Written evidence submitted by Durham Energy Institute[1] (DHH0053)

Durham Energy Institute[2] welcome this inquiry and the recent much-needed focus on decarbonising heat. With only minimal progress made to date, heat decarbonisation is now the most pressing area of energy innovation required to achieve our net zero targets. So far, the emphasis has been on efficiency improvements and electrification of heat. In its current form, this cannot be scaled up to deliver on net-zero.

The transition to lower carbon heating solutions is a key strategic area at Durham Energy Institute[3] and our research addresses these challenges across power generation, industrial processes and domestic energy efficiency. Research into new low carbon heating resources and technologies, and their deployment in different societies stretches across multiple disciplines and research centres at Durham University.

Durham University is meeting the heat decarbonisation challenge by developing a range of technologies for **capturing waste heat; hydrogen for housing, industry and transport; heat storage; direct heat capture through geothermal and minewater geothermal; as well as smart energy infrastructure technologies.**

1. What has been the impact of past and current policies for low carbon heat, and what lessons can be learnt, including examples from devolved administrations and international comparators?

i. Decarbonisation of heat means removing the use of natural gas. Much of the focus in domestic, transport and industrial sectors has been on decarbonisation of heat by shifting from gas to electrification. Switching from fuel (gas, oil or LPG) to power for meeting heating demand has huge potential to reduce both cost and CO2 emissions. However this also leads to increased power load in these houses and nationally. The huge scale and dramatic seasonal fluctuations of energy demand for heat and the problem of intermittent supply of wind and solar sources means the electricity infrastructure alone is inadequate without colossal long-term energy storage capacity. **Therefore other direct-heat and waste heat solutions, as well as gas alternatives such as hydrogen also need to developed and supported by early changes to policy and regulatory structures.**

ii. **<u>Learning lessons from others on heat networks and geothermal:</u>**
Heat networks are not necessarily decarbonised but Low carbon and renewable energy sources for heat networks can significantly lower carbon emissions from heat. Heat networks enable the use of local renewable energy resources (such as geothermal energy) at a larger scale, and the recovery of waste heat from industries and power stations and should be more widely developed in the UK.

iii. **European Union**
Heat networks are a well-established technology in other parts of Europe. EU has recognised the key role district heating plays in transition to a sustainable energy future since 2016 when it published 'An EU Strategy on Heating and Cooling'. District heating can play a key role, based on

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[1] Written by Evelyn Tehrani with inputs from Durham Energy Institute Executive Team and Fellows.
[2] Durham Energy Institute (DEI) is the hub of energy research at Durham. It unlocks research synergies between different disciplines and sectors to tackle the energy demands of the future. Producing world class research for understanding energy decarbonisation issues across science and society and delivering integrated and equitable solutions for the climate emergency and our net-zero ambitions. For more information about Durham Energy Institute visit: www.durham.ac.uk/dei/research
[3] www.durham.ac.uk/dei/research/heat/

waste heat recovery, cogeneration and integration of renewable energy, in fostering energy security and decarbonising buildings. "*District heating can integrate renewable electricity (through heat pumps), geothermal and solar thermal energy, waste heat and municipal waste. It can offer flexibility to the energy system by cheaply storing thermal energy, for instance in hot water tanks or underground.*"[4]

iv. **Heerlen, the Netherlands**
Heerlen has been operating a district mine energy systems for over a decade this receives international renown for its innovative 'demand-supply' system[5]. The renewable energy source has served as a heat source (for heating) and heat sink (for cooling) since 2008. The water, collected from five wells, is transported via an underground exchange station and pipe network and is currently supplied to six locations in Heerlen. Durham Energy Institute are working with engineers involved in the Heerlen a city-wide scheme linked to abandoned flooded mines to gather lessons from their hugely successful initiative.

v. **Scotland's support for Heat networks**
We believe the rest of the UK should follow the example of Scotland on heat networks. In March 2020 became the first country in the UK to legislate on the development of heat networks, creating regulations on the supply of thermal energy by a heat network and the construction and operation of the heat network[6]. They also have an excellent information portal which will help to encourage further roll-out. Currently there are over 830 heat networks operating in Scotland and the government has set a target of 1.5 TWh of heat to be delivered by 2020[7]. Scotland operates the District Heating Loan Fund to address the financial and policy barriers in the UK to district heating projects to circumvent difficulties obtaining commercial borrowing. District heating has operated in Copenhagen a city of a million people for many years.

vi. **Geothermal minewater case studies internationally are being identified by a report** commissioned by the North East LEP into minewater geothermal schemes and the benefits, barriers and enablers of this technology. The report will be available in the new year.

