# Energy Strategy Call for Evidence

# Response Template

## How to Respond

This template replicates the questions asked in the Call for Evidence found at: https://www.economy-ni.gov.uk/energy-strategy-call-for-evidence

It is recommended that you should read the full consultation document before completing your response. Please note that the text boxes used throughout this template can be expanded to accommodate your response – there is no character limit.

For further information on how we handle your personal data please read our Privacy Notice

Early responses are encouraged but all responses should arrive no later than **5pm on 20 March 2020.**

Please send your response to:

**energystrategy@economy-ni.gov.uk**

Or alternatively by post to:

Energy Strategy
Department for the Economy
Netherleigh
Massey Avenue
Belfast
BT4 2JP

Quote the reference "**Energy Strategy Call for Evidence 2019**"

## 1. General Information

1. **Name (required)**

| |
|---|
| **Michael Kerr** |

2. **Are you responding:**

   **X as an individual (please complete 3 to 5 below)**

   **☐ on behalf of an organisation / company (please complete 6 to 8 below)**

**If you are responding as an individual:**

3. **E-mail address**

| |
|---|
| [redacted] |

4. **Address**

| |
|---|
| [redacted] |

5. **If you are responding as an individual, please read the Privacy Notice and tick the statement below as applicable.**

   **X All responses will be published on the Department for the Economy website following completion of the Call for Evidence process. Please tick if you are content for your name to be published alongside your response.**

**If you are responding on behalf of an organisation / company:**

6. **Organisation / Company**

7. **Position within Company / Organisation**

8. **Contact details**

   a. **E-mail address**

   b. **Address**

## 2. Energy in Northern Ireland

Q1. What lessons can we learn from elsewhere in addressing energy within an overarching climate action framework?

Q2. What are the key considerations for decarbonising Northern Ireland's energy sector given existing linkages to other jurisdictions?

Q3. To what extent should Northern Ireland implement the key energy-related recommendations from the CCC 'Reducing Emissions in Northern Ireland' report?

Q4. Do you agree with the 30-year timeframe? If not, please state your preferred approach and reasons.

## 3. The Energy Transition in Northern Ireland

Q5. What are the unique characteristics of Northern Ireland that need to be considered in a net zero carbon energy transition?

Q6. Is your organisation undertaking or planning to undertake projects to support the energy transition? If so, please provide further details.

## 4. Consumers

Q7. How should we ensure that energy remains affordable for domestic consumers? What approach should be taken to eradicate fuel poverty?

Q8. What steps could be taken to improve the relative cost competitiveness of larger non-domestic consumers?

Q9. Is a strategic position of "enable and protect" the correct policy stance?

a) What policies or schemes are needed to enable active consumers?
b) What policies or schemes are needed to protect vulnerable consumers?

Q10. What types of advice and information are required by all consumers and what are the best mechanisms for facilitating this?

Q11. Are there examples of successful citizen energy projects in Northern Ireland and elsewhere that have delivered improved energy efficiency and/or clean energy to local communities?

Q12. What opportunities are there in both urban and rural areas for citizen energy communities in Northern Ireland? What role could government have in facilitating these?

Q13. What evidence can you provide that identifies the challenges and opportunities for NI energy consumers in decarbonising energy?

## 5. Energy Efficiency

Q14. What, if any, energy efficiency target or targets should be set for Northern Ireland?

Q15. How should we define, measure and monitor energy efficiency to optimise its potential in our homes, business, economy and environment?

Q16. What are the most important policy levers for government to ensure zero carbon in:

a) New domestic and commercial buildings by 2050?;

b) Existing domestic and commercial buildings by 2050?

Q17. What should the future of energy efficiency support look like and who should be the key delivery bodies?

## 6. Heat

Q18. What is the appropriate pathway and timeline for the decarbonisation of heat between now and 2030, and subsequently to 2050?

Q19. What are the appropriate ways to measure the progress of decarbonising heat?

Q20. What are the most cost-effective and sustainable steps that government might take to accelerate the reduction of the carbon intensity of heating fuels?

Q21. Is decarbonisation of the gas grid a viable option and what evidence can be provided on both the speed and affordability of decarbonising the gas grid?

Q22. What evidence can you provide on the opportunities for district heating schemes in Northern Ireland and where should responsibility lie for facilitating these?

Q23. Can you provide any evidence or information on the opportunities for geothermal heat supply?

In response to Q23, the report below addresses the potential for geothermal use in NI.

QUEEN'S UNIVERSITY BELFAST

GSNI Geological Survey of Northern Ireland

The Potential of Geothermal Resource Use in Northern Ireland

Michael Kerr

[redacted]

Date: 25th March 2020

Word Count: 5339

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## Introduction

Striving towards net zero carbon emissions in Northern Ireland (NI) forms the basis of the need for research into reliable, efficient and cost-effective renewable energy strategies. NI's Department for the Economy (DfE) identify geothermal as a promising alternative heat source to traditional high carbon fossil fuels (DfE 2019). Busby (2010) suggests the reason behind a lack of geothermal energy development is the historical lack of research and technology, coupled with the low cost and high availability of fossil fuels in the latter part of the 21st century. Research into shallow geothermal potential in NI has been carried out with small scale implementation of proven technologies proving useful in diversifying NI's heat supply but to a very limited scale. Recent deep geothermal research in NI has identified huge potential for projects to contribute to NI's heat supply as well as possibly its electricity production.

*Aims, Objectives & Research Questions*

The primary aim of this project is to explore NI's potential to incorporate geothermal heat into its energy mix with particular reference to geology, heat demand and policy. The objectives set to achieve this include: to explore and present NI's geology and its suitability to geothermal use, to identify technologies most suitable for implementation in NI, to assess policies from European cases studies which are potentially transferable to NI's geothermal industry and finally to explore reasons behind lack of geothermal implementation thus far and provide recommendations to the industry moving forward. These aims and objectives will contribute to two research questions; firstly, what is the geothermal potential of NI? Followed by, what are the best practices in terms of policy to encourage geothermal utilisation in NI? A theoretical background will be provided around geothermal geology and technology as well as general policy strategies to begin, followed by the methodology of the project. Research results will then be presented followed by a detailed discussion around the implications of the research including recommendations before final conclusions are outlined.

*Rationale*

In June 2019 the UK passed laws committing to transitioning to a net zero emissions economy. Since then NI's DfE has been working towards a new energy strategy. As part of this the department opened a public consultation in December 2019. This call for evidence requires stakeholders such as the Geological Survey of Northern Ireland (GSNI) to present evidence supporting certain energy strategies. As such, this research paper contributes to supporting GSNI's geothermal work and in particular seeks to provide evidence supporting the incorporation of geothermal to NI's energy complex through both a geological and policy making lens. This report will help GSNI specifically in providing a link between geology and policy making, supporting renewable energy utilisation in NI and so contributing to sustainable development. Also, DfE highlight locational matching of supply and demand as key to geothermal development which will be explored (DfE 2019).

**Theory – Literature Review**

*Geothermal Energy*

The 2015 worldwide review on direct utilisation of geothermal energy by Lund and Boyd (2015) highlights a growing trend in geothermal energy utilisation. The paper indicates utilisation in a total of 82 countries, up from 78 in 2010 and 58 in 2000. Furthermore, total thermal energy used is 587,786 TJ/yr (163,287 GWh/yr) – a 38.7% increase from 2010. Of this energy, the main user by category is ground source heat pumps (GSHP) at 55.3%. This study illustrates that the global movement towards geothermal energy usage is continuing in North America and Europe. It also indicates an expectation that the UK and NI will grow in this industry despite having not yet incorporated geothermal resources into their energy complex to any large extent. In contrast to this literature, Popovski (2003) highlights how political and social acceptance of geothermal is and will continue to hinder widespread use globally, reducing the global trend illustrated by Lund and Boyd (2015). For example, Popovski identifies poor education of the public, perceived high environmental impact, political preference for fossil fuels and traditional community values (Payera 2018) as barriers to increased geothermal usage.

