



# ZERO-IN ON NI-HEAT

EXPLORING PATHWAYS TOWARDS HEAT DECARBONISATION IN  
NORTHERN IRELAND

## Authors

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**Dr Inna Vorushylo**, Lecturer in Energy Markets and Energy Storage, Ulster University and principal investigator

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**Dr Stephanie Ogunrin**, Research Associate in Energy Modelling, Ulster University

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**Dr Ruchira Ghosh**, Research Associate in Acceptability of Low carbon Technologies, Ulster University

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**Dr Caterina Brandoni**, Lecturer in Energy, Ulster University

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**Prof Neil J Hewitt**, Professor of Energy and Director of the Centre for Sustainable Technologies, Ulster University

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Please contact Dr Inna Vorushylo for more details about the project:  
[i.vorushylo@ulster.ac.uk](mailto:i.vorushylo@ulster.ac.uk)

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## Preface

The Zero-In on NI-Heat project is a multidisciplinary, women-led project that investigates opportunities and barriers on the road towards zero emission targets in heat sector. Zero-In on NI Heat has a focus on the indigenous features of Northern Ireland (NI).

This NI-specific study was carried out because of the unique geographical position of NI, prevalence of oil heating (68 % of domestic sector), high rates of fuel poverty (22%), its abundant renewable energy resources (46.8 % contribution to power sector<sup>1</sup>), and exclusion of NI from the majority of UK wide studies in relation to the subject area. The past political stalemate caused in part by an inefficient Renewable Heat Incentive (RHI) highlights the utmost importance of research in relation to decarbonisation of the NI heat sector.

Ulster University (UU) has been the lead partner on this project with a Steering Committee consisting of female representatives from key organisations in the NI heat sector, including the Department for the Economy, the Utility Regulator, a local renewable industry group (NIRIG), the transmission and distribution system operators (NI Electricity Networks and SONI), an energy charity (NEA Northern Ireland), the Consumer Council and a public affairs consultancy (Stratagem).

**Lisa O'Neill**, Network Connection Design Engineer, NI Electricity Networks

**Meabh Cormacain**, Energy Adviser, NIRIG/later DfE

**Orla Gray**, Energy Transition Advisor, UREGNI

**Pat Austin**, Director, NEA NI

**Roisin McLaughlin**, Head of Network Operations at the Utility Regulator, UREGNI

**Sarah Foster**, Access Planning Engineer, SONI



**Picture 1.** Some members of the Steering Committee

## Steering Committee

**Bronach Graham**, Energy Policy Officer, Consumer Council

**Edel Creery**, Connections Manager, NI Electricity Networks

**Fiona McCausland**, Head of Energy Efficiency Branch, Department for the Economy (DfE)

**Grainne Walsh**, Head of Consultancy, STRATAGEM



**Picture 2.** Some members of the Steering Committee at the final project seminar

<sup>1</sup> Department for the Economy (2020) Electricity Consumption and Renewable Generation Statistics [available at]: <https://www.economy-ni.gov.uk/articles/electricity-consumption-and-renewable-generation-statistics>

## Project Networking Activities

Four stakeholder engagement workshops and a final seminar were organised for this project. Workshops were aimed at identification of barriers and opportunities with the involvement of a wide range of stakeholders and focused on the following topics: (i) domestic, (ii) non-domestic, (iii) infrastructure and (iv) energy policy and regulation for heat decarbonisation in Northern Ireland. A final project seminar was organised to create wider awareness of NI heat decarbonisation issues among a wide range of stakeholders (Figure 1).

The heat sector is one of the most challenging sectors for decarbonisation as it affects all consumers, their homes and lifestyles. Coordinated actions across a wide range of stakeholders and stakeholder groups are required to achieve this challenging target. A Northern Ireland stakeholder map for heat sector decarbonisation was developed during this project (Figure 1). The map highlights the complex structure of the heat sector and the large number of stakeholders involved in its transition. Among the organisations addressed are: policy makers, consumer representatives, manufacturers, infrastructure companies, investment bodies, cross-sectoral representatives (transport, power, sectors) and many others.

As a result, heat decarbonisation policy is defined by the several government departments, such as the Department for the Economy, Department for Infrastructure, Department for Finance, Department for Communities and Department of Agriculture, Environment and Rural Affairs, as well as the Utility Regulators and local government. The most promising heat decarbonisation pathways rely on infrastructure and resources shared between different sectors, such as power and transport. Therefore, engagement with representatives from these sectors is needed to define optimal strategy for heat decarbonisation in NI. Consumer representatives must be involved in the heat sector decarbonisation to protect vulnerable consumers, introduce consumer engagement and education programmes. Finally, engagement with the local and national/international research centres is also vital for energy transition to explore and notify

government, industry and other stakeholders about the latest achievements in the sector. Representatives from a majority of these organisations attended the project workshops and actively contributed to the discussions. 40 to 60 stakeholders attended each of the thematic workshops and over 100 stakeholders participated in the final seminar.

The project connected various players in NI heat sector, built a NI stakeholders' heat sector map, informed policymakers and other stakeholders about key barriers and opportunities, and created visions for the future pathways for heat decarbonisation in NI. The project's events were highly supported by NI key organisations.



**Picture 3.** Attendees at the first project workshop



**Picture 4.** Round table discussions at one of the project workshops

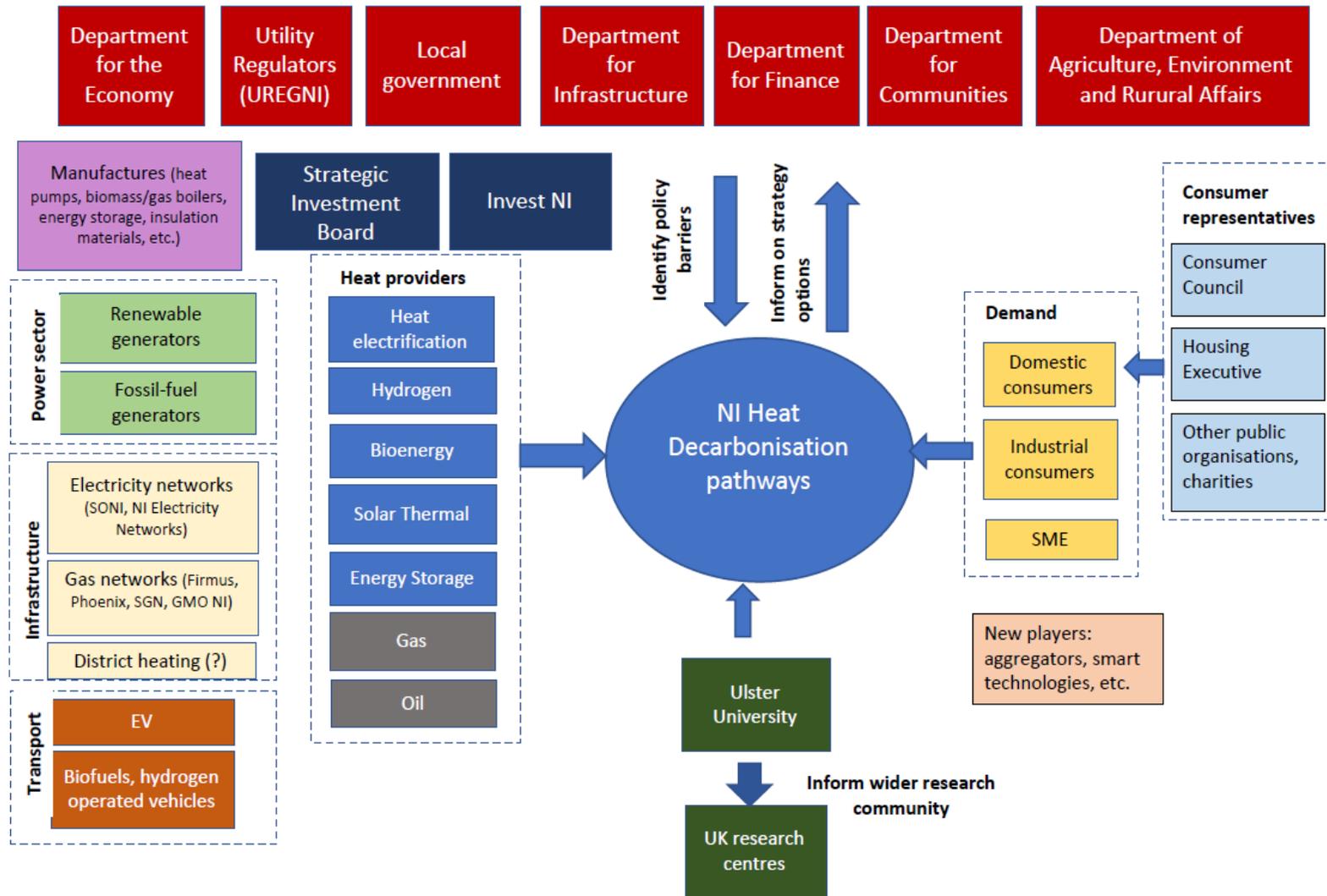


Figure 1. NI Stakeholder map for heat sector decarbonisation

## Feedback from the project workshops

*“I have been involved with the “Zero in on NI Heat” project from the outset from both a policy and regulatory perspective. I have very much supported the project as a much-needed piece of research and evidence on decarbonisation of the NI heat sector. As a member of the Steering Committee I have enjoyed participating in the project and associated workshops. The workshops have covered an interesting and diverse range of subjects and have been attended by a wide range of energy stakeholders. The project has delivered many benefits including, for the first time, building a network of people who have knowledge and experience on NI heat issues and in facilitating discussions hearing different viewpoints and perspectives along with finding out what other organisations are doing in relation to heat decarbonisation. The networking and knowledge sharing aspects have been invaluable in progressing this important piece of work to inform NI’s energy transition. I would like to thank Inna and the rest of the team at UU for inviting me to be part of the project and for their hard work and dedication to it.”*

**Orla Gray**  
**The Utility Regulator**

*“The Zero-In on NI HEAT project has brought together a diverse group of professionals to address one of the biggest policy challenges facing the energy sector: how to decarbonise heat. In preparation for a future that will require technological, social and policy changes, the project opened thoughtful discussions with a wide range of stakeholders to inform key barriers and opportunities. Using workshops and a variety of inputs from academic and partitioning experts, the project has helped to build connections between the facilitators, policy-makers and delivery bodies that will all be required for future heat decarbonisation in NI.”*

**Meabh Cormacain**  
**NIRIG/later Department for the Economy**

*“Thank you for your invite to take part in the ‘Zero in on NI heat’ workshops which was very relevant to the work we are doing in relation to the development of a North West Regional Energy Strategy. We were particularly impressed by the level of the speakers from industry, the opportunity to engage with them during the discussions, and also for their willingness to take part in our own stakeholder engagement sessions in the North West.”*

**Ciaran McGrath**  
**North West Regional Energy Coordinator**



**Picture 5.** Interactive discussions at one of the project workshops



**Picture 6.** Attendees at one of the project workshops

## Introduction: Northern Ireland heat sector overview

Northern Ireland contributed 4% of total UK carbon emissions in 2016. The estimated heat demand of Northern Ireland equates to 9,558 GWh in the domestic sector and 17,643 GWh in the industrial and commercial sectors.<sup>2</sup> The main difference in the Northern Ireland heat sector compared to the remainder of the UK is a dominance of oil heating in both domestic and non-domestic sectors, as opposed to gas heating in the rest of the UK. Charts 1 and 2 below show the technology share of heat across the domestic and non-domestic sectors.

Average consumption per household (with 96.3% of 780,000 households occupied in 2016) can be estimated as 12,718 kWh. Table 1 below suggests that the domestic sector emits the highest amount of greenhouse gases. Emissions in the industrial sector are very close to emissions in the domestic sector in absolute figures (2.4 vs 2.7 MtCO<sub>2</sub>). Proportionally, the industrial sector contributes to a much lower share of CO<sub>2</sub> emissions in comparison with the rest of the UK (13 % in NI compared to 26 % in the UK), which suggests that NI has a less energy intensive industrial sector relative to the rest of the UK.

Generally, the energy efficiency of NI houses is similar to the rest of the UK with the majority of houses belonging to EPC rating D. Composition by house types differs slightly for Northern Ireland in comparison with other UK regions with a larger share of detached houses and a lower number of apartments (Figure 2)<sup>3</sup>.

The Climate Change Act (2008) is the key legislation driving decarbonisation across all sectors in the UK, which set initial aim to achieve 80 % of CO<sub>2</sub> reduction against 1990 by 2050. The Climate Change Act 2008 Order 2019 introduced a new target for at least 100% reduction of greenhouse gas emissions in the UK by 2050. The UK was also the first major economy to adopt net zero targets in the world. The Committee on Climate Change in their Fifth Carbon Budget suggests that in order to achieve net-zero target, a near

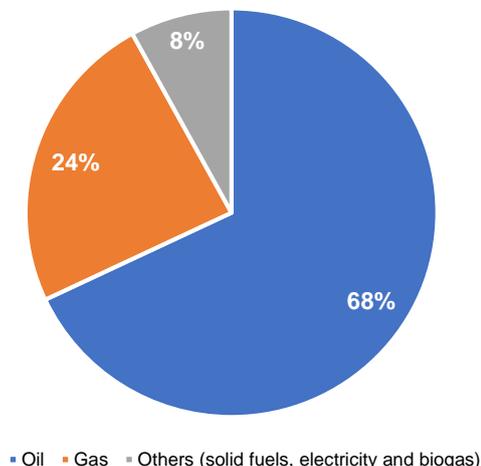


Figure 2. Heat Demand fuel shares in Northern Ireland's domestic sector

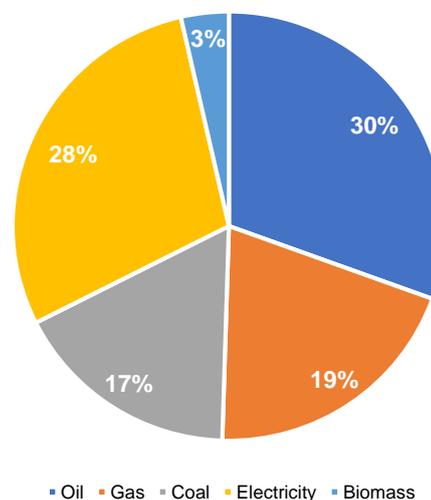


Figure 3. Heat demand fuel shares in Northern Ireland's non-domestic (industry and public) sectors

<sup>2</sup> DfE (2018) Energy in Northern Ireland report

<sup>3</sup> Department for the Economy (2018) Energy in Northern Ireland 2018.

**Table 1.** Carbon emissions across Northern Ireland’s domestic and non-domestic heat sectors

	1990	2008	2015	2016
Domestic (MtCO <sub>2e</sub> )	3.483	2.754	-	2.7
Non-domestic (MtCO <sub>2e</sub> )	0.556	-	0.424	0.4
Industrial (MtCO <sub>2e</sub> )	3.264	-	2.616	2.4

**Source:** CCC 2019 Reducing Emissions in Northern Ireland

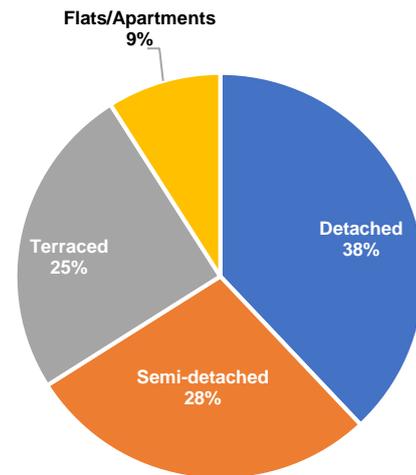
complete decarbonisation of buildings is required<sup>4</sup>.

Northern Ireland, unlike Scotland, for example, does not have any separate climate change legislation and therefore is responsible for delivering decarbonisation under the UK-wide goals. Reductions of carbon emissions in the Northern Ireland heat sector have been driven mainly by the expansion of gas networks and replacing oil with gas heating.

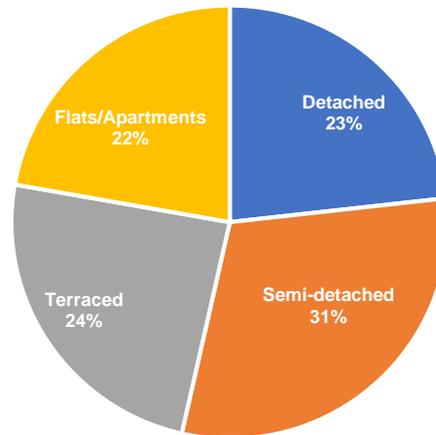
This has been driven in part by two major expansions to NI’s gas network since 1996.<sup>5</sup> The first one was when Belfast connected to the grid through a pipeline from Scotland in 1996. The second one was completed in 2006 and provided connections to over 40,000 households in the 10 Towns Area and along the North-West and South-North gas transmission pipelines.

One of the major recommendations by the Committee on Climate Change concerning heat decarbonisation is to replace oil heating in the off-gas grid area with low carbon heat supply, mainly heat pumps. The GB Government announced its intention to stop connection of new buildings to fossil fuel heating by 2025. Whilst this is not yet legislation, it highlights a positive step towards a net-zero heat sector<sup>6</sup>.

Contrarily, Northern Ireland is progressing with its third gas infrastructure expansion known as ‘Gas to the West’. The expansion will supply the following towns with natural natural gas: Strabane, Omagh, Magherafelt, Enniskillen, Dungannon, Derrylin, Cookstown and Coalisland with total 54,000 customers able to connect to the gas grid.<sup>7</sup>



NI



UK

**Figure 4.** Northern Ireland vs UK housing stock by house-type

It is expected that 60 % of overall NI households will have access to the gas infrastructure by 2022. It should also be noted that only 89,510 of 143,830 households who could connect to the gas grid in Belfast, had natural gas central heating in 2016.<sup>8</sup> Thus, only 62.2 % households have switched to gas heating, despite the infrastructure being available for 20 years<sup>9</sup> and the cheaper cost of gas.

<sup>4</sup> CCC (2015), Sectoral scenarios for the Fifth Carbon Budget. Technical report

<sup>5</sup> CCC (2019) Reducing Emissions in Northern Ireland

<sup>6</sup> UKERC (2019) Review of Energy Policy 2019

<sup>7</sup> Gas To The West (2020) Gas to the West – the Project

<sup>8</sup> NIHE (2016) Northern Ireland House Condition Survey 2016 – Appendix Tables

<sup>9</sup> It should also be noted that gas infrastructure was developed in stages and was not available to all the consumers in 1996 when the project started.

Northern Ireland accounts for high level of fuel poverty. 22% of Northern Ireland households are considered as fuel poor<sup>10</sup>. 1,500 excess winter deaths were registered in NI in 2017-2018<sup>11</sup>. 30 % of these deaths are directly associated with vulnerable consumers living in cold damp homes. There are some regional programmes supporting households with low income and providing financial support for energy efficiency measures and replacing old gas or oil boilers with new ones. The latter partially contradicts net-zero targets. On the other hand, current programmes are designed to help target the greatest number of vulnerable people and therefore utilise the cheapest solutions to help them.

The main energy policy document for Northern Ireland, Strategic Energy Framework (SEF 2010-2020) set a target of 40% of electricity consumption and 10% of heat supply from renewables by 2020.<sup>12</sup> By June 2020, NI had exceeded the 2020 electricity target by generating 46.8% of electricity from renewables.<sup>13</sup> The goal for renewable heating, however, most likely will not be achieved.

According to the NI Strategic Energy Framework (SEF) initial expectations, 17% of domestic houses will be required to have their heat supplied from renewable resources to meet the 2020 target<sup>7</sup>. However, only 2,453 renewable domestic and 2,128 non-domestic heat systems had been installed under the Renewable Heat Incentive by 2016.<sup>14</sup> This is approximately 1% of the total number of domestic and non-domestic buildings in NI. Most installations involved biomass boilers in both sectors. Moreover, the suspension of the RHI Scheme in Northern Ireland<sup>15</sup> due to its design failure has basically halted financial support for any new renewable heat projects in the region and paused heat decarbonisation initiatives.

The past political stalemate caused by the inefficient RHI scheme highlights the paramount importance of research in relation to decarbonisation of the heat sector<sup>16</sup>. Identification of barriers is one of the key elements towards establishing an optimal, achievable and efficient strategy for heat decarbonisation in Northern Ireland.

Therefore, this project can potentially offer valuable benefits for policy, legislation and regulation by identifying these barriers, as well as supporting interactions and dialogue between different groups of stakeholders in the heat energy sector. Moreover, the proposed project is designed to create a wider awareness of heat decarbonisation issues among other stakeholders and decision makers to help inform and realise future environmental, social and economic benefits from heat decarbonisation. It should also be noted that this project was the first initiative to bring stakeholders together, since the SEF (2008-2010) development to consider heat decarbonisation in Northern Ireland.

A wide range of barriers and opportunities were discussed during project workshops. We grouped these into energy policy and regulation, technological and operational, public sector and infrastructural barriers. Major barriers and opportunities discussed during project workshops are presented in the first chapter of this report. In addition to this, we performed two sets of studies researching experts and customer perceptions about heat decarbonisation in Northern Ireland. They are presented in the second chapter of this report.

<sup>10</sup> BEIS (2019) Annual Fuel Poverty Statistics in England, 2019 (2017 data)

<sup>11</sup> Pat Austin, (2020), NEA NI, Presentation during final project workshop

<sup>12</sup> DETI (2010) Energy – A Strategic Framework for Northern Ireland

<sup>13</sup> DfE (2019) 40 per cent electricity consumption from renewable sources by 2020 achieved ahead of schedule

<sup>14</sup> DAERA (2018) Northern Ireland Carbon Intensity Indicators

<sup>15</sup> <https://www.ofgem.gov.uk/publications-and-updates/suspension-northern-ireland-rhi>

<sup>16</sup> At the time of project there was no government in Northern Ireland and Climate emergency in the province had not yet been announced.

