project is developing methods for the 'Orchestration' of energy use within a community – to save imported energy and carbon by aligning energy demand with (local) renewable supply using micro-grid-integrated storage in the process where appropriate. He touched on the tools they were developing to predict of demand and supply using advanced weather forecasting algorithms that enable the planning of energy use in advance and the deployment of smart energy monitoring, control and communication hardware in an economically robust system level model that integrates human behaviour into the optimising strategies it employs.

The plenaries were concluded by **Dr Grant Wilson**, who emphasised that energy storage is nothing new, but what has changed is that we need it to do new things – e.g. balancing renewables – so we to think about energy systems in different ways to build in the best solutions. Traditionally fossil fuels themselves have acted as a form of large scale energy storage, but in the future the challenge will be to both produce and balance energy grids using the best mix of renewable and low carbon technologies.

Workshops

The parallel workshop sessions were split into six themes:

Workshop 1: Thermal Storage Systems for Buildings and Communities

Workshop 2: Energy storage media: Phase Change Materials, oils, chemicals, solids and Thermal Mass

Workshop 3: Grid level energy storage for electricity and transport

Workshop 4: Energy Storage and Conversions with Hydrogen & Fuel Cells

Workshop 5: Origin: Control systems for optimising micro-grids and thermal systems

Workshop 6: Charging ahead with battery technology

The workshop sessions were chaired by experts in each field and facilitated and scribed by ICARB volunteers. The workshops used a standard ICARB structure designed to draw out information and opinions on barriers, drivers and solutions in relation to different aspects of each field (technological, economic, social, etc). At the end of the session workshop chairs reported back to the final conference session, and the notes from each discussion can be found in the appendix to this report.

The level of expertise shared by the participants is reflected in some of the detailed discussions captured in the notes from the workshops, however there are also some clear and consistent messages for decision-makers. First and foremost being the problem of (artificially) low fossil fuel prices depressing the wider value of energy and dis-incentivising investment in storage. Many participants felt that this needs to be addressed by regulatory responses, for example legislating for greater recovery and distribution of 'waste' heat from generation, and using the Building Regulations to leverage thermal storage technologies into new housing. However it will also be important to identify and develop of new applications to grow the wider market and normalise energy storage into everything from heavy industry to transport and IT networks, with participants suggesting many ideas for these.

This growing diversity of technologies and applications is likely to pose its own problems, with potentially very different solutions competing in the same markets, for example the need for increased domestic thermal storage could be met by small scale and distributed solar, integrating liquid storage into structural elements and cladding, or off site solutions such as borehole and sealed-reservoir storage. All this means that the biggest challenge for decision-makers will be to design in energy storage at all scales using technologies that are the most appropriate both for the individual applications and for integrating with other storage solutions and an evolving energy mix.

Conclusions and Ways Forward

When we set out to organise this event we were responding to a need for knowledge identified through our activities on decarbonising our energy networks, however what the event made clear is that energy storage should not be considered as one component of an energy network, but as part of the infrastructure itself. This means thinking beyond wires, pipes, and traditional solutions such as pumped storage, the future potential of which may be limited by the new demands we will need energy grids to meet.

An example of this was highlighted in the final panel session, which identified Orkney as a potentially valuable case study for informing the future development of energy storage in Scotland, particularly in island areas with large renewable energy resources. At the moment the capacity of the grid connection between Orkney and the mainland is insufficient to carry all the electricity produced by Orkney's wind turbines at times of high output and low demand. However the islands' hospital, which is currently being retrofitted, could provide the ideal anchor point at which to integrate storage to balance supply, demand, and export; and as an example of how far integration of storage could go in future, it was suggested that chemical storage could be employed to use this excess electricity to power the islands' ferries.

Such a system could also pose new challenges for carbon accounting practices - for example setting boundaries for reporting at different levels of the ‘system’, and adjusting conversion factors for using stored energy generated from different local renewable and low carbon mixes – and this is something we will need to bear in mind when formulating future activities. Please keep an eye on our website and email list for more on these as they develop.

Acknowledgements

The ICARB Team wishes to thank all our speakers, chairs, scribes and delegators, and all those who have supported our activities over the last year. Special thanks go to our conference funders, The Castanza Trust, ClimateXChange Scotland, and CIBSE.

