Public Perceptions of Hydrogen as an Energy Vector and Aid to Decarbonisation in the Republic of Ireland

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Declaration

The author hereby declares that, except where
duly acknowledged, this thesis is entirely his own work
and has not been submitted for any
degree in any University, Institute of Technology, or other HE Institution by me or anybody
known to me, or for any other qualification/examination.

Name: ___________________________ Date: ______________________

Colm Delaney
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## Glossary of Terms

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<tr>
<td>ALARP</td>
<td>As Low As Reasonably Practicable</td>
</tr>
<tr>
<td>BTU</td>
<td>British Thermal Unit</td>
</tr>
<tr>
<td>CAQDAS</td>
<td>Computer Assisted Qualitative Data Analysis Software</td>
</tr>
<tr>
<td>CPD</td>
<td>Continuous Professional Development</td>
</tr>
<tr>
<td>ESB</td>
<td>Electricity Supply Board</td>
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<tr>
<td>GDPR</td>
<td>General Data Privacy Regulations</td>
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<tr>
<td>IET</td>
<td>Institution of Engineering Technology</td>
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<td>IGEM</td>
<td>Institution of Gas Engineers and Managers</td>
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<td>P2G</td>
<td>Power to Gas</td>
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<td>PSO</td>
<td>Public Service Obligation</td>
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<td>RTE</td>
<td>Raidió Teilifís Éireann</td>
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<td>SEAI</td>
<td>Sustainable Energy Authority of Ireland</td>
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<td>SME</td>
<td>Small and Medium Enterprises</td>
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<td>SMR</td>
<td>Steam Methane Reforming</td>
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<td>USC</td>
<td>Universal Social Charge</td>
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Dedication

To my darling Emma, for your encouragement, support, and sacrifice. None of this would have been possible without you, and I am eternally grateful.

To my parents, Ann and Henry, for only ever asking that I do my best, as I can do no more.

To my son Eoin, for brightening up the darkest days when doubts weighed heavily.

Perseverantia Vincit.
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My sincerest thanks to my supervisor, Dr Angela Wright, for her enthusiasm, guidance, and encouragement over the past two years. Angela’s vast experience and supportive advice helped focus my thoughts and calm my doubts as I navigated through this research study.

I wish to thank all those who willingly gave their time to participate in this study, all of whom enthusiastically provided invaluable insight into their thoughts and beliefs.

Finally, I would like to thank my partner Emma for her encouragement, support, sacrifice, and sympathetic ear over what has been a long journey. You always had faith in me, and I am forever grateful.
Abstract

In the face of global commitments to decarbonise society by 2050, there is growing excitement surrounding the potential of hydrogen to emerge as a solution to many decarbonisation challenges. A transition to hydrogen as an energy vector in place of fossil fuels such as natural gas will require a significant transformation of existing energy policy, infrastructure, and regulations. While the technical aspects of a potential transition to hydrogen as an energy vector are undergoing large scale research, much of which is moving into the trial phase, it is widely presumed that a transition would be met with the widespread acceptance of hydrogen by the public. This research examines how the public perceives hydrogen as an energy vector in the Republic of Ireland, outlining potential obstacles to its acceptance.

This study seeks to address the research question and contribute to knowledge via an interpretive approach employing sequential mixed methods research design combined with a triangulation approach. A detailed literature review was carried out, which informed a quantitative survey of the public with 115 valid responses received. The quantitative aspect of the study was examined thematically using computer-assisted qualitative data analysis software NVivo to identify themes and aid the interpretation of data. The quantitative survey results informed the eight semi-structured qualitative interviews carried out with members of the public to gather more detailed data leading to detailed findings.

This study finds that public perceptions of hydrogen as an energy vector are not entirely hostile, with broad acceptance evident, although some opposition to a transition was observed. The two overarching themes of this study is that of safety and cost. Safety is viewed as a prerequisite to any transition, with the public trusting that the safety of hydrogen will be demonstrated before a transition, and a competent authority will act with safety in mind. The cost of a transition to hydrogen as an energy vector is vital to its acceptance by the public. Increased cost to consumers has the potential to result in the widespread rejection of a conversion as concerns regarding cost far outweighed the environmental benefits of hydrogen among the public.

This research will be of benefit to policymakers, researchers, gas network operators and businesses with an interest in a transition to hydrogen as an energy vector.
1.0 Introduction

*Global warming and energy crises are among the most important issues that threaten the peaceful existence of humankind,*

(Mazloomi & Gomes, 2012).

1.1 – Introduction

Climate change is one of our most significant global challenges, and the implications of not rising to this challenge could be catastrophic. The Government of Ireland (2019) climate action plan believes that increased electrification is the best approach for decarbonising the Irish economy. The vast electrification of sectors serviced by natural gas would require a vast and capital-intensive expansion of the electrical network and deep retrofitting of many homes and businesses. The Irish gas network currently transports three times more energy than the electricity network and can store vast amounts of energy economically; if this gas network is converted to carry hydrogen, it could provide a promising avenue for decarbonising energy systems, (Sgobbi et al., 2016).

Hydrogen can be used in a broad range of new applications as an alternative to fossil fuels or as a complement to the greater use of electricity. (International Energy Agency, 2019). The use of hydrogen as an environmentally friendly alternative to fossil fuels has attracted considerable attention over recent years, with the field gathering significant momentum. Large investments in hydrogen infrastructure have been announced of late, with the ESB announcing the creation of a green hydrogen generation facility at Moneypoint Co. Clare, (ESB, 2021), and energy company EI-H2 announcing a 50MW green hydrogen production facility in Aghada Co. Cork, (O’Sullivan, 2021), indicating growing confidence in hydrogen as an energy vector.
This study investigates public perceptions of hydrogen as an energy vector and aid to decarbonisation in the Republic of Ireland. While the technical aspects of hydrogen as an energy vector are undergoing large scale research and investment, the social aspects of using hydrogen as an energy vector have not received as much attention in comparison.

Understanding and integrating the public needs and concerns with the management of hydrogen projects could be crucial for developing hydrogen technologies and help avoid misunderstandings that may accompany development, (European Commission, 2017).

This research study employs a mixed-method triangulation approach to investigate public perceptions of hydrogen. Understanding the perceptions of hydrogen as an energy vector among the public will allow policymakers and stakeholders to develop a deeper understanding of the potential social challenges of a transition to hydrogen in place of natural gas and provide a foundation for developing a transition strategy combined with further research.

This research study combines the findings of the secondary data with quantitative surveys that informed later qualitative interviews. This approach allowed for the initial gathering of a broad range of information to identify themes followed by targeted semi-structured interviews to gain a deeper understanding. This research strategy allowed the researcher to maximise the information gathered in the time available. The researcher aims to provide perspective on the challenges associated with the social aspect of a transition to hydrogen from natural gas and make recommendations for action and future research.
1.2 – Background

In 1776, hydrogen was first identified as an element by Henry Cavendish. In a demonstration to the Royal Society of London, Cavendish applied a spark to hydrogen gas, yielding a flame and water; this discovery led to his later finding that water is made from hydrogen and oxygen, (Jonas, 2009). Hydrogen and energy have a long-shared history; the first demonstration of water electrolysis captured the attention of scientists and engineers in the 1800s. Hydrogen was used to fuel the first internal combustion engines over 200 years ago, t provided lift to balloons and airships in the 18th and 19th centuries, and propelled rockets to the moon in the 1960s, (International Energy Agency, 2019). Because hydrogen is the most widespread molecule on earth, it can be obtained from several sources, both renewable and non-renewable, (Bičáková & Straka, 2012).

Hydrogen is presently used predominantly to produce chemicals such as methanol and ammonia, (Bičáková & Straka, 2012). Although it is not naturally available as a ready to use substance, the features and properties of hydrogen make it a very promising energy vector or fuel, (Mazloomi & Gomes, 2012). Currently, there is a growing interest in the widespread use of hydrogen for clean energy; this interest is primarily due to two attributes of hydrogen.

Firstly, hydrogen can be used without direct emissions of air pollutants or greenhouse gasses. Secondly, hydrogen can be made from a diverse range of low carbon energy sources, (International Energy Agency, 2019). Hydrogen has become the subject of interest of numerous companies and countries for its broad range of applications and environmental credentials, (Bičáková & Straka, 2012). Currently, vast amounts of technical research and development are underway to develop hydrogen applications further and reduce production costs to an affordable level.

While the technical aspect of hydrogen applications is essential, informing what is required to make the use of hydrogen viable, research regarding how the general public perceives
hydrogen as an energy vector is lacking. Given the potential of hydrogen and the importance of public acceptance in its success, the researcher concluded that examining public perceptions of hydrogen was a worthy pursuit.

1.21 – Hydrogen Defined

Hydrogen is the most abundant and simple molecule on earth; it is a colourless, odourless, and tasteless molecule. Present at the beginning of the universe, hydrogen is the ancestor of all heavier and more complex elements, (Tapan & Malbrunot, 2007). Hydrogen is not naturally occurring but can be extracted from other elements in molecules, such as water, (Tapan & Malbrunot, 2007). Hydrogen is very light, being fourteen times lighter than air and has a very high energy content per unit of mass compared to oxygen, (Tapan & Malbrunot, 2007). Due to hydrogen’s low density, which is eight times lower than natural gas, two and a half times more hydrogen is required to produce the same energy as a volume of natural gas, (Tapan & Malbrunot, 2007).

1.22 – Perception Defined

_Perception is a belief or opinion, often held by many people and based on how things seem,_


The most natural view to take of perception is that it is a process by which we acquire knowledge of an objective world; we take this world to consist of physical objects and happenings, which exist independently of us and our acts of perceiving and which are the things we commonly perceive, (Maund, 2003). It has become widely believed that all perception is theory-laden and strongly conceptual, (Maund, 2003). Perception is one of the significant sources of our acquisition of knowledge in the world. (Maund, 2003). Perception
and perceptual decision-making are strongly influenced by prior knowledge about the probabilistic structure of the world, (de Lange et al., 2018).

The world of perception, or in other words, the world which is revealed to us by our senses and in everyday life, seems at first sight to be one we know best of all. For we need neither to measure nor calculate to gain access to this world and it would seem that we can fathom it simply by opening our eyes and getting on with our lives.


