Decarbonising Heating and Cooling

Interdisciplinary Workshop

26 March 2019 am

Report on the Workshop Outputs

Aims

On the 26 March 2019 UKRI held a Decarbonising Heating and Cooling workshop to address the following aims:

- Understand where future UKRI multi-disciplinary research can best add value to the landscape
- Develop foundation thinking for potential large multi-disciplinary bids
- The workshop will also give attendees the opportunity to feed into strategic development for the area.

Following this workshop, on 26 March 2019, a further workshop focussing on international themes was held.

Contributors

The contributors to the workshop were from a wide range of disciplines, primarily from across the remit of EPSRC, ESRC and NERC funded research. Many thanks to all those who contributed to the workshop.

Format of the workshop

Following an initial introduction to significant interdisciplinary type funding by Kedar Pandya of EPSRC and a brief introduction by EPSRC the group addressed the following

- Barriers to progress in heating and cooling
- Solutions that a large interdisciplinary effort could provide to the barriers
- A debate on the best way forward

Barriers

The barriers identified by the group to decarbonising heating and cooling are described below. These have been grouped into categories following the workshop. There is definitely overlap between the categories identified but the categories do give a loose structure.

Inertia	• Political lobbying and gas incumbents • Inertia – absence of strategic thinking • Sunk costs • Lack of understanding for need for change • Lack of governance arrangement for people to want to invest • Public/social wariness • Appetite

	• Absence of strategic policy for decarbonisation • Uncertainty about the "best" low carbon solutions • Lack of advocacy from policy makers • Public perception/engagement (Potential barrier) • People possibly don't care where their heat comes from • Absence of strategic approach • Energy solutions seen as distant not local
Whole Systems	• Separate heating and cooling from electricity (to get wider/better solutions) • Very different actors not being able to communicate with each other • Different solutions have very different potential impacts, challenges and opportunities → unclear how to expose them all is there an optimal solution? • And who pays? Is lowest cost best? Or highest value solution? • Decision making under uncertainty • No consensus on which questions need answering in which order • Too many options, unsure about which ones will be the most effective in the medium to long term • What will impact of greater electricity of heat on network be, and how to manage this during all states • How to make whole systems thinking a reality across decarbonisation sectors
Business Models	• Market/financial risk • Lack of space for new business models • Lack of forward thinking in policy making – enabling the viability of new business models
Researchers working together	• Academics working together • Co-ordination of knowledge • International working esp with Brexit • Lack of environmental science research on heat (e.g. ecosystem service impacts) • Working with industry • Need lots of money R & D and deployment • Mindset – focus on technical solutions • Barriers between disciplines
Seasonal Demand	• Lack of storage infrastructure/cost • Heat use is different to fuel use • Climate change, demographics change and social changes affect Heating and cooling demands --creating uncertainty • Extreme events may trigger behaviour not averages (e.g. heat waves/boiler failure)

	• Seasonal variations of heating and cooling demand • Energy storage to cope with seasonal fluctuation in demand. –may require geological storage e.g. H2, compressed air → understand storage capacity and risks → short/med term
Incumbency	• Incumbency of existing actors • Lock – in to existing socio –tech system • Incumbent vested interests in power and gas sectors • Low cost of gas and very good carrier of energy and store • Sunk costs
Infrastructure	• Incumbency of supporting infrastructure • Lack of DH infrastructure • Energy (in) efficiency of housing • Building retrofits/insulation difficult – UK housing stock is idiosyncratic – Global impact? • Off-Grid properties – have different challenges to gas but receive relatively little attention • Why is retrofit less successful than expected? • Decarbonisation requires decent building stock – but 'heat' building and 'infrastructure' conversion remains separate • CCS Infrastructure • H Infrastructure • Power grid upgrades • Infrastructure not there for decarbonisation in short and medium term • Huge cost of new infrastructure:- a) more (x3) elec b)H2 c) District heat • Cost of infrastructure • Retrofitting existing infrastructure –e.g. gas grid → economic cost, social acceptance medium term • Cost of deep retrofits to building structures • Geology/Resources – some geology is good, in the right place – some is not
Consumers	• Home ownership / tenant – who controls my heating? • Consumer use - heat pumps work best if on all the time – not what consumers are used to • Unfamiliarity of technology – consumers • Diverse consumer types/needs/opportunities • Fuel poverty and consumer acceptance of policy increase in costs • Heat is cheap to consumer so decarbonising adds larg(er) % • Heat is bad or boring – lack of buy in • Will people accept it (new solutions) in their homes?