*General Geology*

"A geothermal resource is usually described in terms of stored thermal energy content of the rock and contained fluids underlying land masses that that are accessible by drilling" (Tester et al. 2006). Busby et al. (2009) states that the general geology required for geothermal utilisation centres around groundwater availability and subsurface temperatures. In addition to this, factors such as thermal conductivity of soil and rocks as well as rock strength can contribute to identification of most suitable GSHP sites. Much of the UK and NI is suitable for shallow geothermal utilisation according to Busby (2010), however this is based on regional UK maps and so lacks detail for NI in particular.

On the other hand, deep geothermal work is discussed in a paper by Raine and Reay (2019). This is heat extracted from deep aquifers (for example Sherwood Sandstone), where rocks are permeable (allow water to flow), more than a few hundred metres underground up to as deep as a few kilometres depending on the geology. Deep boreholes are drilled and GSHP vertical loop systems abstract heat of less than 150ºC thus providing direct heat to heat networks. In general, the deeper the borehole the warmer the rocks become. As such, in some cases

GSHP's can abstract heat above 150ºC which can subsequently be used for both heat and electricity (Lucia et al. 2017). In comparison to this widely accepted literature, Schumacher et al. (2020) highlights that "quantification of geological risk" is extremely difficult to calculate due to aquifer heterogeneity and sparse hydraulic data. This supports the view that general theory behind geothermal geology is inadequate when discussing possible GSHP systems, rather subsurface modelling is more useful in analysing geothermal geology. This review justifies the first research question of this report which addresses the geothermal potential of NI through exploring NI's geology in detail with reference to accessible resources linked to current policy which is an area of literature currently underdeveloped.

*Heat Pumps*

Heat pumps move thermal energy from a lower to higher temperature medium with an end product of useable heat (Self et al. 2013). It is estimated that GSHPs produce three to four times more heat energy than electricity inputted (GSHPA N.D.). The electricity required can be obtained from renewable sources thus decarbonising the whole system. Furthermore, Chau et al. (2010) in a review of heat pump system advances highlight that studies show around 70% of the energy used in GSHP systems is renewable energy from the ground. A leading example of this is analysed by Esen et al. (2017) in which solar assisted GSHPs are in use experiencing high performance efficiency. These papers are evidence of the generally high acceptance of GSHP technology and its capability, with work continuing to increase efficiency of systems.

There are separate connections ensuring heat it transferred above ground – these are done through either closed loop or open loop configurations. Based on a comprehensive review of GHSPs by Self et al. (2013), closed loop systems are commonly utilised and characterised by the heat transfer fluid being contained within the loop thus experiencing no direct contact with the ground. Heat transfers to the fluid via the pipe. The two main variations of closed loop systems are vertical and horizontal. Vertical closed systems are advantageous due to the low installation area required and relatively constant groundwater temperatures, however, cost of drilling is extremely high thus this system is generally more economically viable for larger projects. In contrast, horizontal closed loop systems require considerable available ground space. However, installation costs are much lower than vertical systems therefore lending itself to residential projects. On the other hand, open loop systems involve the direct heat exchange between loop and ground. Groundwater is pumped through the loop to the heat exchanger and eventually returned back to the ground in most cases. As such, open looped systems tend to be used for larger installations through construction of wells allowing extraction of water from aquifers. Open systems therefore involve less drilling than closed, with relatively constant groundwater temperatures providing a stable heat source (Self et al. 2013).

Piga et al. (2017) highlight alternative views on heat pump development currently. Through work on the thermal impact of groundwater heat pumps in a geothermal system, a lack of research was highlighted surrounding thermal plumes derived from heat extraction. This identifies a potentially serious geological hazard of groundwater impairment. The need for more extensive studies into heat pump induced hazards as well as into the efficiency of heat pumps from low enthalpy geothermal systems (Sircar 2017) are aspects of heat pump technology currently below standard and lacking in research. These studies link to this report's second research question in that highlighting best technologies will link closely to best practice for policy makers which hasn't yet been applied to NI.

*Policy Strategies*

Nowak (2018) highlight ways European governments have influenced heat pump deployment. They argue that official support of fuel switch is necessary, shifting energy carrier through the banning of oil or gas for example. In Sweden, oil for heating was banned in 2005 leading to widespread deployment of alternative heat sources including heat pumps. Norway, after banning oil and gas boilers in new buildings in 2013, have decided to ban oil for heating in 2020. Nowak's (2018) work is useful in identifying proven successful policy however, these examples are of national scale and so to make these policies transferable, countries must have similarities in their energy situation. As such, these polices lack detail in the application of policy.

In contrast, Rybach and Sanner (2017) published trends and achievements of European geothermal heat pump development with a more micro-scale policy lens. Within this, they support an institutional and financial focus on geothermal policy. Specifically, they encourage the provision of infrastructure, favourable tax schemes and installation grants through sufficient funding and scheme transparency. This opinion is useful as guidance to policy makers, however the paper is largely idealistic in that it fails to take into consideration unique policy issues facing counties as well as the limitations to such policies including the huge economic strain it may impose on the government. These studies support research question two, 'what are the best practices in terms of policy

to encourage geothermal utilisation in NI' in that identifying proven successful policies that are transferable to NI is yet to be studied in this context.

**Methodology**

This project utilises secondary data from several different sources, including;

- GSNI Archives – NI geology data.
- Academic Literature – General geology, heat pump technology and policy strategies.
- Industry Information – Heat demand and heat pump data.

Initially, academic literature was used to develop a background on current thinking surrounding geothermal use and heat pumps. With the guidance of GSNI staff, relevant peer reviewed literature was studied and analysed regarding both the geology and the heat demand aspects of the project. Communication with industry and relevant organisations provided the most up to date data available, including;

- Department for Communities – Population and housing stock data.
- NI Housing Executive and Irish Wind Energy Association – Heat roadmap of Europe.
- Geothermal Association Ireland – Heat pump data Ireland.
- NI Statistics and Research Agency – Population and housing data.
- Ground Source Heat Pump Association (GSHPA) – NI heat pump data.

As for policy theory, an industry publication by European Copper Institute by Nowak (2018) provided the majority of data. Once this data was collected, necessary geology and heat demand analyses were carried out using ArcGIS software, further mapping data came from a variety of sources including GSNI and the Ordnance Survey of Northern Ireland – Crown Copyright and Database Right. This was followed by a policy review analysis under the framework of Browne et al. (2018). The methods for this included a three "broad orientations" approach to policy analysis.

The framework begins with a 'traditional' approach aiming to pinpoint the best solution via comparative analysis of possible solutions. This approach is generally quantitative, fact-based analysis, identifying optimum solutions having considered logistical obstacles including economic frameworks via cost-benefit analysis for example. This can include collated analysis of policy from multiple case studies. Secondly, 'mainstream' approaches have an analytical focus on actors and values in policy making. There is particular consideration of political influence in policy and the prioritisation of stakeholders. This approach tends to include more qualitative data via interviews or surveys to better understand policy pathways and agenda setting. Finally, 'interpretive' approaches focus primarily on the social construction of problems and how policies reflect this. This orientation focuses on 'meaning' and the definition of the problem as well as how it is viewed. This can include governmentality through specific, intentional framing of the problem. This approach requires data from quantitative sources such as archives as well as qualitative data via interviews amongst others (Browne et al. 2018). Analysis of geothermal and heat pump policy from a national level will be carried out looking at the example of Norway followed by a more regional, micro-scale analysis of a UK case study. This will enable lessons to be learned via greater understanding of the factors underpinning policymaking thus enabling suitable and effective recommendations to be made in NI's upcoming energy strategy.