# Chapter I: Barriers and opportunities for heat decarbonisation in Northern Ireland - Outputs from workshop discussions

## 1.1: Energy Policy and Regulation

The requirement for a comprehensive long-term energy strategy was one of the most discussed topics during all the project workshops. Northern Ireland is the only region in the UK which does not currently have an energy strategy beyond 2020. Whilst the Northern Ireland Assembly recently declared a Regional Climate Emergency and is to support the setting up of an Environmental Protection Agency by the end of 2020, it is presently under development and there is a lack of present action and development aiming at mitigation of Climate Change.<sup>17</sup>

A comprehensive framework, which will consider **all relevant dimensions and technological solutions** of the decarbonisation concept was suggested by NI experts during the project discussions. Moreover, consumers should be at the heart of the new energy strategy with actions targeting consumer education, motivation and engagement. Furthermore, policy should consider the financial implications of decarbonisation. For example, new business models can be used only if there is adequate policy support in implementing these models, overcoming market risks, secured cashflow to install/maintain heating systems, regulations and support mechanism for the future investments. Summarily, energy policy should consider all relevant dimensions of the heat decarbonisation, as well as outline short-term goals within a long-term framework for achieving decarbonisation. The following points expatiate on what experts consider as main barriers and opportunities of energy policy and regulation in NI.

### Cross-department initiatives and leadership:

Energy policy is devolved to the Northern Ireland government. However, the development of heat policy and its aspects are spread across different government departments:

- Climate Change policy is under responsibility of the Department of Agriculture, Environment and Rural Affairs (DAERA);
- Energy Policy role sits within the Department for the Economy (DfE);
- Energy Poverty is under the jurisdiction of the Department for Communities (DfC);
- Building regulations is under the responsibility of the Department of Finance (DoF);
- Industrial heat decarbonisation is under the responsibility of Invest NI.

This leads to policies that sometimes contradict each other and result in investments in technologies and infrastructure which do not align with the net-zero targets. For example, the Department for Communities provides grants for households in fuel poverty for replacements of their old oil boilers with the new ones, while DfE set targets for decarbonisation of the heat sector. Therefore, clear leadership and cooperation are required in delivering the heat decarbonisation agenda. Some stakeholders supported an idea of the independent committee responsible for climate change, whilst others believe that cross-department cooperation will serve the purpose. Many stakeholders supported an idea of Northern Irish legislation regarding climate change. There were two enquiries from the NI Assembly to the CCC in 2011 and 2015 about the appropriateness of the regional climate change legislation. The CCC advised and advocated for a separate legislation referring

<sup>17</sup> BBC (2020) Northern Ireland Assembly declares a 'climate emergency'

to NI specific contributors to CO<sub>2</sub> emissions and potential actions to tackle climate change. Therefore, many stakeholders believe that setting region-specific environmental targets for Northern Ireland would drive the transition to a net-zero society and green economy in the region.

**Wider cross-department initiatives:** The need for wider cooperation between different departments was discussed during the project workshops. The benefits of heat decarbonisation will potentially bring significant health benefits. Cleaner air, more energy efficient houses with higher levels of thermal comfort can lower rates of asthma,<sup>18</sup> cardiovascular diseases<sup>19</sup> and even rates of cancer.<sup>20</sup> Additionally, consumer awareness and professional development programmes are needed to increase levels of awareness and engagement, as well as train industry professionals in low carbon heat technologies. A cross-departmental group has already been established to work on a new strategic energy framework<sup>21</sup>.

It is believed that a wider cooperation should be established in tailoring future energy policy. Cooperation within the Department for Education and the Higher Education/ Further Education Divisions of the Department for the Economy, Department of Health would help optimise the design of future policy which considers wider spectrum of benefits. Moreover, involvement from emerging players and academia is of vital importance to mitigate the risks around retaining traditional approaches to energy planning, which may act as barriers to future innovative decarbonisation pathways enshrined in law.

**Regulation framework:** The current regulatory framework, which aims to protect consumers through price controls, predates the energy transition and so may not be fit for purpose in a new world. There were general views from local experts that suggested changes to the current regulatory framework in the facilitation of heat decarbonisation. Thus, some participants expressed concern regarding opportunities for small independent

players to enter and participate in the market. Others expressed similar concerns about limited opportunities for consumers to participate in the electricity market. Absence of dynamic and/or time of use tariffs, smart meter rollout and aggregators working with domestic customers indicate a lack of support and an inappropriate regulatory framework.

There were more concerns on how to regulate large incumbents to promote fair competition in the sector. Some experts raised questions about oil heating to be regulated by UREGNI, as very often volatile oil prices are associated with high level of fuel poverty in NI. Some other experts suggested that there is a need to know if new sectors/infrastructure, such as district heat networks should be regulated by the Utility Regulator in Northern Ireland. An answer is required especially as legislation for Ofgem to regulate heat networks in GB is being prepared.<sup>22</sup>

Finally, representatives from the gas sector are concerned about limited support for biomethane injection in Northern Ireland.<sup>23</sup>

**Local government and their power:** Local government can play significant roles in the heat decarbonisation agenda. Some local councils are already preparing their regional strategies. For example, Derry City and Strabane District Council is finalising its North West Regional Energy Strategy with a net zero 2045 target. In general, local councils are lacking frameworks for active implementation of heat decarbonisation. The responsibilities of local energy managers usually consist of general building support, procurement and maintenance services programmes. This affords them limited time and financial resources for more strategic programmes. Some local councils do not have devoted energy managers at all. However, there are GB regions and cities which have set targets to achieve net-zero carbon aims ahead of 2050 government target. Thus, there is potential for NI local authorities to adopt a similar approach. Again, monitoring of local leadership and decarbonisation programmes is a potential requirement to guarantee optimal

<sup>18</sup> Bailey (2019) Thirty Recommendations by 2030 – Expert briefing for the Labour Party

<sup>19</sup> WHO (2018) WHO Housing and Health Guidelines

<sup>20</sup> BEIS (2018) A Future Framework for Heat in Buildings – Call for Evidence

<sup>21</sup> The following departments participate in the cross-departmental panel: DfE, DAERA, DfC, DfI, DoF, Invest NI, local authorities.

<sup>22</sup> GOV.UK (2018) Heat networks must be regulated, CMA study finds

<sup>23</sup> There is no single biomethane injection in Northern Ireland

spending of public money and deliver cost-optimal programmes.

**Energy efficiency policies for existing and new buildings:** Implementation of net-zero carbon standards for new buildings is one of the most desirable options towards heat decarbonisation. Current building regulations are not strict enough to deliver this target. It is important to note, however, that new builds will only account for 14% of houses by 2050 (based on 2016 housing stock)<sup>24</sup>. Policy instruments are required to launch retrofit programmes within existing building stock.

Northern Ireland can learn from positive examples from other regions and countries. For example, Energy Efficient Scotland programme set the target to upgrade all technically feasible and economically efficient buildings to near zero carbon standard by 2050 with mandatory targets to achieve EPC rating C for all privately owned buildings, EPC rating B for households in fuel poverty by 2040 and EPC rating B for socially rented homes by 2032<sup>25</sup>. England and Wales have legislation establishing minimum energy efficiency standard for rented accommodation, which should be at least EPC rating E from 1<sup>st</sup> March 2020<sup>26</sup>.

The Republic of Ireland has set-up high energy efficiency standards for new houses, requiring them to achieve near net zero carbon standards or rating A2 of their energy efficiency system BER<sup>27</sup>. In addition to this, the ROI Climate Action Plan puts built environment at the heart of its policy with the aim of achieving B2 BER efficiency rating for 500,000 homes by 2030<sup>28</sup>. In order to avoid “carbon lock-in” by using cheaper gas heating, it also sets the targets to replace old oil boilers with heat pumps for 400,000 existing households by 2030.

#### **Protection of vulnerable consumers:**

Current measures to tackle fuel poverty in Northern Ireland seem inefficient as the fuel poverty accounts for 22% in the region. Targeted assistance/encouragement for fuel

poor households will be vital considerations while planning for vulnerable consumer protection. Energy digitalization, i.e. enrolment of smart meters, can potentially help in identifying fuel poor households. However, data protection and other regulatory measures can be barriers to targeting these households. The effect of energy distribution and how infrastructural investments impact social equity and fuel poverty must be considered in policy formulation towards consumer protection. Thus, one of the main programmes (Northern Ireland Sustainable Energy Program-NISEP) for energy poor households is funded through levies on electricity bills. This disadvantages electricity driven low carbon heat technologies. Therefore, socialized costs across all energy bills or tax were discussed as a potential alternative to the current approach. Fuel poverty targets and minimum energy efficiency standards for vulnerable households have already been proposed during project workshops.

#### **Strict policy measures driving heat decarbonisation:**

There is no single vision how to phase out carbon intensive heating and drive heat decarbonisation. Some stakeholder’s expressed opinions that strict policy measures, such as new houses should be forbidden from connecting to fossil fuel heating or introduction of green tax is needed. Others believe that support and encouragement must drive heat decarbonisation. Impact of additional taxes/levies on fuel poor households or NI business was among major concerns about strict policy measures.

#### **Fair competition and emerging players:**

Strong incumbents dominate the market and their power<sup>29</sup> can prevent fair competition in the sector and development of the emerging low carbon technologies and services. Policy support and regulatory frameworks are required to address the power of large incumbents and promote competition in the sector. Potential influence of incumbents over shaping a new energy strategy was expressed

<sup>24</sup> NIRSA (2018) Northern Ireland Household projections (2016 based)

<sup>25</sup> GOV.SCOT (2018) Energy efficiency in homes

<sup>26</sup> BEIS (2020) The domestic private rented property minimum standard

<sup>27</sup> Energy efficiency in buildings in the Republic of Ireland is monitored by the Building Energy Rating (BER) certificates. A2 rating is technically close to near zero house standard with energy consumption up to 25 kWh per m<sup>2</sup> per annum.

Department of Housing, planning and local government (2019), New Energy Efficiency Standards for New Dwellings

<sup>28</sup> DCCA (2019) Climate Action Plan 2019 – To Tackle Climate Breakdown

<sup>29</sup> R. Lowes, B. Woodman, M. Clark, Incumbency in the UK Heat Sector and Implications for the Transformation towards Low-Carbon Heating, 2018

during the project workshops as well.

## 1.2: Technology-specific and operational barriers for heat decarbonisation in NI

Among potential low carbon technologies suitable for heat decarbonisation in NI are energy-efficiency improvements in domestic and non-domestic buildings, implementation of heat pumps, biomethane and hydrogen heating and biomass boilers. Solutions for individual combustion (boilers) or for heat networks are considered. The major technological pathways for heat decarbonisation are presented in Figure 5.

There is a range of market and operational barriers and opportunities common for all technological pathways. Among them are an absence of financial support schemes and local demonstration and trial programmes.

Currently, the cheapest form of heating is natural gas and all low carbon heating technologies are presently more expensive than fossil fuel heat providers. Such estimations, however, do not reflect the costs of climate change and its potential impact on society and the economy. Therefore, heat decarbonisation requires significant investments in infrastructure, retrofit measures and low carbon heating technologies, education and awareness programmes, as well as professional training support, support for new business and innovation, research and development.

Whilst various funds exist in Great Britain for local heat network and low carbon heating trials, in general these funds do not extend to Northern Ireland. Due to the political stalemate caused by the inefficient RHI scheme, there is no explicit support mechanism for new domestic applicants wishing to install low carbon heat technologies in NI. Consequently, there is an almost complete absence of local demonstration projects and initiatives and therefore, an even greater gap between Northern Ireland and other UK regions.

There are many visions about types of investors and how they can be encouraged

and supported. For example, institutional investors such as insurance and pension funds can potentially be very interested in long-term infrastructural projects; private investments can be unlocked for retrofit or low-carbon heat community programmes. Clear government goals, support and guarantees are a must have for unlocking such investments. Direct government support programmes funded via general taxation is another vision on how to support heat decarbonisation.

In addition to this, mistrust of technology providers and installers are observed among NI consumers during project workshops and focus groups. It seems that people tend to place little or no trust in the know-how and services of technology providers. This facilitates the low popularity of heat decarbonisation technologies and this lack of trust is partially caused by previous failures and low awareness of NI consumers.

Therefore, there is a need for providers and installers to provide good terms and conditions of service. EU guidelines can be helpful, and examples from other countries that have educated expert engineers can also be considered. Examples from Germany<sup>30</sup> can be used to guide Northern Ireland strategies and training schemes for engineers. The following technology-specific barriers and opportunities were discussed during the project workshops.

**Energy Efficiency:** Energy efficiency improvement is considered as the first and must-have step in dealing with the heat decarbonisation challenge. UK houses are some of the worst in terms of energy efficiency across Europe. As it was indicated in the energy policy and regulation section, it is a consensus among stakeholders that building regulations for new houses must be strengthened. Positive examples from Austria, Sweden and Ireland can be used to drive this initiative in Northern Ireland.<sup>31,32</sup> Likewise, energy efficiency targets for house retrofit must be set up to improve the energy efficiency of NI housing stock. Different visions, however, are seen among stakeholders as to how this should be achieved (supportive or strict policy measures) and to what extent these programmes should be implemented. Some stakeholders believe

<sup>30</sup> Rummeni (2007) Deliverable No 9 – Report on analysis of marketing instruments

<sup>31</sup> Erhorn & Erhorn-Kluttig (2014) Selected examples of Nearly Zero-Energy Buildings – Detailed Report.

<sup>32</sup> UKGBC (2020) Advancing Net Zero.

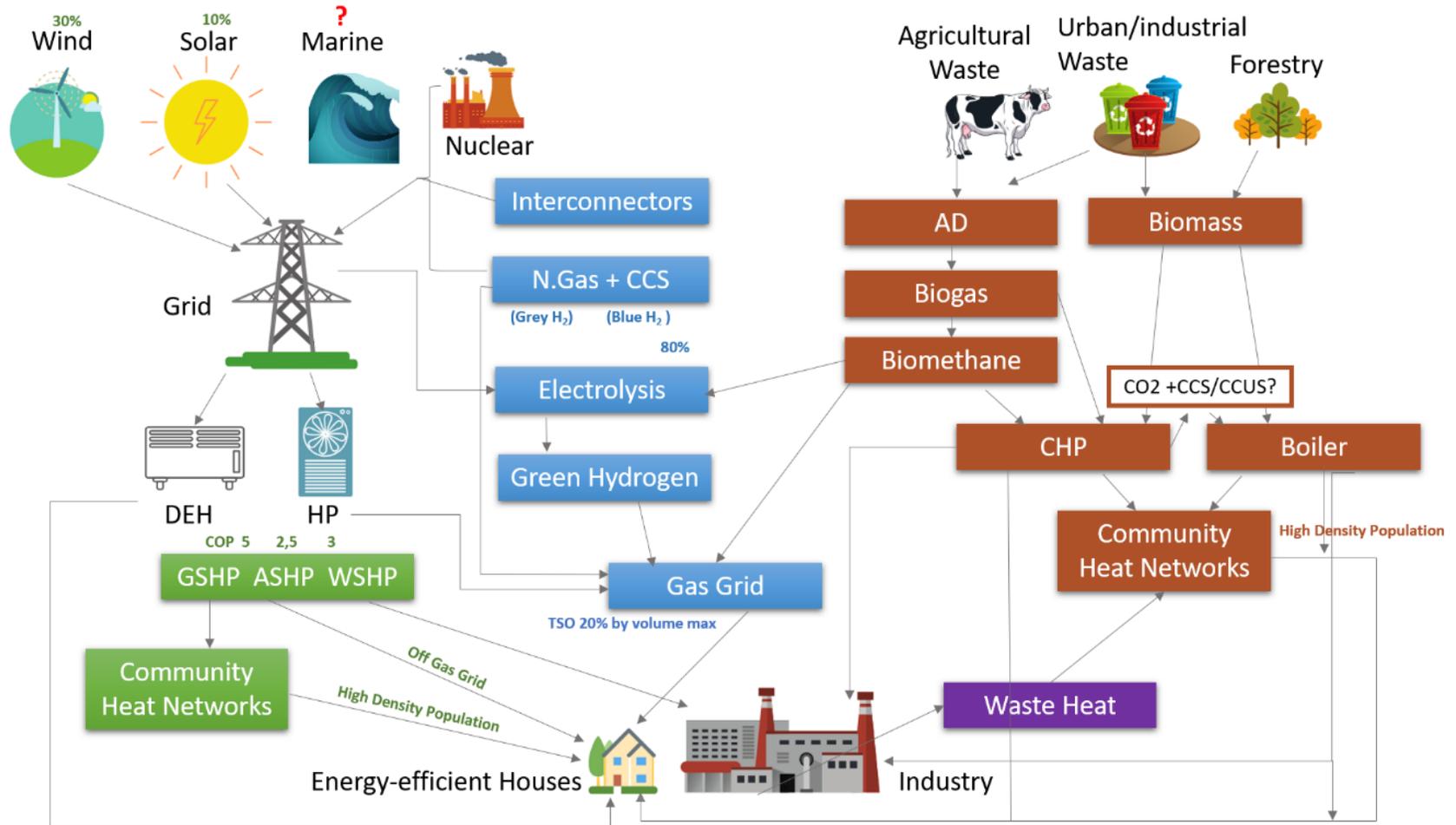


Figure 5. Major technological pathways for heat decarbonisation in Northern Ireland

that new builds should be built to net-zero targets, whilst others support less strict standards. Similarly, some experts believe it would be too expensive to retrofit current house stock in both domestic and public/commercial sectors.

Technically, there are no barriers to energy efficiency improvements, except that of availability of a highly skilled workforce. High retrofit costs are considered the main barrier for energy efficiency improvement. However, there are other barriers.

High energy efficiency standards for new buildings in the neighbouring Republic of Ireland (ROI) and a wide range of retrofit programmes are considered as a learning opportunity for Northern Ireland. Many local architectural firms work in both markets and therefore already hold extensive knowledge and expertise.

Performance and compliance with the established standards have been highlighted by previous studies<sup>33</sup> and were raised in our workshop discussions as another barrier for energy efficiency programmes. Energy efficiency of new buildings and completed retrofit programmes are very often different from the designed standards. This highlights the requirements for alternative measures to monitor their efficiencies. Actual performance-based assessments and greater levels of inspections are among proposed new measures to deal with this barrier.

Lack of engagement programmes with consumers is another barrier to energy efficiency improvement. There are some existing initiatives providing funding towards energy efficiency such as the Northern Ireland Sustainable Energy Programme (NISEP)<sup>34</sup> or the Affordable Warmth schemes<sup>35</sup>. The majority of these programmes are designed for households with low incomes. However, such initiatives will thrive if general attitudes amongst consumers become supportive of decarbonisation.

**Heat pumps:** Heat pumps (HP) are the main technology recommended for off-gas grid

installations by the Committee of Climate Change. Considering that 68% of the domestic sector use oil heating, this is one of the most promising technologies for heat decarbonisation in Northern Ireland. There are several barriers and opportunities for HP rollout in Northern Ireland.

The major opportunity for HPs is when it is allied to the significant regional renewable energy resource, predominantly wind energy in Northern Ireland. There is already great progress in the deployment of wind energy. Electric heating already dominates the public and commercial buildings. This indicates that non-domestic buildings have sufficient electricity network connection for HP installations. HP operating efficiencies of typically 250% or more can reduce the demand on the low voltage network in commercial districts and provide an efficient alternative to current night storage or direct heating in the non-domestic sector. This will not only help to decarbonise the heating sector, but also provide electricity bills savings to non-domestic buildings taking into account that Northern Ireland has one of the highest electricity tariffs for SMEs and industrial customers in Europe.

High capital costs of HP installations, a planning restriction referring to 30m distancing<sup>36</sup> for air-source heat pumps and requirements to strengthen electricity networks are the major barriers for HP deployment in NI. Thus, significant public and private funding has allowed the natural gas network to expand in the region and it is claimed that it will have the capacity to reach more than 60% of households in Northern Ireland by 2022. Contrarily, investment projects for strengthening electricity networks in preparation for heat electrification have not been supported by the government yet.

Nevertheless, heat pumps are already widely implemented across Europe with some successful demonstrations in GB but are relatively unknown and new for Northern Ireland customers. Erroneous perceptions about HP operation dominate in the region. These include the idea that heat pumps cannot

<sup>33</sup> CCC (2019) UK housing: Fit for the future?

<sup>34</sup> UREGNI (2019) Northern Ireland Sustainable Energy Programme Schemes running from April 2019 to March 2020 more details can be found at <https://www.uregni.gov.uk/sites/uregni/files/media-files/19%2005%2001%20Updated%20NISEP%20List%20of%20Schemes%202019-20%20Final.pdf>

<sup>35</sup> NIHE, Affordable Warmth Scheme can be found at <https://www.nihe.gov.uk/Housing-Help/Affordable-Warmth-Boiler-Replacement/Affordable-Warmth-Scheme>

<sup>36</sup> Portal Planning. Home Owners: Heat Pumps

[https://www.planningni.gov.uk/index/advice/advice\\_apply/advice\\_apply\\_homes/advice\\_around\\_home/advice\\_home\\_heatpumps.html](https://www.planningni.gov.uk/index/advice/advice_apply/advice_apply_homes/advice_around_home/advice_home_heatpumps.html)

operate efficiently in the Northern Ireland climate or are required to operate 24x7 with considerable electricity demand and are therefore uneconomic. It is important to note that such misleading perceptions predominate among some industry experts. Meanwhile, consumers generally have no knowledge about these technologies.

There are no incentives, trials and demonstrations for heat pump deployment in the region. There are two local manufacturers of heat pumps and there is almost complete absence of the supply chain supporting HP sales and installations. There was one case of heat pump installation in one of the social housing schemes in Northern Ireland. However, the heat pumps were technically and reputationally damaged due to improper consumer education and support, as well as the absence of local expertise to maintain the equipment. Similar barriers have been faced by other countries. For example, Germany encountered this barrier when it adopted the use of heat pumps. Strict performance standards and regional test centres helped to overcome this barrier.<sup>37</sup> Expert knowledge and test houses within the Centre for Sustainable Technologies at the Ulster University<sup>38</sup>, can provide installation advice and policy recommendation and act as a Northern Ireland test centres respectively.

In addition to this, educated engineers have an important role to play in helping consumers make proper choices. Currently, it is believed that there is a deficit of local engineers able to work with heat pumps. Examples from neighboring Republic of Ireland, suggest that among 5,000 plumbers active in Ireland only 140 have sufficient qualification to work with heat pumps according to SEAI<sup>39</sup>. Therefore, appropriate planning from education divisions and support for professional bodies/organisations, is required to develop skillful engineers in the region.