2. What key policies, priorities and timelines should be included in the Government's forthcoming 'Buildings and Heat Strategy' to ensure that the UK is on track to deliver Net Zero? What are the most urgent decisions and actions that need to be taken over the course of this Parliament (by 2024)?

i. **Ambitious decarbonisation targets with a long-term national strategy and roadmap** to outline how these targets and steps will be achieved, encourage investment and enable the skills development required to meet the ambitions.

ii. **Widen the policy emphasis from electrification to direct heat, waste heat and storage options.** This should include development of Development of Energy Hub technologies, for better managing energy storage, renewable energy and flexible demand.

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[4] An EU Strategy on Heating and Cooling (February 2016) Pg 8
https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v14.pdf
[5] Heerlen mine water geothermal heating system www.mijnwater.com/?lang=en
[6] SP Bill 64 Heat Networks (Scotland) Bill [as introduced] Session 5 (2020)
Waste Heat Mapping: A UK Study (2020) ,M. D.A Albert , K. O. Bennett , C. A. Adams and J. G. Gluyas
[7] District heating Scotland, funding, http://districtheatingscotland.com/funding/, [accessed 19th June 2020]

iii. **Invest in large-scale low carbon heating demonstration projects** to find the best regional and local options for decarbonising heat, which means looking at heat networks from geothermal and waste heat; low carbon hydrogen gas, storage solutions for heat as well as electrification.

iv. **Policy needs to level-up the playing field for viable new technologies**. The UK's commitment to net zero requires the replacement of existing technologies for low or zero carbon technologies. This will require support for the new technologies, via economic incentives and changes to regulation in the energy market and the planning system to assist with wider system integration decisions[8]. At present there is not a level playing field between low-carbon heat options and artificially cheap gas fired heating (or between hydrogen and electric vehicles). The wonderful example of Central Government continued support for the UK offshore wind sector and the sector deal show how effective this can be for growing the sector and reducing costs significantly.

v. **Further expansion and regulation of heat networks across the UK.** Heat networks provide around 2% of UK Heat demand but a much higher share could be achieved, enabling the local integration of renewable electricity, geothermal, solar thermal energy, waste heat and for large scale energy storage systems to be used offering flexibility to the energy system. Heat is a great cascade energy form – you can use and re-use it many times in a system for different ends. For instance capturing waste heat from industry to heat domestic housing and then using the lower grade heat emerging for agriculture and aquaculture. Systems that allow the vertical integration of heat use are therefore needed which enable the use of heat from very hot to lukewarm. BEIS has shown political will and support to implement the opportunity of heat networks but progress has been slower than expected. We support BEIS's recent consultation and push towards bringing in a regulatory framework for heat networks to address investor confidence, protecting consumer rights and move to low-carbon sources[9].

vi. **Policy must remain technology flexible.** The fast pace of innovation and development in low carbon energy technologies, particularly using combinations of technology, means that new technologies and solutions will emerge and these should be accommodated. For instance, major technology shifts can be expected in heat storage, geothermal heat and smart energy hub technologies.
    - **Expanding the development and roll-out of Smart Energy Technology at the household level.** Heat can be most effectively decarbonised at the household level through a combination of low-carbon technologies. Effective smart management of these combined technologies is essential. This is also the case for shifting domestic heating from carbon fuels to electricity which will result in increased power demand at the household level, requiring even more optimal smart management of household appliances and batteries[10].
    - Support the completion of the **smart meter rollout** – a critical national infrastructure upgrade and essential for a digitised energy system**.** Our Customer Led Network Revolution[11] project showed that this must be combined with adequate information and support for households to maximise the benefits flexing their energy usage.