As a constructive or predictive organ, the human brain actively generates predictions of its sensory inputs using an internal or generative model; this is a widely accepted view of perception (Friston, 2012).

1.23 – Energy Vector Defined

An energy vector allows a transfer in space and time, a quantity of energy, (Krajačić et al., 2008). An energy vector is an energy-rich substance that facilitates the translocation and storage of energy with the intention of using it at a distance in time and space from the primary production site, (Abdin et al., 2020). Hydrogen is often referred to as an energy vector as it allows for energy to be transported and then converted to another form of energy, (International Polar Foundation, 2021).

1.24 – Decarbonisation Defined

Decarbonisation is about reducing CO2 emissions resulting from human activity with the eventual goal of eliminating them, (Deloitte, 2021). The 2015 Paris Agreement set an ambition to limit global warming to 2°C above pre-industrial levels and pursue efforts to
limit it to 1.5°C, in part by pursuing net carbon neutrality by 2050, (Delbeke *et al.*, 2019). In practice, getting to zero net emissions requires shifting from fossil fuels to alternative low carbon energy sources, (Deloitte, 2021).

1.3 – Research Justification

As a result of working within the energy industry for the last ten years, the researcher is acutely aware of the challenges society faces in weaning itself off fossil fuels and reducing the impact of climate change. The use of hydrogen as a carbon-free alternative to many fossil fuels, such as natural gas, is increasingly being viewed as a solution to energy problems globally, with many countries and businesses investing heavily in research and development with live trials of hydrogen in place of fossil fuels becoming commonplace. This recent attention is being driven by hydrogens potential to decarbonise vast swathes of society with the least disruption compared to other decarbonisation options.

While vast expense is being burdened in order to overcome the technical challenges associated with a conversion of portions of society dependent on fossil fuels to hydrogen, there is comparably limited research in the area of public perceptions. It is widely believed that social acceptance plays a vital role in the future of hydrogen and a broad market launch of hydrogen technologies. Neglecting the social aspect of a hydrogen transition may result in severe obstacles to the establishment of infrastructure. (Achterberg *et al.* 2010; Bögel *et al.* 2018; Heinz & Erdmann, 2008; Huijts *et al.* 2012; Ingaldi & Klimecka-Tatar, 2020; Iribarren *et al.* 2016; Schulte *et al.* 2003). Given that a detailed understanding of public perceptions of hydrogen can inform a future transition strategy to ensure public acceptance and overall success, the researcher deemed that carrying out the first study into public perceptions of hydrogen in the Republic of Ireland was warranted and would contribute to increasing knowledge in this area.
The cost of our success is the exhaustion of natural resources, leading to energy crises, climate change, pollution, and the destruction of our habitat. If you exhaust natural resources, there will be nothing left for your children. If we continue in the same direction, humankind is headed for some frightful ordeals, if not extinction.

(Christian de Duve).

1.4 – The Research Question

After some consideration and a review of existing relevant literature, the following research question emerged as a suitable and relevant topic of interest at this time:

Public Perceptions of Hydrogen as an Energy Vector and Aid to Decarbonisation in the Republic of Ireland.

1.5 – Research Aims and Objectives

This section presents the aims and objectives of this research.

1.51 – Research Aim

This research has the following aim:

To ascertain, explore and document public perceptions of hydrogen as an energy vector and aid to decarbonisation in the Republic of Ireland while seeking to contribute to knowledge in the area.

1.52 – Research Objectives

This research has the following objectives:

- To review all relevant literature pertaining to the research question.
• To meet the public and explore opinions and attitudes regarding hydrogen as an energy vector.
• To analyse themes emerging and develop detailed findings.
• To investigate if previous research is consistent with the findings of this study.
• To make recommendations for practice and policy based on empirical findings.

1.6 – Research Focus

Chapter 1 introduces the area of study, the background of the research question and relevant definitions. The justification for the research is outlined to provide context for the proceeding chapters of this document. The aims and objectives of this research study are also outlined, concluding with an overview of this document’s structure.

Chapter 2 contains a comprehensive review of the relevant literature surrounding the research question. The chapter opens with an examination of the need for decarbonising society, followed by an outline of hydrogen, hydrogen production methods, perceptions of hydrogen safety, cost, and trust. The chapter concludes with a dive into the literature regarding acceptance and information on hydrogen.

Chapter 3 outlines the research methodology chosen for this study as the researcher progressed through the research journey. The researcher chose an interpretive approach employing a sequential mixed methods design combined with triangulation for this study. The chapter presents the research philosophy, methodologies, research design, research journey for this study and details the primary and secondary data collection methodologies and how the data was analysed. This chapter concludes with the ethical considerations followed during this study, including privacy considerations. The limitations of the study are also outlined in detail.
Chapter 4 presents the main findings of this study, consisting of a quantitative survey of 115 respondents, followed by semi-structured qualitative interviews with eight participants.

Chapter 5 contains a discussion of this study’s main findings, which were gleaned from a comparison of the quantitative and qualitative data found in chapter 4 with the relevant literature presented in chapter 2. The chapter discusses the themes emerging from the research study, provides recommendations for future practice, and outlines areas that the researcher believes warrants further research.
2.0 Literature Review

2.1 – Introduction

This chapter will provide the reader with an overview of the literature relating to the research topic “Public Perceptions of Hydrogen as an Energy Vector and Aid to Decarbonisation in the Republic of Ireland”. To inform this chapter, the researcher extensively reviewed academic journals and reports relating to this topic. In light of increasing pressure to decarbonise society in an attempt to halt climate change, researchers are paying closer attention to hydrogen as an energy vector. The technical aspects of using hydrogen as an energy vector have become increasingly popular in recent years, with many mooting its use as the solution to decarbonising the world’s economies.

While the technical aspects are undergoing large scale research, the social aspects of using hydrogen as an energy vector have gradually become more popular, particularly public perception and acceptance. While all the literature consulted contained gaps, and some even concluded that more research is needed into the area of public perceptions of hydrogen, the researcher has deduced that no research currently exists into public perceptions of hydrogen as an energy vector and aid to decarbonisation in the Republic of Ireland.

2.2 – Climate Change – Irish Context

According to Gas Networks Ireland (2019, p.2), climate change is one of our greatest and most urgent global challenges. This challenge is man-made, and the implications of not solving it are catastrophic. Government of Ireland (2019) agrees, outlining that global warming is having far-reaching and profound impacts on communities, human health, and the world's climate, major economies are falling short of climate change targets, and Ireland is no exception”, (Government of Ireland, 2019).
As economic recovery has taken hold, it is clear that the link between prosperity and emissions has not been broken. To avoid the risk of long-lasting or irreversible changes to the climate system, it is clear that we must make rapid, far-reaching and unprecedented changes across all aspects of society. The transition to clean energy is an essential part of this.

(Government of Ireland, 2019, p.8).

Government of Ireland, (2019) details that the impact of greenhouse gas emissions on the climate must be arrested, and the window of opportunity is fast closing. Government of Ireland, (2019) also states that removing fossil fuels from the electricity grid will be essential in the coming years.

2.3 – Fossil Fuels & Renewables

Devlin et al. (2017, p.1) observed that "no single solution currently exists to achieve zero fossil-fuel electricity generation. Until such time, it is evident that the energy mix will contain a large variation in stochastic and intermittent sources of renewable energy such as wind power. The drive for wind has been highly beneficial in terms of security of energy supply and reducing greenhouse gas emissions. However, it has created an unusual ally in natural gas".

2.4 – Natural Gas

Costello (2017) believes that most environmental groups viewed natural gas favourably in facilitating the transition to a low carbon network until recently. Costello (2017) also outlines that this view has changed radically by opposing the use of natural gas for electrical generation and heating. Today, environmental groups and others have radically changed their perspective by opposing natural gas for electricity generation, (Costello, 2017). According to Krug & Lebelhuber (2018), natural gas is witnessing significant challenges regardless of its
environmental advantages over other fossil fuels. Krug & Lebelhuber, (2018), goes on to suggest that, despite the existing challenges, the natural gas sector can still play a substantial role in meeting EU future energy demand.

*The gas network holds value in relation to flexibility of operation, requiring simpler control and enabling less expensive storage. There may be value in retaining and repurposing gas infrastructure where there are feasible routes to decarbonisation.*

(Balcombe *et al.*, 2018, p.1).

2.5 – Decarbonisation – European Context

In order to fully support renewables and help achieve a net-zero carbon energy system by 2050, the gas network will also need to decarbonise fully, (Government of Ireland, 2019). The EU agrees that the future role of gas and gas infrastructure in the energy system will be strongly influenced by its ability to decarbonise the gas supply and replace natural gas with carbon-neutral gases, such as hydrogen (European Parliament, 2018).

The European Parliament Policy Department (2018, p.7) also states that "improving the integration of the electricity and gas sectors would also allow an optimised use of existing gas infrastructure. Gas pipelines transport renewable energy from supply areas to areas with shortages, reducing the need to expand the electricity transmission capacity".

2.6 – Sector Coupling

Due to the reliance of electricity systems on gas infrastructure for security of supply, it is essential that the gas and electricity networks are planned together in the future, (Devlin *et al.*, 2017). Buttler & Spliedhoff refer to this theory of combined planning as "sector
coupling”, (Buttler & Spliethoff, 2018, p.1). Schiebahn et al. (2015) found that due to the increased presence of fluctuating renewable power production, there is an increased need for power storage to provide balancing capabilities. Schiebahn et al. (2015) also outline that the conversion of surplus renewable electrical power into chemical energy will provide the required energy storage needed by renewables and will require the coupling of the electricity and gas sectors. Boudellal (2018) agrees and concludes that the coupling of electricity and gas networks will lead to the better management of the two. Boudellal (2018) suggests that the development of power to gas technology (P2G) should be integrated into the regulatory and legislative framework.

2.7 – Power to Gas

Qadrdan et al. (2015, p.2) state that "power-to-gas (P2G) converts electricity into hydrogen using the electrolysis process and uses the gas grid for the storage and transport of hydrogen”, further outlining that “hydrogen is injected into a gas network in a quantity and quality compatible with the gas safety regulations and thereby transported as a mixture of hydrogen and natural gas to demand centres". According to Olczak & Piebalgs (2018), excess electricity renewable electricity is currently curtailed; sector coupling allows for the generation of renewable hydrogen using excess electricity, which can then be stored.