A lack of consumer opportunities to provide demand-side flexibility in Northern Ireland is another barrier for HP installations. Time of use or dynamic tariffs can facilitate shifting electricity consumption from peak hours and

support heat pump deployment, especially when considered with energy (heat) storage, which can be as simple as a tank of water. Finally, current retail tariff structure and sustainable programmes are mainly funded through levies applied to electricity tariffs. This is another barrier for heat pump deployment.

Thus, the Climate Change Levy<sup>40</sup> disproportionately applies to electricity tariffs when compared to gas tariffs. The Northern Ireland Sustainable Energy Programme (NISEP)<sup>41</sup> is the only programme contributing to the UK energy efficiency target in Northern Ireland. It is also funded through flat rates on domestic and commercial electricity tariffs, which may be an issue for fuel poverty.

**Repurposing the gas grid (biomethane and/or hydrogen heating):** Biomethane and hydrogen are two major technologies currently considered to replace natural gas and supply heating to consumers that already have gas connections. The obvious opportunity for these technologies is to utilise the already developed gas infrastructure and ensure maximum benefit for taxpayers (and gas consumers) money spent on its development. This opportunity is even more important for NI consumers, considering that the gas grid is relatively new and some parts of it are still under development. Unprecedented political and business support is another opportunity driving decarbonisation of the natural gas subsector globally<sup>42</sup>. Capability to support heat electrification by unlocking system constraints and providing seasonal storage is another factor supporting this pathway for heat decarbonisation.

Finally, a large proportion of CO<sub>2</sub> emissions originating from the agricultural sector in NI suggests another potential to achieve heat decarbonisation by scaling-up regional biomethane production. **Resource availability and competing demand from alternative sectors, however, should be carefully considered.** Thus, biomethane and hydrogen can potentially play significant roles in the decarbonisation of other sectors, such as high-temperature industrial processes, feedstocks,

<sup>37</sup> Hanna, Parrish, & Gross (2016) Best practice in heat decarbonisation policy: A review of the international experience of policies to promote the uptake of low-carbon heat supply.

<sup>38</sup> Shah & Hewitt (2015) High-temperature heat pump operational experience as a retrofit technology in the domestic sector.

<sup>39</sup> SEAI, 2019, Heat Pump opportunities for Irish homes, <https://www.seai.ie/blog/opportunities-for-heat-pu/>

<sup>40</sup> HM Revenue & Customs (2016) Climate Change Levy rates

<sup>41</sup> UREGNI (2020) Review of the Northern Ireland Sustainable Energy Programme (NISEP) & Energy Efficiency Provision

<sup>42</sup> IRENA (2019) Hydrogen: A renewable energy perspective

heavy freight and aviation transport sectors. Some modelling studies already indicate that hydrogen should be used for heating in the “hard to electrify” buildings or as a hybrid solution facilitating heat electrification.<sup>43</sup> Our estimations indicate that agricultural and food waste in Northern Ireland would be able to cover circa 17 % of current gas demand. This indicates that biomethane should be considered in conjunction with other technologies, potentially in a hybrid mode, rather than a stand-alone solution.

It is considered that there are no technical limitations for biomethane injection into the local grid and theoretically up to 100% of biomethane can be transported via existing gas pipelines. Small biomethane injection, however, can be quite costly and therefore aggregations into larger facilities will be required. Thus, DSO Gas Network Ireland (GNI)<sup>44</sup> is planning to implement a clustering approach to local farms in the ROI to inject biomethane into the grid.

On the other hand, large aggregated biomethane injection more likely will happen at the edge of the gas grid with limited heat demand. This will require biomethane distribution upwards into medium or even high-pressure pipes. Investments in reverse flow technology will be needed to technically guarantee such a non-standard distribution of biomethane over the gas network<sup>45, 46</sup>.

For the farms situated away from the gas grid however, it will be uneconomic to produce biomethane and transport it into injection points. Thus, an alternative application e.g. liquified bio-CNG or bio-LNG production will have higher potential. Liquified bio-LNG can be delivered via trucks to local fuel stations and is considered as a more cost-optimal solution. Considering a poorly developed gas grid in the rural areas in NI, transport applications for biomethane production will potentially be a more viable solution for some of the NI regions.

There are 89 anaerobic digestion plants in Northern Ireland. The majority of these facilities produce biogas for electricity production purposes. There are no single

biomethane injection points into the gas grid in NI. Cheaper natural gas costs and the absence of financial incentives are the major reasons for the lack of biomethane development in the region.

Hydrogen is another technology considered for gas replacement in the existing gas grids. Industrial hydrogen production has been available for years. Nevertheless, its production is relatively expensive and not aligned with the net-zero targets eliminating CO<sub>2</sub> emissions. Majority of hydrogen today is produced via steam methane reforming (SMR) process from natural gas or coal. It is very often called a grey hydrogen. Great uncertainty exists concerning how hydrogen will be produced in the future. There are two main technological pathways for hydrogen production aligned with the net-zero targets, so-called green or blue hydrogen. Blue hydrogen can be achieved by the improvement of the current industrial or grey hydrogen production by using Carbon Capture and Storage (CCS) or Carbon Capture, Use and Storage (CCUS) technologies to eliminate CO<sub>2</sub> emissions. The technological and economic viability of CCS is currently under great uncertainty, whilst CCUS technology emits some remaining CO<sub>2</sub> emissions, which should be carefully monitored or utilised elsewhere<sup>47</sup>.

Green hydrogen is produced via electrolysis from renewable electricity. Commercially mature alkaline electrolyzers presently have 65 - 80% efficiency<sup>48</sup>. Wind energy capacity factor of 30% and 70% electrolyzers efficiency indicate overall 22.5% efficiency for green hydrogen production. This has significant implications for the economic viability of green hydrogen heating. Moreover, additional renewable generation resources will be needed to supply significant proportions of current heat demand with green hydrogen. There are requirements for investments in new generators and infrastructure to connect them. Current network constraints already limit wind generators connections in Northern Ireland. Offshore wind will potentially be needed in the region to cover increasing demand from heat and other sectors.

<sup>43</sup> BloombergNEF (2020) Hydrogen Economy Outlook Key messages

<sup>44</sup> J. Hannon (2019) Gas Networks Ireland. A secure low carbon future with renewable and natural gas (A presentation delivered during one of the project's workshops)

<sup>45</sup> One of the gas networks in Germany already installed six reverse-flow facilities  
See: <https://www.ontras.com/en/company/ontras-going-green/our-projects/>

<sup>46</sup> Gas for Climate (2020) Gas decarbonisation pathways 2020 - 2050

<sup>47</sup> IRENA (2019) Hydrogen: A renewable energy perspective

<sup>48</sup> NAVIGANT Gas for Climate (2019) The optimal role for gas in a net-zero emissions energy system

On the other hand, green hydrogen production is at the early stage of its development. For example, alkaline electrolyser costs decreased by 40% from 2014 to 2019<sup>49</sup> in North America and Europe with significant potential for further cost reductions and technological improvements.

Great concerns surround the abilities of existing gas infrastructure to transfer hydrogen to end-users. It is considered that it is technically feasible to locally supply hydrogen via distribution networks. Several R&D projects are currently being conducted in GB and across Europe to investigate hydrogen for heating potential<sup>50</sup>. Some GB led projects investigate the possibility to use existing low-pressure networks (i.e. the Distribution System Operator - DSO) to transfer 100 % of hydrogen or investigate the potential of dedicated for hydrogen distribution networks, as well as investigate safety requirements for hydrogen supplied heating.

The ability of high-pressure networks to transfer hydrogen is currently limited to 10% - 20% of hydrogen by its volume. The volumetric energy content of hydrogen is only one-third of natural gas. This means that only circa 6% of hydrogen by energy volume is currently technically feasible to admixture into the gas grid. Higher levels of hydrogen mixtures into the natural gas grid will require significant infrastructural modifications and appropriate investments. The economic potential of such redesign needs is under great uncertainty at the moment. Although, a dedicated hydrogen infrastructure at the Transmission System Operator (TSO) level is potentially considered as a more cost-efficient option for some applications or network sectors<sup>51</sup>. Therefore, locally produced and distributed green hydrogen is considered a preferable option for hydrogen-based heating at the moment. Blue hydrogen is considered as a favourable option for industrial applications but smaller scale CCS and CCUS would be economically challenging at the moment. Dedicated hydrogen networks into "industrial clusters"<sup>52</sup> is also thought as a preferable solution.

Northern Ireland does not have indigenous natural gas resources and is fully dependent on natural gas import from Great Britain<sup>53</sup>. This means that the future hydrogen supply into the region depends not only on technical feasibility and economic factors but also from the UK wider policy and regulatory framework to transport hydrogen.

Existing gas grid infrastructure requires significant energy storage facilities guaranteeing seasonal and daily variations of gas supply. As hydrogen has three times higher density than natural gas, it will require significantly larger storage capacities. Biomethane will require additional storage capacities too, making further additions to infrastructural costs.

Currently, there are no natural gas storage facilities in NI. However, the Island Magee gas storage project holds planning permission for the development of 500 million m<sup>3</sup> natural gas storage facility in the Larne area<sup>54</sup>. Net-zero carbon targets and the inability of natural gas to meet them indicate requirements to consider this project for hydrogen storage. Repurposing of the gas grid into hydrogen transportation will be disturbing to consumers as well. Additional investments will be needed for replacements of end-user appliances, such as hydrogen boilers, cookers and hydrogen safety detectors.

In conclusion, biomethane is a technologically proven approach, which is ready to help in the decarbonisation of the heat sectors. Hydrogen is considered to be at an early stage of development. It is expected that most of the hydrogen production will be utilised for industrial processes until 2030 with small proportions available for blending into the gas grid. The major contribution of hydrogen for heating purposes is more likely to happen after 2030. Local supplied green hydrogen is considered as a more favourable option for domestic heating among other types of hydrogen production. Changes and new investments to infrastructure will be required to facilitate repurposing of the natural gas grid. A non-biased coordinated approach for infrastructure planning is required across

<sup>49</sup> BloombergNEF (2020) Hydrogen Economy Outlook Key messages

<sup>50</sup> Some leading projects include: HyDeploy (<https://hydeploy.co.uk/>), Hy4Heat (<https://www.hy4heat.info/>), H21 (<https://www.h21.green/>), H100 (<https://www.sgn.co.uk/Hydrogen-100/>) projects.

<sup>51</sup> European Commission (DG ENER) (2019), Impact of the use of the biomethane and hydrogen potential on trans-European infrastructure

<sup>52</sup> Gas for Climate (2020) Gas decarbonisation pathways 2020 - 2050

<sup>53</sup> Mutual Energy, GNI (UK Ltd (2019) Northern Ireland Gas Capacity Statement 2019/20 – 2028/29

<sup>54</sup> The project is currently undergoing public consultation. More details about the project can be found here <https://www.islandmageeenergy.com/>

different sectors to bring the most benefits in the energy transition.

**Biomass:** Biomass boilers were the leading technology deployed under the RHI scheme in both domestic and non-domestic sectors Northern Ireland<sup>55</sup>.

However, the future potential of biomass is considered limited for the domestic heating sector. The impact of biomass boilers on air quality makes this technology suitable for only some niche applications, such as “hard-to-insulate/treat” properties in rural areas. There is also a consensus that it will be more appropriate to utilise biomass resources in other sectors, such as construction or industrial heating applications, for example.

Development of CCS or CCUS technology will be required to make utilisation of biomass resources fully compatible with net-zero targets<sup>56</sup>.

Another opportunity to utilise biomass resources is to use biogas gasification to biomethane or hydrogen upgrade<sup>57</sup>. This technology is still at the early R&D stage as more cost-efficient anaerobic-digestion-based biomethane production dominate in the market. The majority of biogas gasification facilities are used for electricity generation. Energy policy and regulatory changes are needed to shift this application to other sectors.

**District heating:** Similar to heat pumps, district heating is widely used across Europe, whilst being relatively unknown to NI consumers. There are 94 district heating schemes in NI. Almost 60% of them are small-scale schemes applied to block of apartments and small residential areas. There is only one domestic DH network supplying more than 100 dwellings. Nearly all the heat networks in Northern Ireland support communal heating. There are also 30 CHP installations in NI that utilise the waste heat in the micro heating schemes including absorption cooling

technologies. The major limitation for district heating schemes in NI is relatively dispersed population and associated heat demand density. Thus, some NI regions there exists a population density of 43.6 people per square km<sup>58</sup>, whilst in Denmark (one of the leading countries for district heating), there is a population density of 347 people per square km<sup>59</sup>. Usually, high density urban new developments and only in some rural locations are suitable for district heating. The District Heat Association of the Republic of Ireland has already included Northern Ireland in their Heat Atlas and suggest areas potentially suitable for district heat schemes.<sup>60</sup>

Most district schemes nowadays use fossil fuels (i.e. natural gas, oil, household waste or coal) or biomass CHP technologies to supply energy for district heating. However, net-zero targets require CCS or CCUS technologies to eliminate CO<sub>2</sub> emissions associated with heat production by these methods. Alternatively, waste heat or large-scale heat pumps can be used for low carbon heat networks compatible with the net-zero targets.

Moreover, there were some unsuccessful initiatives to introduce heat networks in NI. An example is Woodbrook EcoHeating in Lisburn<sup>61</sup>, which damaged the technology's reputation and consumer trust. One of the promising opportunities for district heating is the ability to efficiently deal with fuel poverty, which accounts for 22% of households in NI. Many stakeholders also believe that district heating schemes must be regulated at least at the early stages of their development in the region.

Causeway Coast and Glens Borough Council, in partnership with industrial partners and University of Ulster, developed a concept for the Northern Ireland's first smart district energy scheme in Coleraine to support existing businesses and attract more business investment to the area<sup>62</sup>. The feasibility study confirmed a significant and concentrated demand for heat within a relatively small area

<sup>55</sup> Department for the Economy (2018) Domestic and Non-Domestic Renewable Heat Incentive (RHI) - Statutory Information.

<sup>56</sup> The CCC (2018), Biomass in a low-carbon economy

<sup>57</sup> Gas for Climate (2020) Gas decarbonisation pathways 2020 - 2050

<sup>58</sup> NI Assembly research and innovation centre (2017), A demographic profile of Northern Ireland in 2017

<sup>59</sup> World Population Review (2020) can be found at <https://worldpopulationreview.com/countries/denmark-population/>

<sup>60</sup> IRDEA (2018) Heat Atlas

<sup>61</sup> Woodbrook district heating scheme was designed for 400 houses, but only 196 of them were built. This led to the significantly higher heating tariffs to consumers that were initially promised. More details can be found here: <https://www.belfasttelegraph.co.uk/news/northern-ireland/homeowners-face-huge-bills-as-eco-dream-becomes-living-nightmare-2877768.html>

<sup>62</sup> SustainableNI (2017) Developing a smart district energy scheme for Coleraine

of the town which would lend itself to a smart district heat network. The study also found that the expansion of the network to include domestic loads would add significantly to its economic viability.

As with other low carbon heat technologies, there are currently no explicit support mechanisms for district heating in Northern Ireland (unlike England & Wales and Scotland). Therefore, the smart micro-grid project in Coleraine and/or any other low carbon district heat initiatives have not been maximised in Northern Ireland.

### 1.3: Consumer barriers and opportunities

Heat decarbonisation is going to be disruptive, affecting every consumer. Traditional, fossil fuel heating technologies presently provide cheaper solutions when compared with any of the low carbon technologies. EPC certificates are a compulsory measure, which show potential buyers or tenants the energy efficiency of the house they intend to live in. However, consumers usually have limited understanding of EPC certificates and their indicators. Consumers today are aware of the heating system they use in their houses but the information they possess is usually about fuel types and the cost of using them. Heat decarbonisation is far more than that.

There are multiple barriers from the consumer's point of view in achieving decarbonisation, such as lack of education, enhancement of sector responsibility, financial and policy support, importance of financial viability of new investments, lack of information to consumers and accessibility, and adopted approaches in strategizing the consumers' engagement. To have more consumers who are informed about the residential heat decarbonization, the following challenges and opportunities must be carefully considered.

**Consumer education and awareness:** A bottom-up approach through education can be

applied to build the capacities of consumers. Education can be used as a tool to impart awareness for environment friendly approaches, realise citizen's responsibility towards nature, and build robust and technical knowhow for new technologies for heating systems and energy services towards decarbonization. Information from user experience on installing/using heating systems, the challenges they face and the improvement they expect from energy service providers, can be utilized to enhance the energy services for informed choice and better accessibility. The Northern Ireland Housing Executive (NIHE), the Department for the Economy (DfE), the Department for Communities (DfC) and the Consumer Council (CC) can play a crucial role in educating energy consumers. Nevertheless, the challenge here is that these organizations also require baseline scenarios about the level of education and knowledge needed by energy consumers towards residential heat decarbonization. Policy support from the government is needed to make a robust change in society.

**Unlocking consumer flexibility:** Power systems dominated by variable renewable generators (predominantly wind and solar), require significant levels of flexible solutions and energy storage to mitigate variations in generated power. Consumers can provide such flexibility. Highly motivated consumers, such as environmentally concerned consumers or consumers in fuel poverty can become a viable asset for the future decarbonized energy systems by becoming exemplars to society. In order to peruse this opportunity, appropriate education and incentivization in terms of smart tariffs, aggregators, innovative business models for example are required. Currently, there is an absence of such incentives in the market for domestic consumers in Northern Ireland, but there are several schemes existing in neighboring GB regions. Thus, smart-meter roll-out has been postponed for Northern Ireland due to concerns about their cost-efficiency<sup>63</sup>. Similar concerns existed in GB, but the project was initiated and achieved 17.3 million installations to date in GB<sup>64</sup>. Contrary to initial concerns, the smart-meter roll-out finally

<sup>63</sup> This statement is based on the project discussions. A consultation about smart-meters roll-out was carried out in 2013 <https://www.economy-ni.gov.uk/consultations/energy-efficiency-directive-articles-9-11-consultation>. It received 8 responses <https://www.economy-ni.gov.uk/publications/articles-9-11-energy-efficiency-directive-consultation-responses>; however decisions from this consultation, are not available in the public domain.

proved its economic viability and passed the project's breakeven point in GB.<sup>65</sup> Whilst, there are currently no plans for smart meters roll-out in Northern Ireland, it has significant implications for unlocking consumer flexibility.

**Financial incentives:** Typical high costs associated with deep retrofit programmes or investments in low carbon heat technologies, dictate a necessity for financial incentives in the sector. Different approaches and visions exist for the origin of such incentives including direct government support, provision of green mortgages, alternative business models, community schemes and many others. Currently, there is an absence of any support for low carbon heating schemes and limited support for energy efficiency measures available for some households with low incomes. However, the future decarbonisation legislation agenda highlights the requirement for new support. Moreover, citizens were not actively involved in such schemes in the past, which indicate requirements for education, awareness and engaging programmes. For example, low carbon heat installations in the GB domestic sector are significantly lower than government estimations of their potential uptake. This suggests a significant gap between energy policy and its implementation in practice.

**Non-monetary motivation:** Non-monetised schemes can be applied through recognition of the consumers' efforts. Rewards have the 'feel good factor'. Thus, they can encourage consumers to embrace low carbon options and ensure continuation of such efforts into the future. A "Green" agenda, Climate rewards or an Energy Efficiency recognition scheme can be considered in implementing non-monetised motivation. Alternatively, it would be useful to inform consumers about some wider benefits, such as air quality and associated levels of respiratory deceases, thermal comfort and/or level of cardiovascular deceases among elderly population. Consequently, consumers may be encouraged to invest in house retrofit, low carbon heating technologies or participate in the demand side response programmes.

**Fair approach:** Low carbon technologies in heat and other sectors, such as electric vehicles and heat pumps, will require significant network upgrades. Socialized

network investments among wide population would potentially lead to the disproportional benefit of such investments. This will be the case especially when fuel poor households must pay for innovations only affordable by the wealthy. One approach is to socialize these investments through general taxation.<sup>66</sup> General taxation is a reserved policy of the central government.

Alternatively, regional strategies could include setting tariffs for various ranges of consumers. Such strategies can be quite challenging but achievable by following examples from other countries such as Sweden and Denmark that have successfully addressed fuel poverty.<sup>67</sup>

**Independent information:** There is a requirement for proper information and support for consumers. They need to know about their current impact on environment, the benefits and technological aspects of low carbon technologies, installation process and paperwork requirements, investment needs and potential savings from energy bills and maintenance information. There should be schemes which can educate consumers on environmental and social benefits from heat decarbonisation and encourage people to make good choices. An independent centralized information resource, for example the Sustainable Energy Authority (SEAI) in the ROI, is a good example of such provision.

**Local expertise:** Another factor strengthening the requirement to support local expertise and training for engineers is that they are usually key advisors when domestic users want to install a new heating system. As stated earlier, educated engineers are needed to help consumers make proper choices.

## 1.4: Public and Commercial Sectors

The public sector will face many challenges just as domestic customers in their route to sector decarbonisation. Among them are challenges to improve the thermal efficiency of the buildings, the lack of engineers and installers with appropriate knowledge of low

<sup>64</sup> BEIS (2020) Smart Meter Statistics in Great Britain: Quarterly Report to end September 2020.

<sup>65</sup> BEIS (2019) Smart Meter roll-out. Cost-benefit analysis.

<sup>66</sup> CCC (2019) Reducing Emissions in Northern Ireland

<sup>67</sup> BPIE (2014) Alleviating Fuel Poverty in the EU

carbon technologies, the insufficient expertise and knowledge for implementation of low carbon technologies or even limited resources to conduct energy efficiency programmes. Non-domestic buildings are more diverse in their design and therefore will be more challenging to develop retrofit programmes for the public and commercial sectors. Many stakeholders, however, expressed their vision that the public sector could lead the heat decarbonisation agenda by setting precedents. These precedents could motivate domestic consumers. More so, such precedents would build expertise and knowledge as there would be opportunity to launch pilot projects, build expert capacity and establish a background for new businesses. More detailed suggestions are listed below.

**Lead by example:** Leadership by example could be beneficial for individual consumers and their awareness/motivation, as well as for the group of stakeholders, i.e. community heating/heat networks. The public sector presents a perfect opportunity to launch some energy efficiency and low carbon heating programs to support this. Such leadership would drive the capacity building of local expertise, open and support a new market for emerging players involved in deep retrofit programmes and instigate the installation of low carbon heating technologies.