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[8] Durham Energy Institute published written evidence (CGE0065) Clean Growth: Technologies for meeting the UK's emissions reduction targets, House of Commons Science and Technology Committee inquiry http://data.parliament.uk/WrittenEvidence/CommitteeEvidence.svc/EvidenceDocument/Science%20and%20Technology/Technologies%20for%20meeting%20Clean%20Growth%20emissions%20reduction%20targets/written/93458.html

[9] BEIS (Feb 2020) Heat networks: building a market framework - consultation

[10] www.durham.ac.uk/dei/projects/solidwallii/ and https://swiiproject.co.uk/

[11] http://www.networkrevolution.co.uk/

- In conjunction with the smart meter roll-out we recommend the Government considers **introducing requirements for sensors, such as humidity and temperature sensors**, in new buildings and/or existing housing stock. Our research with Durham County Council[12] shows the introduction of these sensors with smart meters is a much more effective and accurate way of identifying real thermal performance and energy losses in homes than the current SAP evaluation and would help support future energy management systems – enabling improved identification of necessary energy efficiency improvements.

vii. **Policies for decarbonising heat must be in conjunction with further efforts to improve energy efficiency in housing and buildings.**

- **Improving efficiencies of buildings** through smart insulation, metering and demand management, retrofitting and zero carbon new builds is an on-going effort which needs speeding up. House and building insulation is poor by the standard of many northern nations. Much of the inevitable growth in energy demand for a growing (clean) economy could be offset by better use of energy and this means managing heat as well as managing other vectors such as electricity, gas, oil and coal.
- **A National Energy Efficiency Programme** is needed, . A particular focus needs to be on investment and support for fuel poor households and ensuring vulnerable customers are protected. We welcome the Government recent announcement of a £3 Billion energy efficiency package. The scheme is an important start but more action is needed if we are to retrofit our existing housing stock and introduce the low-carbon solutions outlined such as heat pumps and smart meters.
- **Ambitious national building standards** need to be introduced. Given the government's ambitious housebuilding targets this is the time to tighten standards in order to impact a significant proportion of the housing stock cheaply. This will support Local Authorities and Regions to aim higher who fear that introducing localised targets will make their areas less attractive for building investment. It will also avoid having to retrofit the housing stock which would be far more expensive.

DEI supports the following priorities outlined by our partners EnergyUK 'Steps to Net-zero'[13] :

- From 2025 new builds should be required to have a low carbon heating system or a connection to a heat network.
- Restrict the sale and new tenancy of properties rated below EPC band C from 2030, while simultaneously creating a package of incentives and products (e.g. stamp duty and green mortgages) to encourage and assist compliance.

viii. **Supporting the development of geothermal systems from decarbonised minewater:**

- Policy needs to distinguish the geothermal resource from abandoned mines flooded with hot water from deep geological geothermal – the risks and costs associated with drilling and implementing the former are much less and benefits will accrue more to deprived communities.
- It should be a requirement in the planning law that the feasibility of minewater geothermal is considered in all areas where this is available.

ix. Energy Justice aims must frame heat decarbonisation and energy efficiency policies to ensure they are aligned with measures to alleviate energy poverty and vulnerability. Local Authority strategies and structures should be directed at meeting combined social and environmental

[12] One example is the Solid Wall Insulation project (SWii)
[13] Energy UK (2020) 14 Steps the Government can take in the Energy White Paper and Budget to support a net-zero economy by 2050.

objectives. Durham Energy Institute worked with Haringey Borough Council to develop a new approach to this which has resulted in their new Affordable Energy Strategy[14].

- **Comprehensive communication strategy, including peer-to-peer support and network of advice services.** Engagement and education play a vital role in improving energy efficiency, and speeding up the acceptance of any new technologies (see below).

i. **Explore options for raising carbon tax and implementing waste-heat taxes** to encourage and fund adoption of low-carbon heat options , whilst mitigating regressive impacts on poorer households (see below)

3. Which technologies are the most viable to deliver the decarbonisation of heating, and what would be the most appropriate mix of technologies across the UK?

i. A number of effective energy technologies already exist that can help us to meet our climate change targets in combination – policy needs to focus on distribution, scale and integration into existing systems of these technologies. **In many cases a combination of technologies is the most viable, flexible, low-cost and socially-inclusive option for decarbonising heat in homes.** The optimal combination of technologies is determined by local and household factors such as age and construction of housing, geographical location, renewable resources available etc. Further research is required within the UK context on the carbon reduction of specific technology combinations such as Air Source Heat Pumps combined with Solar Panels and battery or smart control.