	• People don't always behave logically – performance gap – Communications issue • Scale of potential disruption • What is combined consumer proposition? (alongside EVs, electricity) • People – the decision process, the scale of the need, medium term –education hard – slow progress • How to have a conversation with the public about heat decarb ..not as simple as new, lower cost & better…. • Technology specific – consumer proposition – how to make it attractive … HP cost, H2 boiler disruption • Consumer acceptance of new tech • Need lots of (co-ordinated) changes at all levels of society
Policy, government	• Heat in the sub-surface is not licensed – no one owns it! • Net Zero emissions – need for a greater focus on reducing energy demand behaviour • Wrong governance structures • Lack of Govt Support/planning • Very different actors not being able to communicate with each other • Political cycles and structures don't align with investment cycles • Lack of incentives for consumers to change anything (existing system works well) • Where the responsibility lies (national or local govt) • Need to de risk investments • Lack of whole systems heat regulation and governance
Industry	• Difficult for innovators to capture value if - low utilisation (e.g. storage) – policy changes e.g. H2 – customers won't pay more – Business as Usual is still an option • Difficult for innovations to demonstrate potential on commercial scales • Linking private investment with research know how • Very large ramp rates • Limited incentive for industry to make long term investment to efficiently use thermal energy • Overselling of electrification (particularly for industry)
Information	• Not many comparable international examples • Lack of roadmap –market stalls – decisions don't become clearer • Lack of knowledge of global experience in heat/cooling
Technology	• Higher efficiency H & C equipment needed

	• Technologies not mature enough for short term take up • CCS & BECCS – capacity and risks – demonstrate at scale
Costs	• Need Lower capital cost for new heating and cooling technologies • Cost was, is and always will be a major barrier for heating and cooling decarbonisation • Cost of technical solutions – long payback periods • Gas is too cheap • Higher capex of most low Carbon heat technology • Energy poverty – solutions that only the wealthy can afford • Moving to more mixed heat economy. How do you ensure equity both during transition and steady state

Solutions

The group then looked at solutions to decarbonise heating and cooling. The outputs have been collated into headings which illustrate the multi- and inter-disciplinary nature of the work that needs to be done.

Inertia	• Research to understand and model causes of inertia • Stakeholders? – who are they – what do they want/need/contribute • Understand public perceptions about low carbon heat pathways • Understand market response to change
Whole systems	• Different solutions for different areas (Rural vs Urban) • Assess long term options in detail – "whole systems" • Integration with other systems • Understand interactions between elec, heat, transport, policy to enhance system integration • A UK Energy roadmap – to explore the consequences of decisions • Societal scale LCA for energy – define/present the problem • Whole system approach – diverse barriers – team of disciplines – problem focus • Data – availability, accuracy, transparency • Cost reduction through understanding system level requirements and low carbon pathways and reducing options • Evaluate system trade-offs e.g. EVs/Heat/Other

	• Balancing of multi – vector demands e.g. electricity, gas electric vehicles
Researchers Working Together	• More cross council networking events • Small new advisory grants (£50K) to develop ideas, engage shareholders etc. • Feasibility/scoping projects for approx. £50-60K • More cross council workshops to bring people together (sandpit without a prize/winner) • Common language to prevent confusion/misinterpretation • Common, shared vision - Research opportunities to enable this • Managed UKRI calls of £2-10M • Enabling/Learning from bottom up initiatives
Seasonal demand	• H_2, Geothermal +++, storage and system implications • Supply loads similar to meet demands • Increased effort on energy efficiency including retrofit • Phase change materials • Scales of storage • Policy & regulatory incentives • Integration of :- Technology, Policy & consumers, Business & consumers
Low carbon deployment for the UK	• Already a lot of players but need to be better integrated • Needs demonstrators to get mass take up. Pilots? V multi/inter discipline. • Comms issue across community – do businesses know what is being done? • Short term need + benefit in 5-10yrs • Full implementation could be very expensive • Required to be short term to maximise benefit • Joining up optimum whole system solutions with consumer impacts + behaviours → exploring interactions → rewarding flexibility for systems service → and political acceptability • Multi vector (E.g. gas and heat pump) EP/ES/NE/IUK → Hybrid systems – development – pricing – market issues → EP/Es/IUK future pricing models for low-carbon heat(ESRC, EPSRC) • Identify opportunities for economies of scale • Thermal energy storage (EP/IUK/ES,NERC) • How would the cost of low Carbon deployment be minimised? Where are the opportunities in the system? • Inter/Multi disciplinary solutions for efficiency