Appendix: Workshop Reports

Workshop 1: Thermal Storage Systems for Buildings and Communities

Chaired by Ian Arbon, Engineered Solutions & Newcastle University

Facilitated by Daniel Rylatt, Heriot Watt University

Scribed by Emma Church, Glasgow Caledonian University

Barriers and Drivers

- Definition of markets agreed to be more encompassing of need as opposed to the traditional economic sense.
- Scotland's "market" in this sense presents a challenge due to the population distribution; a large proportion is off the gas grid in stand-alone dwellings or small rural communities. Alternative to gas is using electrical, oil or LPG to provide heating which is costly.
- In cities and more densely populated areas the existing building stock can be difficult to heat and retrofit (e.g. Victorian tenements). The solutions are often costly and public concern for stripping of building character.
- Relatively cheap cost of gas has knocked out older established district heating systems.
- Utility companies have a stranglehold on the energy system; since they are profit driven there is not enough incentive or pressure for the government to make them care enough about DH or renewables in a way that will make a significant or lasting impression on our energy generation or storage.
- Scottish Government appear to be promoting heat from biomass which is an issue as we are not reforesting at an appropriate rate – more support for other thermal energy generation with different storage potential e.g. heat pumps, geothermal etc.
- Media has power to influence perceptions and opinions with regards to energy e.g. recent coverage on 'hoover' regulations introduced by EU; there was very little explaining the reasoning behind such measures and no context majority of coverage was negative and promoted the idea that legislation is out of touch with people and patronises the public.
- There is still climate change scepticism within SG – will have an effect on the importance given to energy and thermal energy storage.

Solutions

- DH networks/ thermal storage should be considered at the early stages when planning new towns and developments.
- See the small rural communities as an asset rather than a barrier – more opportunity to engage with small scale/ community wide energy generation and storage. Potential for ownership and control over own energy supplies and demands. Government could do more to incentivise and support such projects.
- More dissemination of knowledge about options for insulation of 'difficult to treat' housing stock, this could encourage more engagement with increasing thermal efficiency of tenement buildings (e.g. back-court wall insulation, maintenance and understanding of thermal mass).
- Historic Scotland could be a key player here as they have specialist knowledge and are often in support of increasing energy efficiency and do not support the idea that development and conservation are in opposition with one another.
- New way of thinking is needed to include thermal storage as a main component of an energy system not an after-thought.
- In terms of technical changes required it is felt that this is not an issue. It was agreed that research and development should be encouraged and may be needed in some fields but this is not a reason not to get started now.
- Encourage media to engage positively with energy legislation and relay important information to the public as they can really drive change e.g. Blue Peter green book which promoted recycling and awareness of global environmental issues.
- More support and information for public; need to take control of their energy e.g. small community projects (information about options and funding), changing supplier/tariff, changing behaviours to ease pressure on energy system and benefit homes financially.
- Fuel poverty is an issue in Scotland, DH could be a solution to this but difficulties arise on how to charge tenants e.g. should benefits be linked with fuel provision/ fuel poverty? What strain would that put on the benefits system?
- In Denmark unemployed or those on low incomes are taught about energy consumption and how to reduce it and how to understand energy bills etc. then they paid to disseminate that information among the households in their community. A whole community as well as individuals can benefit and there is no preaching or patronising as it is peer-to-peer discussion.
- Smart meters could be a good source of information if they allowed two way communications e.g. alert when there is an excess of energy in the system and so cheaper energy cost at this time. But current smart meter only supply information to the utilities – this could be addressed in future roll outs.

Workshop 2: Energy storage media: Phase Change Materials, oils, chemicals, solids and Thermal Mass

Chaired by Professor Colin Pulham, University of Edinburgh

Facilitated by Professor David A. Reay, University of Newcastle/Heriot-Watt University

Scribed by Ademola Odunsi, Heriot-Watt University

Markets

Potential markets for thermal energy storage were identified as follows:

- Vehicle/transport
- Chemical/Industrial Processes
- Concentrated Solar power (CSP)
- Domestic
- Seasonal /District heating
- Electronics/computing
- Cooling and/or cold storage
- Batteries (cooling of lithium ion batteries, etc.)