*The production of hydrogen through electrolysis is an area that provides significant opportunity. The synergies of reducing renewable energy curtailment, providing alternative energy sources for transport and possibly heat, as well as decarbonising the gas network all point to hydrogen as being a real opportunity for the integration of energy systems. It also reduces the reliance on electricity network infrastructure as the hydrogen can be transported by different means.*

(UCD Energy Institute, 2020, p.4)
2.8 – Hydrogen

Hydrogen produces zero CO2 when combusted and has the potential to play an increasing role in Ireland’s decarbonisation strategy. Much like natural gas, hydrogen can be used for heating, transport, industry, and power generation. Hydrogen can be mixed with natural gas or renewable gas in small percentages to form a blended gas or it can also be used on its own.

Gas Networks Ireland (2020, p.11)

Around the world, there is growing excitement about the potential for an emerging hydrogen economy to transform many countries’ energy supply, (Lambert & Ashworth, 2018). With a global energy sector in flux, hydrogen’s versatility is attracting stronger interest from a diverse group of governments and companies (International Energy Agency, 2019).

Presently, hydrogen is used mainly in the chemical industry; in the near future, hydrogen will become a significant fuel, (Bičáková & Straka, 2012). Because hydrogen is the most widespread component on earth, it can be obtained from several renewable and non-renewable sources (Bičáková & Straka, 2012). Scott and Powells (2019) agree, further stating it is possible that hydrogen could replace natural gas in the gas network, achieving key carbon emissions reduction targets while enabling homes to be heated to a similar level and standard as they currently are. As a pure element, hydrogen leaves no carbon footprint; the only product of its combustion is water; therefore, hydrogen is a clean source of energy at the point of use (Hull & Kane, 2016). Unlike Natural Gas, hydrogen is not found naturally and must be industrially produced, (Hull & Kane, 2016).

Gas Networks Ireland (2020) is investigating the potential of hydrogen production and transportation using the gas network. Similarly, hydrogen is being piloted and evaluated for
use in gas networks for heating transport and power generation in many countries worldwide, (Gas Networks Ireland, 2020). Hull & Kane (2016) believe that using alternative gases such as hydrogen is technically feasible today, detailing that much of the existing gas infrastructure can be used, thereby limiting the inconvenience of change for gas customers and society overall. Conversion at scale will be logistically challenging, although it was carried out in the 1960s and 1970s where networks were converted from towns gas to natural gas, (Hull & Kane, 2016). Pellegrini et al. (2020) outline that hydrogen can be blended with natural gas in the gas network and detail that the blending of hydrogen into the natural gas network is key to enabling hydrogen production in a preliminary and transitional phase.

2.9 – Blended Hydrogen

Hydrogen blending is the injection of hydrogen into existing natural gas infrastructure, (ENTSOG et al., 2021). According to Pellegrini et al. (2020), hydrogen blending into natural gas networks has a huge potential in terms of environmental and social benefits, but it is still facing several technological, economic, and legislative barriers. Kouchachvili & Entchev (2018) also agree, stating that blending hydrogen into existing natural gas networks would provide a boost to hydrogen supply technologies without incurring the investment costs and risks of developing new hydrogen transmission and distribution infrastructure. Kouchachvili & Entchev (2018) also argue that blending hydrogen into existing natural gas infrastructure would also avoid the significant capital costs involved in developing new transmission and distribution infrastructure.

According to Gas Networks Ireland (2019), hydrogen can be mixed with natural gas in small percentages to form a blended gas and further details that existing natural gas boilers are understood to be compatible with small percentage blends of hydrogen in natural gas. Syron & Doorly (2020), agree stating that hydrogen can be blended with natural gas, and such an approach would reduce the amount of consumer disruption as low concentrations of hydrogen
(<20%) would not require any infrastructure changes. Gas Networks Ireland (2019) suggest that Ireland’s gas network has the potential to transport large volumes of hydrogen, detailing that the low-pressure distribution network is understood to be compatible with 100% hydrogen. Work is also underway to evaluate the compatibility of the high-pressure steel transmission pipelines with hydrogen. (Gas Networks Ireland, 2019). If hydrogen blending were to be carried out at low levels, it might increase the cost of natural gas delivery to consumers; however, it would also provide reductions in CO2 emissions, (Kouchachvili & Entchev, 2018). European Commission (2020) believe that the blending of hydrogen in the natural gas network may enable decentralised renewable hydrogen production.

2.10 – Hydrogen Production

Presently, hydrogen is mainly produced by steam reforming of natural gas, which has led to massive emissions of greenhouse gasses, close to 50% of the global demand for hydrogen is currently generated via steam reforming of natural gas, (Dincer, 2012). Gas Networks Ireland (2019) agrees that hydrogen is primarily produced by separating it from methane through a process called ‘steam methane reforming (SMR), which produces CO2 emissions. According to National Grid Group PLC (2021), hydrogen produced from natural gas or methane using SMR without capturing the greenhouse gasses is known as “Grey hydrogen”.

Van Melle et al. (2018) defines renewable gas as any gas produced from renewable sources. Van Melle et al. (2018) further outlines that a scale-up of renewable gas can play an essential role in the decarbonisation of the gas supply. According to Abbasi & Abbasi (2011), hydrogen can be renewable if generated by employing genuinely carbon-free renewable energy sources. In order to address the challenges associated with decarbonising our entire energy system, we must examine the role that green hydrogen can play, (Syron & Doorly, 2020). Hydrogen produced from sustainable energy sources is known as green hydrogen, (Dincer, 2012). According to Ricci et al. (2010), using renewable energy sources to produce
hydrogen was generally favoured by the public. Zimmer & Welke (2012) agree, concluding that hydrogen needed to be “green” as hydrogen produced from fossil fuels did not incentivise its use among the public.

Renewable energy sources were seen as the most desirable way forward for hydrogen production.

(Cherryman et al., 2008, p.408)

2.11 – Potential of Hydrogen

Hydrogen can enable renewables to provide an even greater contribution; it has the potential to help with variable output from renewables, whose availability is not always well-matched with demand, (International Energy Agency, 2018). Hydrogen is one of the leading options for storing energy from renewables and looks promising to be the lowest-cost option for storing electricity over days, weeks or even months, (International Energy Agency, 2019). Cherryman et al. (2008) warn that while technological aspects of hydrogen are well researched, the social aspects of the transition are not. Cherryman et al. (2008), goes on to state that the public’s attitude and perception of hydrogen energy will be of great importance as we move closer to the implementation of the technologies.

2.12 – Public Awareness of Hydrogen

Ricci et al. (2010) found that many people are largely unaware of the distinctive properties of hydrogen and its applications. Ricci et al. (2010), goes on to conclude that public awareness of hydrogen, both in general and in relation to local demonstration projects, proved minimal, with the exception of the few who had direct experience of the chemical industry. Scott & Powells (2019) agree, finding that there is limited awareness and knowledge of hydrogen as a
possible fuel for homes among the public. Fylan et al. (2020) reinforce these findings, citing that none of the participants in their study was aware of hydrogen as a domestic fuel, and many had thought about where their gas and electricity came from and had very little interest in it. Flynn et al. (2013) summarise that given the relatively recent commercial and industrial interest in hydrogen energy, the relatively slow pace of technological innovation and the minimal number of publicly accessible demonstration projects, it is not surprising that public awareness of hydrogen energy is meagre. Interestingly, Flynn et al. (2013) found that public awareness of hydrogen was low; however, opinions were not hostile, citing that laypeople expected to be shown the advantages and benefits it could provide and were somewhat disappointed when these benefits were not unambiguously evident. Ricci et al. (2010) agree, finding that participants did not have established opinions or views on hydrogen as an energy carrier.

Reassuringly, Ricci et al. (2007) found that public perceptions of and attitudes towards hydrogen energy and applications indicated a very low level of public awareness and knowledge but rather widespread support. While Williams et al. (2018) report that just under half of their survey respondents heard of hydrogen fuel boilers. Ricci et al. (2007) further reported that awareness of hydrogen as an energy carrier varied widely, ranging from basic knowledge of what hydrogen is to an articulated understanding of its properties and uses. Interestingly, Schulte et al. (2003) detail that high environmental awareness seemed to influence attitudes to hydrogen more than technical knowledge. Schulte et al. (2003) argue that there needs to be a campaign to raise awareness of hydrogen and hydrogen technology before products come to market in order to alleviate public concerns. Schulte et al. (2003), goes on to outline that no effort has been made to provide the public with a coherent awareness campaign, further arguing that no such effort can be made until the public view of hydrogen is understood. Social acceptance plays a vital role in the future of hydrogen and a
broad market launch of hydrogen technologies, neglecting the aspect of public acceptance and attitude may become a severe obstacle to the establishment of mass-market infrastructure, (Heinz & Erdmann, 2008).

2.13 – Social Acceptance

Interest in hydrogen as a fuel and energy carrier has significantly grown internationally due to increasing concerns with environmental and energy security issues, and massive investments in research and demonstration programmes are being made worldwide, (Ricci et al., 2008). At the same time, hydrogen energy has attracted the attention of both natural and social scientists concerning questions about public perception and acceptance, (Ricci et al., 2008). According to Zimmer & Welke (2012), it is well known in socio-economics that the success of an innovation depends to a great extent on public acceptance.

While there are ambitious government targets to increase the share of renewable energy in many countries, it is increasingly recognised that social acceptance may be a constraining factor in achieving this target, (Wüstenhagen et al., 2007). Heinz and Erdmann (2008) agree, outlining that social acceptance plays an important role in the future hydrogen economy and a broad launch of hydrogen technologies. Segreto et al. (2020) found that social acceptance has proven to be a significant barrier in implementing renewable energy systems; while general acceptance is high, low local acceptance has hindered the development of renewable energy projects. Segreto et al. (2020) also suggest that the social acceptance by the general public, the stakeholders, and the potential customers of hydrogen projects and applications across Europe is widely recognised as a critical dimension in hydrogen technologies sustainable implementation. European Commission (2017) supports the findings of Segreto et al. (2020) by outlining that if hydrogen technologies are to play a significant role in Europe's new energy and transport systems, a careful consideration of social acceptance issues is needed.
According to European Commission (2017), the identification and understanding of the social acceptance of hydrogen technologies may help officials, planners, developers and the public identify and address potential conflicts of interest and misunderstandings that may accompany development. European Commission (2017) expands further, outlining that understanding and integrating the public needs and concerns with the management of hydrogen projects could be crucial for developing hydrogen technologies.