**Local authorities' leadership:** A promising decarbonisation option is community heating systems. The public sector can lead and guarantee financial contracts with infrastructure companies to build necessary infrastructure, whilst the domestic sector would be able to participate in these schemes later. District heating in other countries, such as Denmark and Finland<sup>68</sup> are very often managed by local government, community not-for profit organisations and commercial companies. Therefore, local government in NI should be empowered and supported by central government in order to be able to lead such schemes. Furthermore, unsuccessful examples of district heating schemes from NI and other UK regions show that quality assurance and

regulation of community schemes is needed to guarantee their efficient implementation and operation.

**Strict policy measures (carbon tax):**

Workshop discussions indicate a lack of motivation among public and commercial sectors to decarbonise their heat. A previous very attractive feed-in-tariff supporting solar PV installations did not increase installations across the region. This is despite the fact that electricity tariffs for non-domestic users are ranked among the highest in Europe, especially for medium and large energy users<sup>69</sup>. Some stakeholders believe that a lack of motivation among management is the main reason for this. Others believe that limited resources and expertise in the company are the major barrier. Organisational energy managers that usually work within maintenance divisions of the companies are not motivated enough to propose and operate innovative technologies. Therefore, some stakeholders support strict policy measures, such as green tax. They believe that carbon emission price is too low and does not reflect the risks and consequences of climate change. Others believe that additional taxes can discourage business development in the region.

**Energy consumption monitoring:** Currently there is no requirement to monitor energy demand in the non-domestic sector. Energy monitoring in commercial sector, especially SME is currently often performed by accountants by simply paying utility bills. Moreover, SMEs very often rent their buildings and have limited interests to invest in energy efficiency or low carbon heating technologies. The Strategic Investment Board (SIB) developed a database to collect aggregated energy consumption data for central government buildings.<sup>70</sup> Detailed fuel statistics are recorded and publicly available for all regions<sup>71</sup> except for Northern Ireland. Temporal (hourly) monitoring of energy consumption is not registered in any sub-sector. This creates a significant drawback for establishing a baseline picture of sub-sectoral energy demand and potential heat decarbonisation pathways.

<sup>68</sup> Hanna, Parrish, & Gross (2016) Best practice in heat decarbonisation policy: A review of the international experience of policies to promote the uptake of low-carbon heat supply.

<sup>69</sup> UREGNI (2020) RETAIL MARKET MONITORING Quarterly Transparency Report Quarter 4: October to December 2019

<sup>70</sup> SIB (2019) Energy Management Strategy and Action Plan to 2030 for Northern Ireland Central Government.

<sup>71</sup> GOV.UK (2019) Energy consumption in the UK.

**Quality assurance and performance**

**monitoring:** As with the domestic sector, independent monitoring and quality assurance are required for retrofit programmes and low-heat installations in non-domestic sector. This also means that appropriate expertise or service provision are required to fulfil such functions. Some experts were very sceptical about retrofit viability in the non-domestic sector due to the non-standard designs of non-domestic buildings.

**Resource sharing and collaboration:**

Collaboration and resource sharing in terms of expertise and knowledge will be very beneficial for the non-domestic sector. Additionally, technology sharing can have successful applications. For example, waste heat from various industrial processes can be utilised for heat networks. One of the few reports produced for NI<sup>72</sup> suggest that there is lack of economically viable sources of waste heat in NI suitable for district heating. It is necessary to have up-to-date studies, which will account for future net-zero carbon challenges and compare economic viability of waste heat recourses with alternative low-carbon solutions. There are approximately 30 CHP installations in NI that utilise waste heat for micro heating schemes including absorption cooling technologies. Data centres and their growing installations across the island of Ireland can be potential sources for waste heat for low grade schemes. Thus, another example from project discussions suggests that the majority of bioenergy supplied CHP schemes in NI waste all their heat into the atmosphere as only electricity production is currently incentivised and supported. The CHP unit at Ulster University has been running for years wasting excess heat, which could potentially be a valuable resource for the nearby community and new DH scheme.

In conclusion, a whole system approach and planning is needed to assess resource availability and best utilisation strategies. In addition, there are potentially significant but as yet, fully explored and exploited geothermal heat resources in NI that could add to heat network viability.

**Unlocking consumer flexibility:** One of the major concerns regarding heat electrification is its impact on the system during peak hours. The non-domestic sector will have less impact

on evening peak demand and more opportunity to utilise electricity from some renewable generators such as solar energy for example. This means that the non-domestic sector can also offer flexibility to the energy sector if appropriate support is provided. Flexible tariffs could potentially encourage the non-domestic sector to invest in energy storage technologies. Differences in consumption patterns for domestic and non-domestic sectors can encourage partnership for district heating schemes.

Stakeholders who participated in the project's poll supported the following major opportunities (see Figure 6) and barriers (see Figure 7) for non-domestic sector heat decarbonisation. Major opportunities for non-residential decarbonisation in Northern Ireland include the potential to use renewable energy sources, setting carbon saving targets for non-residential buildings and the industry and public sector leadership in driving energy transition in NI. Factors such as consumer education and transforming the energy market to open up more opportunities to consumers are among opportunities in the non-domestic sector as well.

Dominant barriers to non-residential heat decarbonisation include the absence of a robust energy policy, a lack of necessary leadership and framework and the high capital costs of low-carbon technologies. The voting poll also highlights the importance of end-user incentives, as well as awareness and education programmes for non-domestic sector users. Thus, among stakeholders attending the project final seminar, 5 % were unaware of the EPC rating of their houses, whilst 8% have houses with the EPC rating E. This indicates a significant gap of knowledge and awareness about heat decarbonisation not only among consumers, but among specialists and industry professionals.

## 1.5: Infrastructural barriers and opportunities

Northern Ireland's heat decarbonisation will involve the development of new technologies and accompanying infrastructure. Most experts believe that there is "no silver bullet" from a technological perspective. They propose that a

<sup>72</sup> NIA (2011) District Heating - Northern Ireland Assembly Research and Information Service briefing Paper

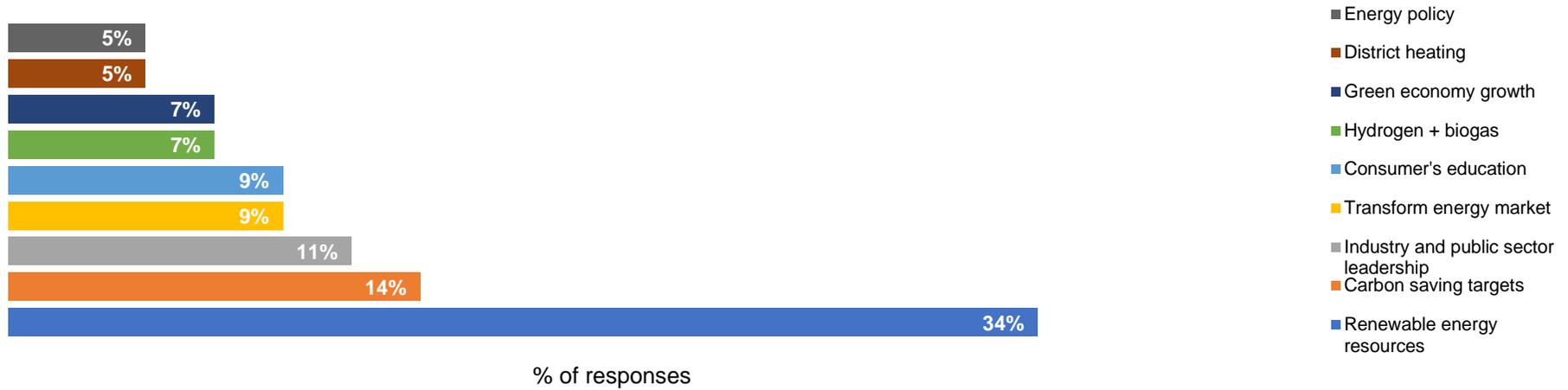


Figure 6. Major opportunities for non-residential heat decarbonisation in Northern Ireland

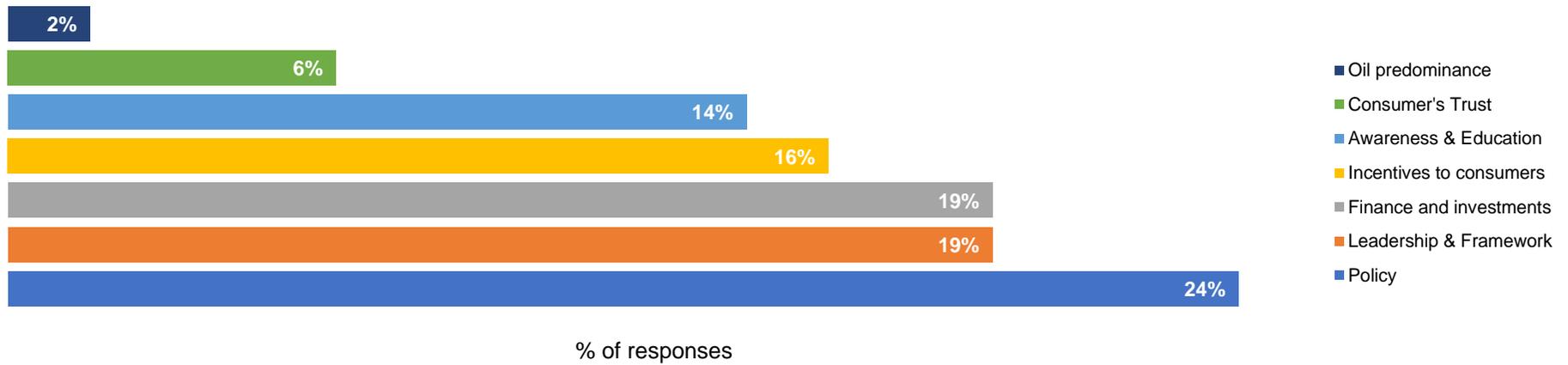


Figure 7. Major barriers for heat decarbonisation in NI

combination of resources is required to achieve complete sector decarbonisation. This raises the question of how optimal plans and investment in infrastructural projects can be made to maximise benefits from heat decarbonisation. There is currently an absence of large district heating schemes in NI. Neither existing electricity networks or gas networks are able to deliver the heat decarbonisation agenda. Moreover, existing infrastructure is currently benefitting from flexibility provision from some commercial and industrial customers, whilst consumers currently remain quite inactive. Nevertheless, the following must be considered when reviewing the role of infrastructure in NI's heat decarbonisation.

#### Smart investments in infrastructure:

Strategic level thinking around infrastructure implications is needed to deliver optimal investments in low carbon heating infrastructure. Currently, 68% of oil heating is found in the domestic sector and this means that oil heating systems should be substituted with alternative technologies, which will require additional infrastructure. Smart investment strategies should include sector coupling<sup>73</sup> strategies considering potential benefits of energy storage technologies and demand response flexibility. These strategies will avoid double investments and lead to consumer tax savings in the long term.

**Hybrid solutions:** can be a viable option for dealing with infrastructure limitations with medium-term timeframes and uncertain risks of future technological developments. Combined technological solutions would more likely be region-specific due to factors such as the availability of resources in certain areas (i.e. biomass, biogas, excess wind, etc.). They would likewise depend on heat demand profiles (i.e. industrial and domestic heat demand concentrations). The use of combined technologies may be made easier by the confidence of a back-up solution for new technologies. It is necessary that stakeholders work together to facilitate collaboration on how best to combine technologies; therefore knowledge-sharing is very important. A hybrid pathway is suggested as the most cost-

effective option amongst three pathways (hybrid, electricity and hydrogen) to meet a zero-carbon target by 2020 in the UK.<sup>74</sup> Taking into account regional differences in the heat sectors between Northern Ireland and the rest of the UK, techno-economic modelling and analysis of low-carbon heat scenarios with specific focus on NI is required.

**Optimal planning:** It is necessary to maximise energy transition potential and avoid unnecessary competition between low carbon technologies through optimal planning. For example, district heating (DH) schemes would maximise their potential in highly densely populated areas. Other solutions could potentially enter the area before necessary infrastructure for DH is built or successful agreements with consumers are signed. Heat maps based on available resources and demand estimations could help with the appropriate allocation of technologies based on spatial needs. Denmark has developed maps for heat pumps and district heating and restricted installations of certain technologies.<sup>75,76</sup> SEAI developed a heat map for the ROI which describes the spatial distribution of heat demand based on building type and area, heating fuel, current and planned energy efficiency measures.<sup>77</sup> The District Heat Association of Republic of Ireland has extended its study and included Northern Ireland in their Heat Atlas suggesting areas potentially suitable for district heat schemes.<sup>78</sup>

**Unlocking demand side flexibility - Providing smart tariffs and load controls (network specific):** Smart energy consumption will be useful in heat decarbonization to optimize new investments and reduce limitations of existing infrastructure. Therefore, smart energy control tools such as smart meters and smart tariffs, active load controls, etc. can significantly help in the heat decarbonization agenda by providing demand flexibility. Some experts suggested that implementation of regional smart tariffs to account for network-specific limitations of distribution networks in Northern Ireland will be required.

<sup>73</sup> Electricity, heat, transport and water sectors are mainly discussed during project workshops

<sup>74</sup> Strbac et al (2018) Analysis of Alternative UK Heat Decarbonisation Pathways.

<sup>75</sup> Hanna, Parrish, & Gross (2016) Best practice in heat decarbonisation policy: A review of the international experience of policies to promote the uptake of low-carbon heat supply.

<sup>76</sup> Lund & Persson (2016) Mapping of potential heat sources for heat pumps for district heating in Denmark.

<sup>77</sup> Sustainable Energy Authority of Ireland (SEAI) (2017) Heat Demand Map.

<sup>78</sup> IRDEA (2018) Heat Atlas

**Energy storage technologies to help managing renewable energy variability and network constraints:** Significant wind resources and a growing contribution of solar PV generation will require energy storage technologies to manage variability of renewable resources and support security of supply. To maximise energy storage potential, removal of regulatory barriers for its implementation and efficient operation should be provided.

**Potential Climate Change impact and infrastructural changes:** Climate Change is already causing an impact worldwide significantly affecting people, their homes and existing infrastructure. Potential implications for Northern Ireland indicate a need for efficient planning involving additional needs for infrastructural systems to be able to accommodate flooding, higher summer (air conditioning) demand, and any other changes due to a changing climate. Some potential solutions include system decentralisation for the areas potentially affected by flooding, as well as requirements to install renewable resources with energy storage for buildings with air conditioning. As stated before, effective planning accounting for future risks of weather impacts as well as collaboration with wide range of stakeholders are required across society to mitigate those changes and prepare infrastructure for future needs.

Among technologies stakeholders would most likely install in their house are significant improvements to energy efficiency and heat pumps. Once again, implementing high energy-efficiency standards seems to be an important first step towards heat decarbonisation (see Figure 9). Other technologies, such as biomethane and hydrogen supplied heating, district heating and biomass boilers should have their role in the future heat sector as well.

Finally, stakeholders believe that Northern Ireland could become a leader in heat decarbonisation in UK primarily if a robust policy of pro- decarbonisation was developed, a market for low-carbon heat was encouraged and there is more collaborative research from industry, academia, end-users and policy makers on low-carbon heating. Leadership, financial support programmes, consumer motivation and education support are required as well. Optimal, non-biased infrastructural planning across all sectors is also one of the key factors, which can lead NI and guarantee its success in heat decarbonisation.

Region-specific heat maps indicating optimal technological solutions and infrastructural planning, underpinned by robust policy are among potential solutions to achieve synergy among sectors in NI and drive its energy transition.

## 1.6: Conclusions

A wide range of opportunities and barriers have been identified through project workshops and associated presentations, panel and round-table discussions. The NI heat sector remains highly carbon intensive in 2020. Challenging heat decarbonisation requires a joined-up approach across a wide range of government bodies, industry, charitable and consumer organisations and every citizen in NI.

The consensus at the project's final workshop was that NI's heat decarbonisation would be achieved by a combination of different technological solutions (see Figure 8). However, building regulations for new houses together with energy efficiency targets and appropriate retrofit programmes for existing domestic stock, must be enforced to the highest technologically possible and economically viable standards, before these solutions are explored.

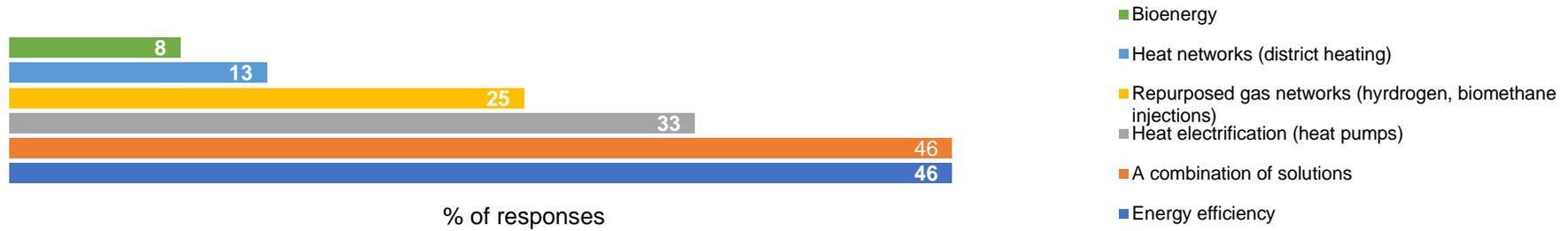


Figure 8. Technologies which will have a major role in NI heat decarbonisation

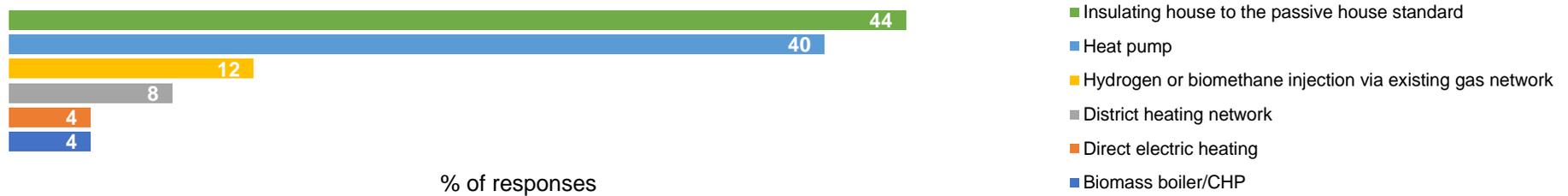


Figure 9. Low carbon heating technology the participants would most likely install in their house

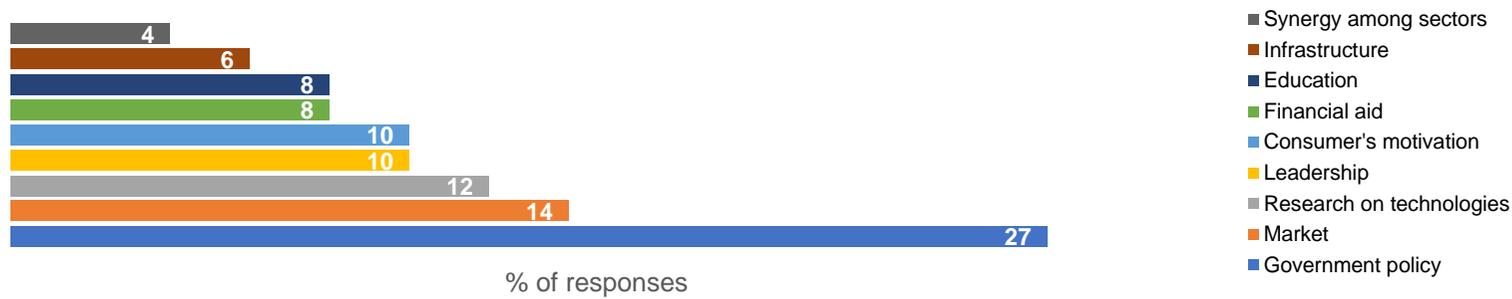


Figure 10. Ways through which NI could become a leader in heat decarbonisation

## Chapter II: Expert and consumer perceptions towards heat decarbonisation and low carbon heat technologies in Northern Ireland

Initial outcomes from the project workshops revealed a wide range of barriers, as well as visions and strategies for NI heat sector decarbonisation. Different groups of stakeholders, similar to other regions, support different technological pathways for heat decarbonisation, among which the most popular are heat electrification, hydrogen and hybrid routes<sup>79</sup>.

It is, however, important to understand whether there is any agreement in visions of these groups of stakeholders concerning other aspects of heat decarbonisation, such as the role of government and consumers, innovative business models and the role of intermediaries, how to protect vulnerable consumers and reduce fuel poverty in Northern Ireland. Perceptions towards strict policy measures or alternatives to them supporting programmes to drive transition in the heat sector. It is also vital to investigate if specified technological routes are foreseen as exclusive by particular groups of experts or if they accept or support a combination of solutions.

As a result, a study measuring expert perception on heat decarbonisation in NI has been conducted. The Q-methodology was used to investigate energy professionals' perceptions of heat decarbonisation in Northern Ireland. Heat decarbonisation will be highly disruptive to all consumers and their participation will be required to succeed in heat decarbonisation. Therefore, a pilot

study identifying consumers' perceptions towards heat decarbonisation and adoption of low carbon technologies was also conducted within the project timeframes.

The Q-methodology is a widely applied research method for the investigation of social perceptions, visions or narratives and very often applied in built environment studies<sup>80</sup>, and studies in relation to environmental policy design and planning<sup>81</sup>. It combines the strengths of both qualitative and quantitative research methods and aims to investigate social perspectives through identified patterns within individuals' narratives. From a high-level perspective, the main idea of the Q-methodology is to gather a concourse of statements representing a wide range of visions within the subject area. Subsequently, participants are asked to prioritise developed statements via a grid representing forced quasi-normal distribution. Individual narratives with similar visions are analysed and grouped by implementing a factor analysis. Resulting factors represent perceptions in the subject area. The strength of the Q-methodology is that the resulting perceptions are achieved by grouping visions or narratives among the examined cohorts rather than by investigating opinions within already established socio-demographic groups as used in traditional research methods.