ii. Dual Hydrogen Gas and Electrification

This solution is likely to be the overwhelmingly dominant solution for decarbonisation in the future, responsible for 95-99% of heat delivered. Our future is increasingly likely to take the form of a significantly scaled-up electricity network underpinned by a hydrogen gas based distribution and energy storage network[15]. This combination is fundamental to being able to deliver the necessary flexibility and resilience that our energy system needs. The analysis shows that an "electricity only" or a "hydrogen only" solution is more expensive and technically complex – we must without reservation embrace both. The dual approach, enabling the use in UK homes of either electrically driven heat pumps or ones using hydrogen gas, will ensure peak demand for winter heating demand is more distributed across the electricity and gas networks ensuring a more resilient system and lower costs. Durham Energy Institute leads two new EPSRC Network+ on Decarbonisation of Heating and Cooling as well as Hydrogen for Transport: Network-H2. As part of the work to advance the multi-disciplinary challenges and opportunities in these areas, over the next four years, we will launch major technological road-mapping exercises, support research activities and hold dozens of events to help seed the energy transition.

iii. Geothermal Energy – deep and minewater

Direct use of geothermal energy is significantly under-utilised in the UK and improvement of uptake needs to be a focus of policy moving forwards.

- Geothermal energy is near carbon neutral and environmental impacts are benign at most.
- The UK's geothermal resources are significant and could supply heat to the UK for well over a century.

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[14] Affordable Energy Strategy 2020-2025: London Borough of Haringey https://www.haringey.gov.uk/sites/haringeygovuk/files/affordable_energy_strategy_2020-2025.pdf

[15] Smallbone, A (6 October 2020) Making net zero by embracing solutions for heat transport and electricity https://www.durham.ac.uk/research/news/item/?itemno=42565 (6 October 2020 on https://www.openaccessgovernment.org/making-net-zero-easier-by-embracing-solutions-for-heat-transport-and-electricity/95591/])

- In 2004 the Department of Trade and Industry estimated that up to a million jobs could be created in the UK to develop and operate geothermal energy systems. Certainly hundreds of thousands is a possibility.
- Using Geothermal heat as an alternative to burning gas will have a dramatic effect on lowering greenhouse gas emissions. We could cut the UK's GHG emissions by up to 30%.
- Geothermal energy is also intrinsically low-carbon, indigenous and a sustainable heat source which will mean less reliance on external imports and less vulnerability to fluctuating global prices and political shifts. Thereby ensuring future energy security for the UK.
- All of the UK's major population centres lie above or close to major geothermal resources – sedimentary basins and flooded mines.

Decarbonised heat from minewater[16]:

- With the right policy framework minewater geothermal could be **upscaled over the next 10 years.**
- **This source is technically less risky because it is shallower and due to the excellent mapping the Coal Authority already possess.** The UK has 23,000 flooded, abandoned coal mines and 25% of the built environment lies above abandoned coal mines.
- **Minewater Goethermal also be used for storage integrated into the grid** for other intermittent energy sources and cooling. It does not fluctuate with weather conditions and is useful baseload capacity.
- Former coal mining areas need regeneration and this investment would particularly benefit more deprived communities across the UK.
- We work with local and regional authorities including the Coal Authority to develop heat networks using the warm water from flooded abandoned mines as the geothermal resource[17]. Heat exchangers are used to extract the heat from the mine waters and heat fresh water which is then circulated in district heating systems. The heat can be upgraded locally using heat pumps which use about one quarter of the electricity of comparable grade direct electrical heating systems.
- Minewater geothermal resource could be tapped into in Kent, S Wales, West Midlands, Nottinghamshire , Derbyshire, Lancashire , South Yorkshire, Durham, Northumberland, Cumbria and Central Scotland. In the northeast a 3.6MW scheme is running at Lanchester Wines and a 4MW development is underway at Seaham Garden Village. There is also a demonstration project in construction at Bridgend. Our partners at the Coal Authority have a pipeline of 30 projects many of which are in the North East[18].

Development of deep geothermal heating systems has already been proven by the Southampton District Energy Scheme, operating since 1986. This type of scheme could and would be replicated on the South Coast, Bristol, Midlands, Liverpool and Manchester.

iv. **Hybrid systems: Solar storage and heat**

Only 1% of renewable heat from solar is currently exploited in the UK. The paramount reason for that is the seasonal mismatch between heating demand and solar thermal energy availability, the lack of extensive deployment of thermal energy storage in the UK, as well as relatively weak solar radiation in the UK. Durham University has developed a hybrid seasonal solar storage and heat pump system which stores thermal energy and electric energy in summer simultaneously as chemical potential [19], coupled with a solar thermal-photovoltaic (T-