Fylan et al. (2020) found that there is limited understanding of the public’s perception of hydrogen, the information that people need to make an informed choice about using hydrogen in their homes, and how misunderstandings could present barriers to the uptake of hydrogen technology. Fylan et al. (2020) expand further, stating that gaining a greater understanding of public perceptions is crucial to ensure future policy and investment success. Iribarren et al. (2016) voiced a similar opinion but details that the assessment of public perception and social acceptance of hydrogen energy systems is crucial to avoid reluctance to deploy hydrogen technology and infrastructure. Iribarren et al. (2016) also found that the number of regional studies evaluating these aspects is scarce.

Bögel et al. (2018) argue that the social acceptance by the general public across Europe is widely recognised as a critical dimension in the sustainable implementation of hydrogen technologies. Bögel et al. (2018) conclude that if hydrogen is to play a significant role in Europe's new energy and transport systems, a careful consideration of social acceptance issues is needed.

Fascinatingly, Ricci et al. (2008) found that environmental benefits alone may not be sufficient to persuade people to make sacrifices that may be required in order to introduce cleaner technologies, citing that there is also a risk in associating hydrogen with increased prices. Acceptance is dynamic and will be subject to change as the hydrogen economy,
whatever this may be, unfolds (Ricci et al., 2008). Bögel et al. (2018) agree, suggesting that understanding and integrating the public needs and concerns with the management of hydrogen projects could be crucial for developing hydrogen technologies. Bögel et al. (2018) conclude that in-depth social research on hydrogen acceptance would provide insight into the state of public and stakeholder acceptance and about relevant factors affecting those levels of awareness and acceptance. Fylan et al. (2020) conclude that gaining a greater understanding of public perceptions is crucial to ensure future policy and investment success.

2.14 – Public Perception

According to Achterberg et al. (2010), the general public is generally supportive of hydrogen technology; however, knowledge about hydrogen is reasonably low. Iribarren et al. (2016) agree, citing that overall, the public was willing to accept hydrogen as a key energy carrier within the energy sector. Interestingly, Fylan et al. (2020) concluded that only 20% of the population would accept conversion to hydrogen with little reassurance, while 12% of the public will reject a conversion to hydrogen as they do not believe carbon emissions lead to climate change. Ricci et al. (2008) claim that opinions regarding hydrogen are generally neutral. Fylan et al. (2020) support this view, stating that 68% of the public are indifferent or undecided about a hydrogen conversion. Lambert & Ashworth (2018) agree, finding that neutral associations with the word “hydrogen” were the most common response.

*Overall, hydrogen appears to be a largely unknown and unfamiliar issue, which most people are unable to relate to their daily lives and experiences. Since people have little or no meaningful experience of hydrogen, they may not necessarily have an opinion about it. Across all groups, attitudes towards hydrogen were neither totally positive nor totally negative,* (Ricci et al., 2008, p6).
Ingaldi & Klimecka-Tatar, (2020) contradicts this, stating that despite the benefits of hydrogen energy, it creates considerable controversy in many countries. Ingaldi & Klimecka-Tatar, (2020), goes on to claim that negative attitudes to hydrogen energy can be an important barrier to the development of this energy in many countries.

Ricci et al. (2010) found that while support for the development of hydrogen as a fuel appears to be high in principle, support for specific applications or infrastructure appeared to be less enthusiastic. Ricci et al. (2010) suggest that the lay public as a whole is poorly informed about hydrogen; however, responses to attitudinal questions revealed a generally positive stance suggesting that most people would be prepared, in principle, to use hydrogen as a fuel. Interestingly, Achterberg et al. (2010) found that, while a significant portion of the general public would be supportive of hydrogen, 45% of participants were neither supportive nor unsupportive. Scott & Powells (2019) support this, claiming that there is little evidence that strong opposition or support for hydrogen currently exists among the public. Flynn et al. (2013) also support this claim, stating that public awareness of hydrogen is low, but opinions are not completely hostile. Interestingly, Achterberg et al. (2010) contradict the findings of Flynn et al. (2013), stating people who know very little about hydrogen technology tend to be unsupportive of hydrogen technology.

According to Scott & Powells (2019), overall, hydrogen is currently neither accepted nor rejected by the public, likely indicating that the majority do not know enough about it to offer a firm opinion. Similarly, Ricci et al. (2010) found that people felt reluctant to express definitive judgements about different hydrogen applications, as they had no knowledge and experience of any of them. Interestingly, Ricci et al. (2008) suggest that while public attitudes towards hydrogen are neutral, public attitude is not yet shaped by the altruistic concern for the wider public good. Heinz & Erdmann (2008) states that the number of people who are indifferent or need more information to come to a decision regarding the use of
hydrogen as a fuel is important for the balance of acceptance. According to Fylan et al. (2020), incorrect messaging could mean the large neutral proportion of the public may reject hydrogen as a fuel based on misperceptions or unfounded fears. Scott & Powells (2019) adds that if costs are passed to consumers, there will be considerable resistance to and even a rejection of hydrogen as part of the solution to the decarbonisation of energy systems. Cherryman et al. (2008) conclude that attitudes to the development of hydrogen technology were supportive with the caveat that price and safety should not be compromised.

2.15 – Perceptions of Safety

Lambert & Ashworth (2018) found that, consistently, safety was the number one concern in relation to the production and use of hydrogen. Flynn et al. (2013) further detail that public risk perception is a critical factor in the acceptance of hydrogen. According to Dodds & Demoullin, (2013), there are several safety concerns among the public surrounding the use of hydrogen in buildings as hydrogen has different properties to natural gas. These findings were echoed by Lambert & Ashworth (2018), whose study found that safety concerns existed among the public, with many expressing concern about the volatility and flammable nature of hydrogen and its comparative risk when compared to other fuels. Chaube et al. (2020) summarise that society is not convinced that the safety of hydrogen is adequate. Interestingly, Ricci et al. (2008) found that concerns about the safety of hydrogen as an energy carrier and fuel were widely expressed but seldom the cause of outright opposition. Fylan et al. (2020) disagree with the findings of Chaube et al. (2020) and Dodds & Demoullin (2013), finding very little concern among participants in their study about the safety of either their current natural gas supply or a future hydrogen supply, the participants of the study assumed that if hydrogen were to be supplied to their home, it would have been thoroughly tested and found to be safe. Lambert & Ashworth (2018) agree, finding that the majority of the public believe that there would be adequate safety precautions to keep the risks under control, further
detailing that this appeared to stem from a trust in the government to act in the best interests of society. This finding was echoed by Ricci et al. (2008), who found that despite the concerns with hydrogen safety, there was a recurring expectation that hydrogen technology and infrastructure would be engineered to be safe for use by inexperienced consumers. This is echoed by Scott & Powells (2019), who found that, while there are negative perceptions about hydrogen safety, there is simultaneously a strong sense of trust and confidence that these risks would be adequately mitigated before any public use of hydrogen. This finding is reinforced by Ricci et al. (2008), who found that safety is indeed important, but it is not the unique criterion by which hydrogen would be assessed by the public, concluding that it appeared that safety is regarded as a pre-requisite attribute and that hydrogen technologies are expected to be safe if rolled onto the market.

*Safety, while seen as important, was not a determining factor affecting people’s overall view; it was assumed that any new hydrogen technology would be deemed safe from the outset.*

(Flynn et al., 2013, p.389).

Ricci et al. (2008) warn that the apparent lack of concern about hydrogen safety should be taken with caution. A view which is supported by Scott & Powells (2019), who outlined that the level of initial safety concerns that respondents had was associated with their overall support for hydrogen, negative safety perceptions of hydrogen do exist and are important. Ricci et al. (2008) believe that given the limited public awareness of hydrogen, it is likely that current beliefs are strongly dependent upon the type of available information about hydrogen. According to ARUP (2018), consumer confidence in hydrogen needs to be built incrementally, with safety concerns addressed over time in a planned and strategic way.
Cherryman et al. (2008) concludes that the main concerns among the public were safety and cost, outlining that cost remained paramount, even in the light of environmental considerations.

2.16 – Cost

Scott & Powells (2019) found that the most notable initial negative perception of hydrogen was that it would be expensive. Flynn et al. (2013) agree, finding that the principal concerns among participants were costs to them as consumers as a result of using hydrogen, Flynn et al. (2008) agrees, finding that economic factors were highly significant in people’s approach to environmental and energy issues, therefore, people’s interest in, and willingness to adopt, new energy systems and technologies were heavily influenced by considerations of cost or price. According to Cherryman et al. (2008), unless hydrogen technology is more cost-effective than current technologies, participants would be reluctant to shift to hydrogen technology, citing that cost remains paramount, even in light of environmental considerations.

Lambert & Ashworth (2018) found that less than half of the participants in their study would be willing to pay more for hydrogen technologies, even if there were clear environmental benefits. Concluding that while many participants felt that the environment was important and were concerned about climate change, they were still unwilling to transition to hydrogen if it was felt that it would place unnecessary cost burdens on society, (Lambert & Ashworth, 2018). Interestingly, Scott & Powells (2019) agree, outlining that the most significant objection raised by participants of their study was the cost, with 77% of respondents unwilling to pay more for hydrogen than they currently spend on energy bills. Scott & Powells (2019) concludes that it is, therefore, possible that a changeover to hydrogen will be resisted if the costs are passed onto the public. Flynn et al. (2010) conclude that the public raise critically important questions about the relative costs and benefits of hydrogen
compared with other energy sources and expect to be shown demonstrable gains in
cconvenience, cost and practicality of everyday use.