The Q-methodology research instructions and previously performed projects suggest that 40 to 60 respondents are typically required to perform a study. This range has been determined based on the observation that data

<sup>79</sup> Strbac G., Pudjianto D., Sansom R et.al (2018) Analysis of Alternative UK Heat Decarbonisation Pathways. For the Committee on Climate Change

<sup>80</sup> Kerr, N., Gouldson, A. & Barrett, J. (2018) Holistic narratives of the renovation experience: Using Q-methodology to improve understanding of domestic energy retrofits in the United Kingdom.

<sup>81</sup> Chang, R., Cao, Y., Lu, Y. and Shabunko, V. (2019) Should BIPV technologies be empowered by innovation policy mix to facilitate energy transitions? - Revealing stakeholders' different perspectives using Q methodology.

from additional respondents would not create any differences in the results. A variety of respondents rather than their quantity play a major role in the perception analysis with Q-methodology.

The target number of respondents was 40 participants for both expert and consumer studies. 42 experts and 44 consumers participated in the studies. Two sets of project statements have been created for this study. The expert concourse was established by using statements reflecting major barriers and opportunities discussed during project workshops and indicated by leading literature.

The consumer concourse was mainly established via project workshops and reflects experts' visions about consumers and their expected roles in heat decarbonisation in Northern Ireland. A wide range of statements reflects attitudes, motivations and beliefs about consumer impact on the environment and the potential adoption of low carbon heat technologies. They also reflect actions that consumers would potentially accept or reject designed from discussions with leading experts during project workshops. The list of all statements is presented in Appendix B.

Experts and consumers have been asked to prioritise all given statements into the Q-sort grid (figure 11), by putting statements that they agree or believe are more important into the right part of the grid and those, they disagree with into the left part of the grid. Statements with a neutral attitude must be allocated into the central part of the grid. Factor analysis was applied to analyse the results of both expert and consumer studies by using KADE software, dedicated for Q-methodology studies tool<sup>82</sup>. The principal component analysis was used for factor extractions, leading to the identification of six factors<sup>83</sup> in the expert study and five factors in the consumer study. The varimax rotation has been applied to extracted factors to maximise the variance or, in other words, to increase the squared correlation between loadings (or individual narratives) in extracted factors. The following criteria were applied to determine resulting factors: minimum of three loadings per factor and loadings with the majority of common variance at  $p < 0.01$ <sup>84</sup> were selected to represent resulting factors.

## 2.1: Experts' perceptions towards heat decarbonisation in NI

The six factors, identified in the expert study, account for 56% of variance<sup>85</sup>. Factor descriptions are presented below and are based on the statements with the highest and lowest priorities in identified composite Q-sorts, as well as on distinguished statements at  $p < 0.05$  and  $p < 0.01$ . A full list of statements defining resulting factors is presented in Appendix C.

Broadly speaking, six factors represent six categories of perceptions identified among experts for heat decarbonisation in NI. Attitudes, motivations and beliefs all contribute to the 6 categories of expert views, and these are outlined below and on Figure 12.

**Perception I – “Barriers-focused”:** The first strategic vision for heat decarbonisation indicates that high capital costs of low carbon technologies is the major barrier for heat decarbonisation in NI. The experts in this group have very often opinions opposite to all other identified perceptions in this study. They believe that NI can become a leader in heat decarbonisation. There is a limited or less important role for community and district heating schemes, intermediaries, alternative financial models, and so on. Damaged consumer trust in renewable heat technologies is the challenge for heat decarbonisation. Local demonstration projects are not important or needed in Northern Ireland. Alternative business models and aggregators would have a limited role in energy transitions.

This factor suggests that the best strategy for heat decarbonisation is strong government leadership with the support focused on one technological option. **Experts representing this vision are from the government or gas industry.** Therefore, gas heating and its future potential substitutes, such as biomethane and hydrogen can be assumed as a preferred technological solution for the future heat supply in NI. This strategy has the lowest

<sup>82</sup> Banasick, S (2019) KADE: A Desktop Application for Q-Methodology

<sup>83</sup> Factor is a technical term used in Q-methodology to represent a group of participants sharing the vision

<sup>84</sup> p-value represents probability of the results rejecting null hypothesis. A p-value less than 0.01 under normal circumstances mean that there is substantial evidence against the null hypothesis.

<sup>85</sup> Variance explanation of at least 35 % is considered satisfactory in factor analysis and studies applying Q-methodology.





Figure 12. Expert perception toward heat decarbonisation identified in the project

support from the experts who participated in the study.

#### **Perception II – “More action is needed”:**

The second expert vision highlights the importance of stricter building regulations for new houses. Experts supporting this strategy believe that NI consumers will primarily be driven by financial incentives, therefore, the government needs to introduce a new financial scheme for low carbon heating support, as the old RHI scheme was suspended. Local demonstration projects, the introduction of dynamic tariffs and support for community schemes combined with energy storage are the key measures to progress with heat decarbonisation under this strategy. This strategic vision also supports strict measures, such as forbidding new houses to connect to fossil fuel heating. **Representatives from government departments and academia mainly contribute to this factor.**

#### **Perception III – “Community and greater cooperation”:**

The third strategy indicates the need for greater cooperation, community and district heating schemes to lead heat decarbonisation. Stakeholders from this group believe that one of the main barriers to heat decarbonisation in NI is that regulation models are not fit for their purpose.

**Representatives from the gas industry and government departments are the main supporters of this strategy.** They also believe that one of the immediate steps required to progress heat decarbonisation in NI is the introduction of a new regulatory framework supporting the biomethane injection into the gas grid in Northern Ireland. The transitional period should encourage technologies with the highest immediate potential (natural gas and energy efficiency measures) to accumulate resources and facilitate energy transition in the future. Supporters of this vision believe that a range of technological resources is needed to deliver heat decarbonisation in NI.

**Perception IV – “Market-driven”:** The fourth strategic vision is very similar to the second narrative (strategic vision II) – support for strict building regulations, the necessity for demonstration projects and financial support for consumers in NI. However, experts in this group also strongly encourage the necessity for retrofit programmes. This strategy also supports the implementation of alternative and

novel business models, aggregators and intermediaries. Experts in this group are against policy forbidding connection of new houses to fossil fuel heating. They believe that support, not restrictions, should work in a democratic society. They are also against the idea of greater cooperation or introduction of a Heat Forum in NI. They believe that central government support and the independent body responsible for Climate Change in Northern Ireland is needed to drive heat decarbonisation in NI. **Representatives from government/public bodies, consultant organisations and academia support this vision.**

#### **Perception V - “Public sector leadership”:**

The fifth expert vision suggests that heat decarbonisation should be applied through the leading role of commercial, industrial and public sectors. Stakeholders from this group believe that consumers have limited knowledge and capacities to drive heat decarbonisation, at least in the early stages of heat decarbonisation. A top-down approach should be applied to consumers in NI, but the government needs to lead consumer education about low carbon heat technologies. Demonstrations through public buildings would also help to build capacity and change consumer perceptions of low carbon heat technologies. Aggregators should unlock financial opportunities for consumers. Better cooperation among stakeholders is the key factor of energy transition too.

**Representatives from a wide range of organisations, including government organisations, charities, as well as industry and consultancy firms support this vision.**

**Perception VI – “Consumer-focused”:** This vision put consumers at the heart of the heat energy strategy. This strategic vision supports requirements for education and new opportunities for consumers. Experts from this group believe in the necessity for strict policy measures, such as forbidding fossil fuel heating in new houses. Protection of vulnerable consumers is required as current support is not adequate. Targeted assistance is one of the potential options to protect vulnerable households. This vision is strongly against a top-down approach for consumers. It supports the introduction of an independent body responsible for climate change in NI. It highlights that individual responsibility must drive the energy transition. **Representatives from a wide range of organisations,**

**including charities, academia, as well as industry and consultancy firms, representing renewable heat technologies, support this vision.**

One of the main benefits of this study, apart from identified strategic visions, is the characterisation of the degree of polarisation and consensus among these visions. The insights presented could serve future heat policy planning and design in Northern Ireland by representing common visions and steps required to progress with heat decarbonisation. There is a great consensus concerning the range of heat decarbonisation statements among all groups of stakeholders. Thus, two statements were put into the categories of most important/agree or most disagree/least important by the majority of participants contributing towards a significant level of correlations between the extracted factors. They are as follows.

**The lack of long-term policy in NI is the major barrier for heat decarbonisation.**

The current strategic energy framework is the main energy policy document setting NI strategy up to 2020. A new strategy is under development at the time of writing. Stakeholders believe that the absence of a new strategy is one of the major barriers to heat decarbonisation in NI. Some quotes from the discussions and feedback received indicate:

*"Lack of policy in NI is leading to a fragmented approach to decarbonisation. If the policy issue was addressed it would allow parties to work together and take a more coordinated approach, which would ultimately be more effective."*

*"Need over-arching policy, joined-up approach to determine how targets are best achieved."*

**Significant renewable resources (especially wind, agricultural waste, etc.) are the major opportunity for heat decarbonisation in Northern Ireland.**

Northern Ireland has one of the best wind resources in the world.<sup>86</sup> Agriculture contributes circa 28% of CO<sub>2</sub> emissions in the province.<sup>87</sup> Significant wind resources can supply renewable energy for electrified heat in NI households or be used for green hydrogen

production. Agricultural waste can be utilised for biomethane or hydrogen production.

Vision I 'Barriers-focused' represents views being often polar opposite to the views supported by all other visions, whilst a great level of consensus is observed for the strategic visions II – VI regarding a wide range of statements, represented in Table 3.

Therefore, almost all stakeholders believe that a combination of technologies will be needed to decarbonise the heat sector. Local demonstration projects and community schemes, which are almost absent in Northern Ireland are of vital importance as well. Trust challenges of previously unsuccessful schemes exist but should be overcome with the new projects and demonstrations that have transparent and independent design, implementation and analysis of social, technical and economic performance data. Consumers' trust should be then recovered. Almost all experts indicate the urgent need for stricter building regulations. Visions II 'More Action is needed' and IV 'Market-driven' visions give the highest priority to new building regulations.

During the discussions at the workshops, several participants argued that either public buildings or domestic stock would be too expensive to retrofit due to the complex and non-uniform designs of public buildings and significant retrofit costs needed when considering all the houses of the domestic stock. Results of the Q-sort analysis indicate that, in general, the majority of stakeholders disagree with these statements. Only Strategic vision I 'Barriers focused' believes that these challenges will be impossible to overcome (see Table 4). Discussions, following project workshops also highlight requirements for stricter energy efficiency standards for rented accommodation in Northern Ireland.

Identified perceptions also demonstrate polarised visions regarding several statements, in particular: strict policy measures, such as carbon tax or restriction to connect new houses to fossil fuel heating (see Table 5).

Vision II 'More action is needed' supports strict measures in the transition towards decarbonised heating in NI, reflecting in both introductions of green tax and restricting the

<sup>86</sup> Department for the Economy (2020) Wind Map for Northern Ireland.

<sup>87</sup> Committee for Climate Change (2019) Reducing Emissions in Northern Ireland.

**Table 2.** Consensus among all strategic visions identified in an expert perception study

N	Statement	I Barriers focused	II More action is needed	III Community/ Co-operation	IV Market-driven	V Public sector leadership	VI Consumer - focused
1	The lack of a long-term policy is the main barrier to heat decarbonisation in NI	3*	4	4	4	4	4
2	Significant renewable resources (in particular wind, agricultural waste, etc.) is the major opportunity for heat decarbonisation in Northern Ireland	4	2	3	4	2	2

\*The most important factors have weighting factor +4, whilst the least important has weighting factor -4. E.g. We can see that the first group of stakeholders – ‘barriers-focused’ - are slightly less supportive of the notion that long-term policy is the main barrier to heat decarbonisation. However, this statement did receive overall a high level of support across all stakeholder groups /strategic vision and had the highest (green) level of agreement of all the statements in the study.

**Table 3.** Consensus among strategic visions II – VI and their disagreement with the strategic vision I

N	Statement	I Barriers focused	II More action is needed	III Community/ Co-operation	IV Market-driven	V Public sector leadership	VI Consumer focused
8	There is no silver bullet for heat decarbonisation in NI; heat decarbonisation will involve a combination of low carbon technologies and strategies taking into account local resources	-1	3	4	3	2	3
20	Local demonstration projects are needed to encourage positive consumer behavioural change towards low-carbon heating systems	-3	3	2	3	3	2
9	Trust challenges is the main barrier to heat decarbonisation in NI	2	-2	-4	-1	-4	-2
27	Community energy systems do not have great potential in Northern Ireland	2	-4	-4	-1	-1	-1
24	Setting dynamic tariffs would not significantly facilitate smart energy consumption in NI	3	-4	-3	0	-3	0
35	New houses should be built to the highest possible energy-efficiency standards	0	4	2	4	3	3

**Table 4.** Strategic visions in relation to energy efficiency policies

N	Statement	I Barriers focused	II More action is needed	III Community/ Co-operation	IV Market-driven	V Public sector leadership	VI Consumer - focused
35	New houses should be built to the highest possible energy-efficiency standards	0	4	2	4	3	3
34	Retrofit of old houses is too expensive, therefore more likely it would be impossible to retrofit most of the houses in NI up to the EPC rating C or higher	1	-1	-1	-2	-2	0
36	Typically, non-domestic buildings are more complex than domestic buildings and therefore would be too expensive to retrofit	-3	-3	-1	-1	-4	-4

**Table 5.** Strategic visions in relation to strict policy measures for heat decarbonisation

N	Statement	I Barriers focused	II More action is needed	III Community/coo peration	IV Market-driven	V Public sector leadership	VI Consumer- focused
32	Mitigatory measures such as green tax should be introduced in NI to help phase out less efficient fossil fuel technologies	0	1	0	0	0	0
33	High carbon taxes would discourage certain consumers such as industries	-2	0	-1	-2	-3	-2
43	More strict measures are needed to deliver low carbon agenda, such as forbidding new houses from connecting to the gas or oil heating	-4	3	-2	-4	0	4

connection of new houses to fossil fuel heating. Vision VI 'Consumer-focused' highly supports only the latter statement and gives this statement the highest priority. Strategic visions I 'Barriers-focused' and IV 'Market-driven' are strongly against this measure, which can be logically explained by the fact that participants from gas industry support these factors.

Discussions following Q-sorts during the project workshop revealed concerns that green taxes could be counterproductive in tackling fuel poverty or drive businesses out of NI. Therefore, most factors displayed neutral position towards this statement. The level of fuel poverty in the province is very high and correlates with the oil prices<sup>88</sup> as oil supplies heating to 68% of households. It was discussed that general taxation as opposed to green tax can potentially be a solution. However, general taxation is a reserved policy of the central government and therefore, beyond the responsibility of NI energy policy.

An example of the discussions following Q-sorts expressing concerns regarding the impact on business is quoted below:

*“High carbon taxes might risk driving industry out of NI. This would be counter-intuitive to what is required i.e. incentives to support business and consumers to take appropriate action to decarbonise”*

Strategic visions II 'More action is needed', III 'Community and greater cooperation' and IV 'Market-driven' disagree, whilst 'Consumer-focused' vision strongly disagrees that the current measures tackling fuel poverty in NI are optimal, even considering the current political and financial situations<sup>89</sup> (see Table 6). The Consumer-focused strategy VI highly supports targeted assistance for vulnerable households. Strategies I 'Barriers-focused', II 'More action is needed' and V 'Public sector leadership' consider this as a potentially important option, whilst Strategy IV 'Market-driven' strongly disagrees with such an approach. Strategy III 'Community and greater cooperation' is neutral towards it.

A wide range of views dominates in identified strategies concerning new opportunities for

consumers and the government role to support them (see Table 7).

There is currently very limited support and opportunities for consumers in Northern Ireland to participate in the market or drive heat decarbonisation. There is an absence of time of use or dynamic tariffs, except for the Economy 7 tariffs. Smart meter rollout has not been implemented in NI to date and aggregators for domestic customers are also absent.

Despite this, there are contradictory visions regarding whether new opportunities for consumers should be introduced and the importance of policy instruments and regulatory measures supporting consumer access to the market. In general, NI experts do not consider the lack of consumer opportunities in the region as a major barrier to heat decarbonisation.

Strategic visions II "More action is needed", III "Community/cooperation" and V "Public sector leadership" are highly supportive of establishing dynamic tariffs. Strategic visions II to VI are generally quite supportive for aggregators and third parties providing support for consumers and encouraging energy transition. Nevertheless, they are less supportive or neutral towards risk-sharing models with the public sector.

The strategic vision I or "Barriers-focused" vision is opposed to the necessity for dynamic tariffs, alternative business models or aggregators to support heat decarbonisation in the province. Contrarily, strategic vision IV or "Market-driven" vision supports all alternative or novel business models indicating higher support than among all other visions.

Strategies I – IV, suggest that government financial support is required (statement 28). All factors strongly disagree that institutional investors will have limited interest in NI's low carbon heat projects. This means that NI experts believe private investments can play a vital role in heat decarbonisation. However, a conducive environment should be created to encourage institutional investors to consider NI projects.

The identified strategic visions have quite polarised views for consumer education and

<sup>88</sup> Walker, R., McKenzie, P., Liddell, C. and Morris, C., 2015. Spatial analysis of residential fuel prices: Local variations in the price of heating oil in Northern Ireland, Applied Geography.

<sup>89</sup> Northern Ireland was functioning without a devolved government for almost three years during the project timelines

**Table 6.** Strategic visions in relation to fuel poverty policy in NI

N	Statement	I Barriers focused	II More action is needed	III Community/ cooperation	IV Market-driven	V Public sector leadership	VI Consumer- focused
39	Measures such as targeted assistance and unlocking consumer flexibility can protect fuel poor and vulnerable consumers.	1	1	0	-3	1	3
31	Current programmes for vulnerable households is the only possible way to assist in the current political and financial situation	-1	-2	-2	-2	-1	-3

**Table 7.** Strategic visions in relation to new opportunities for consumers and potential financial support

N	Statement	I Barriers focused	II More action is needed	III Community/ cooperation	IV Market-driven	V Public sector leadership	VI Consumer- focused
16	Lack of opportunities for consumers to participate in the electricity market is the main barrier to heat decarbonisation in NI	-1	-2	-1	-1	-1	-2
24	Setting dynamic tariffs would not help in unlocking consumer flexibility in NI	3	-4	-3	0	-3	0
23	Aggregators would help consumers access significant financial benefits of using low-carbon systems	-3	0	1	2	3	2
25	Alternative business models such as the provision of low-carbon heating technologies through third parties can encourage energy transition	-2	1	2	2	1	1
26	Alternative business/ownership models such as risk-sharing in public-private partnerships can help prospective owners accept the risk of investing in low-carbon technologies	-3	0	1	2	0	0
28	The government should provide financial support to encourage private investments into low-carbon technologies	2	2	1	1	0	0
30	Institutional investors, such as life assurance companies or pension funds, would have limited interest in the project in Northern Ireland even if appropriate government support is guaranteed	-4	-3	-3	-3	-1	-3

engagement programmes (see Table 8). Visions I, II, V and VI support the need of the government to lead consumer education about low carbon heat technologies, whilst only visions I 'Barriers-focused' and V 'Public sector leadership' believe that the lack of consumers understanding is one of the main barriers to heat decarbonisation. One of the quotes from the discussions state:

***“NI consumers have enough understanding of low carbon heating. Therefore, no need for local demonstrations or education.”***

Strategic visions II 'More action is needed' and V 'Public sector leadership' agree that lack of knowledge regarding current heating systems and their impact on the environment requires a top-down approach for consumers, whilst all other visions disagree with this statement. Erroneous perceptions regarding low carbon heat technologies even among stakeholders are identified during workshops. Still, a majority of the respondents disagree with this statement or believe this barrier is not important.

Even though most experts indicate that NI consumers will only be interested in financial motivation during project workshop, in general, all stakeholders agree that non-financial rewards and motivation should have a great role in the energy transition towards a decarbonised system in the future.

The greatest levels of disagreement are observed among identified narratives about the leadership of heat policy in Northern Ireland and a requirement for greater cooperation among stakeholders, infrastructural investments and the role of energy storage systems. Perception towards requirements for more strict policy measures mentioned earlier is the most significant statement of disagreement<sup>90</sup>.

Thus, strategic visions I, III, IV and VI are very supportive in establishing an independent body responsible for the implementation of Climate Change Policy in Northern Ireland. Strategic vision V 'Public sector leadership', however, is strongly against it believing that greater cooperation between already established bodies and stakeholder groups is more important. Greater cooperation is also supported by strategic visions I 'Barriers-

focused', III 'Community and greater cooperation' and VI 'Consumer-focused'.

Stakeholders supporting strategic visions I 'Barriers-focused' and III 'Community and greater cooperation' believe that NI can become a leader in heat decarbonisation. It should be noted that experts from the gas industry and government bodies are the major supporters of this optimistic statement.

Visions II 'More action is needed' and IV 'Market-driven' highlight that significant investments in infrastructure are the main barriers for heat decarbonisation in Northern Ireland. Majority of academic, government and industry experts from electricity transition/distribution companies are representatives of these factors and supporters of this statement. An example of a quote from a representative of Vision I 'Barriers-focused', strongly opposed to this statement, reflects:

***“Significant investment in infrastructure is not the main barrier, existing infrastructure such as gas network can be repurposed i.e. green the gas”***

Whilst strategic visions I-III 'Barriers-focused', 'More action is needed' and 'Community and greater cooperation', strongly support energy storage technologies in the future decarbonised heat sector, strategies IV-VI have neutral visions towards energy storage systems. Again, some quotes from the discussions state:

***“Energy storage technologies have a limited role in the energy transition in NI. Heat storage has a huge role to play”***

***“Energy storage is key to removing peaks and driving down overall costs of decarbonisation to end consumers”***

<sup>90</sup> It has a z-score variance of 1.94.