**Results**

*Geology of NI*

There are numerous geological considerations before installing GSHP systems (Busby et al. 2009). It is crucial to assess potential sites based on their geological characteristics to ensure accurate installations enhancing cost-effectiveness. Figures 1-5 aim to illustrate the geological characterisation of NI relevant to GSHP deployment.

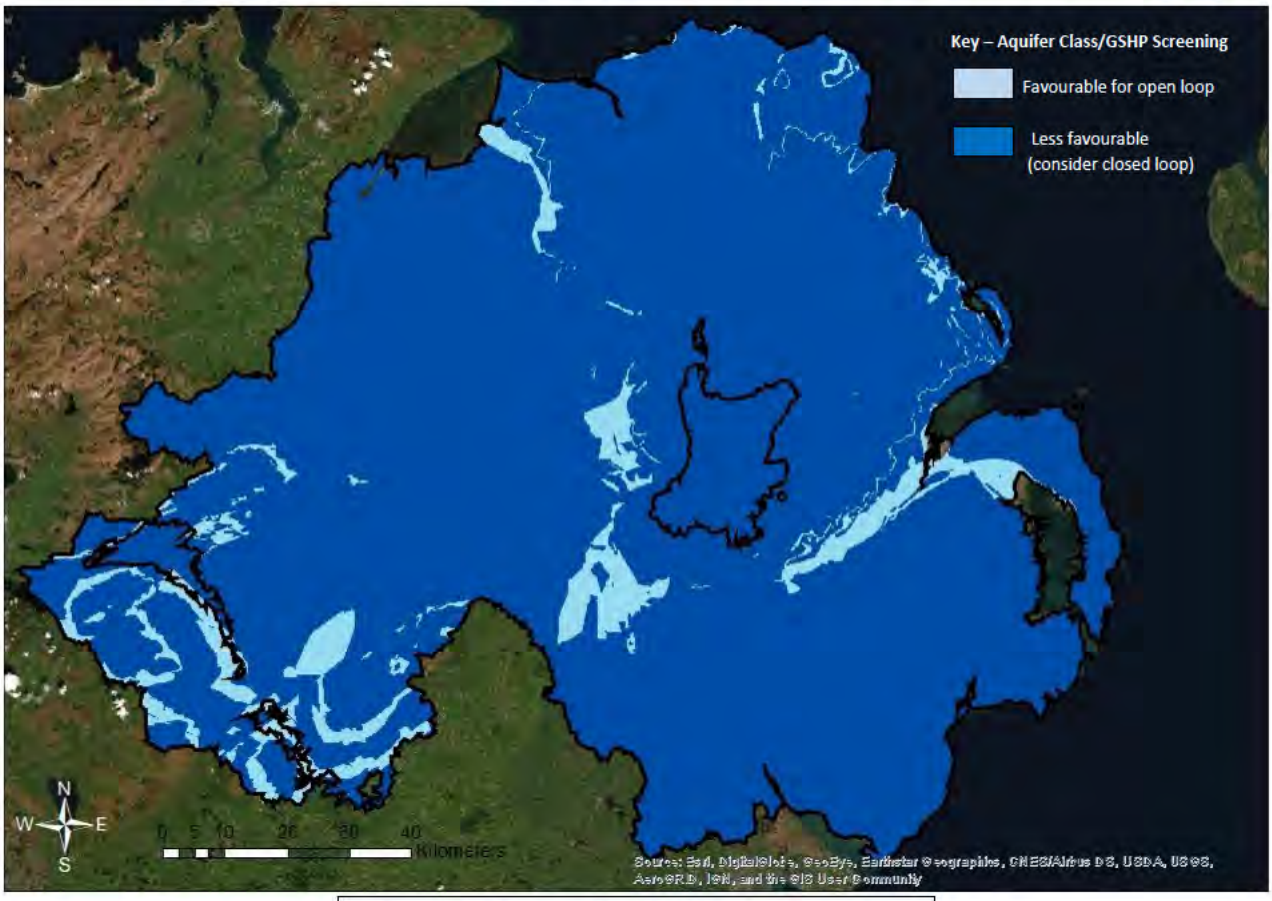


**Figure 1.** Aquifer class/GSHP screening map (heating and cooling output >100kW).

An aquifer class map aims to identify locations best suited to vertical GSHP systems in superficial geology by illustrating the distribution of various aquifers at a depth of 100-200m. In the above map, areas shown in light blue represent the most suitable aquifers in NI for shallow geothermal exploitation via open loop GSHPs. These areas include geology of high porosity such as sandstones and limestones – most notably the Sherwood Sandstones seen in the Greater Belfast area and west of Lough Neagh. Open loop systems are favourable here as these pumps require direct contact with groundwater in order to exchange heat to the surface. On the other hand, the dark blue areas on the output represent less favourable areas for open loop systems due to low porosity superficial geology. This includes clays, low grade metamorphics and low porosity clastics and volcanics. Due to the limited flow of water in these rocks open loop systems are unsuitable, however, closed loop systems should be considered as they do not require direct contact with water, rather heat from surrounding geology transfers to a fluid within the loop before being pumped to surface.

When assessing the suitability of superficial geology to horizontal closed loop systems it is necessary to identify the thermal properties of the deposits. Typical properties are illustrated in Figure 2.

| Class | Thermal conductivity ($W\ m^{-1}\ K^{-1}$) | Thermal diffusivity ($10^{-6}\ m^2\ s^{-1}$) |
|---|---|---|
| Sand (gravel) | 0.77 | 0.45 |
| Silt | 1.67 | 0.60 |
| Clay | 1.11 | 0.54 |
| Loam | 0.91 | 0.49 |
| Saturated sand | 2.50 | 0.93 |
| Saturated silt or clay | 1.67 | 0.66 |

**Figure 2.** Typical thermal properties for superficial deposits (Busby et al. 2009).

Thermal conductivity refers the energy required to increase rock temperatures by 1°C whilst diffusivity is the speed at which heat can go through the rock. When locating a site for horizontal closed loop systems superficial geology with high thermal conductivity is desirable. This is illustrated in Figure 4 by the colour red. The distribution of thermal conductivity of superficial deposits is extremely variable across NI, however high levels are seen in large parts of the north- and mid-west. This is due to the presence of superficial deposits such as peat, sand and gravel. County Antrim is the location of large sections of moderate levels of conductivity deriving from sand mixed with silt and clay as well as till from sandstones and granite. Low conductivity is focused largely in the south-east with parts of the south-west also experiencing similarly low conductivity superficial deposits. These include silt and clay, as well as diamicton such as till from limestones, acidic volcanic rocks and basic igneous rocks.

Saturated deposits have a much higher thermal conductivity (Figure 2). This occurs when the groundwater table is above said rocks, however, there is currently a lack of data relating to NI water tables and so Figure 3 is an estimation based on Figure 2's data above. Furthermore, NI has large areas of sandy diamicton (glacial till) which are largely misunderstood but have high potential as they have, in some areas, sand, clay and clasts which means they may have higher thermal conductivity than other glacial till deposits thus they have been categorised in this study as moderate.