A final important issue for hydrogen is its cost implications. More specifically, because
hydrogen is likely to be more expensive to produce, distribute, and transmit than natural gas,
there are unanswered questions about what the costs of hydrogen for homes will be, who will
bear that cost, and more broadly how any costs of hydrogen will be justly (or unjustly)
distributed across society,

(Scott & Powells, 2019).

Cherryman et al. (2008) conclude that environmental arguments alone seem unlikely to
change fuel usage behaviour, citing that participants found the environmental argument to be
reassuring, making hydrogen worthy of consideration but not compelling.

2.17 – Environmental Citizenship

Flynn et al. (2008) argue that while there is an awareness of the importance of energy issues
among the public, opinions regarding using hydrogen are generally neutral. Flynn et al.
(2008) further argue that there is little indication of the collective band of solidaristic values
said to characterise environmental citizenship. Schulte et al. (2003) agree, arguing that even
for those who are environmentally aware, the cost of a fuel was ultimately more important
than the impact of the fuel on the environment. Ricci et al. (2008) suggest that while public
attitudes towards hydrogen are neutral, public attitude is not yet shaped by the altruistic
concern for the wider public good.
Environmental benefits alone may not be sufficient to persuade people to make sacrifices (in the form of increased costs to consumers) for the introduction of cleaner technologies

(Ricci et al., 2008, p.12)

Interestingly, Scott & Powells (2019) conclude that people who display or identify as having strong environmental values or awareness are more likely to support hydrogen. However, Von Borgstede et al. (2013) warns that people are more likely to change their behaviour in an environmentally friendly direction when the cost difference is small, as compared to when this difference is large. Notably, Ricci et al. (2010) warn that trust and mistrust also play a major part in the public’s willingness to accept the use of hydrogen.

2.18 – Trust

Ricci et al. (2010) claim that the trust the public has in some sources of information and mistrust in others requires the special attention of policymakers and major players in the energy industry. A view reinforced by Cherryman et al. (2008), who discovered that some participants in their study were sceptical of politicians while others were sceptical of scientists. In addition, Scott & Powells (2019) found that the media is perceived negatively by the public. Interestingly, Scott & Powells (2019) found that while the public displayed a modest trust in government bodies, the same could not be said for politicians. Ricci et al. (2010) expand on these findings, detailing that there is a lack of trust in political authorities, business and industry. Surprisingly, Flynn et al. (2008) outline that the public frequently noted that innovation and change needed leadership; however, this was counterbalanced by some opposition to vested interests. Ricci et al. (2007) conclude that a frequent issue raised by many people was their ambivalence about what, and whom, to trust in the provision of information about hydrogen.
There is a backdrop of diffused public distrust of those who are in charge of regulating the risks (government and government agencies) and those who develop the technologies (industry and business). Further research would be needed to shed light on this issue. (Ricci et al., 2008, p.11).

Ricci et al. (2008) conclude that people need to trust government, industry and ‘other people’ to be committed towards a more sustainable energy future that incorporates hydrogen, citing that this contrasts starkly with the diffused sense of distrust that emerged from participants of their study. Ricci et al. (2008) further state that such ambivalence makes it difficult to engage in communication with and involve different publics in the development of hydrogen futures but suggests that attempting to re-build public trust might be a worthwhile preliminary goal. Ricci et al. (2008) believe that providing factual information on the whole hydrogen chain, not just applications and the implications it might have on the lives of citizens, is a necessary first step, adding that this should be followed by genuine forms of public engagement if hydrogen is to become an important player in the energy system.

2.19 – Information

Scott & Powells (2019) believe that as hydrogen moves into the mainstream and begins to be used in homes over the coming decade, there is an urgent need to better involve the public. Interestingly, however, Cherryman et al. (2008) found that knowledge of hydrogen does not influence acceptability as they found that there is a general interest in learning more among the public.
Educating the public will be a key challenge

(Williams et al., 2018, p.31).

Flynn et al. (2013) outline that participants in their study wanted to know how hydrogen would materially affect and improve their lives, citing that their attitudes depended on obtaining impartial information from unbiased experts. A view shared by Cherryman et al. (2008), who believe that there needs to be a campaign to raise awareness of hydrogen and hydrogen technology before products come to market in order to ameliorate public concerns.

Schulte et al. (2003) also believe that marketing has the potential to be highly effective in improving attitudes towards hydrogen; however, the problem in creating a marketing strategy for hydrogen is that the first step would be to create a positive image of hydrogen in general rather than promoting a specific product. Ricci et al. (2008) warn that demands for more information on hydrogen from the public should not be interpreted as a deficit of knowledge, finding that the public needs to be reassured that they can trust information providers in telling them that hydrogen is truly beneficial, and to show them the evidence.

2.19 – Research Purpose

According to Ricci et al. (2007), more engagement with public perspectives is needed to better understand the social and cultural contexts in which hydrogen-based technologies and systems might be appropriated and used. Schulte et al. (2003) agree that further research is needed to identify the potential misconceptions about hydrogen technologies; these would need to be addressed to optimise projects. Schulte et al. (2003) conclude that, in the past, feasible technologies have failed to be accepted due to an inadequate method of introduction; it would be a shame to render research efforts and investments useless because of a badly planned introduction of hydrogen fuel.
"The assessment of public perception and social acceptance of hydrogen energy systems is crucial to avoid reluctance to the deployment of hydrogen technology and infrastructure. However, the number of regional studies evaluating these aspects is scarce."

(Iribarren et al., 2016, p1).

2.20 – Summary

This chapter provided an extensive review of the literature pertaining to public perceptions of hydrogen as an energy vector in the Republic of Ireland. Due to increasing pressure to decarbonise society and halt climate change, governments, researchers and businesses are paying closer attention to hydrogen as an energy vector and its potential to decarbonise large sections of society. Previous studies have argued that it is possible that hydrogen could replace natural gas in the gas network, achieving key carbon emissions reduction targets while enabling homes to be heated to a similar level and standard as they currently are.

The production of hydrogen from renewable energy provides a significant opportunity for the future. Much like natural gas, hydrogen can be used for heating, transport, industry, and power generation. Hydrogen’s versatility and environmental credentials are attracting increasingly more substantial interest from a diverse group of governments and businesses, with hydrogen currently being piloted and evaluated for use in gas networks worldwide.

Through research, the researcher has discovered that the literature warns, while the technological aspects of hydrogen are well researched, the social aspects are not, further warning that the public’s attitude and perception of hydrogen will be of great importance, as it is well known that the success of an innovation depends to a great extent on public acceptance. Understanding and integrating public needs and concerns with the management of hydrogen projects are crucial to avoid reluctance to deploy hydrogen technology and
infrastructure. Conflicting views of public acceptance and perceptions were found among previous studies; however, some common themes were apparent. Safety was found to be an important factor in the acceptance of hydrogen among the public, although, rather interestingly, the literature outlines that the public trusts that hydrogen will be thoroughly tested and found to be safe before being supplied to homes. The safety of hydrogen is viewed as a prerequisite to any future conversion.

Public awareness of hydrogen as an energy vector was found to be minimal; however, attitudes were not found to be hostile. In addition, it was found that the environmental benefits of hydrogen may not be sufficient to persuade the public to accept its use. The literature has found that economic factors are highly significant in the public’s perception and acceptance of hydrogen as an energy vector, further finding that while a fuels environmental impact was substantial, they were unwilling to burden extra costs that could result from a transition to hydrogen. The trust and mistrust the public has in some sources of information require special attention from policymakers and stakeholders within the energy industry. The secondary data also warns that the public needs to be reassured that they can trust information providers in telling them that hydrogen is truly beneficial while showing them evidence. Educating the public will be a crucial challenge in a transition to hydrogen.
3.0 Methodology

*Methodology. the theory of method*


3.1 – Introduction

The purpose of this chapter is to introduce the research methodology for a mixed-methods study into public perceptions of hydrogen as an energy vector and aid to decarbonisation in the Republic of Ireland. Chapter 2 examined the literature findings and concluded that a greater understanding of public perceptions of hydrogen would help optimise future projects. It was also found that establishing a greater understanding of public perceptions of hydrogen as an energy vector is critical to avoid reluctance or opposition to its adoption.

This chapter outlines the research philosophy, research methodology, secondary data, the design of the research, primary data collection, the research sample, data analysis, reflective practice and the reliability and validity of the research. This chapter also outlines the limitations of the research study.

3.2 – Research Philosophy

3.2.1 – What is research

According to Wisker (2008), research underpins and informs our understanding and appreciation of all aspects of the world; its insights can lead to physical, social and personal growth and change. Wisker (2008), also states that research is about asking and beginning to answer questions, seeking knowledge and understanding of the world and its processes, and testing assumptions and beliefs. Adams *et al.* (2013) define research as a diligent search, studious inquiry, investigation, or experimentation aimed at discovering new facts and findings. In addition, Adams *et al.* (2013) state that, fundamentally, research is undertaken in order to enhance our knowledge of what we already know, to extend our knowledge about
aspects of the world of which we know either very little or nothing at all and to enable us to better understand the world we live in.

Robson (1993) believes that research needs to be ethical, sceptical, and systematic. According to Wisker (2008), research is based on enquiry methods, questioning hypotheses that need to be tested, and it contributes to our fund of knowledge about the elements and areas of the world with which we are involved in the research. Kellett (2005) supports this view by stating that research seeks to establish knowledge and understanding. Research is “guided by the researcher’s set of beliefs and feelings about the worlds and how it should be understood and studied”, (Denzin & Lincoln, 2005, p.22). In other words, all research is guided by beliefs about ontology and epistemology, (Williamson & Johanson, 2017).

Ontology refers to how the researcher experiences and perceives themselves in the world, (Wisker, 2008). Epistemology is knowledge, most particularly of how different disciplines construct, interpret and represent knowledge in the world, (Wisker, 2008).

Research sets out to establish the truth of something through a systematic and rigorous critical inquiry process where even the most commonplace assumption is not readily accepted until it has been validated (Kellett, 2005).