	• Design of low C heating and cooling regulation and markets (ES,IUK) • Survey hard to treat homes and Off gas homes – techs,- infrastructure limits
Energy Demand Uncertainty	• Understand system uncertainty on heating / cooling options • Demand projections to 2100 (climate demographics, economy, retrofit behaviour, NERC, ESRC, EPSRC) • Smart clothes (ES/AH/EP/IUK) • Looking at biggest sources of uncertainty and actively seeking to reduce them • Planning for heating and cooling needs in the future • Mass migration as a solution to extreme heat and cold
Making it Happen	• Scales – how do you scale up demonstrator • Pilots and demonstrations e.g. geothermal, hydrogen, housing retrofit • Carry out demonstrations and innovation projects at the right levels to learn from it • Test technology & monitor and understand end user experience • "Living lab" experimentation for consumer and business heat solutions • Review range of consumer experiences with heat techs internationally • "what works in heat policy?" – regulation, upfront subsidy, training and certification, taxation • Development of tool to meaningfully reduce bills and evaluate interventions • Greater deployment of low carbon heat techs to build market & skills/innovation/cost reduction
Encouraging Investment	• Better investment climate • Bring the housing industry in better • Financial mechanisms that reward carbon reductions in heat • Involve the investment community in the discussion • Research on distributional impacts of diff funding approaches
Democratise the Solution	• Improvements in air quality • Fuel poverty • Health & Well being approach, make clear the benefits • Financial products for consumers • Consumer and other benefits of lower c tech • Ensure Consumer protection to supply

	• Greater understanding of consumer impacts of heat decarb options to inform public debate! • Understand user acceptability • Carbon accounting→ approaches to waste heat – "war on waste" public movement • Perception issue/ not grabbing attention • Some solutions could be very expensive, but benefit could still be realised for relatively low cost
Infrastructure	• Develop a strategy for the gas grid • To address Infrastructure barriers – planning and building according to higher level system level analysis, taking into account existing and new technologies • Integration of heating/cooling with transport infrastructure & EVs. • Optimise infrastructure & its management to minimise carbon →transport →heating/cooling • Different approaches to retrofit → diff houses →diff tenures • Work with developers/construction industry to figure how to ensure houses/building are well built • Radical overhaul of built environment for climate change
Technology	• Assess cost reduction requirement for main tech options – H, HP, DH • Cost reductions through hybridisation of technologies, not only existing, but also new and future technologies • What are the game changers? - Splitting into 2 areas: 1) NEW Thermal Storage TECh (PCM/Thermochem) - Low cost - Compact - Flexible T - High power 2) NEW Heat pump Tech:- (Gas and Elec) - Low cost - High Cop - User friendly - Installer friendly • Exploitation of energy dense vectors such as ammonia & hydrogen • Innovation to bring about cost reduction and new forms of interday & seasonal energy storage

	• Technology – better integration of technologies – which ones best?
Geography	• Cluster support for Hydrogen • City/area level governance/ownership • Decarbonisation in geographical clusters with similar advantages
Local structures	• Bring together LEPs and other local business stimulators • Clarity for local authorities as to how they will make returns on their investment • Enable new entrants including local authorities
Interdisciplinary Solutions	• UK Energy tech centre: 10 yrs funding: - Engineering - Biology - Geoscience - Economics - Business - Consumer science A partner to UKERC • Raise awareness of key role of geoscience & the subsurface plays in decarbonisation - Public, policy, industry, academic - Interdisciplinary: NERC, EPSRC, ESRC, BBSRC - Acceptability and efficiency of transport of thermal energy + 'over the fence' use • Exploitation of all low grade heat sources – solar thermal, geothermal, waste heat • AI data management and utilisation • Energy and environment • View CO2 as a resource – carbon recycling
Political/Regulation	• Increased political (cross party) understanding of heat decarb • Doing nothing is the largest overall cost, but investment is a significant cost which looks politically unfavourable • What's worked elsewhere and with other systems • Understand policy and regulatory changes • Impose carbon taxes etc • Policy transfer and learning community • Greater sense of political urgency • Governance and regulatory options • Find out what governance structures work for lower C heat • Regulator – lead solutions • Govt being bolder and braver with innovation

Manufacturing	• Cost reduction via increasing scales e.g. international markets • Cost reduction via developing low cost manufacturing technologies for heating/cooling • Cost reduction through reducing "length" of supply chain • Sustainable materials, Circular economy • Build up in manufacturing base in thermal technologies

Current Research

This was a session in the EPSRC focussed workshop on Current Research in Decarbonising Heating and Cooling that occurred the day before this workshop. It was thought to be useful to include the output of the Currrent Research session in this report. The categories are based on the barriers identified in the EPSRC focussed workshop.