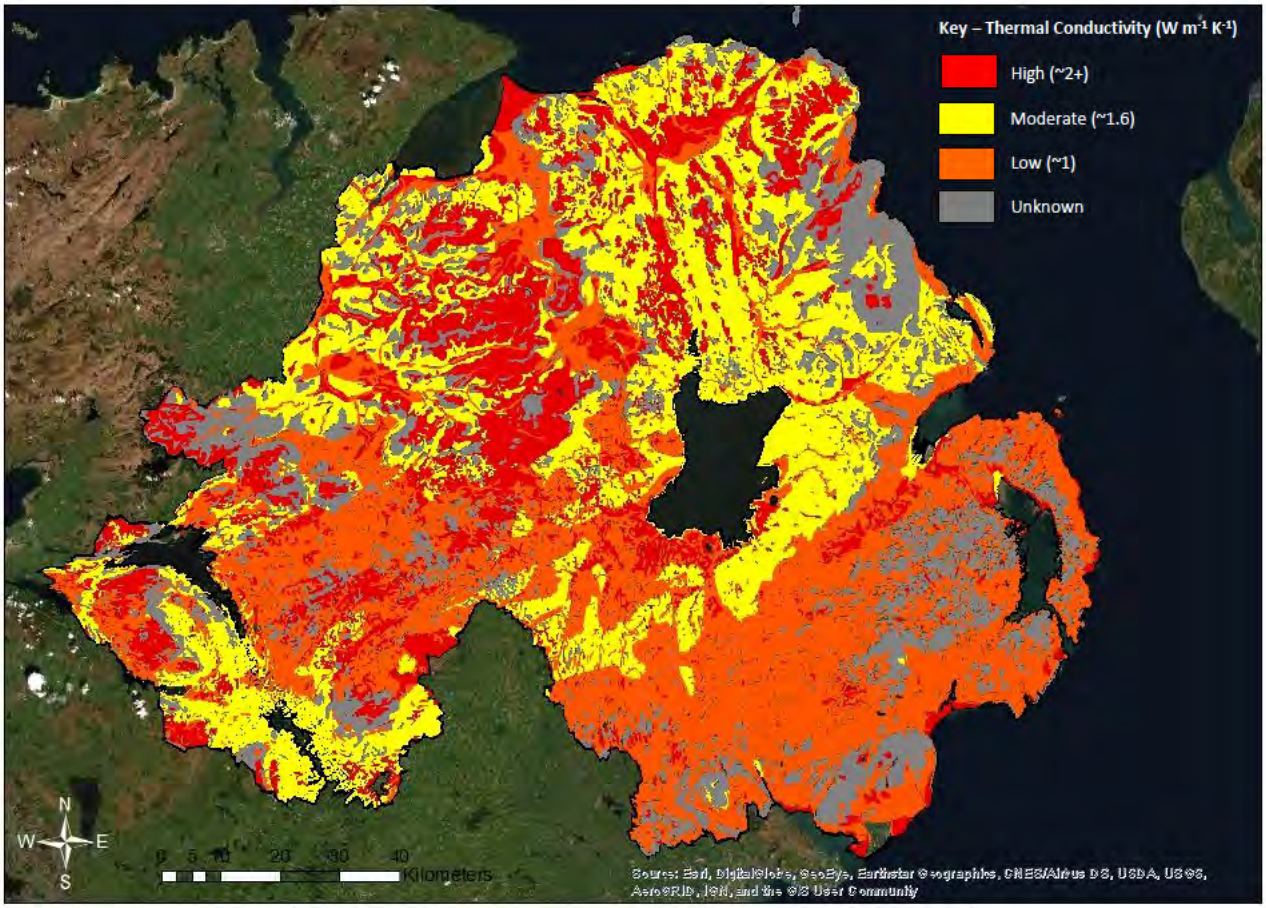


**Figure 3.** Thermal conductivity of superficial deposits.

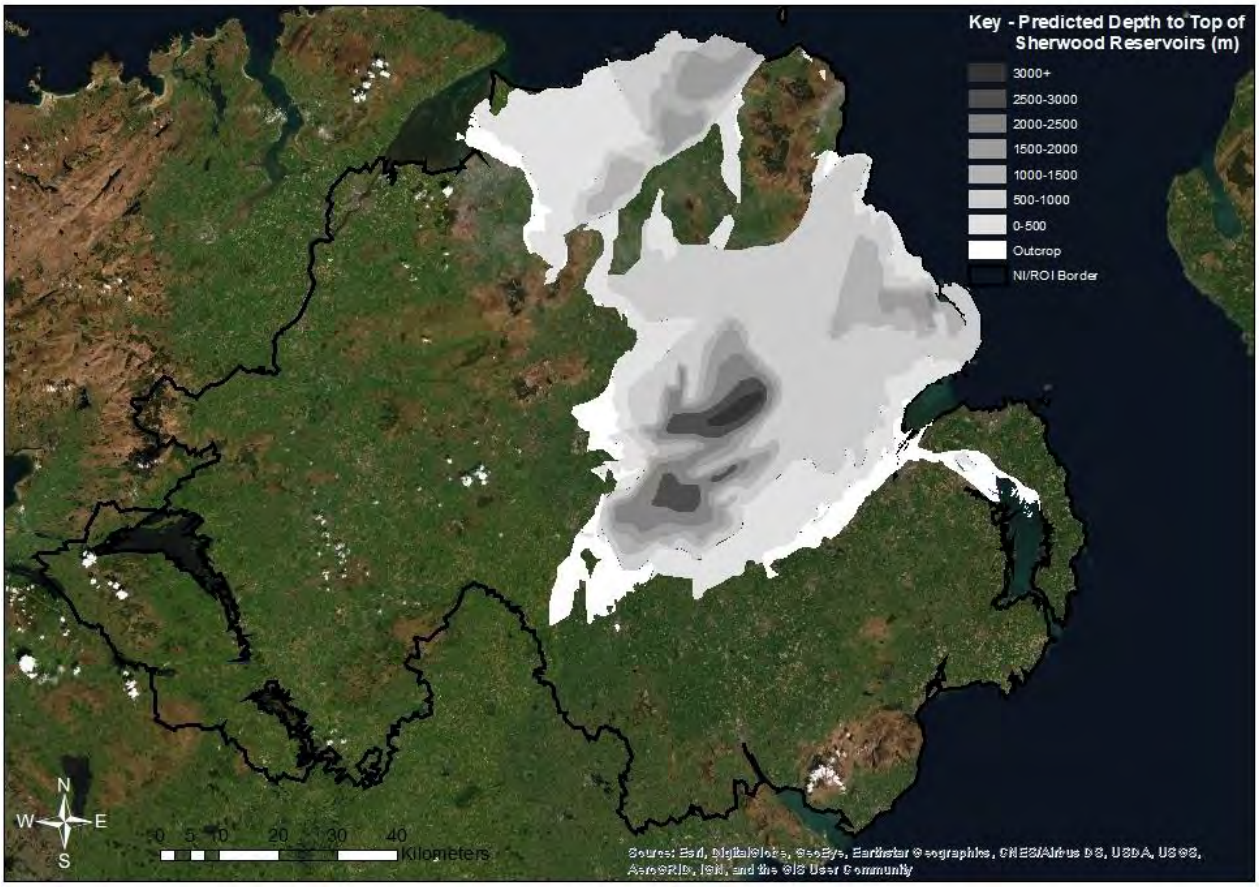


**Figure 4.** Predicted depth to top of Sherwood Sandstone reservoirs.

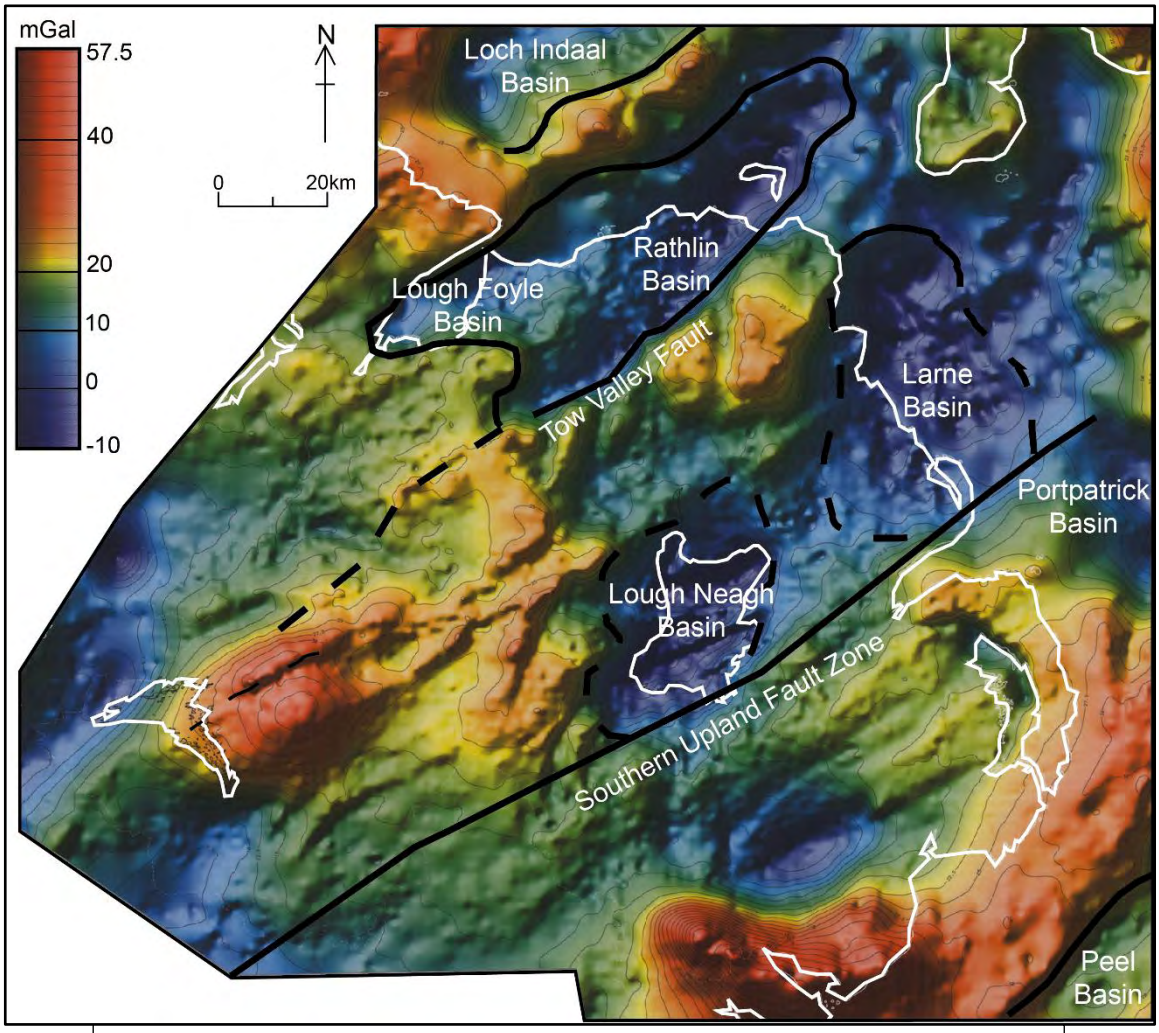


**Figure 5.** Relief gravity anomaly map – gravity lows (blues and greens) relate to sedimentary basins (Reay 2004).

Figure 4 illustrates the distribution of sedimentary basins where Sherwood Sandstone is found in the subsurface with Figure 5 highlighting the extent of these sedimentary basins both on and offshore. Areas shown in Figure 4 are porous and so are optimum sites for deep geothermal extraction. As shown in Figure 1 there are Sherwood sandstone outcrops and subsurface deposits 0-500m from the surface which can be exploited for shallow GSHP use via vertical open loop systems. However, as aquifer depth increases so does the groundwater temperature. The greater the temperature the more heat can be used for direct heating on the surface or in some cases for electricity generation. Deep geothermal is expensive with high capital costs involved in drilling, therefore identification of deep aquifers such as in the Lough Neagh basin seen in Figure 5 as well as the darkest grey section