Barriers

Barriers to thermal energy storage:

- **Cost**: The cost of conventional (fossil fuel derived) energy has remained inexorably cheap. In addition, fossil fuels are far more readily accessible in comparison to other forms of energy- including stored thermal energy. It seems to be the case that the economics and relative ease of exploiting an energy source outweighs the "greenness" of the energy source, in spite of the long term adverse effects (global warming, etc.), this manner of prioritisation may have.
- **Size/Compactness:** particularly significant in the case of sensible heat storage such as the use of water tanks. Water is relatively dense and large volumes are often required to store thermal energy. Compactness is often highly desirable in many applications of thermal energy storage including use in vehicles, etc.
- **Degradation of Material:** thermally cycled PCM do degrade over time and would require to be changed.
- **Material compatibility/safety:** The toxicity, flammability, phase transition temperature and tendency of the material to encourage corrosion could significantly reduce the pool of materials available for thermal energy storage
- **Material Enhancement:** There is no "perfect" PCM, possessing all the desirable qualities. It is therefore necessary to enhance the quality of materials. One property usually requiring

modification is the thermal conductivity. Upgrades of this type may lead to a rise in the cost of thermal energy storage.

- **Transport Phenomena:** thermally charged PCMs are difficult and expensive to transport from one place to another (over long distances). There may also be heat loses/gains in the process If they are subject to temperature changes, this drawback in effect limits the number of cycles which such thermally charged masses could be put through, thus reducing the efficiency of the system.

Thermal Energy- Transport Phenomena

As already mentioned earlier, the transport of heat-charged thermal storage materials with minimal heat loss poses quite a challenge. A few options of tackling this include:

- Resorting to sensible heat storage e.g. use of water as a storage medium. Water is easily pumped and can be readily transported in pipelines
- Fluidisation of micro-encapsulated PCMs. It was noted that this could only be applied over short distances as it was still susceptible to heat loss and in particular, the constant contact of particles with the walls of the containment vessel at high velocities could significantly increase the rate of erosion and corrosion
- Thermochemical reactions: It was noted this this method had huge potentials which have hardly been explored. The heat storage potential is many orders of magnitude (10-100 times) greater than its contemporaries (sensible and latent heat storage methods). It was however agreed that if the appropriate reversible chemical reactions (e.g. the dehydrogenation of cyclohexane to produce benzene and hydrogen) are identified, the transport of the thermally charged chemicals with minimal heat losses is made possible, since the materials can be moved about in a dissociated state and only need to be combined when required.

Where do PCMs lie on the Technology and Manufacturing Readiness Levels (TRL)?

It was noted that PCMs had advanced significantly beyond the laboratory test phase and were now being used in domestic applications including the use of PCMs in plasterboards and concrete mixes of buildings for temperature regulation. Other commercial applications identified were in the transport of organs and vaccines where use of ice as a cooling medium was undesirable. This led the group to assign the use of PCMs a value of between 5 and 6on a TRL scale.

The thermochemical (TCM) on the other hand was agreed to be largely in the embryonic phase as hardly any commercial applications could be identified. It was thus assigned a value of between 1 and 2 on the TRL scale.

Environmental Impact of PCM

Some key areas highlighted include:

- The life-cycle and disposal of spent PMC
- The sourcing of the PCM Materials, what are the carbon cost implications if the materials have to be sourced from other parts of the world?
- Toxicity, flammability, corrosive tendency of materials
- Lifespan and longevity of materials used

Solutions to some of the challenges of using PCMs

Some ways of making the use of latent energy storage more competitive are listed below:

- Government and policies: It was concluded that government through its policies had a great role to play. One way of doing this is through strategically targeted incentives such as feed-back tariffs system. A good example of this was when government paid commission to people who generated and sold excess electricity to the national grid. Another way of selling the idea of thermal storage to the wider populace is through granting tax holidays to investors in this area, tax breaks will help drive down the cost until such companies break even and begin making profit.
- Academic and Industry engagement: A closer partnership between investors in the area thermal energy storage and universities/research institutes could be greatly beneficial. New ideas that could possibly form the basis for cheaper and more competitive technology through the sponsorship of Master's and Doctorate and Doctoral training programmes.
- Professional Bodies: Bespoke professional bodies could also be set up for thermal energy storage to further create awareness and to disseminate information about technological progress through their journals, seminars, conferences, etc. A Thermal Storage Network was proposed.
- Venture Capital/Shareholders: Companies in the area of thermal storage may consider becoming public liability companies in order to raise more capital from the stock market and by extension, engage the attention and influence of their shareholders.

Workshop 3: Grid level Energy Storage for Electricity and Transport

Chaired by Dr Ian Staffell, Imperial College London

Facilitated by Andrew Peacock, Heriot Watt University

Scribed by Kevin Bowe of IESVE, Glasgow.