**Table 8.** Strategic visions in relation to consumer education and engagement programmes

<b>N</b>	<b>Statement</b>	<b>I Barriers focused</b>	<b>II More action is needed</b>	<b>III Community/ Co-operation</b>	<b>IV Market-driven</b>	<b>V Public sector leadership</b>	<b>VI Consumer- focused</b>
19	The government should support the provision of education and engagement programmes for low-carbon heating systems	2	1	0	-2	3	1
13	The erroneous perception and knowledge gaps about heating technologies among a wide range of stakeholders is one of the main barriers to heat decarbonisation in NI	0	-1	1	0	-2	-2
22	Education of stakeholders about low-carbon heating technologies should also be encouraged	0	0	0	0	-1	1
5	Individual leadership and responsibility must drive heat decarbonisation in Northern Ireland in the current political situation	2	-1	-2	1	-1	3
18	Lack of customer understanding of heating usage and its impact is one of the main barriers to heat decarbonisation in NI	1	-2	-3	0	1	-4
17	NI consumers have limited understanding and interest in low carbon heating, therefore, a top-down model for heat decarbonisation should be applied.	-1	1	-2	1	2	-3
37	Non-financial incentives such as climate rewards, energy-efficiency awards etc would not have a significant role in consumer motivation to accept low-carbon heating systems and/or smart energy behaviour	-2	-3	-1	-1	-3	-1

Table 9. Major disagreements in the identified strategic visions

N	Statement	I Barriers focused	II More action is needed	III Community/ Co-operation	IV Market-driven	V Public sector leadership	VI Consumer - focused
3	An independent body responsible for the implementation of Climate Change Policy at the local level similar to Scottish Committee on Climate Change is required to lead the energy transition in Northern Ireland	3	0	2	3	-3	4
41	A central heat decarbonisation forum for stakeholders would support heat decarbonisation goals	1	-3	3	-3	4	1
1	Northern Ireland can become a UK leader of heat decarbonisation	4	-1	3	-1	-4	0
43	More strict measures are needed to deliver low carbon agenda, such as forbidding new houses connecting to the gas or oil heating	-4	3	-2	-4	0	4
12	The need for significant investments in infrastructure is the main barrier to heat decarbonisation in NI	-2	2	0	2	-2	-3
15	Energy storage technologies have a limited role in the energy transition in Northern Ireland	-4	-4	-4	1	1	0

## 2.2: Consumers' perceptions towards heat decarbonisation in NI

There is a very limited number of studies exploring consumer motivation and visions towards heat decarbonisation in Northern Ireland. Two visions dominate in literature and among stakeholders' views about consumers' role in energy transition. Consumers are divided into active consumers, which are very often are also prosumers and 'others' or ordinary consumers. Prosumers are believed to be active participants who are willing to or have already installed low carbon technologies. They also actively participate or are willing to participate in the community trading schemes. Ordinary consumers adopt a passive role in the energy transition; they normally do not purchase low carbon/renewable energy technologies and potentially are less motivated for participation in community schemes.

Some concerns were also highlighted during project workshops because of the previously unsuccessful schemes such as a district heating scheme in Lisburn or RHI scheme. A negative experience can potentially damage consumer trust and make it difficult to motivate consumers for the installation of low carbon heat technologies in the future.

Moreover, several studies indicate the gap between energy policy and consumer engagement; this gap has caused the failure of decarbonisation targets and established programmes to reach their goals. The best example concerning heat decarbonisation is significantly lower uptake of domestic low carbon technologies under RHI programme in GB than was initially planned by this policy measure.<sup>91</sup>

Therefore, the pilot study aims at establishing heterogeneous visions of consumer perceptions towards heat decarbonisation in Northern Ireland. It also aims to investigate if trust issues have a significant impact on current views towards low carbon heat technologies and policy associated with them.

Six consumer focus groups were organised during the project. Participants with different demographic profiles participated in the study. These profiles vary by age, gender, education level, homeownership status, type of accommodation, number of occupants and indicated level of environmental concerns. Focus groups were conducted in the Ulster University and community centres; participants included staff, students, professionals and community members.

Similar to the expert perception analysis, 43 statements were established based on experts' visions of actions required from consumers to decarbonise the heat sector. Statements were based on outcomes from project workshops or local expert visions and key literature sources.<sup>92, 93, 94</sup>

Five consumer perception groups were established during this study. These five groups describe 56% of the variance among consumer response and could be described as follows (see Figure 13). The consumer perceptions description is based on a synthesis of the strongly agreed and disagreed statements, statements which have higher or lower ranks compared to other factors and distinguishing statements<sup>95</sup>. A full list of these statements is presented in Appendix D.

### Perception I – Environmentalists:

Environmentalists are highly motivated to reduce the carbon emissions of their households. They believe that environmental concerns are the joint responsibility of government, industry and every citizen and are the most important factors of heat decarbonisation. They agree to observe smart energy behaviour and a wide range of measures if it leads to environmental benefits. They are also more interested in minimising their impact on the environment over financial gains. They look positively towards innovative business models but feel that they have limited knowledge about them. Some of the participants supporting this vision have already installed low carbon technologies in their homes. Many others would agree to invest in low carbon heat technologies but require financial support to do this.

<sup>91</sup> M. Lockwood, C. Kuzemko, C. Mitchell, R. Hoggett (2017) Historical institutionalism and the politics of sustainable energy transitions: a research agenda.

<sup>92</sup> Committee for Climate Change (2019) Reducing Emissions in Northern Ireland.

<sup>93</sup> DETI (2010) Energy – A Strategic Framework for Northern Ireland

<sup>94</sup> M. Chaudry, M. Abeysekera, S. Hamid Reza Hosseini, N. Jenkins, J. Wu. Uncertainties in decarbonising heat in the UK, Volume 87, December 2015, Pages 623-640

<sup>95</sup> Distinguishing statements at  $p < 0.05$  have been selected to define consumer perceptions

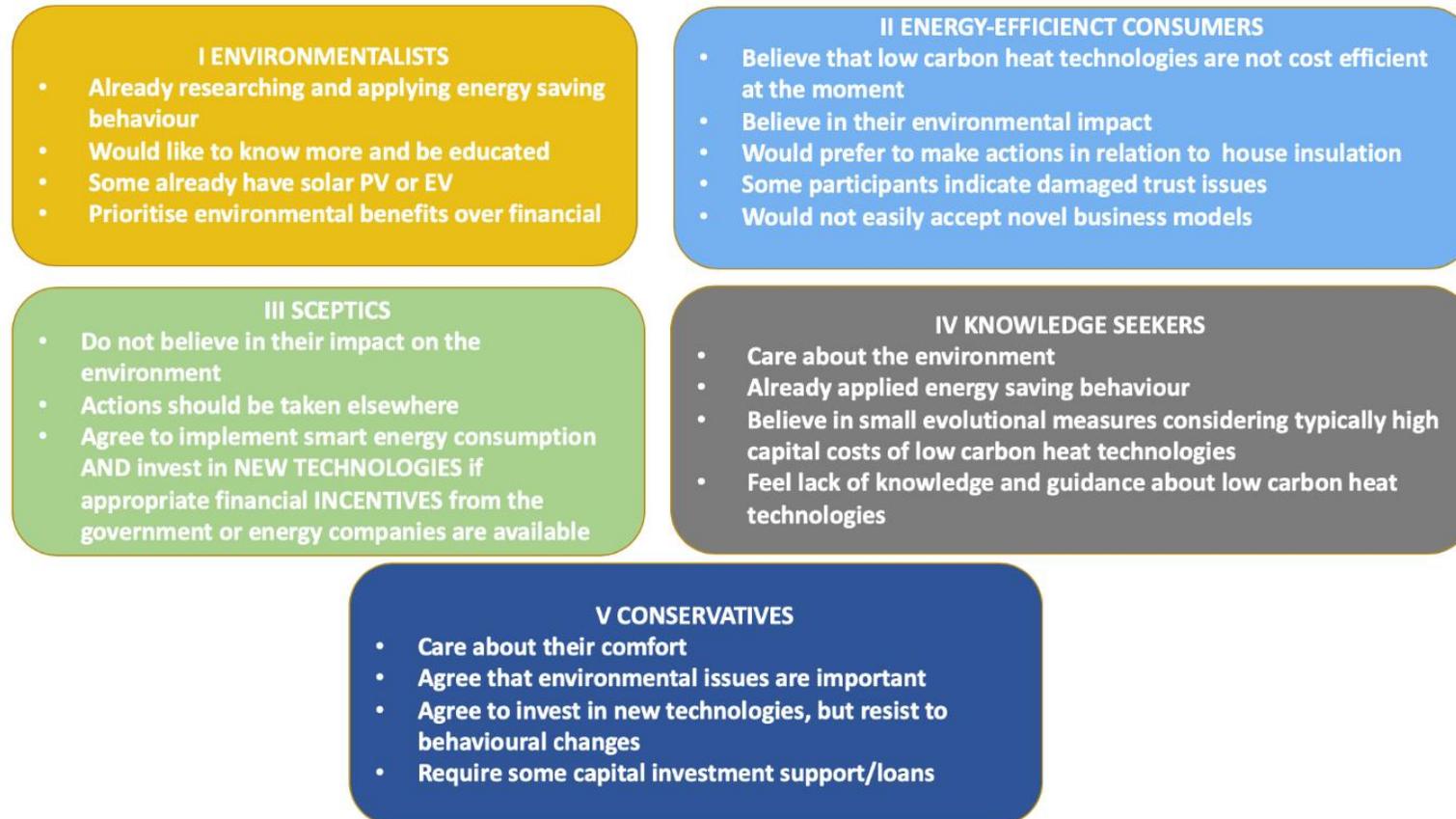


Figure 13. Consumer perceptions towards heat decarbonisation in Northern Ireland

**Perception II – Energy-efficient Consumers:**

The second group indicates the necessity of the government to financially support the heat decarbonisation agenda as low carbon technologies are not cost-efficient at the moment. Consumers with this perception, however, believe that increasing the energy efficiency performance of their houses is the strategy to support energy transition. They also value the comfortable temperature of their homes. They would prefer to be the sole owner of their household heating system and are not supportive of alternative business models in 2020. Some participants explain this as being due to concerns associated with past failures in terms of heat decarbonisation in Northern Ireland. Consumers renting accommodation are often part of this group. Discussions following Q-sorts indicate that consumers would like to see a stricter policy regarding energy efficiency standards for rented accommodation in NI.

**Perception III – Sceptics:** Sceptics are mostly not motivated to reduce carbon emissions of their households and have never explored the potential of installing low carbon technologies in their houses. They admit that their houses are not very well insulated, but they also believe that a comfortable indoor temperature is not a very important factor for their wellbeing. An example of one of the statements during the discussions following Q-sorts:

*“If I feel cold, I would wear a jumper rather than switch on the heating in my house. This is how we learn to behave from our childhood here, in Northern Ireland. Not sure if a new generation would behave in the same way”*

In some cases, the sceptical attitude towards the impact on the environment and willingness to adopt more active measures can be explained by low education levels of consumers supporting this vision. A quote from the workshop states:

*“My house is adequately insulated already. We insulated our roof and have a boiler jacket”*

Participants in this group, however, would potentially agree to implement a wide range of

smart energy behaviour, but only if they get financial support.

**Perception IV - Knowledge-seekers:** This group indicates a lack of knowledge and understanding of the current heat decarbonisation challenge and/or potential solutions to solve it. They also argue that insignificant uptake of low carbon heat technologies can be explained by there being insufficient knowledge among consumers about these technologies. Supporters of this vision are highly motivated to reduce their carbon footprint, but sometimes feel they have a lack of knowledge on how to do it. They would agree to implement some energy-saving behaviour strategies or insulate their houses better. They also suggest that if they agree to install low carbon heating technologies, they must be easily operational and controllable. Discussions following focus groups indicate that lack of knowledge among consumers has led to actions opposite to the energy-saving behaviours needed for the energy transition, for example:

*“I specifically do not use a dishwasher at home to save water and the environment”*

**Perception V – Conservatives:** The conservatives prioritise their own comfort over environmental issues. Participants belonging to this group would not easily agree to compromise their comfort or set the household thermostat to keep an internal temperature of 19°C or lower. They believe that a comfortable indoor temperature is the key factor for their wellbeing. They do not support energy-saving or smart behaviour and would potentially refuse to shift their appliances to different timeframes. They believe, however, that implementation of low carbon technologies to support their comfort is the way forward in the energy transition. They believe they would be more motivated to install low carbon heat technologies if the payback period would be adequate or if zero interest loans are available.

**Table 10.** Consensus among consumers

N	Statements	I Environmentalists	II Energy efficient consumers	III Sceptics	IV Knowledge- seekers	V Conservatives
16	I believe that the government has to lead and support installations of low heat technologies	2	4	3	2	3
7	I am very interested in insulating my house better	1	4	3	4	2
15	I would agree to install low carbon heating system in my household if appropriate government support (grants, tariffs, etc.) is available	2	2	4	2	4
11	I am struggling to heat my house at the moment	-4	-3	-2	-4	-2
35	I know where to find reliable information about low carbon technologies (planning, economics, operation aspects, etc.)	-1	-4	-2	-1	0
10	The failures of past eco-friendly heating schemes have discouraged me from considering eco-friendly heating systems in my house in the future	-3	1	-4	-3	-3
29	When choosing a heating system in my household I primarily listen to the advice of local installers	-3	3	-3	-4	-1

**Table 11.** Perceptions in relation to financial motivations and thermal comfort

N	Statements	I Environmentalists	II Energy efficient consumers	III Sceptics	IV Knowledge-seekers	V Conservatives
1	Cost is the major factor influencing my choice for the heating system	-1	-1	2	0	2
25	I will need to have financial savings on my energy bill to implement any carbon saving measures	-2	0	4	-3	3
26	I will need to save at least 10% of my monthly energy bill to implement any carbon saving measures	-2	1	1	-2	0
5	I would agree to lower my thermostat to 19°C in winter to help the environment	3	-4	0	1	-4
4	I believe a comfortable indoor temperature is a key aspect of my wellbeing, therefore, I would prefer to take other actions to help the environment rather than lower heat/electricity demand in my house	-2	4	-3	-1	2

## 2.3 Consensus among respondents

There are several statements in which all or majority of respondents achieved consensus. All participants believe that the government should drive heat decarbonisation in Northern Ireland. Some feedback from focus groups indicates that the current stalemate concerning heat decarbonisation is not acceptable in this period of climate emergency.

It is important to note that despite the intention to capture a wide range of respondents for the current study, no participants were struggling to heat their houses, as indicated by statement 35 from Table 10. Therefore, narratives of fuel poor households were not captured by this pilot study.

Most consumers are interested in improving the insulation of their houses and would agree to install low carbon heat technologies if government support is available. Perception I indicates the lowest level of desire to better insulate houses (statement. 7, weighting factor +1), which can be explained by typically high level of insulation of the "Environmentalists" houses.

Most respondents admitted that past failures should not be a barrier for heat decarbonisation policies in the future (statement 10). It was also observed that NI consumers do not, in general, trust local installers when considering their home heating systems (statement 29). Post-study discussions indicate that consumers believe that new programmes are urgently needed in the province to minimise the impact of current heating systems on the environment.

Consumers highlight current lack of guidance and information about heat decarbonisation, low carbon heat and low carbon solutions in general. During focus groups, some respondents shared that they sometimes need to rely on different blogs of leading environmentalists and try to estimate if such solutions could be implemented to their households. They highlighted that it is very hard to find independent and reliable information about low carbon technologies and their benefits, potential impact, suitability to different types of houses, disadvantages, etc.

For Groups III and V ('Sceptics' and 'Conservatives'), cost is the major factor influencing the choice of heating system and

agreement to implement energy-saving measures (Table 11). It means that all other consumer groups would potentially prioritise other motivations including environmental concerns when choosing heat systems or adopting energy-saving behaviours.

Very different visions are observed when asked about comfortable indoor temperature and agreement to lower thermostats to 19°C. All groups except for "Conservatives" and "Energy-efficient consumers" (groups V and II) do not prioritise internal temperature over environmental concerns.

A range of statements reflecting various demand-side response (DSR) programmes for heating and electrical consumptions have been proposed to consumers in this study (see Table 12). In general, DSR for heating is more acceptable among respondents than in electricity (statement 24 vs 22, 23 and 43). Study outcomes revealed that:

**"Environmentalists" are quite supportive towards all of the proposed energy-saving programmes;**

**"Sceptics" are ready to support the programmes, but only if financial gains can be achieved;**

**"Conservatives" are strongly against any of the proposed demand-side programmes;**

**"Energy-efficient consumers" have, in general, neutral attitude towards them;**

**"Knowledge seekers" do not support any of the DSR electricity programmes, but agree to implement DSR actions concerning heating usage.**

Discussions following the Q-study revealed, that in some cases limited knowledge and general nature of proposed statements caused negative reactions to some DSR programmes especially among "knowledge seeking" respondents. For example, a respondent does not agree to limit their peak demand for a limited number of times per year (statement 43) considering that this time could be Christmas. It is obvious that no real DSR programme would assume limiting energy consumption during festive periods.

Another example and a quote from discussions indicate:

**Table 12.** Perceptions in relation to demand-side response programmes

N	Statements	I Environmentalists	II Energy efficient consumers	III Sceptics	IV Knowledge- seekers	V Conservatives
23	I would agree to change the way I consume energy during my regular hours of use (i.e. to choose cooker over an oven, limit TV watch time or substitute with laptop) if it leads to cost savings on my bill or helps the environment	1	1	2	-2	0
22	I would agree to change the time of day in which I use some appliances (for example washing, electric drying and hot water heating).	3	-1	1	-1	-1
43	I would agree to limit my energy consumption for up to 5 peak times per year if it leads to cost savings on my bill or helps the environment	0	0	3	-3	-2
24	I would easily agree to shift my household heating timeframes by up to two hours earlier if it helps the environment	3	-1	2	4	-2

**Table 13.** Factor loading towards novel business models

N	Statements	I Environmentalists	II Energy efficient consumers	III Sceptics	IV Knowledge- seekers	V Conservatives
20	I like the idea of future low carbon technologies supplying energy in the basis of the level of consumption (similar to broadband or mobile phone tariffs)	2	0	0	1	0
17	I would not object if a heating system will be owned by third company, as long as it is regulated by the government	0	-3	-3	1	-2
19	I would not object if heating and electricity in my household were managed (controlled, operated) by a third party, as long as I have primary control and appropriate financial savings	0	-2	-3	1	1

*"I believe it isn't wise to agree to limit my energy consumption at some days. If I avoid cooking, for example, I would have to buy take-away in that day. This wouldn't help the environment as I would produce more CO<sub>2</sub> emissions by driving my car to and from the take-away"*

Obtained outcomes provide very valuable insights into consumer positive attitudes towards potential energy-saving measures and demand-side response crucially needed for the energy transition. We understand that there is a huge gap between agreements for actions during the desk-based study and their real application in practice and on a continuous basis. On the other hand, even conceptual agreements for actions among consumers and the desire to receive new knowledge is a great opportunity for heat decarbonisation. It is currently almost completely unexploited by policymakers and industry. Generally, alternative and novel business models are new and unknown to consumers (see Table 13). Whilst different respondents differently prioritise their role and applicability in their homes, we believe it is fair to state that local demonstration projects are needed in Northern Ireland to investigate their applicability and increase consumer awareness.

## 2.4 Conclusions

This study identified six strategic expert visions and five consumer narratives for heat decarbonisation in Northern Ireland.

Expert strategic visions addressed a wide range of attitudes and views ranging from "Barrier -focused", "More action is needed", "Community cooperation", "Market-driven", "Public sector leadership" and "Consumer-focused".

A high level of consensus is observed among experts with regard to supporting a new strategic framework supporting heat decarbonisation in Northern Ireland, which should exploit great indigenous renewable resources in the region. The new policy should also create a plausible environment for attracting private investment in the heat decarbonisation transition. Institutional investors could play a vital role in heat decarbonisation.

Most stakeholders support the necessity for retrofit programmes and strict building regulations for new houses. The consensus about actions required to tackle fuel poverty and provide non-monetary motivation and consumer engagement in heat decarbonisation programmes are likewise of vital importance.

According to the project outcomes, most experts believe that trust challenges should not act as a barrier. Local demonstration programmes can help in restoring trust and increasing awareness among NI consumers and, consequently, stimulate private/consumer investments in low carbon heat technologies. Nevertheless, the government needs to provide financial support for consumers to stimulate the energy transition. Some experts state that direct financial support is needed, whilst others highlight the importance of community schemes, provision of new opportunities to consumers through dynamic tariffs, as well as consideration of novel business models via aggregation and third parties.

Previous evidence of expert disagreement towards technological options for heat decarbonisation is further supported by this study. Still, most NI experts believe in the combination of solutions required to meet the heat decarbonisation challenge. Greater cooperation among current bodies and/or the establishment of an independent body responsible for Climate Change is needed to progress heat decarbonisation in NI. Regional heat maps establishing the roles for individual technological solutions and guaranteeing efficient infrastructural investments are also needed.

Opposed visions exist concerning strict measures and taxes/levies to drive heat decarbonisation in the region. This is explained by concerns about new businesses and their competitiveness in international markets or vulnerable consumers and high level of fuel poverty in NI. Questions regarding choice, but not restrictions in the democratic society, are raised concerning restrictive measures in the energy transition. Additionally, differences in visions regarding new investments in infrastructure and the role of energy storage are observed. They largely originate in the experts' visions supporting different technological options and their enablers.

Most experts do not support the idea that a lack of consumer knowledge or erroneous perceptions among stakeholders about heat decarbonisation are main barriers in NI. Moreover, they are not very supportive towards education and engagement programmes for consumers.

However, a pilot study investigating consumer perceptions indicated opposite to expert visions about the importance of consumer education about heat decarbonisation issues. Most consumers highlighted a willingness to learn more about their impact on the environment and potential low carbon solutions. During the pilot study, it was observed that there was a low level of awareness and knowledge about current impact of households and their heating systems on the environment and potential solutions to minimize them. A lack of independent information on the topic was indicated by consumers in all conducted focus groups.

Five consumer groups were identified by the study: “Environmentalists”, “Energy-efficient consumers”, “Sceptics”, “Knowledge seekers” and “Conservatives/comfort-seekers”. The outcomes of the consumer study indicate that many consumers are interested in actions they can implement to help the environment. Majority of consumers that participated in the study found a different range of actions acceptable to help the environment without requirements for financial gain or support. These outcomes contradict dominant among the expert views that consumers in NI will be primarily driven by financial gains. Most consumers also highlighted that the government should lead heat decarbonisation in NI. They agreed that trust issues associated with past failures are not barriers from their points of view.

Almost all participants were interested in improving energy efficiency in their houses and indicate that they would potentially consider low carbon technologies installations if appropriate support is made available.