of Figure 4 can inform potential deep geothermal sites for NI (Pasquali et al. 2010). Both Figures 4 and 5 highlight the highest potential for deep geothermal across large sections of the north and north east of NI.

*Heat Demand of NI*

In terms of domestic heating, 99.7% of NI's 798,971 housing stock (NISRA 2019) has central heating, 24% of which use gas as the fuel and 68% using oil. The proportion using gas is increasing whilst those using the remaining percentage (solid fuel, electrical and duel fuel) is decreasing (NIHE 2016). As such, there remains a need to incorporate a renewable heat source to the network especially with an ever-increasing population as illustrated in Figure 6.

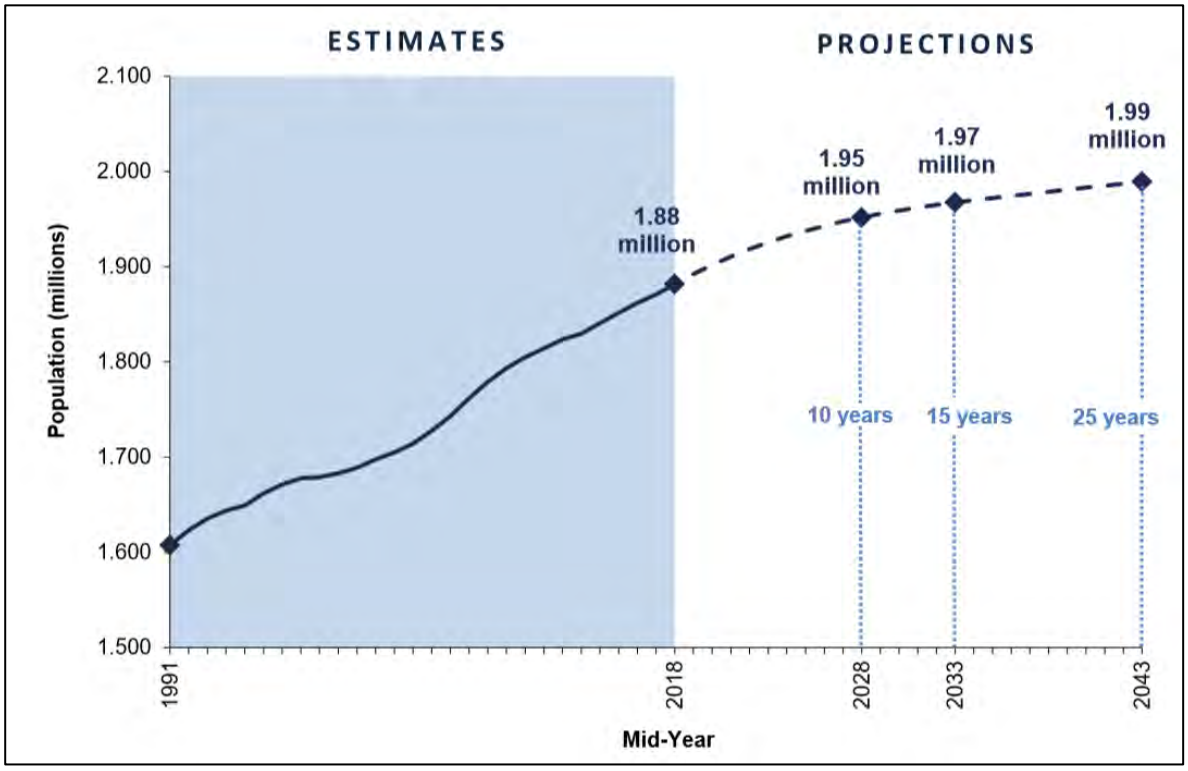


**Figure 6.** Estimated and projected population, mid-1991 to mid-2043 in Northern Ireland (NISRA 2019).

Northern Ireland Statistics and Research Agency (NISRA) have produced projections of population growth in NI over the next 25 years. They estimate an increase in 107,600 people between 2018 and 2043. Such a population increase will have a significant impact on heat demand across the country, however it is important to understand the distribution of this heat demand in planning geothermal resource exploitation.