Markets and Politics

The issues associated with a market solution for storage being realised in the market place are manifest and perhaps encapsulated by the following overarching factors;

- The current market is dysfunctional with respect to its ability to create a value for stored energy (for either electricity or heat)
- In the short to medium term there is little appetite for legislative or regulatory change that would address this issue for instance through the creation of a subsidy scheme to promote the deployment of storage.
- Changing legislation to remove barriers is a time consuming process

As a consequence the consensus of the discussion was that in the short term (say the next 5 years) no major market driven mechanism could be foreseen that would act to create an innovator or early adopter class of storage solutions. It was, for instance pointed out that there is not even a basic plan in place that explores the energy storage needs of Scotland and that storage will not be considered in energy systems thinking until 2020 at the earliest.

The constraints indicated above substantially limit the number of options or solutions that could be considered to create some form of stimulus for the adoption of storage (or at the very least reduce the barriers to stimulus). Of these, widely supported solutions discussed by the group were:

A) A mechanism that would place a storage requirement on any energy infrastructure project. This would require that for each amount of capacity built, low carbon storage equivalent to some % of that capacity (e.g. 10%) must also be deployed. A critical aspect of this suggested solution was that the government or legislative body responsible for administering this amended infrastructure requirement would not constrain technology choice but to leave open to the market. The only criteria that would need to be stipulated would be that it would have to be low carbon , i.e. to exclude for instance diesel gen sets.

B) The group had consensus that storage solutions needed to pay for themselves but that there was considerable potential for Government to fund demonstration of pilot projects through R&D funding to help create market ready storage technologies.

C) The government can also stimulate the market place through its public procurement programme to ensure that storage solutions are introduced to through estates procurement.

D) There was also a suggestion that Local Energy Authorities be developed that could catalogue storage needs and solutions in their area that would be suitable for funding under, for instance, the schemes indicated above. It was also suggested that their remit could be extended to include low exergy regional planning.

E) This concept of developing a plan to determine storage needs was further discussed with the concept of creating a storage boxes which have defined properties that would include location and magnitude. A techno-economic storage matrix could then be used to define cost optimal technical solutions for each storage box on the map.

Some points on the nature of storage

The wide spread assumption that transport and heat electrification would continue apace would create substantial future storage issues. To some extent, transport would be less complex to solve as it is not (as) seasonal. However, heat storage presented significant challenges due to its highly seasonal nature. Creation of seasonal storage solutions through for instance physical storage or through strategic load growth is a major planning task and given the status of storage in the political discourse on energy one that is unlikely to attract the appropriate level of intellectual rigour. It was also discussed that whilst there is a renaissance in demand side management thinking that could for instance modify the scale of the evening gradient rise in electrical demand, inter-seasonal solutions that would be useful if space heating became electrified would require radical intervention

The possibility that storage could be deployed in the form of interconnection was discussed and found to have limited usefulness due to the nature of Northern European weather fronts. These lead to the situation where surplus wind output in Scotland is likely to occur when there is surplus wind output in countries to which it may be connected.

The societal necessity of energy system architecture was discussed and the need in discussions of this nature to emphasise its links with safe, healthy environments, provision of survival levels of energy for people and fuel poverty. In addition there is a considerable lack of trust in the current system that is revealed by the overwhelming view that the system is not constructed or working in the consumer's interest. This societal perspective brings into view issues around system ownership and system scale that to some degree align with a number of seemingly critical technological developments. These include:

The significant stimulus of the transport sector was causing significant reductions in the cost of Lithium Ion batteries and this was creating the possibility of it been seen as a market ready solution in other sectors, (e.g. building integrated power systems)

The reported potential for pumped hydro schemes to be economically achievable with a heads of 150m (Australian research done by Andrew Blakers at the Australian National University demonstrated the commercial viability of 100m off-river systems).

The historical legacy of thermal storage that used to be contained in domestic properties and as such was dispersed throughout the built environment – i.e. this was a recent phenomenon.

That this level of dispersed storage could be reintroduced through the widespread adoption of solar water heating systems (a market ready technology) and would assist to some degree with seasonal heat storage issues across regions.