Infrastructure	• Energy Networks Hub • UKCRIC Buried Infrastructure • H21 Project - Global, strategic (large scale) Hydrogen appliances (Small Scale appliances) HY - NET (National) - Gap in medium scale • Japan is pushing forward in the H2 faster than others. Can learn from them - can't compete with home energy systems, transport, fuel cells (China too) • Netherlands alternate gas infrastructure ECN. Not going to keep pursuing @ same rate, therefore UK can pick up and continue • BEIS EINAS • EPSRC - Zero Hydrogen cycle emmission CHP (TR) • EPSRC- ABC • Industry - Segragated packed tool Themal Storage (TR) • CESI - Energy system integration modelling (TR)
Replacement of Gas Grid	• BEIS HY4HEAT • Domestic H2 appliances - recent BEIS appraisal • EPSRC - Seasonal storage of solar thermal energy (TR) • CESI • Integration of Hydrogen, electrical networks (TR) • LOT-NET 5th gen D.H. • Thermo chemical netwrosk (H - DISNET-EU)(TR) • Industrial Decarbonisation ISCF • BEIS Hy4 Heat • Ofgem H2 in networks

Lack of data on real performance at scale	• Non-open data • CIBSE/BRE : Building performance gap policy and verification • Learning from International experience of low carbon heat transitions - UKERC 3 - unconvinced that more needs to be done • IEA Annex 52 Heat Pump - UK participants but still quality data shortage • Leeds Citygate • H2 Grid …KEELE UNI --> Northern gas networks
Uncertainty	
Costs	• BEIS - Thermal Innovation Challenge: Retrofitting domestic energy retrofit demonstrators for groups of homes ---> Newcastle did the same 15 years ago, EPS needs to extract learning from this • Cost studies: ESC, Natinal Infrastructure Commission, CCC (Committee of climate change) • UKERC • EPSRC Next Generation of Thermal storage technologies • EPSRC - Supergen challenge project - domestic storage heaters/coolers
Policy & Regulation	• BEIS & OFGEM plan (+ScotGOV) to regulate heat (networks) • Politics of heat transition: Role of Incumbents - UKERC 3 • Regulation & Governance of continuity and change in Energy networks including for heat! UKERC 4 • UKERC (T&A) IDLES •ESC (Energy Systems Catapult)
Consumers	• BEIS pilot projects to assess Energy Efficiency approaches across different regions & tenures • Demonstrators on incentivising efficent behaviours- private orgs - look at Network Awards nominations for egs • Energy systems catapult : - living labs -heat as a service -consumer attitides to heat choices • BEIS smart meter & technology integration: --smart controls -- load/demand shifting • Public attitudes to heat pathways - UKERC 4
Whole Systems	• IUK smart local energy networks • ETI/Catapult whole systems modelling (esme) CESI • Whole systems heat pathways for the UK - UKERC4 • Multi Vector local energy systems modelling - UKERC 3+4 • Flexibility of local energy systems for heat - UKERC 3+4 • Thermal energy challenge, thema pump project (ZY) • IDLES • CREDS - Energy systems catapult