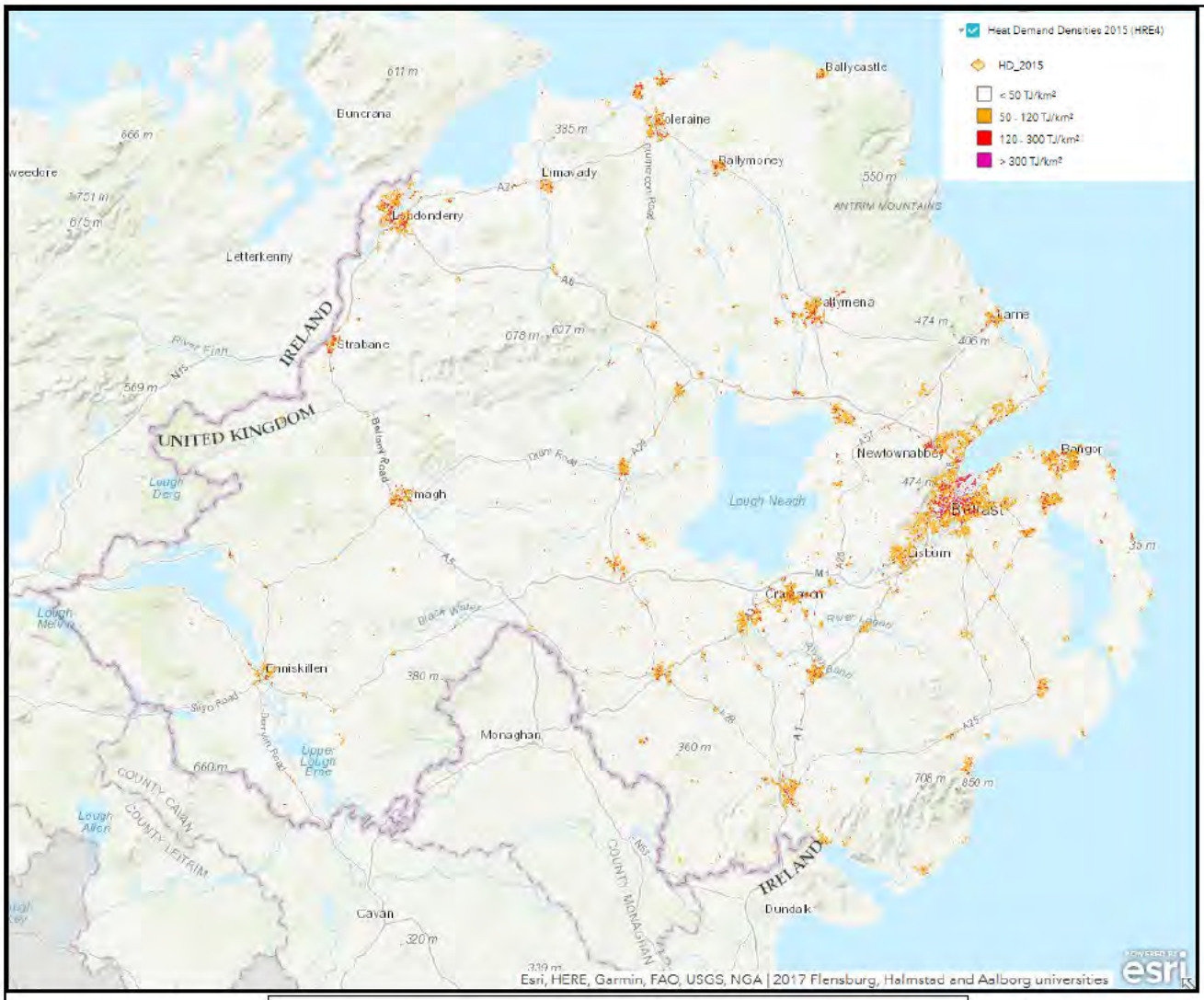


**Figure 7. Heat demand densities NI (Heatroadmap.eu 2018).**

Distribution of this population can be observed via Figure 7, illustrating the distribution of heat demand with the largest populated urban areas such as Belfast and Londonderry displaying figures of >300 Tj/km$^2$ in places contrasting with larges rural areas with extremely low heat demand. This information can be used to inform locations for geothermal heat pump deployment where the need is greatest. The main population hubs are generally linked via good infrastructure, however it is the remote heat demand sites that will require special policy focus.

*Relevant case studies – policy review analysis*

It is important to consider both national interests and small-scale consumer interests when developing geothermal policy. Analysis of policy in Norway will be firstly made with a broad overview of governmental policy followed by policy evaluations from a small-scale case study in Derbyshire, UK. The framework proposed by Browne et al. (2018) will be utilised here, splitting the analysis into three orientations: traditional, mainstream and interpretive.

Focussing on Norway who are increasing their geothermal use (Kvalsvik 2019), their policy of restricting oil and gas boilers in new buildings as well as banning oil for heating in 2020 is an example of a 'mainstream' approach to policy making with emphasis on stakeholders as actors (Nowak 2018). In this example, consumers will be 'forced' into alternative fuel options i.e. deploying heat pumps due to the near non-existent gas network in the country following the oil ban when operational (Reuters 2017). This has aspects of the 'traditional' approach in that the Norwegian government recognised this policy as the optimum solution to achieve their aims of carbon reductions. Similarly, Norwegian government have framed the problem around carbon emissions and so an 'interpretive' approach influences policy to reduce oil consumption despite the petroleum and gas industry

making up half it's export revenue. The industry is so large that such a policy may have huge economic and social impacts, however under this 'interpretive' approach they have framed the problem around $CO_2$ emissions thus justifying the policy leading to wider public acceptance and tolerance.

The Department of Energy and Climate Change (DECC) (2016) published case study information from heat pumps used in district heating, this included a study from Derbyshire in the UK. This project was in a rural, off-gas grid location like much of NI. The council adopted a 'traditional' policy approach to implementing this scheme due to its optimum value compared to other policy and scheme options. This was as a result of available governmental funding for installation of renewable energy thus reducing cost to residents as well as the superior reliability of GSHP's supply. Regarding a 'mainstream' approach the council had pressure from residents as well as political duty to cut carbon emissions. Consequently, this policy has been designed and altered to meet the needs of these policy actors. Finally, an 'interpretive' approach highlights the councils framing of the problem. They had identified the problem as aging properties (built in 1982) and their individual electric heaters as being a poor heat supply and so produced a unique policy in retrofitting not just central heating network but also individual components within homes. This project has led to high resident satisfaction and greater system efficiency (DECC 2016).

**Discussion and Recommendations**

In relation to the first research question, NI boasts a "huge variety of rock types" (Mitchell 2004) contributing to an extremely diverse geology. The implications of this geology to potential geothermal exploitation are illustrated in Figures 1-5. As mentioned, accurate subsurface modelling is crucial to ensuring cost-effectiveness in geothermal projects. In this case an NI wide view has been taken which is useful for a national policy overview, however, individual projects would need supplementary modelling in the micro-scale. Based on results seen in Figure 1 and Figure 3 there is evidence supporting heat pump deployment country wide. However, these figures also pinpoint specific areas recommended for both open and closed loop shallow vertical systems which are ideal due to their lack of surface landscape impact. Figure 1 identifies the Sherwood Sandstone aquifer of Greater Belfast, geology to the west/south-west of Lough Neagh as well as sporadic sections of County Fermanagh as being most suitable for shallow, open looped, vertical systems and therefore recommended investment locations. Most interestingly here, Greater Belfast is an area of high population density and heat demand as Figure 7 illustrates. Therefore, shallow vertical heat pumps are recommended here as an extremely viable option. Limitations to this recommendation include high capital cost of installation as well as increased risk of water contamination. Financial incentives and accurate subsurface modelling would mitigate these issues.