Workshop 4: Energy Storage and Conversions with Hydrogen & Fuel Cells

Chaired by Dr. Nigel Holmes, Scottish Hydrogen & Fuel Cell Association

Scribed by Ayi Iboh, Heriot-Watt University

This session had in attendance about 12 participants drawn from various RE sectors like funding bodies, academia, project participants and regulators. Most discussions were centred on barriers and drivers, however time did not permit the forum to look into technology and manufacturing readiness based on levels (1-9) overleaf the brochure. Below are extracts of key discussions and recommendations of the group

Barriers and drivers

- Size and scalability of the market depends on the availability of hydrogen, cost and geographical location of project
- Scotland has a clear sense of direction in green hydrogen production
- The market for green hydrogen is growing and is most viable where Renewable Energy is available – already bio-fuels, bio-ethanol is being substituted for petrol and use of biomass in place of coal in power stations

- Carbon intensity of hydrogen from electrolysis of water varies according to grid power carbon intensity.
- It is important to not just consider production and storage of hydrogen, conversion of green hydrogen to products and various uses in chemical or microbial processes is equally important
- Technology readiness is proven at 100MW electrolyser scale since the 1920's
- Investing in hydrogen driven vehicles for public transportation will create highest value and demand for hydrogen.
- Car clubs and similar shared ownership will also speed up deployment and benefits in urban areas
- There are many stranded renewable assets that can be used to produce hydrogen
- There is need to be able to clearly show full impacts of each source of hydrogen – from methane, coal, or renewables

Solutions

- In terms of technological changes and readiness levels of manufacturers, there is hope in manufacture and use of hydrogen cars, vans, buses, ships (e.g. in Orkney), small tractors and in household heating and domestic
- There is need to enable these technologies in rural areas due to prevalence of stranded renewables, not just as at present where location is driven from likely vehicle sales/density
- However, there are lots of work to be done with the installers, installers market reform is necessary to boost hydrogen acceptance as alternative and viable fuel options
- Cultural and Behavioural changes can be enhanced by creation of more awareness to the public on the benefits of replacing hydrogen with other source of fuel. at the moment there is low level of awareness and understanding that hydrogen poses less risk compared to other fuel sources
- Adherence to design and safety requirement, and proper communication of risks associated with hydrogen use – it is erroneously believed that hydrogen cars are dangerous and can go up in flames at a slight collision
- Improvement of the efficiency of domestic combined heat & power (CHP) can be an incentive – Japan, German, South Korea are big markets for domestic micro-CHP but these are using natural gas rather than hydrogen

- Hydrogen can be produced to be cost-competitive with petrol / diesel equivalent, and the cost of fuel cell vehicles will come down steadily. By 2025 some Japanese manufacturers have a target of producing fuel cell car for the same price as the hybrid car.
- Underground pipe transportation of hydrogen is already being achieved at very large scale – for example Texas to Louisiana hydrogen pipeline to Gulf Coast refineries. Also uses very large scale salt caverns for hydrogen storage with equivalent electrical energy content to about 15 Cruachan pumped hydro storage schemes.

Workshop 5: Origin: Control systems for optimising micro-grids and thermal systems

Chaired by Dr Eddie Owens, Heriot-Watt University

Facilitated and scribed by Dr Jim Hart, Napier University

Barriers and Drivers

Markets

Micro-grid – difficult to define, from a technical point anything that is beyond the step down transformer but that just considers electrical load. It can also be considered from a social, philosophical and geographical view point and also consider heat, transport and water. In this context a micro-grid can be anything from an individual building to a much larger network grouped by a common theme. Current key barriers grid structure, size of utility companies, energy policy, data security and technology readiness of control systems. The key drivers are communities wanting micro-grids and the current issues with curtailment and supply security.

Political, regulatory and legal issues

No real fiscal incentives at present, smart meter roll out is really only going to provide one way communication. At present still undecided as to how the 'Control system' will operate – will it be compulsory (big brother) or participatory – what sort of Tariffs might work and what behaviour do we expect people to adopt.

Technology Readiness Level

The control system is likely to either be an informational system or something that involves more complex automation and actuation. The informational system is probably at TRL5-6 and the hardware system is at TRL4-5 (costs of system currently not cost effective). The increasing movement towards the 'internet of things' will help improve the TRL.

Environmental and resource impacts

How do you present the data and engage the users? How public is the data and who can use it? Who can take part? How much time does it take? Computer storage

Costs in context

Current informational system could be in the region of £50 to £100. A more complex actuation system would likely be in the region of £1000/ household.