[16] Durham Energy Institute briefing on Minewater Geothermal https://www.durham.ac.uk/resources/dei/briefs/5609_Geothermal_lft_FINAL.pdf
[17] DEI Geothermal Expertise https://www.durham.ac.uk/dei/research/geothermal/
[18] https://www2.groundstability.com/geothermal-energy-from-abandoned-coal-mines/

PV) collector and the energy is released at relatively higher temperature for space heating in winter. This is designed to meet UK-specific solar radiation levels with increasing the solar fraction for heating. The core technology employed in the system is thermochemical adsorption which has been developed for many years, the innovative integration of compressor in this project enhances the energy conversion efficiency and extends the applicable heat source temperature range. Over the next 3 years of the project this technology will be demonstrated in the lab with a storage capacity of 20 kWh, which **can be easily scaled up** by adding more modular reactors to the system. This promising technology **is highly reliable** due to its simple thermodynamic cycle and maturation of each component. **After validation and demonstration, the technology is highly possibly commercialised in the following 3 years.**

v. Durham University researchers are also testing and undertaking techno-economic analysis of other hybrid systems for domestic contexts and have been shown to be effective at reducing energy such as the Innovative Combined Cooling, Heating, and Power (CCHP) system with hybrid energy storage unit[20]; hybrid renewable energy system (HRES) to supply power and heat for a household[21] and Bio-fuel Micro-Tri-Generation with Energy Storage .

vi. Using waste heat for heating homes

Nationally, the total amount of waste heat produced by large industries is 35 per cent more than the heat needed to warm our homes. Research by Durham Energy Institute[22] has mapped out how much waste heat there is, how it is distributed across the UK and compared to population density distributions. The report has found that there is significant overlap between the spatial distribution of waste heat in the UK and the population demand for domestic heating[23]. Equally beneficially the seasonal variation in waste heat production is correlated with the seasonal variation in demand for heat. The study shows there is a large, well-distributed resource of waste heat from non-domestic sources in the UK that has the potential to be utilised in heat recovery schemes, such as in district heating. Findings also reveal the lack of nation or region wide coordination on waste heat reuse. As of 2019, only 450,000 homes, out of about 25 million, are heated from district heating networks. However, only 3% of the proposals reported in the Heat Network Delivery Unit's 2019 pipeline utilised a 'primary energy source' (heat source) from industrial waste heat. While high grade heat can be used directly in heat networks without modifications to domestic buildings lower grade waste heat needs to be combined with a heat pump and/or gas/biomass boiler. Low-grade heat capture is currently not commercially viable compared to burning cheap gas so government intervention will be required to encourage uptake and reduce the financial disparities.

vii. **Demand Side Management, Response and Engagement through Energy hub technologies.**

Energy Hubs have the great potential of integrating all energy vectors and making best use of them by using cloud infrastructure, demand forecasting and optimisation etc. These

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[19] EPSRC funded 'Advanced hybrid thermochemical-compression seasonal solar energy storage and heat pump system (Solar S&HP)' led by Dr Zhiwei Ma, Durham University Engineering, https://gow.epsrc.ukri.org/NGBOViewGrant.aspx?GrantRef=EP/T023090/1

[20] Ji, Jie, Ding, Zujun, Xia, Xin, Wang, Yeqin, Huang, Hui, Zhang, Chu, Peng, Tian, Wang, Xiaolu, Nazir, Muhammad Shahzad, Zhang, Yue, Liu, Baolian, Jia, Xiaoying, Li, Ruisheng & **Wang, Yaodong** (2020). System Design and Optimisation Study on a Novel CCHP System Integrated with a Hybrid Energy Storage System and an ORC. *Complexity* **2020**: 1278751.

Miao, Chunqiong, Teng, Kaixiang, **Wang, Yaodong** & Jiang, Long (2020). Technoeconomic Analysis on a Hybrid Power System for the UK Household Using Renewable Energy: A Case Study. *Energies* **13**(12): 3231.

[21] Miao, Chunqiong, Teng, Kaixiang, **Wang, Yaodong** & Jiang, Long (2020). Technoeconomic Analysis on a Hybrid Power System for the UK Household Using Renewable Energy: A Case Study. *Energies* **13**(12): 3231.