On the other hand, large swathes of high thermal conductivity are observed in the north-west of NI. These areas, excluding the city of Derry show relatively low heat demand and so can better utilise horizontal heat pumps thus reducing installation costs. These heat pumps will generally be suitable for only heating due to the lack of availability of deep aquifers in NI. The deepest aquifer NI does have with potential for electricity generation can be located in the Lough Neagh sedimentary basin with depths of more than 3000m in some areas. Also, depths to the Sherwood Sandstone reservoirs reach more than 2000m in the Larne and Rathlin sedimentary basins (Pasquali et al. 2010). Installation costs for these deep, open looped, vertical systems are very high, however,

electrical power feedback into networks would help lead to an eventual cost off-set. There are increased environmental concerns with deeper geothermal extraction which again can be mitigated via comprehensive subsurface modelling prior to installation.

NI's ever-increasing population (Figure 6) will in turn increase heat demand in the country in the coming years. This heat demand will continue to be distributed to the most populous areas and so large-scale geothermal energy use should be focussed here. The Sherwood Sandstones aquifer (Figure 1 and 4) can be seen in the greater Belfast area and so initial deep geothermal exploration and feasibility should focus on this area with lessons learned being applied to further reservoirs as seen in Figures 4 and 5. In particular, Figure 5 indicates the extent of sedimentary basins with potential for geothermal exploration stretching offshore in places. Despite this, initial investment and research should focus on areas identified in Figure 4 to increase the probability of successful geothermal harnessing. Figures 6 and 8 highlight the need to improve NI's energy infrastructure in order to ensure that a potential future geothermal influx will be efficiently managed with minimal wastage. This recommendation will be a long-term, expensive project however when improved, infrastructure can ensure efficient energy distribution.

To answer research question two, based on the policy analysis above and work done by Goodman et al. (2010) around the legal and economic support for geothermal development, some points for discussion and recommendations have been made. Beginning with legal guidelines (Goodman et al. 2010), in many cases legislations are unclear or vague and so clarification of geothermal resource ownership is important alongside the appointment of an authority to oversee licensing for exploration and development. In NI, currently there is no legal obligation for consumers to notify an authority prior to GSHP installation, however in specific sites it is sometimes necessary to obtain planning permission. Similarly, if there is a risk of groundwater contamination (usually associated with open looped systems) NI's Environment Agency (NIEA) should be informed. Notably, there is not one overarching authority specifically for geothermal energy in NI which can create uncertainty in the industry and potentially discourage smaller scale heat pump deployment. This suggestion is likely to take months to years to properly integrate correct structures into the industry and public engagement with developments will be key here to ensure all stakeholders are aware of changes.

Supplementary to this, creation of a regulated licensing system would ensure a common standard of subsurface modelling prior to installation thus ensuring higher cost-effectiveness of projects. This, however, must not be financially prohibitive to consumers, rather useful guidelines to be met in order to ensure environmental safety and efficient GSHP deployment. Recruitment of professional geothermal experts and suitable funding towards their research would ensure established geological standards are met during projects. The likes of the GSNI could therefore receive case-specific funding and carry out detailed subsurface modelling and subsequently partner with an overarching authority in issuing licenses and providing accurate information to the public. This can only be done through adequate funding of mentioned organisations, however, the advantage of this will be to encourage the public, increase public geothermal knowledge and ensure high levels of cost-effectiveness within NI projects. As mentioned, a disadvantage to this would be the need for government funding as well as necessary manpower within GSNI or another professional organisation, although if done correctly, this recommendation would aim to vastly increase NI's geothermal energy production thus reducing costs nationwide.

Goodman et al. (2010) highlight that governmental financial incentives for GSHP's has led to an increase in Europe's shallow geothermal industry. The main issue with GSHP's are their high initial installation costs. Therefore, reducing the financial burden on consumers is crucial. Prior to its discontinuation in 2016, NI's renewable heat incentive (RHI) allowed a £3,500 payment towards installations of GSHP's with a tariff of 9.24p/kWh. Since then, however, no such grants or subsidies have been available. NI would benefit from a geothermal grants system based on case specific research carried out by a professional body (such as GSNI) where by if a case has potential for high heat extraction and potentially electricity production they would be entitled to apply for larger grants due to increased cost of deep geothermal systems. This would prompt further industry investment in deep geothermal and allow smaller scale projects to be installed also. Realistically, fees must be charged for exploration licences and professional research, however this cost must be a once off fee with no additional costs to consumer stemming from findings or further exploration. It is important that the energy extracted from GSHP's is subject to preferential tax rates over oil and gas, promoting the industry above fossil fuel use. These taxes and financial incentives must come with a long-term guarantee to both maximise the measures' impact and to encourage consumers to commit to a project. These incentives may be best utilised in NI through firstly national promotion followed by local council guidelines which ensure a straightforward and clear pathway to geothermal use. Furthermore, completion of a NI wide geothermal life cycle assessment is

recommended to increase public confidence in the long term benefits of geothermal use, leading to higher GSHP deployment.

To an extent NI may find use in developing policy using an 'interpretive' approach. As in Norway, framing the problem around $CO_2$ emissions could be useful in implementing a $CO_2$ emission credit scheme where avoidance of $CO_2$ emissions through the use of geothermal is financially rewarded versus tariffs on oil and gas for example. Like Norway, NI lacks national coverage of the gas grid (Figure 8) Consequently, a 'mainstream' policy approach may include increased tariffs or taxation on oil almost forcing consumers towards an alternative heat source, paving the way for geothermal. This is not a quick fix, rather allowances must be made for a 10 year + transition away from oil with due regard taken for the economic and social impacts of a declining oil industry in NI. Numerous off-gas grid, rural dwellings in NI (Figure 8) draws comparison with the case study in Derbyshire where a larger scale heat pump was installed to supply heat to 18 dwellings. A similar idea is transferable to NI in that council's may install GSHP's to supply their residents. This could be done in partnerships with neighbouring residents and facilitated by the council thus increasing efficiency and spreading initial cost across multiple owners. This would require NI councils to adopt their own public engagement strategies, however, may experience complications in the form of stakeholder disagreement.