3.2.2 – Research Paradigms

According to Wisker (2008), research methodology springs from how we see the world; the same is the case for the subject area in which we work and the specific research question. Wisker outlines that a research paradigm, or perspective, is the underlying set of beliefs about how elements of research fit together, how we can inquire of it, make meaning, and make meaning of our discoveries (Wisker, 2008). Denzin & Lincoln (2005, p.22) define a research paradigm as “the net that contains the researcher’s epistemological, ontological and methodological premises”. While Kuhn (1970) defines research paradigms as “a set of
interrelated assumptions about the social world which provides a philosophical and
conceptual framework for the systematic study of that world”. According to Blaxter (2010),
there are five paradigms: positivist, post-positivist, interpretive, critical and postmodern.

3.2.2.1 – Positivism

The term positivist was first used in 1830 by the philosopher Comte, one of the founding
fathers of sociology, (Williamson & Johanson, 2017). The intellectual roots of positivism lie
as far back as Plato and his conviction that there was an objective, even a perfect order
underlying the world, even if our understanding was imperfect, (Hammond & Wellington,
2020). There are many interpretations of positivism, but the term is often used to describe a
belief, first, that the world is capable of objective interpretation and that, second, social
science should follow the methodologies and methods established in natural science,
(Hammond & Wellington, 2020).

According to Guba & Lincoln (1981), positivists are sometimes referred to as “rationalists or
realists”. The word “positivist” is a misleading one as it tends to conjure up someone who is
very sure of themselves or even someone of a sunny disposition, but its etymology lines in
the verb “to posit” – to put forward and by implication throw open to criticism, (Hammond &
Wellington, 2020).

According to Wisker (2008), some people, in some instances, believe that the world is
essentially knowable; that it consists of knowable facts; and that if we ask the right questions
in the right way, use the correct research methods, carry out the right kinds of experiments
and processes, we will discover these facts or truths, this is often called a positivistic research
methodology. If one believes that the world, particularly human behaviour, is definable,
fixable, provable and can be discovered and described in a manner somewhat resembling
rigid and unchanging facts, one might be undertaking positivistic research, (Wisker, 2008). In
the positivist view, it is contended that there is a reality out there to be studied, captured and understood, (Denzin & Lincoln, 2008). Positivistic research tends to attribute scientific status to social research, (Wisker, 2008).

3.2.2.2 – Post-positivism

Post-positivism is used to refer to an approach that accepts some of the basic tenets of positivism but that these tenets are modified by accepting that research is fallible, social realities are subjectively perceived, and causality may be on the balance of probability rather than the absolute, (Hammond & Wellington, 2020). In terms of methodology, post-positivism implies a flexible approach and a commitment to provide an audit trail and address bias and subjectivity as threats to objectivity (Hammond & Wellington, 2020). In short, post-positivism accepts old-style positivism has had its day but resists the embrace of subjectivity or relativism; it moves away from the presumption of positivism, (Hammond & Wellington, 2020).

In terms of methodology, many post-positivists are flexible in the methods they use and in how data is analysed, they will freely admit that their work is subject to challenge but believe they are doing something which is rigorous and that they are making justifiable statements about how the world is, (Hammond & Wellington, 2020). If one feels that the world is essentially indefinable, interpreted, shifting in meaning based on who, when, and why anyone carried out and adds the meaning, then one might be undertaking post-positivistic research, (Wisker, 2008). Postpositivists argue that reality can never be fully apprehended, only approximated, (Guba & Lincoln, 1981).

3.2.2.3 – Interpretism/ Constructivism

According to Wisker (2008), human beings have consciousness or a mind, and human behaviour is affected by knowledge of the social world, which exists only in relation to
human beings. The mind interprets experiences and events and constructs meaning from them – meaning does not exist outside the mind and the agreement of human beings, (Wisker, 2008). Hammond & Wellington (2020) outline that interpretivism views the world as capable of multiple interpretations and seeks to uncover the meaning that human beings invest in social activity. Hammond & Wellington (2020) further outline that interpretivist research aims to understand the meaning that cultural and institutional practices have for those taking part. Interpretivists would be expected to consider the world's subjective nature, treat meaning as socially constructed, and have a special concern with the unique character of human activity and the agency that creates social action (Hammond & Wellington, 2020).

The term constructivism can generally be used to offer a view that we are meaning-makers: the world is one in which we are required to seek out meaning rather than enter a world of behavioural associations, (Hammond & Wellington, 2020, p.38). Wisker (2008, p.69), agrees, having previously reported that constructivism is based on similar beliefs as interpretivism, as constructivism believes that human beings construct knowledge and meaning from experience and relationships between things, people and events.

An interpretive approach to research aims to understand how individuals make meaning of their social world and can be considered conterminous with a qualitative approach in general, (Hesse-Biber, 2010). A mixed-methods project from an interpretive perspective often uses quantitative research as an auxiliary to a primary qualitative methodology to understand the broader objective context and contextualise people’s experiences, (Hesse-Biber, 2010). Constructionism and interpretivism share a view that we are required to actively seek out meaning rather than enter a world in which meanings are fixed, (Hammond & Wellington, 2020).
3.2.2.4 – Triangulation

Triangulation refers to using multiple methods or data sources in qualitative research to develop a comprehensive understanding of phenomena, (Patton, 1999). Triangulation is the most commonly cited reason that mixed methods are incorporated into research, (Greene, et al., 1989). Triangulation refers to using more than one method while studying the same research question; the researcher is looking for a convergence of the data collected by all methods in a study to enhance the credibility of the research findings, (Hesse-Biber, 2010). Triangulation ultimately fortifies and enriches a study’s conclusions, making them more acceptable to advocates of both quantitative and qualitative methods, (Hesse-Biber, 2010).

The use of multiple data collection techniques and sources strengthens the credibility of outcomes and enables different interpretations and meanings to be included in data analysis; this is known as triangulation, (Williamson & Johanson, 2017). Triangulation adds rigour, breadth and depth to a study, (Williamson & Johanson, 2017). Method triangulation is the use of multiple methods in the same project, (Janesick, 1998).

The idea of triangulation is to collect data by different means in the hope that there is convergence on the truth, (Adams et al., 2013). Triangulation combines the findings of two or more methods to get the best possible single answer, (Hesse-Biber & Johnson, 2015). Triangulation is a popular approach that enables the checking of findings by using different data-collection methods, sources and using different theoretical constructs (Williamson & Johanson, 2017). Triangulation ultimately fortifies and enriches a study’s conclusions, making them more acceptable to advocates of both qualitative and quantitative methods, (Hesse-Biber, 2010). Triangulation has also been viewed as a qualitative research strategy to test validity through the convergence of information from different sources. (Denzin, 1978; Patton, 1999)
In order to carry out methodological triangulation, researchers also need to identify and observe the consistency and adequacy of the two methods, positivistic and phenomenological, regarding the research questions, data collection, methods of analysis and conclusions, (Östlund et al., 2011). Triangulation is implemented to add depth and richness; however, triangulation assumes that data from two distinct research methods are comparable within the research enquiry, (Heale & Forbes, 2013).

3.3 – Research Methodologies

Methodology underpins and informs research; the underpinning methodology chosen can inform and then action research while helping to produce and interpret findings, (Wisker, 2008). Hesse-Biber (2010), supports and further states that methodology leads the researcher to ask specific research questions and prioritise what questions and issues are most important to the study. The methodology is the rationale and the philosophical assumptions underlying a particular study rather than a collection of methods, though the methodology leads to and informs the methods, (Wisker, 2008). Salmon (1992), believes that achieving a
methodological approach consistent with one’s values and concerns typically involves the most prolonged struggle in research work and the most profound kinds of engagement.

The basic premise is that methodology provides a theoretical perspective that links a research problem with a particular method or methods and supports the choice of a method based on the researcher’s worldview, (Hesse-Biber, 2010; Wisker, 2008). According to Adams et al. (2013), research methodology is the science and philosophy behind all research; it allows us to understand how knowledge can be created in different ways. Adams et al. (2013) stress that this is especially important since if we know how knowledge can be created, then we can also understand what might be wrong with it.

3.2.4 – Research Design & Research Journey

*Research is about asking and beginning to answer questions, seeking knowledge and understanding of the world and its processes, and testing assumptions and beliefs.*

(Wisker, 2008, p.51)

Research design is concerned with turning a research question or hypothesis into a manageable project, (Hammond & Wellington, 2020; Schwartz-Shea & Yanow, 2011). Schwartz-Shea & Yanow (2011) expand further, stating, research design is about making choices and articulating a rationale for the choices one has made, as the term “design” evokes expectations of a carefully formulated plan.

3.2.4.1 – Research Journey

When first embarking on the research journey, the researcher faced challenges in defining the research question and what research methodologies to use throughout the process. At the outset, the researcher intended to examine Sector Coupling via hydrogen and the impact it could have on the electricity and gas networks in the Republic of Ireland as a method of
decarbonisation. While carrying out the literature review on this topic, the researcher found a more significant gap in knowledge regarding public perceptions of hydrogen as a domestic energy vector in the Republic of Ireland. The researcher found that, while the technical aspects of hydrogen as a domestic fuel are well researched and studied, public perceptions of hydrogen as a domestic fuel was not well researched with no research carried out in the Republic of Ireland. The researcher felt a research study of this area would present a more significant contribution to knowledge.

3.2.4.1 – Initial Approach – Qualitative Research

According to Hammond & Wellington (2020), the term qualitative means data that has been generated in a non-numeric form, which can be interviews. Interviews allow the researcher to meet the research subjects; they can provide detailed information a researcher set out to collect and some fascinating contextual information, (Wisker, 2008). Adams et al. (2013), expand further, stating that qualitative research uses several methodical approaches based on diverse theoretical principles; it employs data collection and analysis methods to explore social relations and describe reality as experienced by the respondents. Qualitative research methods have long been used in social sciences, (Adams et al., 2013).

The researcher’s initial approach to gathering primary data for this research project was to interview subject matter experts based on information from secondary data research.

3.2.4.2 – Pivot to Mixed Methods Approach

Hesse-Biber (2010) defines the mixed methods approach to research as a research design that employs quantitative and qualitative data to answer a particular research question. Quantitative research is based on the methodological principles of positivism and neo-positivism and adheres to the standards of strict research design developed before the actual research, (Adams et al., 2013). According to Williamson & Johanson (2017), mixed methods
are a popular approach with some researchers who believe that this is an excellent way to gain a deeper understanding of issues and experiences. Hammond & Wellington (2020) define quantitative methods as ones in which data is collected in the form of numbers and further state that it can be gathered through surveys.