[22] Waste Heat Mapping: A UK Study (2020) ,M. D.A Albert , K. O. Bennett , C. A. Adams and J. G. Gluyas

[23] http://www.mygridgb.co.uk/wp-content/uploads/2020/08/Waste-Heat-Mapping.pdf

technologies can reduce energy demand and ensure the lowest levels of carbon emissions. Examples include:

- **Smart System– Virtual power plant (VPP) smart technology** capable of aggregating the capacities of diverse distributed energy resources (DERs, e.g., solar panels) and flexible demands as a single operating profile[24][25]. Our research outcomes[26] show that VPP brings benefits in terms of reducing power loss, achieving up to 18.8% energy bill savings for energy consumers; Enhanced power system stability that enables more renewable energy sources to be integrated in power networks.
- **Household peer-to-peer energy trading –** water tanks have high energy inertia so you can use gas or electricity flexibly, such as delaying heat by half hour when the electricity price shifts so you can trade energy with neighbours, and use energy flexibly to reduce costs. Our smart energy research group is developing the smart technologies and novel blockchain-based peer-to-peer trading frameworks to enable households to trade energy and carbon allowance[27]

4. What are the barriers to scaling up low carbon heating technologies? What is needed to overcome these barriers?

i. **Big costs but big returns with right enabling structures:**

These technologies currently have a higher upfront cost but will provide significant and long-term benefits to UK carbon emissions and the associated long-term social and economic benefits.

If we are to meet our decarbonisation targets these technologies need to be accelerated and adopted now. **Experience shows us that the costs of new technologies can dramatically fall when the right enabling structures are put in place and they begin to be used more widely.** This requires:

- large-scale demonstrators
- levelling-up the technology field by ensuring carbon-heavy fuels and technologies are not subsidised to be artificially cheap in comparison.
- An appropriate balance of regulation, taxes and subsidies will need careful thought.
- Review of legislation or regulation to encourage Local Authorities, Houseowners, Landlords, Planners and Industry to adopt them
- Effective communication with and support for households and communities on the importance and benefits of decarbonising heat.

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[24] UK EPSRC Project (EP/P005950/1) "Towards Joint PowerCommunication System Modelling and Optimisation for Smart Grid Application: Virtual Power Plant (TOPMOST)", led by Durham University, working with Sunamp and Intel ltd.

[25] See Durham University Smart Grid Laboratory projects https://www.durham.ac.uk/smart.grid/projects/ and Durham Energy Institute published written evidence (CGE0065) - reference above

[26] Hua, Weiqi and Sun, Hongjian and Xiao, Hao and Pei, Wei (2018) 'Stackelberg game-theoretic strategies for virtual power plant and associated market scheduling under smart grid communication environment.', IEEE International Conference on Communications, Control, and Computing Technologies for Smart Grids. Aalborg, Denmark, 29-31 October.

You, Minglei You and Hua, Weiqi and Shahbazi, Mahmoud and Sun, Hongjian (2018) 'Energy Hub scheduling method with voltage stability considerations.', The seventh IEEE/CIC International Conference on Communications in China (ICCC 2018). Beijing, China, 16-18 August 2018.

[27] https://www.durham.ac.uk/smart.grid/projects/

Hua, Weiqi, Jiang, Jing, Sun, Hongjian & Wu, Jianzhong (2020). A Blockchain Based Peer-to-Peer Trading Framework Integrating Energy and Carbon Markets. Applied Energy 279: 115539.

Meinke, Robin-Joshua, Sun, Hongjian & Jiang, Jing (2020), Optimising Demand and Bid Matching in a Peer-to-Peer Energy Trading Model, 2020 IEEE International Conference on Communications (ICC). Dublin, Ireland, IEEE, Piscataway, NJ, 1-6.

ii. Lack of motivation due to cost and regulatory barriers

A recent review of technology for low-grade heat recovery and uses[28] has shown that the number of commercial applications of low-grade heat recovery and reuse is still very limited, even though industrial waste heat is abundantly available and the concept of utilization or recovery is not new. This is because of resource constraints and lack of motivation due to the technical, regulatory, business, and organizational barriers. Industrial willingness to go beyond business as usual can be stimulated by **tax breaks or exemption and new feed-in tariffs** for low-grade heat utilization and recovery[29]. Government should consider **financial incentives and penalties** (such as a waste heat tax) to encourage industry to invest and innovate in the higher cost but hugely impactful waste-heat reuse options available. Equally **regulatory structures** need to be improved and **new business models developed** which balance risk and share up-front capital costs with a view on long-term pay-back, to encourage the introduction of Geothermal heating schemes by Local Authorities.