In conclusion, we can agree that many NI citizens are ready to help the environment and participate in the heat decarbonisation transition in NI. Experts and consumers agree that strong government leadership and comprehensive policy are required. Both top-down and bottom-up approaches are needed to support and motivate consumers to engage in heat decarbonisation programmes.

## Appendix A: List of organisations that attended project workshops

S.No	Organisation
1	4 Energy Solutions
2	AFBI
3	agriAD
4	Airlie Management Services Limited
5	Antrim and Newtownabbey Council
6	Ards and North Down Borough Council
7	Armagh City, Banbridge and Craigavon Borough Council
8	ARUP
9	B.I. Electrical Services (N.I.) Ltd
10	B9 Energy
11	Balcas Timber Ltd
12	Balfour Beatty plc
13	Belfast City Council
14	BLGroup
15	BR Design
16	Bryson Energy
17	BS Holdings Limited
18	Calor Gas Ireland
19	Causeway Coast and Glens Borough Council
20	CBI NI
21	Chambré Public Affairs LLP

22	Choice Housing Ireland Ltd
23	Climate NI
24	Close Focus Limited
25	Colloide
26	Consumer Council
27	Department for Communities
28	Department for the Economy
29	Department of Finance
30	Derry City and Strabane District Council
31	Ecoerne Consulting
32	Education Authority
33	EGM Vent limited
34	Electric Ireland
35	Energia Technologies
36	Energy Institute
37	Energy Saving Trust
38	Engage Strategy
39	Fermanagh & Omagh District Council
40	Fichtner Consulting Engineers Belfast
41	Firmus Energy Distribution
42	Flowgas Gas Company
43	Future Renewables

44	Gas Market Operator Northern Ireland
45	Gas Networks Ireland
46	Glen Dimplex
47	GNI
48	Heat boss
49	Hegan Biomass Ltd
50	Herschel Infrared
51	IAHySAFE
52	IN2 Engineering Design Partnership
53	Interservefm Ltd
54	Invest NI
55	JCP consultancy
57	Libero
58	Lisburn & Castlereagh City Council
59	Mid Ulster Council
60	Mutual Energy
61	National Energy Action NI (NEA NI)
62	Northern Ireland Community Energy
63	Northern Ireland Electricity Networks
64	Northern Ireland Housing Executive
65	Northern Ireland Renewables Industry Group
66	Norel Energy Services Limited

67	Northern Ireland Health and Social Care
68	Oak Foundation
69	Phoenix Natural Gas Ltd.
70	Piperhill Bioenergy Limited
71	Phoenix Natural Gas Ltd
72	Power NI
73	PowerOn Technologies Ltd
74	Project Design Engineers Ltd
76	Queens University Belfast
77	R&S Biomass Equipment

78	Red Limited
79	Renewable Energy Devices Limited
80	RHANI
81	SC Consulting Ltd
82	SDS Energy
83	SGN Natural Gas
84	Strategic Investment Board Limited
85	Simon Community
86	SONI Ltd
87	Stratagem

88	Troup Bywaters and Anders
89	UKERC
90	Ulster University
91	University of Edinburgh
92	University of Exeter
93	Utility Regulator Northern Ireland (UREGNI)
94	William & Shaw Limited
95	You generate

## Appendix B: List of statements for the expert study

1. Northern Ireland can become a UK leader of heat decarbonisation
2. Significant renewable resources (in particular wind, agricultural waste, etc.) is the major opportunity for heat decarbonisation in Northern Ireland
3. An independent body responsible for implementation of Climate Change Policy at local level similar to Scottish Committee on Climate Change is required to lead energy transition in Northern Ireland
4. There is limited scope for the use of heat networks/district heating systems in Northern Ireland
5. Individual leadership and responsibility must drive heat decarbonisation in Northern Ireland in current political situation
6. The transitional period should encourage technologies with highest potential to accumulate resources and facilitate energy transition
7. Typically high costs of low carbon technologies is the main barrier to heat decarbonisation in NI
8. There is no silver bullet for heat decarbonisation in NI; heat decarbonisation will involve a combination of low carbon technologies and strategies taking into account local resources
9. Trust challenges is the main barrier to heat decarbonisation in NI
10. The predominance of the heating oil is the main barrier to heat decarbonisation in Northern Ireland
11. The lack of a long-term policy is the main barrier to heat decarbonisation in NI
12. The need for significant investments in infrastructure is the main barrier to heat decarbonisation in NI
13. The erroneous perception and knowledge gaps about heating technologies among wide range of stakeholders is one of the main barriers to heat decarbonisation in NI
14. Regulation models not fit for purpose is the main barrier to heat decarbonisation in NI
15. Energy storage technologies have a limited role in energy transition in Northern Ireland
16. Lack of opportunities for consumers to participate in the electricity market is the main barrier to heat decarbonisation in NI
17. NI consumers have limited understanding and interest in low carbon heating, therefore, top-down model for heat decarbonisation should be applied.
18. Lack of customer understanding of heating usage is one of the main barriers to heat decarbonisation in NI
19. The government should lead the provision of education and engagement programmes about low-carbon heating systems
20. Local demonstration projects are needed to encourage positive consumer behavioural change towards low-carbon heating systems
21. Demonstration through public buildings can support positive behavioural changes and capacity buildings of low-carbon heat technologies
22. Education of stakeholders about low-carbon heating technologies should also be encouraged
23. Aggregators would help consumers access significant financial benefits of using low-carbon systems
24. Setting dynamic tariffs would not significantly facilitate unlocking consumer flexibility in NI

25. Alternative business models such as provision of low-carbon heating technologies through third parties, can encourage energy transition
26. Alternative business/ownership models such as risk-sharing in public-private partnerships can help prospective owners accept the risk of investing in low-carbon technologies
27. Community energy systems do not have great potential in Northern Ireland
28. Government should provide financial support to encourage private investments into low-carbon technologies
29. Private investors will only be interested in projects with short payback period
30. Institutional investors, such as life assurance companies or pension funds, would have limited interest in project in Northern Ireland even if appropriate government support is guaranteed
31. Current programmes for vulnerable households is the only possible way to provide assistance in current political and financial situation
32. Mitigatory measures such as green tax should be introduced in NI to help phase out less efficient fossil fuel technologies
33. High carbon taxes would discourage certain consumers such as industries
34. Retrofit of old houses is too expensive, therefore more likely it would be impossible to retrofit most of houses in NI up to the EPC rating C or higher
35. New houses should be built to the highest possible energy-efficiency standards
36. Typically, non-domestic buildings are more complex than domestic buildings and therefore would be too expensive to retrofit
37. Non-financial incentives such as climate rewards, energy-efficiency awards etc would not have significant role in consumer motivation to accept low-carbon heating systems and/or smart energy behaviour
38. Northern Ireland consumers would primarily be driven by financial incentives in adopting low carbon heating systems or measures
39. Measures such as targeted assistance and unlocking consumer flexibility can protect fuel poor and vulnerable consumers.
40. Heat decarbonisation can be achieved if greater interaction and cooperation amongst stakeholders is supported
41. A central heat decarbonisation forum for stakeholders would support heat decarbonisation goals
42. Third parties (intermediaries and aggregators) should work with stakeholders in achieving maximum benefits of proposed low-carbon systems
43. More strict measures are needed in order to deliver low carbon agenda, such as forbidding new houses from connection to the gas or oil heating

## Appendix C: Distinguishing factors for the expert study

C stands for Consensus statements, D for Distinguishing statements, \* for Distinguishing statements at  $p < 0.01$

**Table C1.** Relative Ranking of Statements in factor 1, “Barrier Focussed” perception

N	Statements	factor 1	Distinguishing	factor 2	factor 3	factor 4	factor 5	factor 6
<b>Highest Ranked Statements</b>								
1	Northern Ireland can become a UK leader of heat decarbonisation	4	D*	-1	3	-1	-4	0
7	Typically high costs of low carbon technologies is the main barrier to heat decarbonisation in NI	4	D	3	-1	3	0	-1
2	Significant renewable resources (in particular wind, agricultural waste, etc.) is the major opportunity for heat decarbonisation in Northern Ireland	4		2	3	4	2	2
<b>Positive Statements Ranked Higher in factor 3 Array than in Other Factor Arrays</b>								
24	Setting dynamic tariffs would not significantly facilitate unlocking consumer flexibility in NI	3	D*	-4	-3	0	-3	0
28	Government should provide financial support to encourage private investments into low-carbon technologies	2		2	1	1	0	0
27	Community energy systems do not have great potential in Northern Ireland	2	D*	-4	-4	-1	-1	-1
9	Trust challenges is the main barrier to heat decarbonisation in NI	2	D*	-2	-4	-1	-4	-2
10	The predominance of the heating oil is the main barrier to heat decarbonisation in Northern Ireland	1		-1	0	0	1	-2
18	Lack of customer understanding of heating usage is one of the main barriers to heat decarbonisation in NI	1		-2	-3	0	1	-4
34	Retrofit of old houses is too expensive, therefore more likely it would be impossible to retrofit most of houses in NI up to the EPC rating C or higher	1		-1	-1	-2	-2	0

4	There is limited scope for the use of heat networks/district heating systems in Northern Ireland	0		-2	-3	0	-2	-1
<b>Negative Statements Ranked Lower in factor 3 Array than in Other Factor Arrays</b>								
32	Mitigatory measures such as green tax should be introduced in NI to help phase out less efficient fossil fuel technologies	0		1	0	0	0	0
21	Demonstration through public buildings can support positive behavioural changes and capacity buildings of low-carbon heat technologies	0	D	2	1	1	2	2
35	New houses should be built to the highest possible energy-efficiency standards	0	D*	4	2	4	3	3
8	There is no silver bullet for heat decarbonisation in NI; heat decarbonisation will involve a combination of low carbon technologies and strategies taking into account local resources	-1	D*	3	4	3	2	3
25	Alternative business models such as provision of low-carbon heating technologies through third parties, can encourage energy transition	-2	D*	1	2	2	1	1
20	Local demonstration projects are needed to encourage positive consumer behavioural change towards low-carbon heating systems	-3	D*	3	2	3	3	2
23	Aggregators would help consumers access significant financial benefits of using low-carbon systems	-3	D*	0	1	2	3	2
26	Alternative business/ownership models such as risk-sharing in public-private partnerships can help prospective owners accept the risk of investing in low-carbon technologies	-3	D*	0	1	2	0	0
<b>Lowest Ranked Statements</b>								
30	Institutional investors, such as life assurance companies or pension funds, would have limited interest in project in Northern Ireland even if appropriate government support is guaranteed	-4		-3	-3	-3	-1	-3
15	Energy storage technologies have a limited role in energy transition in Northern Ireland	-4		-4	-4	1	1	0
43	More strict measures are needed in order to deliver low carbon agenda, such as forbidding	-4		3	-2	-4	0	4

	new houses from connection to the gas or oil heating							
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Table C2. Relative Ranking of Statements in factor 2, “More action is needed” perception

N	Statements	factor 2	Distinguishing	factor 1	factor 3	factor 4	factor 5	factor 6
<b>Highest Ranked Statements</b>								
35	New houses should be built to the highest possible energy-efficiency standards	4		0	2	4	3	3
38	Northern Ireland consumers would primarily be driven by financial incentives in adopting low carbon heating systems or measures	4		3	1	-2	4	-1
11	The lack of a long-term policy is the main barrier to heat decarbonisation in NI	4	C	3	4	4	4	4
<b>Positive Statements Ranked Higher in factor 2 Array than in Other Factor Arrays</b>								
20	Local demonstration projects are needed to encourage positive consumer behavioural change towards low-carbon heating systems	3		-3	2	3	3	2
28	Government should provide financial support to encourage private investments into low-carbon technologies	2		2	1	1	0	0
21	Demonstration through public buildings can support positive behavioural changes and capacity buildings of low-carbon heat technologies	2		0	1	1	2	2
12	The need for significant investments in infrastructure is the main barrier to heat decarbonisation in NI	2		-2	0	2	-2	-3
32	Mitigatory measures such as green tax should be introduced in NI to help phase out less efficient fossil fuel technologies	1		0	0	0	0	0
42	Third parties (intermediaries and aggregators) should work with stakeholders in achieving maximum benefits of proposed low-carbon systems	1		-2	0	-4	1	1
33	High carbon taxes would discourage certain consumers such as industries	0	D*	-2	-1	-2	-3	-2
29	Private investors will only be interested in projects with short payback period	0	payback period	-1	-2	-4	0	-4

Negative Statements Ranked Lower in factor 2 Array than in Other Factor Arrays								
14	Regulation models not fit for purpose is the main barrier to heat decarbonisation in NI	-1		0	4	2	0	-1
16	Lack of opportunities for consumers to participate in the electricity market is the main barrier to heat decarbonisation in NI	-2	C*	-1	-1	-1	-1	-2
41	A central heat decarbonisation forum for stakeholders would support heat decarbonisation goals	-3		1	3	-3	4	1
37	Non-financial incentives such as climate rewards, energy-efficiency awards etc would not have significant role in consumer motivation to accept low-carbon heating systems and/or smart energy behaviour	-3		-2	-1	-1	-3	-1
Lowest Ranked Statements								
24	Setting dynamic tariffs would not significantly facilitate unlocking consumer flexibility in NI	-4	D	3	-3	0	-3	0
27	Community energy systems do not have great potential in Northern Ireland	-4		2	-4	-1	-1	-1
15	Energy storage technologies have a limited role in energy transition in Northern Ireland	-4		-4	-4	1	1	0

Table C3. Relative Ranking of Statements in factor 3, "Community and greater cooperation" perception

N	Statement	factor 3	Consensus /Distinguishing	factor 1	factor 2	factor 4	factor 5	factor 6
Highest Ranked Statements								
11	The lack of a long-term policy is the main barrier to heat decarbonisation in NI	4	C	3	4	4	4	4
8	There is no silver bullet for heat decarbonisation in NI; heat decarbonisation will involve a combination of low carbon technologies and strategies taking into account local resources	4	D	-1	3	3	2	3
14	Regulation models not fit for purpose is the main barrier to heat decarbonisation in NI	4	D*	0	-1	2	0	-1

Positive Statements Ranked Higher in factor 1 Array than in Other Factor Arrays								
40	Heat decarbonisation can be achieved if greater interaction and cooperation amongst stakeholders is supported	3		1	2	-3	2	2
25	Alternative business models such as provision of low-carbon heating technologies through third parties, can encourage energy transition	2		-2	1	2	1	1
6	The transitional period should encourage technologies with highest potential to accumulate resources and facilitate energy transition	2		-1	0	1	-2	1
13	The erroneous perception and knowledge gaps about heating technologies among wide range of stakeholders is one of the main barriers to heat decarbonisation in NI	1		0	-1	0	-2	-2
Negative Statements Ranked Lower in factor 1 Array than in Other Factor Arrays								
32	Mitigatory measures such as green tax should be introduced in NI to help phase out less efficient fossil fuel technologies	0		0	1	0	0	0
7	Typically, high costs of low carbon technologies is the main barrier to heat decarbonisation in NI	-1		4	3	3	0	-1
5	Individual leadership and responsibility must drive heat decarbonisation in Northern Ireland in current political situation	-2	D	2	-1	1	-1	3
4	There is limited scope for the use of heat networks/district heating systems in Northern Ireland	-3		0	-2	0	-2	-1
Lowest Ranked Statements								
9	Trust challenges is the main barrier to heat decarbonisation in NI	-4		2	-2	-1	-4	-2
27	Community energy systems do not have great potential in Northern Ireland	-4		2	-4	-1	-1	-1

15	Energy storage technologies have a limited role in energy transition in Northern Ireland	-4		-4	-4	1	1	0
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**Table C4.** Relative Ranking of Statements in factor 4, "Market-driven" perception

N	Statements	factor 4	Distinguishing	factor 1	factor 2	factor 3	factor 5	factor 6
<b>Highest Ranked</b>								
11	The lack of a long-term policy is the main barrier to heat decarbonisation in NI	4	C	3	4	4	4	4
35	New houses should be built to the highest possible energy-efficiency standards	4		0	4	2	3	3
2	Significant renewable resources (in particular wind, agricultural waste, etc.) is the major opportunity for heat decarbonisation in Northern Ireland	4		4	2	3	2	2
<b>Positive Statements Ranked Higher in factor 4 Array than in Other Factor Arrays</b>								
20	Local demonstration projects are needed to encourage positive consumer behavioural change towards low-carbon heating systems	3		-3	3	2	3	2
12	The need for significant investments in infrastructure is the main barrier to heat decarbonisation in NI	2		-2	2	0	-2	-3
25	Alternative business models such as provision of low-carbon heating technologies through third parties, can encourage energy transition	2		-2	1	2	1	1
26	Alternative business/ownership models such as risk-sharing in public-private partnerships can help prospective owners accept the risk of investing in low-carbon technologies	2	D	-3	0	1	0	0
15	Energy storage technologies have a limited role in energy transition in Northern Ireland	1		-4	-4	-4	1	0
4	There is limited scope for the use of heat networks/district heating systems in Northern Ireland	0		0	-2	-3	-2	-1
<b>Negative Statements Ranked Lower in factor 4 Array than in Other Factor Arrays</b>								

32	Mitigatory measures such as green tax should be introduced in NI to help phase out less efficient fossil fuel technologies	0		0	1	0	0	0
38	Northern Ireland consumers would primarily be driven by financial incentives in adopting low carbon heating systems or measures	-2		3	4	1	4	-1
34	Retrofit of old houses is too expensive, therefore more likely it would be impossible to retrofit most of houses in NI up to the EPC rating C or higher	-2		1	-1	-1	-2	0
19	The government should lead the provision of education and engagement programmes about low-carbon heating systems	-2	D*	2	1	0	3	1
39	Measures such as targeted assistance and unlocking consumer flexibility can protect fuel poor and vulnerable consumers.	-3	D*	1	1	0	1	3
40	Heat decarbonisation can be achieved if greater interaction and cooperation amongst stakeholders is supported	-3	D*	1	2	3	2	2
41	A central heat decarbonisation forum for stakeholders would support heat decarbonisation goals	-3		1	-3	3	4	1
<b>Lowest Ranked Statements</b>								
42	Third parties (intermediaries and aggregators) should work with stakeholders in achieving maximum benefits of proposed low-carbon systems	-4		-2	1	0	1	1
29	Private investors will only be interested in projects with short payback period	-4		-1	0	-2	0	-4
43	More strict measures are needed in order to deliver low carbon agenda, such as forbidding new houses from connection to the gas or oil heating	-4		-4	3	-2	0	4

**Table C5.** Relative Ranking of Statements in factor 5, "Public sector leadership" perception

N	Statements	factor 6	Distinguishing	factor 1	factor 2	factor 3	factor 4	factor 5
<b>Highest Ranked Statements</b>								
11	The lack of a long-term policy is the main barrier to heat decarbonisation in NI	4	C	4	4	3	4	4
41	A central heat decarbonisation forum for stakeholders would support heat decarbonisation goals	4		3	-3	1	-3	1
38	Northern Ireland consumers would primarily be driven by financial incentives in adopting low carbon heating systems or measures	4		1	4	3	-2	-1
<b>Positive Statements Ranked Higher in factor 6 Array than in Other Factor Arrays</b>								
20	Local demonstration projects are needed to encourage positive consumer behavioural change towards low-carbon heating systems	3		2	3	-3	3	2
19	The government should lead the provision of education and engagement programmes about low-carbon heating systems	3		0	1	2	-2	1
23	Aggregators would help consumers access significant financial benefits of using low-carbon systems	3		1	0	-3	2	2
21	Demonstration through public buildings can support positive behavioural changes and capacity buildings of low-carbon heat technologies	2		1	2	0	1	2
17	NI consumers have limited understanding and interest in low carbon heating, therefore, top-down model for heat decarbonisation should be applied.	2		-2	1	-1	1	-3
15	Energy storage technologies have a limited role in energy transition in Northern Ireland	1		-4	-4	-4	1	0
18	Lack of customer understanding of heating usage is one of the main barriers to heat decarbonisation in NI	1		-3	-2	1	0	-4
10	The predominance of the heating oil is the main barrier to heat decarbonisation in Northern Ireland	1		0	-1	1	0	-2
42	Third parties (intermediaries and aggregators) should work with stakeholders	1		0	1	-2	-4	1

	in achieving maximum benefits of proposed low-carbon systems							
29	Private investors will only be interested in projects with short payback period	0		-2	0	-1	-4	-4
<b>Negative Statements Ranked Lower in factor 6 Array than in Other Factor Arrays</b>								
28	Government should provide financial support to encourage private investments into low-carbon technologies	0		1	2	2	1	0
32	Mitigatory measures such as green tax should be introduced in NI to help phase out less efficient fossil fuel technologies	0		0	1	0	0	0
22	Education of stakeholders about low-carbon heating technologies should also be encouraged	-1	C	0	0	0	0	1
6	The transitional period should encourage technologies with highest potential to accumulate resources and facilitate energy transition	-2		2	0	-1	1	1
34	Retrofit of old houses is too expensive, therefore more likely it would be impossible to retrofit most of houses in NI up to the EPC rating C or higher	-2		-1	-1	1	-2	0
13	The erroneous perception and knowledge gaps about heating technologies among wide range of stakeholders is one of the main barriers to heat decarbonisation in NI	-2		1	-1	0	0	-2
3	An independent body responsible for implementation of Climate Change Policy at local level similar to Scottish Committee on Climate Change is required to lead energy transition in Northern Ireland	-3	D*	2	0	3	3	4
37	Non-financial incentives such as climate rewards, energy-efficiency awards etc would not have significant role in consumer motivation to accept low-carbon heating systems and/or smart energy behaviour	-3		-1	-3	-2	-1	-1
33	High carbon taxes would discourage certain consumers such as industries	-3		-1	0	-2	-2	-2
<b>Lowest Ranked Statements</b>								
9	Trust challenges is the main barrier to heat decarbonisation in NI	-4		-4	-2	2	-1	-2

36	Typically, non-domestic buildings are more complex than domestic buildings and therefore would be too expensive to retrofit	-4		-1	-3	-3	-1	-4
1	Northern Ireland can become a UK leader of heat decarbonisation	-4	D*	3	-1	4	-1	0