Ricci et al. (2010) outline that surveys are widely used to test opinion, and they undoubtedly have merit in addressing large populations and goes on to state that the underlying assumption of polls is that those polled know enough about the topic to have an opinion. According to Wisker (2008), interviews can be used to follow up a survey. Wisker (2008) also states that, for some research questions, it is both helpful and more robust to combine quantitative and qualitative research methods. After gathering secondary data, the researcher concluded that a more significant contribution to knowledge lay in a mixed methods research design. This decision was taken due to the lack of secondary data regarding public perceptions of hydrogen in the Republic of Ireland. The researcher decided that gathering primary quantitative data via a representative survey and using this data to inform further research in the form of qualitative interviews with subject matter experts was the most prudent approach.

3.2.4.3 – Mixed Methods – Survey and Focus Groups

When seeking to identify subject matter experts for interviews on the topic, the researcher found that establishing gender equality among the interviewees would be challenging. The researcher found that subject matter experts in the field were predominantly male, and there was little opportunity to attain a representative female opinion. After a period of reflection, the researcher also concluded that, while the subject matter experts would be well-versed in the technical aspects of hydrogen, they may only have a technical opinion on public perceptions, which may not be representative. Given that the two issues mentioned above
would present a flaw in the research, the researcher once again decided to adapt the research design.

The revised research design involved carrying out an online survey of the public followed by focus groups involving willing survey respondents. The reasoning for this approach was that findings from the survey would help inform the focus groups. The researcher chose to carry out focus groups as the research study required discussing the complex and technical subject matter with what the researcher believed was an uninformed general public. The researcher expected that the public would be largely uninformed on the research topic from the literature review. The researcher deduced that the best way to ascertain opinion on a topic that the participants are not well informed of was to carry out a focus group. Essentially, the researcher believed that to elicit opinion of the unknown, it would be necessary to provide the basic principles to participants to gather opinions.

3.2.4.4 – Chosen Approach – Survey and Individual Interviews

According to Hesse-Biber (2010), a mixed-methods project from an interpretive perspective often uses quantitative research as an auxiliary to a primary qualitative methodology to understand the broader objective context and contextualise peoples experiences. Hesse-Biber (2010) provided further detail, stating that an explanatory sequential design (see Figure 2 below) is one in which the collection and analysis of quantitative data are followed by the collection and analysis of qualitative data; therefore, a researcher might employ a quantitative study first to provide a more representative sample as input into their primary qualitative study in order to produce a more robust way of generating theory.
After comprehensively reviewing the research methodologies available, the researcher adopted an interpretive approach employing a sequential mixed methods design approach to this study. The reasoning for implementing this method of research is, an explanatory sequential design allows for the collection of quantitative data that helps inform the collection of qualitative data. The researcher believed this approach would garner more informative findings and a more significant contribution to knowledge. Conducting a quantitative demographic survey on a random sample of the researcher’s target population, followed by a qualitative study enabled the researcher to select a qualitative subsample from this population representative of the target population, (Hesse-Biber, 2010).

The researcher circulated a survey on LinkedIn which resulted in 127 respondents, of which 115 responses were deemed valid. Valid responses were deemed to be those from
respondents who consented to their data being processed and were resident within the Republic of Ireland. Upon examining the primary survey data, the researcher concluded there was a greater level of awareness and understanding of hydrogen amongst the respondents than the researcher initially expected. Given that there appeared to be a foundation of knowledge among the respondents, the researcher decided to modify the research methodology one final time. The refined methodology sought to carry out individual semi-structured interviews with a selection of willing survey respondents to gain more detailed insight into individual perceptions in place of focus groups. The researcher believed that individual interviews would allow for a greater understanding of individual perceptions of hydrogen as a domestic energy vector. The researcher sought to carry out eight interviews with an equal balance of males and females to gather representative data.

3.4 – Secondary Data Collection

Secondary data refers to data generated within other studies and made available to the broader research community, (Hammond & Wellington, 2020). Secondary data can be used to supplement data collected and validate a sample, (Adams et al., 2013).

3.4.1 – Literature Review

A research student's first exposure to a collection of academic research known as literature usually involves finding and reading academic research to form the basis of their thesis, (Fernandez, 2019). Hammond & Wellington (2020), outlines that a literature review gives an overview of what has been written about a particular field or topic; it covers what has been said, who has said it and sets out prevailing theories and methodologies. Wisker (2008), reports that the reasoning for literature reviews is that the researcher needs to read oneself into the field of study and determine where the researcher's work can contribute to existing knowledge and extend meaning and understanding. The researcher needs to read background literature in order to contextualise and underpin a researcher's own work, (Wisker, 2008).
literature review is an integral part of research as it enables the researcher to work at a high conceptual level with other researchers' work and see how one's own work contributes to knowledge and meaning, (Wisker, 2008).

Figure 3 - The Literature Review Puzzle (Fernandez, 2019, p190)

Figure 3 depicts the three sequential stages of a literature review; the literature has to be assembled, arranged and assessed, (Fernandez, 2019, p.190). A good literature review demonstrates the researcher's knowledge of prior work on relevant topics, identifies research gaps, develops a precisely stated research question for further research, (Fernandez, 2019). A researcher needs to connect their work to what has already been said and acknowledge their “intellectual indebtedness”, (Colquitt, 2013, p.1211).

For this study, the researcher conducted a comprehensive review of the literature informing the research topic. This literature review was performed continually throughout the research process and refined as the research matured. The literature review formally began in September 2019 and continued up until June 2021. Literature that was published after this date has not been included within this body of work. All literature was sourced from Munster Technological Universities online databases, electronic book services and available internet resources such as Google Scholar.

The researcher utilised Computer Assisted Qualitative Data Analysis Software (CAQDAS) NVivo to analyse the secondary data available on the research topic. Di Gregorio (2000) supports this approach and outlines that software packages such as Nvivo can support the
analysis process involved in a literature review, further arguing that a literature review is a form of qualitative analysis. This analysis involved reading and reflecting on the secondary data available, identifying interesting themes, coding them thematically utilising NVivo software, interlinking similar themes and using this data to weave a coherent analysis of secondary data with links to supporting evidence within the literature.

3.5 – Primary Data Collection

3.5.1 – Quantitative Design

Quantitative studies emphasise the measurement and analysis of causal relationships between variables, (Denzin & Lincoln, 2008). Quantitative research refers to research that is based on methodological principles of positivism and adheres to the standards of a strict research design developed before the actual research, (Adams et al., 2013). In conducting surveys, the construction and design of the questionnaire are critically important, as is the sample selection, (Adams et al., 2013). Surveys gather data that describe and explain population or sample characteristics, behaviours, attitudes or opinions and may be used to predict future behaviour, (Williamson & Johanson, 2017).

The quantitative aspect of this mixed-method study involved a survey of the sample. The survey goals and objectives were first defined; the researcher sought to gain insight into the public's general awareness and understanding of hydrogen while seeking to ascertain the respondent's perceptions of hydrogen as a domestic energy vector. The survey methodology was next defined; given that this study was carried out amid the COVID-19 pandemic, the researcher concluded that using an online survey platform such as Microsoft Forms was the most prudent approach. It was intended to carry out the quantitative aspect of this study before the qualitative research so that further insight into the survey findings could be gleaned from the semi-structured interviews. The survey sample was identified as residents within the Republic of Ireland. Adams et al. (2013) outline that there are often two phases to
collecting data: pre-testing and the main study. Adams et al. (2013) further state that a small-scale test provides the opportunity for the researcher to check the data collection to minimise error due to improper survey design.

The survey was designed and piloted using Microsoft Forms; the pilot survey achieved completion times that were on average three minutes. Given the relatively short time it took participants to complete the pilot online survey, additional questions were added to gain further data while being cognisant of a target completion time of five minutes. This target completion time was used to minimise partial completion of the survey amongst respondents. The researcher also rewrote aspects of the survey to aid understanding based on the answers received from the pilot survey. The finalised survey was made live and shared via the researchers LinkedIn account. Expressed consent was attained from participants at the outset of the online survey, an extract of which is visible below as Figure 4. Where participants indicated that they disagreed, the survey ended, and a thank you message was displayed. Only where participants agreed with the statement in Figure 4 did the form allow the answering of survey questions.

![Figure 4 - Survey Consent Question](image)

This approach was also taken regarding asking the respondent if they were resident within the Republic of Ireland. When a respondent indicated that they did not live in the Republic of
Ireland, the survey ended, and a thank you message was displayed. These efforts ensured that as far as was reasonably practicable, only the target research sample was surveyed.

3.5.2.1 – Research Sample

Sampling is the process of selecting a suitable sample to determine parameters or characteristics of the whole population, (Adams et al., 2013). A sample is a selection of elements from the total population to be studied, (Williamson & Johanson, 2017). The sampling strategy selected for this study was a non-probability random sample, where each member of the public has an equal chance of being included in the given sample, (Hesse-Biber, 2010). In survey research, non-probability samples are typically used for exploratory studies, (Williamson & Johanson, 2017).

This study sought the opinions of adults living within the Republic of Ireland, therefore where responses from outside of the Republic of Ireland were received, they were excluded. As the researcher works within the natural gas industry, it was deemed appropriate to not circulate the survey for response among the researcher's colleagues so far as was reasonably practicable given the random nature of the sample. This approach was adopted as the researcher concluded that their colleagues could create bias within the survey results as they may have a greater understanding of the research topic than the wider public.

3.5.2.2 – Research Data Collection

The online survey collected responses over a two-week period; the survey was then closed to allow for the collection of data and analysis of results. The survey was designed to include a combination of Likert scale answers and open-ended responses from the respondents. The survey results were analysed using Microsoft Excel’s suite of tools, while the open-ended answers were from the survey were coded and analysed thematically using NVivo. The researcher also used NVivo’s suite of data presentation tools to create hierarchy charts and
word clouds (such as Figure 10) to gain insight into the data. Open-ended responses to the online survey were analysed thematically using Computer Assisted Qualitative Data Analysis Software (CAQDAS) NVivo. NVivo was used to aid the analysis process and develop helpful insight. The primary function of NVivo was to support the analysis of a large volume of data while the researcher retains complete control. According to Zamawe (2015), CAQDAS such as NVivo now form an integral part of qualitative data analysis and helps boost the accuracy and speed of the analysis process. The researcher used word frequency queries to identify themes from the data that would not have been apparent if analysed manually. Word frequency queries returned visual word cloud representations of qualitative data. NVivo’s coding function was also used to aid in identifying, collating, and analysing themes in qualitative data across large amounts of data. Quantitative aspects of the online survey data were analysed using Microsoft Excel’s built-in suite of data analysis and presentation tools in order to develop insight.