Technological change

'Internet of things', smart devices, standardisation – engage with policy makers and manufacturers, reduction in cost required, accessibility, open source and security, prize for data but is this legal. Not just about amount of energy you save but about your devices, what you do etc. but who controls that data is it at a national level or at a local level. New business model required to cope with novel microgrids

Cultural and behavioural changes

Two-way process but privacy rights and how to use data just for energy use is key. Behavioural changes need to be longitudinal. Stakeholders need to be involved early. Implementation and what is wanted should be driven by the customers as opposed to being imposed on the customer. Customers need to understand why a change is required and what is in it for them.

Structural and institutional changes

Energy policy needs to encourage micro grid operation. We need bottom up control of energy use rather than top down control, and clear presentation of data.

Workshop 6: Charging Ahead with Battery Technology

Chaired by Chair Dr Nick Bennett, Heriot-Watt University

Facilitated by Keith Baker, Glasgow Caledonian University

Scribed by Anne Miller, Heriot Watt University

Barriers and Drivers

Markets

A key barrier identified was cost. Currently other types of grid-level electrical storage – such as pumped-hydro – are preferred, as a much cheaper option. However electric vehicles (EV) were quickly identified as a growing user of battery energy storage. This is a growing market with big opportunities. This focussed the discussion to allow for the identification of barriers and drivers within this market. It was identified that the current market for such technology is strong although there are some technological and societal barriers that must be addressed if the market is to become sizeable to and for the reduction of cost needed. Otherwise battery storage was felt to be applicable only for small-scale solutions, such as at the home level / small community, although this could be combined with the use of EVs. The recycling of old EV batteries for domestic storage is an additional potential market.

Political, regulatory and legal issues

With the current tariff structure there are few fiscal incentives for people to use electricity when it is most abundant. By introducing a varying, flexible tariff that will fluctuate with electricity production and demand variability an incentive for energy storage could be introduced that would utilise the difference of demand and production on a domestic level. Although incentives must be introduced there must also be a change in tax, when considering the high percentage taxation on fuels. Incentives will not be enough to shift from fossil fuel cars to electric cars. If such a drastic change is to occur there must be behavioural changes on a national scale. Problems exist, for example, if the battery of the car was to be let to each person, i.e. instead of recharging the battery, the dead battery is replaced by one that has been charged at a garage or filling station - would people agree to this? This problem may be overcome on the other hand by the development of new technologies - batteries that allows for faster charging time but with the same high energy capacity.

Technology Readiness Level

For the markets identified current technology batteries still remain in the early stages of technological readiness, the main drawback is the high cost of batteries, the lengthy recharge time, the life span of a battery and the trade-off on the depth of a discharge with the number of cycles. Some installations do exist at grid-level but are small in number with very small capacity. For electric cars the barriers more specifically are the seasonal changes in distance performed by the car (in winter energy from the battery must be used to heat the car, reducing the driving distance substantially) and the current network infrastructure that would simply be unable to cope with a large electricity demand especially in the evenings.

Environmental and resource impacts

The current materials used in battery production such as lithium is cheap and plentiful, however some batteries contain materials that can be harmful to the environment, e.g. Cadmium. The method of producing batteries must also be considered, the high cost of batteries leads to the assumption that the production must be energy intensive. Fire hazard is an issue with some batteries. Recycling and disposal need to be addressed.

Costs in context

The cost of batteries is currently an order of magnitude too high per kW for their use in the mass market. Currently the main cost of an electric car is the price of the battery making the cars out of financial reach for many.

Technological change

A lot is achievable with current technology, but the cost must be reduced to allow for EV to be competitive with petrol cars. It has been predicted in some academic studies that the price will have a factor of 5 reductions in 5 years but this is still not enough. R&D and investment will be required for post-Li technologies. Much of this will probably be driven by EV uptake more than for electrical storage.

Cultural and behavioural changes

Municipal retailing must be encouraged, allowing local tariffs that reflect local needs. Also encouraging local people in decision making that will lead to greater social understand. The current infrastructure must be altered if electric cars to compete with petrol cars. The introduction of renting electric car batteries rather than buying them will allow for cheaper cars and also reduce the time needed for charging by swapping an empty battery for a charged battery. Test projects could be used to benchmark the wide-scale uptake of EV by communities and how these can be used for electrical storage, including links to renewables and wide scale demand monitoring. Orkney was suggested as a potential test case.

Structural and institutional changes

The current infrastructure must be altered if electric cars are to compete with petrol cars. Incentives. Also a change in taxes will be required if the use of petrol and diesel is reduced substantially. It is also not clear from policy makers what the future plan is for battery storage so clear direction needs to come at governmental level.

-ends-

OUR THANKS TO ALL CONTRIBUTORS