iii. Technology pricing and installation costs

Despite the significant challenge of decarbonising domestic heating, there is relatively poor data availability on 'experience rates' for domestic heating technologies in the UK, even for the most deployed technology, i.e. natural gas boilers. More analysis and forecasting is required in this area. DEI Research through the Centre for Energy Systems Integration (CESI) analysed how the economies of scale and learning effects have influenced the adoption of Low-carbon Heating Technologies in the UK by analysing experience rates (ER). The experience rates (ER) typically depict the price reduction over cumulative installed capacity and are broadly employed in energy models to predict future trends. The research found that experience rates of low-carbon heating technologies in the UK (air-source heat pumps, ground-source heat pumps, solar thermal collectors, and biomass boilers) are relatively low for equipment price-based rates, and even negative for heat pumps in the total installation costs-based rates[30]. It also found that although all heating technologies have experienced equipment price reduction, it is not the case for their total installation cost which are highly varied according to technology and context. The installation rate of heat pumps after the introduction of Domestic RHI has been lower than expected, which could lead to a lack of competition between installers and lack of price reduction. Although the total installation costs do not change significantly, there can still be positive impacts in deployment rates through **supporting innovation in technological performance, fuel cost reductions, and business models**.

iv. Carbon pricing

Progress in decarbonising residential buildings and energy efficiency improvements (as monitored by Energy Performance Certificates) has been extremely disappointing over the last 10 years (see above). A key factor in this is that **gas is subsidised and artificially cheap**. This means that there is less incentive for households (or industry) to consider investing in more expensive low-carbon heat options such as heat pumps even if economic gains can be proved over the long-term. As the majority of UK homes still use gas for heating it is particularly important that the carbon content of this fuel is appropriately priced. **A carbon price which reflects the costs of carbon emissions will make low-carbon heat options and energy**

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[28] Ling-Chin, Janie, Bao, Huashan, **Ma, Zhiwei**, Taylor, Wendy & Roskilly, Anthony Paul (2018). State-of-the-Art Technologies on Low-Grade Heat Recovery and Utilization in Industry. In Energy Conversion: Current Technologies and Future Trends.

[30] Experience Rates of Low-Carbon Domestic Heating Technologies in the United Kingdom (2020) Renaldi Renaldi*, Richard Hall, Tooraj Jamasb, Anthony P. Roskilly, CSEI Working Paper 2020-14 https://research.cbs.dk/en/publications/experience-rates-of-low-carbon-domestic-heating-technologies-in-t

efficiency measures more attractive and cost-effective for households and industry. Schemes for introducing waste heat tax for industry could also be explored. Recognising the carbon cost and other costs of waste heat may help highlight the long-term economic benefits of existing technologies for capturing waste heat and increasing efficiencies and encourage industry investment. These could be combined with incentives and subsidies linked to introducing low-carbon heat, reducing waste heat or re-using waste heat.

v. **Reluctance to share information**

The nature of ventures such as **district heating schemes depend on the collaboration of different industrial sites** to provide the necessary amount of waste heat. Industry is currently reluctant to share what they consider commercially sensitive information however this information gathering is required to properly identify available waste heat. It is paramount that the **government encourage the sharing of information and expertise, as well as** more collaboration across industry in order to create the most suitable heat reuse schemes for housing. This includes ensuring manufacturers, dealers and technicians are informed about R&D advance on a regular basis in the fast-changing landscape of low-carbon heat and waste heat recovery technology[31].

5. How can the costs of decarbonising heat be distributed fairly across consumers, taxpayers, business and government, taking account of the fuel poor and communities affected by the transition? What is the impact of the existing distribution of environmental levies across electricity, gas and fuel bills on drivers for switching to low carbon heating, and should this distribution be reviewed?

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6. What incentives and regulatory measures should be employed to encourage and ensure households take up low carbon heat, and how will these need to vary for different household types?

i. Ensuring a Just Transition

Given the scale and urgency of the changes we need, we have to stay focused on the need to ensure that the benefits of the transition to a low carbon economy can be shared by all. It is essential that new policies, technologies and systems for decarbonisation which are implemented are socially inclusive[32]. Key issues are to ensure that 'green' energy is affordable and does not disadvantage poorer households and to ensure that the new 'green' jobs that are created are quality jobs with accessible training for lower skilled workers.

ii. Fuel poor households and carbon tax

There is evidence that a carbon tax/energy tax can affect poor households more than rich ones (regressive) and may cause fuel poverty. We would therefore recommend any increased carbon taxing, or pricing which reflects the carbon content of gas, needs to be combined with other initiatives to ensure unequal impacts are avoided. The extra funding made available through these measures should be directed towards energy efficiency measures and compensation measures to reduce the energy costs of lower-income households to ensure fuel-poor households are not adversely affected by carbon taxation[33].