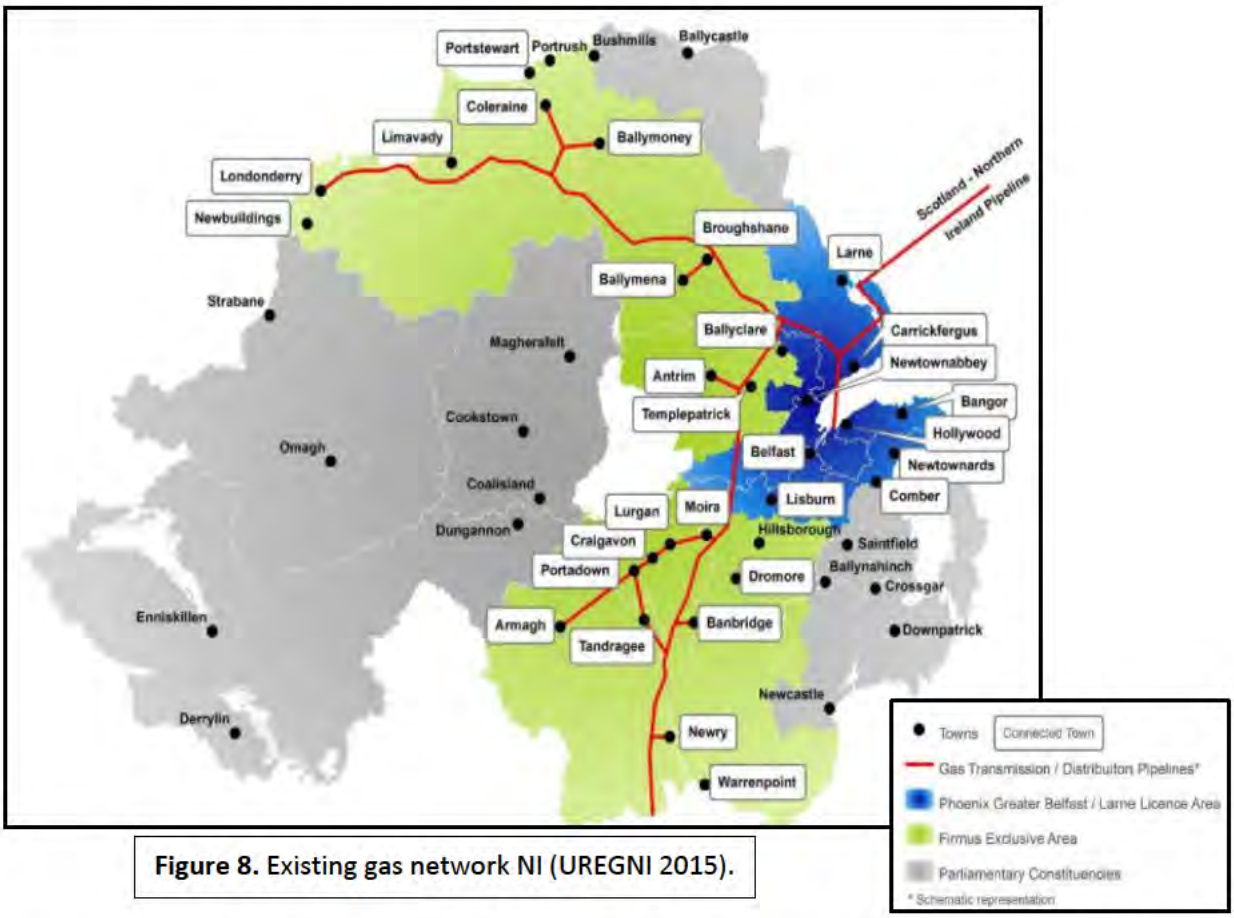


**Figure 8.** Existing gas network NI (UREGNI 2015).

There are commonly raised issues with geothermal utilisation, for example heat extraction can induce seismicity and in the case of open looped systems, groundwater may become contaminated. These hazards can be mitigated by accurate subsurface modelling which will inform planners as to the inherent risk at a given site allowing for implementation of certain heat pump and monitoring systems enhancing cost-effectiveness (Han et al. 2017).

**Conclusion**

In order to influence NI governmental policy, it is necessary to provide evidence supporting a certain strategy through a capability framework supported by a policy analysis. To encourage implementation of geothermal energy into the DfE's upcoming energy strategy it was necessary to first assess NI's potential for geothermal alongside its capability as outlined in research question one. Based on Figures 1-5, there is evidence suggesting NI has the geological capability for country-wide closed loop vertical systems. This is supplemented with site specific geology supporting open-looped systems (Figure 1), particularly around the sedimentary basins (Figure 5) and Sherwood Sandstones of Greater Belfast (Figure 4). Based on these results, it is recommended that allowances for small scale closed loop systems are made across NI with particular focus on the Greater Belfast Sherwood Sandstone aquifer as a source of large volumes of geothermal energy via open looped systems. Based on Figure 7, these sites are of high population density therefore vertical GSHP's are recommended to reduce landscape surface impact.

Regarding policy (research question two), recommendations surround both legal and financial guidelines for NI government to follow with consideration to clear, consumer friendly legislation alongside guaranteed and realistic financial incentives. More specifically, clarification of resource ownership, assigned leading authority for the industry and a regulated licensing system are recommended. These suggestions will help ensure certain standards are maintained whilst mitigating environmental issues associated with geothermal energy. Similarly, re-introduction of a revised RHI – /like system would reduce the initial financial burden of GSHP installation. This must be set up alongside preferential taxation and tariff systems compared with oil and gas, again to encourage consumers via financial benefits. Transferable lessons learned via policy analysis of European case studies lead to recommendations including realistic time frames for strategies as well as continuous public engagement with projects in order to realise NI's high potential for geothermal utilisation.

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## 7. Power

Q24. What is the appropriate pathway for the decarbonisation of power from now to 2030, and subsequently to 2050?

Q25. What target for electricity consumption generated from renewable sources by 2030 is ambitious, achievable and affordable?

Q26. How can the new infrastructure necessary to meet a new renewable electricity target be delivered in a timely, affordable and acceptable way for consumers and society?

Q27. What innovations and solutions could contribute to meeting a new renewable electricity target?

Q28. What market incentives and support are necessary for investors to deliver the investment in renewable generation assets at a scale that will achieve a new renewable electricity target?

Q29. What steps need to be taken by Government to facilitate investment in offshore and marine renewables for NI?

## 8. Transport

Q30. What would be an appropriate pathway to decarbonised energy for transport to 2050?

Q31. What role should active travel have in the decarbonisation of the transport sector and what should government do to support this?

Q32. What energy infrastructure is needed to facilitate the uptake of electric vehicles in line with UK Government's 'Road to Zero' targets?

Q33. How will transport integrate with other energy uses (e.g. homes with solar generation, battery storage, EV charging) and what can government do to optimise the opportunities represented by this integration?

Q34. To what extent can alternative low carbon transport fuels contribute to decarbonisation of the transport sector?

Q35. Do you have any data/research to help inform and reduce the carbon intensity of our transport energy in order to achieve net zero carbon by 2050?

## 9. Other Issues:

### a. Security of Supply

Q36. What specific risks to security of energy supply are likely to emerge as a result of our changing energy mix, and what actions can be taken to mitigate these?

Q37. What measures or indicators could be adopted or developed to monitor energy security of supply?

### b. The Role of Data

Q38. What is the most cost-effective method of capturing consumer energy usage data in electricity and natural gas (where meters are in place)? In heating oil (where there is no metering obligation)?

Q39. What concerns need to be addressed regarding data privacy, security and/or ownership?

Q40. What are your views on applying the key recommendations of the Energy Data Taskforce for NI?

Q41. What organisations or businesses do you see as having a key role in optimising the value of data? How will they do this?

### c. Carbon Capture and Storage

Q42. What steps, if any, should NI policy-makers consider with regard to the development or implementation of CCUS in NI?

### d. Energy and the Economy

Q43. What specific economic opportunities will arise from the decarbonisation of energy?

Q44. What skills are needed to realise the potential economic benefits of energy in the future?

Q45. What are your views on the future of overall energy demand in NI and how can we ensure that any potential demand growth aligns with our net zero carbon target?

### e. Delivery Framework for an Energy Strategy

Q46. Do the existing division of responsibilities and powers across government enable the most effective approach to the overall aim of decarbonising energy? If not, what are your suggestions for improvement?

Q47. What are the opportunities for local government to contribute to the delivery of the net zero carbon target?

Q48. What are your views on how statutory duties and accompanying legislation and regulatory frameworks would need to change to facilitate the transition to net zero carbon by 2050?

Q49. Is there a need for a dedicated organisation to champion, lead and deliver sustainable energy interventions? If so, what should this look like?

## 10. Additional information

Q50. Is there anything else you would like to add in response to this Call for Evidence?