**Table C6.** Relative Ranking of Statements in factor 6, "Consumer-focused" perception

N	Statements	factor 6	Distinguishing	factor 1	factor 2	factor 3	factor 4	factor 5
<b>Highest Ranked Statements</b>								
11	The lack of a long-term policy is the main barrier to heat decarbonisation in NI	4	C	3	4	4	4	4
3	An independent body responsible for implementation of Climate Change Policy at local level similar to Scottish Committee on Climate Change is required to lead energy transition in Northern Ireland	4		3	0	2	3	-3
43	More strict measures are needed in order to deliver low carbon agenda, such as forbidding new houses from connection to the gas or oil heating	4	D	-4	3	-2	-4	0
<b>Positive Statements Ranked Higher in factor 5 Array than in Other Factor Arrays</b>								
5	Individual leadership and responsibility must drive heat decarbonisation in Northern Ireland in current political situation	3		2	-1	-2	1	-1
39	Measures such as targeted assistance and unlocking consumer flexibility can protect fuel poor and vulnerable consumers.	3		1	1	0	-3	1
21	Demonstration through public buildings can support positive behavioural changes and capacity buildings of low-carbon heat technologies	2		0	2	1	1	2
42	Third parties (intermediaries and aggregators) should work with stakeholders in achieving maximum benefits of proposed low-carbon systems	1		-2	1	0	-4	1

22	Education of stakeholders about low-carbon heating technologies should also be encouraged	1	C	0	0	0	0	-1
<b>Negative Statements Ranked Lower in factor 5 Array than in Other Factor Arrays</b>								
32	Mitigatory measures such as green tax should be introduced in NI to help phase out less efficient fossil fuel technologies	0		0	1	0	0	0
28	Government should provide financial support to encourage private investments into low-carbon technologies	0		2	2	1	1	0
14	Regulation models not fit for purpose is the main barrier to heat decarbonisation in NI	-1		0	-1	4	2	0
7	Typically, high costs of low carbon technologies is the main barrier to heat decarbonisation in NI	-1		4	3	-1	3	0
16	Lack of opportunities for consumers to participate in the electricity market is the main barrier to heat decarbonisation in NI	-2	C*	-1	-2	-1	-1	-1
13	The erroneous perception and knowledge gaps about heating technologies among wide range of stakeholders is the main barrier to heat decarbonisation in NI	-2		0	-1	1	0	-2
10	The predominance of the heating oil is the main barrier to heat decarbonisation in Northern Ireland	-2	D	1	-1	0	0	1
12	The need for significant investments in infrastructure is the main barrier to heat decarbonisation in NI	-3		-2	2	0	2	-2
31	Current programmes for vulnerable households is the only possible way to provide assistance in current political and financial situation	-3		-1	-2	-2	-2	-1
17	NI consumers have limited understanding and interest in low carbon heating, therefore, top-down model for heat decarbonisation should be applied	-3		-1	1	-2	1	2
<b>Lowest Ranked Statements</b>								
36	Typically, non-domestic buildings are more complex than domestic buildings and therefore would be too expensive to retrofit	-4		-3	-3	-1	-1	-4
18	Lack of customer understanding of heating usage is one of the main barriers to heat decarbonisation in NI	-4		1	-2	-3	0	1

29	Private investors will only be interested in projects with short payback period	-4		-1	0	-2	-4	0
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## Appendix D: List of statements for the consumer study

1. Cost is the major factor influencing my choice for the heating system
2. A comfortable indoor temperature is the most important factor for installing and operating heat technology in my house
3. I would install any low-carbon/eco-friendly heating system only if they are easy to operate and maintain
4. I believe a comfortable indoor temperature is a key aspect of my wellbeing, therefore, I would prefer to take other actions to help the environment rather than lower heat/electricity demand in my house
5. I would agree to lower my thermostat to 19 C in winter to help the environment
6. My house is a well - insulated house already, I do not believe that further insulation will bring any significant benefits
7. I am very interested in insulating my house better
8. I have not installed low-carbon heating systems in my house because I do not have the financial support
9. I have not installed eco-friendly heating systems in my house because I have no/insufficient knowledge about them
10. The failures of past eco-friendly heating schemes have discouraged me from considering eco-friendly heating systems in my house in the future
11. I am struggling to heat my house at the moment
12. I believe low carbon technologies are not cost-efficient at the moment
13. I would agree to purchase low emission heat technologies for my household if the payback period for investment will be 5 years or less
14. I would be interested in installation of low carbon technologies if zero loans are available with adequate payback period
15. I would agree to install low carbon heating system in my household if appropriate government support (grants, tariffs, etc.) is available
16. I believe that the government has to lead and support installations of low heat technologies
17. I would not object if a heating system will be owned by third company, as long as it is regulated by the government
18. I would prefer community shared heating technologies for my house if appropriate benefits are gained and the security of supply is guaranteed
19. I would not object if heating and electricity in my household were managed (controlled, operated) by a third party, as long as I have primary control and appropriate financial savings
20. I like the idea of future low carbon technologies supplying energy in the basis of the level of consumption (similar to broadband or mobile phone tariffs)
21. I want to be a sole owner and operator of my household heating system
22. I would agree to change the time of day in which I use some appliances (for example washing, electric drying and hot water heating).
23. I would agree to change the way I consume energy during my regular hours of use (i.e. to choose cooker over oven, limit TV watch or substitute with laptop) if it leads to cost savings on my bill or helps the environment
24. I would easily agree to shift my household heating timeframes by up to two hours earlier if it helps the environment
25. I will need to have financial savings on my energy bill in order to implement any carbon saving measures

26. I will need to save at least 10% of my monthly energy bill to implement any carbon saving measures

27. I would be more interested in minimising my impact on environment than in financial gain

28. I believe that lowering air pollutions can reduce the rate of cancer, therefore very interested what actions I can introduce to mitigate this impact

29. When choosing a heating system in my household I primarily listen to the advice of local installers

30. My friends'/family members' advice is the most valuable in choosing a heating system

31. I would be very interested in learning how different low carbon technologies operate compared to traditional heating systems

32. At least once I have explored the potential of installing low-carbon technologies in my household

33. I have limited knowledge about low-carbon heat technologies and their benefits, and therefore would be very interested in learning more about them.

34. I believe it will be more efficient if industry leads the education about low heat technologies, rather than government

35. I know where to find reliable information about low carbon technologies (planning, economics, operation aspects, etc.)

36. I believe environmental issues are the individual responsibility of every citizen

37. I believe that environmental issues are the joint responsibility of government, industry and every citizen

38. I do not believe that using low carbon heating technologies could significantly help to reduce my environmental impact

39. I believe that my household energy consumption does not significantly impact the

environment, therefore actions should be taken elsewhere

40. I would prefer buying an electric vehicle or other renewable technologies (for example solar PV) to any low carbon heating technology (house insulation, heat pump, biomass, etc.)

41. I would be more motivated if I know more about how they already helped the environment (recycling, renewables supplied electricity to houses from the grid, etc.)

42. I am highly motivated to reduce carbon emissions of my household

43. I would agree to limit my energy consumption for up to 5 peak times per year (i.e. to choose cooker over oven or even avoid cooking and order food, limit TV watch) if it leads to cost savings on my bill or helps the environment

## Appendix E: Distinguishing factors for the consumer study

C stands for Consensus statements, D for Distinguishing statements, \* for Distinguishing statements at  $p < 0.01$

**Table E1.** Relative Ranking of Statements in factor 1, “Environmentalism”

N	Statements	factor 1	Distinguishing	factor 2	factor 3	factor 4	factor 5
<b>Highest Ranked Statements</b>							
37	I believe that environmental issues are the joint responsibility of government, industry and every citizen	4		0	4	3	2
42	I am highly motivated to reduce carbon emissions of my household	4	D*	-1	-1	-1	0
36	I believe environmental issues are the individual responsibility of every citizen	4	D*	2	0	-2	2
<b>Positive Statements Ranked Higher in factor 1 Array than in Other Factor Arrays</b>							
22	I would agree to change the time of day in which I use some appliances (for example washing, electric drying and hot water heating).	3	D*	-1	1	-1	-1
5	I would agree to lower my thermostat to 19 C in winter to help the environment	3	D*	-4	0	1	-4
27	I would be more interested in minimising my impact on environment than in financial gain	3	D*	0	-2	-1	-1
20	I like the idea of future low carbon technologies supplying energy in the basis of the level of consumption (similar to broadband or mobile phone tariffs)	2		0	0	1	0
32	At least once I have explored the potential of installing low-carbon technologies in my household	2	D*	-2	-4	0	0
18	I would prefer community shared heating technologies for my house if appropriate benefits are gained and the security of supply is guaranteed	0	D	-2	-2	-1	-1
<b>Negative Statements Ranked Lower in factor 1 Array than in Other Factor Arrays</b>							
21	I want to be a sole owner and operator of my household heating system	0		2	1	1	1
41	I would be more motivated if I know more about how they already helped the environment	0		1	0	3	0

	(recycling, renewables supplied electricity to houses from the grid, etc.)						
2	A comfortable indoor temperature is the most important factor for installing and operating heat technology in my house	0	D*	3	2	4	4
1	Cost is the major factor influencing my choice for the heating system	-1		-1	2	0	2
33	I have limited knowledge about low-carbon heat technologies and their benefits, and therefore would be very interested in learning more about them.	-1		3	0	2	-1
26	I will need to save at least 10% of my monthly energy bill to implement any carbon saving measures	-2		1	1	-2	0
30	My friends/family members' advice is the most valuable in choosing a heating system	-3		0	-1	-3	-2
9	I have not installed eco-friendly heating systems in my house because I have no/insufficient knowledge about them	-3		0	0	2	-3
<b>Lowest Ranked Statements</b>							
39	I believe that my household energy consumption does not significantly impact the environment, therefore actions should be taken elsewhere	-4	D	-2	-1	0	-3
11	I am struggling to heat my house at the moment	-4		-3	-2	-4	-2

**Table E2.** Relative Ranking of Statements in factor 2, "Energy-efficient consumers"

N	Statements	factor 1	factor 2	factor 3	factor 4	factor 5
<b>Highest Ranked Statements</b>						
7	I am very interested in insulating my house better	4	1	3	4	2
16	I believe that the government has to lead and support installations of low heat technologies	4	2	3	2	3
4	I believe a comfortable indoor temperature is a key aspect of my wellbeing, therefore, I would prefer to take other actions to help the environment rather than lower heat/electricity demand in my house	4	-2	-3	-1	2

Positive Statements Ranked Higher in factor 2 Array than in Other Factor Arrays						
29	When choosing a heating system in my household I primarily listen to the advice of local installers	3	-3	-3	-4	-1
12	I believe low carbon technologies are not cost-efficient at the moment	3	-1	0	2	-3
33	I have limited knowledge about low-carbon heat technologies and their benefits, and therefore would be very interested in learning more about them	3	-1	0	2	-1
21	I want to be a sole owner and operator of my household heating system	2	0	1	1	1
10	The failures of past eco-friendly heating schemes have discouraged me from considering eco-friendly heating systems in my house in the future	1	-3	-4	-3	-3
26	I will need to save at least 10% of my monthly energy bill to implement any carbon saving measures	1	-2	1	-2	0
40	I would prefer buying an electric vehicle or other renewable technologies (for example solar PV) to any low carbon heating technology (house insulation, heat pump, biomass, etc)	1	-1	1	-4	1
30	My friends/family members' advice is the most valuable in choosing a heating system	0	-3	-1	-3	-2
Negative Statements Ranked Lower in factor 2 Array than in Other Factor Arrays						
37	I believe that environmental issues are the joint responsibility of government, industry and every citizen	0	4	4	3	2
20	I like the idea of future low carbon technologies supplying energy in the basis of the level of consumption (similar to broadband or mobile phone tariffs)	0	2	0	1	0
13	I would agree to purchase low emission heat technologies for my household if the payback period for investment will be 5 years or less	-1	1	1	0	4
1	Cost is the major factor influencing my choice for the heating system	-1	-1	2	0	2
22	I would agree to change the time of day in which I use some appliances (for example washing, electric drying and hot water heating)	-1	3	1	-1	-1
42	I am highly motivated to reduce carbon emissions of my household	-1	4	-1	-1	0

18	I would prefer community shared heating technologies for my house if appropriate benefits are gained and the security of supply is guaranteed	-2	0	-2	-1	-1
14	I would be interested in installation of low carbon technologies if zero loans are available with adequate payback period	-2	2	2	0	3
17	I would not object if a heating system will be owned by third company, as long as it is regulated by the government	-3	0	-3	1	-2
8	I have not installed low-carbon heating systems in my house because I do not have the financial support	-3	-1	3	-2	1
<b>Lowest Ranked Statements</b>						
6	My house is a well - insulated house already, I do not believe that further insulation will bring any significant benefits	-4	-2	-4	1	-1
5	I would agree to lower my thermostat to 19 C in winter to help the environment	-4	3	0	1	-4
35	I know where to find reliable information about low carbon technologies (planning, economics, operation aspects, etc	-4	-1	-2	-1	0

**Table E3.** Relative Ranking of Statements in factor 3, “Sceptics”

N	Statements	factor 3	Distinguishing	factor 1	factor 2	factor 4	factor 5
<b>Highest Ranked Statements</b>							
15	I would agree to install low carbon heating system in my household if appropriate government support (grants, tariffs, etc.) is available	4		2	2	2	4
37	I believe that environmental issues are the joint responsibility of government, industry and every citizen	4		4	0	3	2
25	I will need to have financial savings on my energy bill in order to implement any carbon saving measures	4		-2	0	-3	3
<b>Positive Statements Ranked Higher in factor 3 Array than in Other Factor Arrays</b>							

8	I have not installed low-carbon heating systems in my house because I do not have the financial support	3		-1	-3	-2	1
43	I would agree to limit my energy consumption for up to 5 peak times per year (i.e. to choose cooker over oven or even avoid cooking and order food, limit TV watch) if it leads to cost savings on my bill or helps the environment	3	D*	0	0	-3	-2
23	I would agree to change the way I consume energy during my regular hours of use (i.e. to choose cooker over oven, limit TV watch or substitute with laptop) if it leads to cost savings on my bill or helps the environment	2		1	1	-2	0
1	Cost is the major factor influencing my choice for the heating system	2		-1	-1	0	2
26	I will need to save at least 10% of my monthly energy bill to implement any carbon saving measures	1		-2	1	-2	0
40	I would prefer buying an electric vehicle or other renewable technologies (for example solar PV) to any low carbon heating technology (house insulation, heat pump, biomass, etc.)	1		-1	1	-4	1
<b>Negative Statements Ranked Lower in factor 3 Array than in Other Factor Arrays</b>							
20	I like the idea of future low carbon technologies supplying energy in the basis of the level of consumption (similar to broadband or mobile phone tariffs)	0		2	0	1	0
41	I would be more motivated if I know more about how they already helped the environment (recycling, renewables supplied electricity to houses from the grid, etc.)	0		0	1	3	0
31	I would be very interested in learning how different low carbon technologies operate compared to traditional heating systems	-1	D*	1	2	3	1
42	I am highly motivated to reduce carbon emissions of my household	-1		4	-1	-1	0
27	I would be more interested in minimising my impact on environment than in financial gain	-2		3	0	-1	-1
18	I would prefer community shared heating technologies for my house if appropriate benefits are gained and the security of supply is guaranteed	-2		0	-2	-1	-1

19	I would not object if heating and electricity in my household were managed (controlled, operated) by a third party, as long as I have primary control and appropriate financial savings	-3		0	-2	1	1
17	I would not object if a heating system will be owned by third company, as long as it is regulated by the government	-3		0	-3	1	-2
4	I believe a comfortable indoor temperature is a key aspect of my wellbeing, therefore, I would prefer to take other actions to help the environment rather than lower heat/electricity demand in my house	-3		-2	4	-1	2
<b>Lowest Ranked Statements</b>							
32	At least once I have explored the potential of installing low-carbon technologies in my household	-4		2	-2	0	0
6	My house is a well - insulated house already, I do not believe that further insulation will bring any significant benefits	-4		-2	-4	1	-1
10	The failures of past eco-friendly heating schemes have discouraged me from considering eco-friendly heating systems in my house in the future	-4	D	-3	1	-3	-3

**Table E4.** Relative Ranking of Statements in factor 4, “Knowledge-seekers” perception

N	Statements	factor 4	Distinguishing	factor 1	factor 2	factor 3	factor 5
<b>Highest Ranked Statements</b>							
2	A comfortable indoor temperature is the most important factor for installing and operating heat technology in my house	4		0	3	2	4
24	I would easily agree to shift my household heating timeframes by up to two hours earlier if it helps the environment	4	D*	3	-1	2	-2
7	I am very interested in insulating my house better	4		1	4	3	2
<b>Positive Statements Ranked Higher in factor 4 Array than in Other Factor Arrays</b>							
3	I would install any low-carbon/eco-friendly heating system only if they are easy to operate and maintain	3	D*	1	1	1	1

31	I would be very interested in learning how different low carbon technologies operate compared to traditional heating systems	3		1	2	-1	1
41	I would be more motivated if I know more about how they already helped the environment (recycling, renewables supplied electricity to houses from the grid, etc.)	3	D	0	1	0	0
9	I have not installed eco-friendly heating systems in my house because I have no/insufficient knowledge about them	2	D*	-3	0	0	-3
19	I would not object if heating and electricity in my household were managed (controlled, operated) by a third party, as long as I have primary control and appropriate financial savings	1		0	-2	-3	1
17	I would not object if a heating system will be owned by third company, as long as it is regulated by the government	1		0	-3	-3	-2
6	My house is a well - insulated house already, I do not believe that further insulation will bring any significant benefits	1	D*	-2	-4	-4	-1
38	I do not believe that using low carbon heating technologies could significantly help to reduce my environmental impact	0		-4	-3	-1	-4
34	I believe it will be more efficient if industry leads the education about low heat technologies, rather than government	0		-2	-1	-2	-4
39	I believe that my household energy consumption does not significantly impact the environment, therefore actions should be taken elsewhere	0		-4	-2	-1	-3
<b>Negative Statements Ranked Lower in factor 4 Array than in Other Factor Arrays</b>							
22	I would agree to change the time of day in which I use some appliances (for example washing, electric drying and hot water heating).	-1		3	-1	1	-1
42	I am highly motivated to reduce carbon emissions of my household	-1		4	-1	-1	0
26	I will need to save at least 10% of my monthly energy bill to implement any carbon saving measures	-2		-2	1	1	0
23	I would agree to change the way I consume energy during my regular hours of use (i.e. to choose cooker over oven, limit TV watch or substitute with laptop) if	-2		1	1	2	0

	it leads to cost savings on my bill or helps the environment						
28	I believe that lowering air pollutions can reduce the rate of cancer, therefore very interested what actions I can introduce to mitigate this impact	-2		1	2	-1	3
36	I believe environmental issues are the individual responsibility of every citizen	-2	D*	4	2	0	2
25	I will need to have financial savings on my energy bill in order to implement any carbon saving measures	-3		-2	0	4	3
43	I would agree to limit my energy consumption for up to 5 peak times per year (i.e. to choose cooker over oven or even avoid cooking and order food, limit TV watch) if it leads to cost savings on my bill or helps the environment	-3		0	0	3	-2
30	My friends/family members' advice is the most valuable in choosing a heating system	-3	D	-3	0	-1	-2
<b>Lowest Ranked Statements</b>							
29	When choosing a heating system in my household I primarily listen to the advice of local installers	-4		-3	3	-3	-1
40	I would prefer buying an electric vehicle or other renewable technologies (for example solar PV) to any low carbon heating technology (house insulation, heat pump, biomass, etc.)	-4	D*	-1	1	1	1
11	I am struggling to heat my house at the moment	-4		-4	-3	-2	-2

Table E5. Relative Ranking of Statements in factor 5, "Conservatives" perception

N	Statements	factor 5	Distinguishing	factor 1	factor 2	factor 3	Factor 4
<b>Highest Ranked Statements</b>							
13	I would agree to purchase low emission heat technologies for my household if the payback period for investment will be 5 years or less	4		1	-1	1	0
2	A comfortable indoor temperature is the most important factor for installing and operating heat technology in my house	4		0	3	2	4

15	I would agree to install low carbon heating system in my household if appropriate government support (grants, tariffs, etc)	4		2	2	4	2
<b>Positive Statements Ranked Higher in factor 5 Array than in Other Factor Arrays</b>							
14	I would be interested in installation of low carbon technologies if zero loans are available with adequate payback period	3		2	-2	2	0
28	I believe that lowering air pollutions can reduce the rate of cancer, therefore very interested what actions I can introduce to mitigate this impact	3		1	2	-1	-2
1	Cost is the major factor influencing my choice for the heating system	2		-1	-1	2	0
19	I would not object if heating and electricity in my household were managed (controlled, operated) by a third party, as long as I have primary control and appropriate financial savings	1		0	-2	-3	1
40	I would prefer buying an electric vehicle or other renewable technologies (for example solar PV) to any low carbon heating technology (house insulation, heat pump, biomass, etc)	1		-1	1	1	-4
35	I know where to find reliable information about low carbon technologies (planning, economics, operation aspects, etc)	0		-1	-4	-2	-1
<b>Negative Statements Ranked Lower in factor 5 Array than in Other Factor Arrays</b>							
20	I like the idea of future low carbon technologies supplying energy in the basis of the level of consumption (similar to broadband or mobile phone tariffs)			2	0	0	1
41	I would be more motivated if I know more about how they already helped the environment (recycling, renewables supplied electricity to houses from the grid, etc)	0		0	1	0	3
33	I have limited knowledge about low-carbon heat technologies and their benefits, and therefore would be very interested in learning more about them	0		-1	3	0	2
22	I would agree to change the time of day in which I use some appliances (for example washing, electric drying and hot water heating)	-1		3	-1	1	-1
24	I would easily agree to shift my household heating timeframes by up to two hours earlier if it helps the environment	-1		3	-1	2	4

9	I have not installed eco-friendly heating systems in my house because I have no/insufficient knowledge about them	-2		-3	0	0	2
12	I believe low carbon technologies are not cost-efficient at the moment	-3		-1	3	0	2
<b>Lowest Ranked Statements</b>							
5	I would agree to lower my thermostat to 19 C in winter to help the environment	-4		3	-4	0	1
34	I believe it will be more efficient if industry leads the education about low heat technologies, rather than government	-4		-2	-1	-2	0
38	I do not believe that using low carbon heating technologies could significantly help to reduce my environmental impact	-4		-4	-3	-1	0