Efficiency	• BEIS - Thermal Efficiency Innovation Fund • - Insulation • - Air source heat recovery • MHCLG - Building regs review (Part L) will look at energy eff/performance gap (summer 2019) • Green building council - 'zero carbon buildings' (summer 2019) • Integral development - open for collaboration but by existence, indicates a need • Local and smart energy systems: Energy Rev • OFGEM low carbon network fund: mainly electricity but minor amount on heat • BEIS/Warwick - Low cost, medium efficiency gas heat pump • CREDS • EPSRC- ABC • UKCRIC - PLEXUS pump priming heat from buried infrastructure • +LEEDS Fellowship (INSTEP) • Cmbridge UNI - City Scale Geothermal • NERI - Geoenergy observatories • DEPP Geothermal Durham, Newcastle etc.
Non Domestic	• BEIS low carbon heat for glass industry • 3D Stock model(UCL) - Industry low grade heat recovery and use (TR) • Data centre cooling (LEEDS) • VLSTER - H.T. pump • Warwick/TNO Industrial sorption heat transformed (PILOT Study)
Skills	• EU - Real skills refrigerants • Infrastructure: ABC Swansea • Gas Grid - Supergen Bioenergy Hub • LOT-NET: Low temperature heat distribution • Flexibility of local energy systems for heat - UKERC 3+4 • Gap of knowledge - NIC?
Technologies not proven at scale	• Thermal driven heat pumps -->not enough • BEIS - Energy Entrepreneur Fund • Cornwall - United downs project (EU & Cloud funding) Pilot with a view to become commercial - Geothermal • BEIS + Scottish Government looking at what can be learn't from international appraoches to regulation, consumer protection • Search for H2020 grants • Smart Cities (EU Commission) • Zero +(Zero energy settlements) - has heat in it. Settlements in York and other parts of Europe (5-6 million) • Netherlands - Greenhouses very far ahead • LSBU - Bunhill/Islington - Luster (T & L) • BEIS/CT Prisma • BEIS - Droplet programme

Innovation Process	• Bristol already researching international lessons for heat networks • Consumer ESC - heat as a service • UK-GEOS sites/demonstrators, will run for 15-20 yrs (NERC) - end target EPSRC targetting: Thermal Energy Research Accelerator - new technologies, Smart local energy systems - IUK Demonstrators - Hybrid trial, Wales + Cadent • UKERC • BEIS • EINAS

Discussion

The group had a wide ranging discussion concerning the scope and nature of a Strategic Priorities Fund (SPF) type bid. Brief notes of this discussion are below.

- **Fraunhofer Model**

The Fraunhofer Model was proposed as a good fit to the demands of decarbonizing heating and cooling – having a critical mass of 50 researchers from a wide variety of disciplines and a lifetime of more than 10 years would give scale and give potential to develop momentum. It was felt that the above was not compatible though with an SPF funded project. The Energy System Catapult was mentioned – it was commented that the Catapult focusses on modelling.

- **Living labs/demonstrators**

The value of living labs and demonstrators was discussed. The strong consumer dimension was mentioned as was informing regulation, political science and system trade-offs.
Interacting with demonstrators was commented as important. The need for more living labs/ demonstrators was questioned as we have over 120 demonstrators. (Work has been done by UKERC to map energy demonstrators - http://www.ukerc.ac.uk/publications/review-of-uk-energy-system-demonstrators.html)

- **Interdisciplinary**

The interdisciplinary nature of the challenge of decarbonizing heating and cooling was commented. A bid led by a partnership of social and natural science but incorporating engineering and physical science was a view put forward.

- **Scale and Nature of what is funded**

Comments included - The scale of what is funded should be big enough to get industry involved, private funding should match government funding. What is delivered should be 'practical' and 'real' in nature. It will be hugely challenging to bring all the partners together. The nature of what is possibly funded - is it physically one centre (which can appear attractive to the outside world), a virtual centre, whether there are central labs, should there be a lot of smaller projects - was discussed and a compromise between the options was suggested by some to be best. Policy, social interactions, regulation, natural sciences should all be included in the remit of a possible funded project was promoted. There was some discussion around the Australian CRC model (which is a national centre 50% from research funders and 50% from industry).
Other comments included:

Heating and cooling linked to the built environment. Building Regs mentioned.
Geographical differences, fuel poverty and the consumer interactions should be addressed
Biofuels are important to link in BBSRC.
Map the interactions in a systematic form.

Interaction with the regulator and considering the innovation funding dimension is important. Regulator will be able to encourage/require companies to do innovation.

- **Heating and Cooling together**

There was a discussion around how integrated work should be between heating and cooling. It was proposed that they should be treated together because there is much to gain from doing so. Examples were given of poor processes in industry and retail where, because heating and cooling were considered separately, opportunities were lost and heat/energy is wasted. It was felt to be important to change mind sets for decision makers to realise the benefits of considering heating and cooling together.

Conclusion

The area of Heating and Cooling is currently generating a lot of media and public interest. This workshop certainlty confirmed the multidisciplinary and interdisciplinary nature of the challenges that face decarbonising heating and cooling. Hopefully the workshop and the outputs formed some foundation thinking for a Strategic Priorities Fund type bid.

Thanks again to all those who contributed to the workshop and we look forward to working with you in the future.

Gerard Davies

17/05/2019