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[31] *Ibid.* and Waste Heat Mapping: A UK Study (2020) ,M. D.A Albert , K. O. Bennett , C. A. Adams and J. G. Gluyas

[32] Abram, S *et al* (October 2020) 'Just Transition Pathways to Socially Inclusive Decarbonisation' Durham Energy Institute co-led COP26 Universities network briefing https://www.durham.ac.uk/resources/dei/briefs/COP26JustTransitionPolicyPaper-Final.pdf

[33] Distributional impacts of a carbon tax in the UK Report 1: Analysis by household type (March 2020)

7. What action is required to ensure that households are engaged, informed, supported and protected during the transition to low carbon heat, including measures to minimise disruption in homes and to maintain consumer choice?

i. **A strong emphasis must be placed on communication and support in homes and the community**

- **Tailored advice provision** in needed that helps householders with decarbonised heating options, renewables, and energy efficiency measures, is pivotal to building public engagement and consumer trust. For instance, **one stop high street "energy shops"** where people can get immediate advice and referrals to find assistance or **innovative 'Peer to Peer' whole place energy advice and support system** as implemented in our Solid Wall Insulation project with Durham County Council[34] . Engagement and education play a vital role in improving energy efficiency, and speeding up the acceptance of any new technologies
- Our research with **Haringey Council[35]** has shown that people seriously mistrust energy suppliers - support with addressing energy efficiency is better sourced from community groups, local authorities and third sector energy efficiency organisations that are more trusted and closer to the householders. Community groups, friends and neighbours are effective means through which to diffuse information about energy efficient and low-carbon heat measures / options.
- Our Customer-led Network Revolution project[36] with British Gas and Northern Powergrid showed that people are not always able to understand and make use of potential changes towards low-carbon and energy efficiency measures such as the installation of new smart meters, in house display units, etc., because they have not been sufficiently well explained and/or understood. Customers require enough information and support to understand their energy efficiency options, the 'capacities' of their appliances and tools, as well as the potential changes they can make in their energy practices.

8. Where should responsibility lie for the governance, coordination and delivery of low carbon heating? What will these organisations need in order to deliver such responsibilities?

i. **Local and regional authorities are best placed to tailor and target support where it is most needed supported by ambitious national targets and regulatory frameworks.** Localised decarbonisation plans ensure that specific local needs are addressed taking into account variations in local demands, existing infrastructure, availability of renewable resources such as solar and wind, housing stock characteristics and socio-economic characteristics the local population.

ii. **Regional University-Industry-Government partnerships are developing exciting research, innovation and demonstrator initiatives aimed at decarbonising heat and facilitating green growth.** These aim to enable industry to remain cost competitive whilst achieving net-zero targets, and supporting Local Authorities to meet the heat demands of their buildings and communities e.g. through the exploitation of waste heat, hydrogen, CCUS and energy systems

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[34] https://swiiproject.co.uk/ Solid Wall Insulation innovation project funded by Durham County Council, Durham University and European Regional Development Fund.

[35] Bell S and Astbury J. (2015) Report: *Assessing the potential of community-based initiatives to ameliorate energy vulnerability in Haringey (2015).* https://www.dur.ac.uk/resources/dei/EnergyVulnerabilityinHaringeyFinalReport12Dec15.pdf

[36] http://www.networkrevolution.co.uk/

integration. Good examples are DEI engagement with the Tees Valley Combined Authority and the Teesside Industrial Cluster to develop regional Industrial Carbon Capture and Storage clusters and Hydrogen Transport initiatives[37]; the Durham Heat Hub led by the University and Local Council to support Heat innovation[38]; and our work with the North East LEP, Durham County Council and the Coal Authority to develop geothermal from minewater schemes in the region. These initiatives have multiple wins and should be supported and encouraged.

November 2020

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[37] https://ukccsrc.ac.uk/project-grant/ccs-from-industrial-clusters-and-their-supply-chains-ccsinsupply/ and http://www.net-zero-research.co.uk/network-hc/

[38] https://durhamheathub.com/