3.5.2 – Qualitative Design
The word qualitative implies an emphasis on the qualities of entities and on processes and meanings that are not experimentally examined or measured in terms of quantity, amount, intensity, or frequency. Qualitative researchers stress the socially constructed nature of reality, the intimate relationship between the researcher, studies and the situational constraints that shape inquiry. They seek answers to questions that stress how social experience is created and given meaning, (Denzin & Lincoln, 2008, p14). Qualitative research methods have long been used in social sciences, (Adams et al., 2013). Qualitative data is required to understand in-depth motivations for people’s behaviour or feelings, (Adams et al., 2013). Interview research methods involve capturing an individual's opinions, feelings, experiences, and the kind of atmosphere and context in which they act and respond (Wisker, 2008). The choice of an interview as a data collection method affords the researcher...
the ability to collect detailed and rich data relating to the emotions, feelings, insider experiences and privileged insights within the field of study, (Wisker, 2008).

The qualitative research was conducted after the quantitative element of this study. The interview guide was drafted in order to glean further information from the findings of the quantitative survey. The primary source of data for the qualitative aspect of this study was eight semi-structured interviews with willing respondents to the quantitative survey. These interviews sought to document the interviewee's attitudes, beliefs, perceptions and opinions regarding the survey's findings and secondary data. The researcher chose to conduct semi-structured interviews as it afforded some flexibility to the research process.

The researcher contacted all respondents to the survey that indicated they would be willing to partake in an interview. Given that this study was carried out amid the COVID-19 pandemic, all interviews were carried remotely out via Zoom. Interviewees were chosen randomly on a name out of a hat basis until the research sample contained four women and four men. When an interviewee became unavailable or unwilling, the process was repeated to replace them with an interviewee of the same gender.

3.5.2.1 – Research Data Collection

The researcher developed an interview guide based on the findings of the quantitative survey and secondary data. To ensure consistency, the interview guide was drafted thematically with ten broad initial questions related to the study with numerous follow up questions available for each theme to garner further detail. The researcher also drafted up a written interview consent form to inform interviewees of the purpose of the study and how its data would be processed and retained. As it was not always possible to sign this form, recorded verbal acceptance over Zoom was deemed appropriate given the remote nature of this study.
Dr. Wright aided the research study by reviewing the interview guide and suggesting amendments. As some questions lacked context to the interviewee, short introductions were added in for clarity. A pilot interview was carried out with a willing participant of the quantitative survey and recorded to ensure it was formatted correctly and ensure rich primary information was attained. After the pilot interview, the researcher concluded that three questions were confusing to the interviewee. These were subsequently reworded in the interview guide, and additional follow up questions were added. The pilot interviewee was reinterviewed using the three reworded questions, and their input was included within this study. The interview guide is available in Appendix 2 of this document. Using the finalised interview guide, a further seven interviews were carried out via Zoom. The interview consent was explained to all interviewees, and the consent and interview was recorded using Zoom’s built-in recording function. All interviews were transcribed post-interview manually and stored electronically for analysis.

3.5.1.2 – Research Data Analysis

According to Wisker (2008), analysing qualitative data involves close and thorough reading, coding, looking for themes in interviewees' responses, and categorising responses to these themes. Wisker (2008), further outlines that if a researcher can put their qualitative data through computer programs such as NVivo, these programmes can help with thematic analysis. With this in mind, the eight qualitative interview transcripts were analysed thematically and coded post-interview using CAQDAS NVivo. The use of NVivo aided the analysis process and helped the researcher identify common themes among the interviews and generate useful findings that contribute to knowledge. As stated previously, the primary function of NVivo was to aid the analysis of a large volume of data while the researcher retains complete control.
3.5.3 – Integration

According to Hanson et al. (2005), researchers who use mixed methods employ a research design that uses quantitative and qualitative data to answer a particular question; this combination of methods involves collecting, analysing, and integrating quantitative and qualitative data in a single study. Mixed methods research involves the joint use of quantitative and qualitative methods and the integration of these, (Hesse-Biber & Johnson, 2015). The integration of data and results derived from different methods is intrinsic to multi-method, and mixed methods research has been, for many researchers, a challenging goal to achieve, (Hesse-Biber & Johnson, 2015).

Mixed method research, where quantitative and qualitative research methods are combined, is increasingly recognised as valuable because it can potentially capitalise on quantitative and qualitative approaches' respective strengths, (Östlund et al., 2011). There is a lack of pragmatic guidance in the research literature on combining qualitative and quantitative approaches and integrating qualitative and quantitative findings, (Östlund et al., 2011).

Using triangulation as a methodological metaphor can facilitate the integration of qualitative and quantitative findings and help researchers to present both their theoretical propositions and the basis of their results, (Östlund et al., 2011). Several advantages can accrue from integrating two forms of data; qualitative data can be used to assess the validity of quantitative data, while quantitative data can help generate the qualitative sample or explain findings from the qualitative data, (Fetters et al., 2013).

3.5.4 – Reflective practice

The process of observing one’s own research practice and examining the way one did things is known as reflection, (Adams et al., 2013). Reflection is seen as a basic mental process with either a purpose or an outcome or both, that is applied in situations where material is ill-
structured or uncertain where there is no obvious solution, reflection is related to thinking and learning, (Moon, 2013). Schon (1979), establishes a theory of how professionals and practitioners learn from experience by arguing that professionals respond to and reflect on the varied experiences that arise in their work; they then seek development and change. According to Wisker (2008), reflection is more than merely a descriptive comment; it involves evaluating researchers' work, reflecting on how well a piece of work or research has worked and how effective it has been. Reflections about research should be recorded throughout the research process in a reflective journal; this will enable the researcher to undergo a continuous cycle of experience, reflection, evaluation, and review practice (Adams et al., 2013). A researcher's values and attitudes are essential parts of reflection, (Hesse-Biber & Johnson, 2015). Multimethod research is not a magic bullet to truth but a style that still demands rigour and reflection in addressing the central question, (Hesse-Biber & Johnson, 2015).

Figure 5 - The Gibbs' Cycle, (The University of Edinburgh, 2020)
The researcher maintained a research journal on Microsoft OneNote during the research process. The research journal helped the researcher to reflect on the research journey using the Gibbs cycle. The post research reflection is contained in Appendix 4 of this document.

3.5.5 – Reliability and Validity

A reliable measure is a consistent one; a question might be deemed reliable if it is clear enough to be interpreted in the same way by different people, (Hammond & Wellington, 2020). Reliability relates to how well one has carried out one's research; it is considered reliable if another researcher carrying out the same research activities with the same kind of group would likely replicate the researcher's findings, (Wisker, 2008). For reliability in measurement, especially in survey research, we must have a clear, unambiguous definition of all the concepts and artificial constructs being used in the research design, (Adams et al., 2013).

Validity has a range of meanings in social research and is often contrasted with reliability. Reliability represents the consistency of measurement; validity considers the appropriateness of the measure, (Hammond & Wellington, 2020). Reliability estimates the consistency of measurement and is a necessary condition for validity but is not a sufficient condition on its own, (Adams et al., 2013). If one’s methods, approaches and techniques fit with and measure the issues the researcher has been researching, then the findings are likely to be valid, (Wisker, 2008). Validity is the strength of our conclusions, inferences or propositions. There are four types of validity commonly examined in research methods – internal validity, external validity, construct validity and conclusion validity, (Adams et al., 2013). It is believed that validity is more important than reliability because if an instrument does not accurately measure what it is supposed to, there is no reason to use it, even if it measures reliably, (Adams et al., 2013).
The researcher ensured that data collected in this mixed-methods research was valid and reliable by first carrying out the quantitative portion of the study with a large sample before carrying out the qualitative portion and triangulating the findings. The triangulation method provided the researcher with a more comprehensive picture of the research and allowed for collecting data from multiple sources. The quantitative portion of this study was designed with simplicity in mind to ensure the reliability and validity of the data received. The qualitative interview questions were purposefully designed, reviewed, trialled and finalised to ensure reliability, clarity and validity.

Although the researcher endeavoured to provide accurate data, some potential sources of bias are worth noting. The quantitative survey was circulated to the population via the researchers LinkedIn. The researcher believes gender imbalance among the survey respondents results from women’s underrepresentation within STEM combined with the gender imbalance on LinkedIn at the time of the survey. Wang & Degol (2017), have outlined that women are underrepresented within math-intensive fields such as Science, Technology, Engineering & Maths. Given that the researcher is currently employed within the engineering field and connected to others via LinkedIn, the survey may have reached more males on LinkedIn than females.

![Figure 6 - Gender Demographics on LinkedIn January 2021](Wang & Degol 2017)
Education level is another potential source of bias within this study. According to Anderson & Smith (2021), those with higher levels of education are more likely to report being LinkedIn users than those with lower levels of educational attainment. Anderson & Smith (2021) further detail that 51% of adults in the United States with a bachelor’s degree reported using LinkedIn, with only 10% who have no college experience reporting being users. Given that the quantitative survey element of this research was circulated on LinkedIn primarily, this research study may be biased in favour of those with college educations and lack the input of those without a third level education.

3.5.6 – Ethical Considerations

The term “ethics” usually refers to the moral principles guiding conduct, which are held by a group or even a profession, the conduct of research should not only be ethical in the particular sense that relevant procedures have been followed but ethical in spirit and the respect shown to others, the purpose of the research, whom it benefits and how it is reported, (Hammond & Wellington, 2020). Ethical considerations are crucial throughout a research project, requiring continuous reflection and evaluation, (Adams et al., 2013). In order to ensure the validity and accuracy of one’s research, it is essential for researchers to discuss the ethical implications of their research and to remain conscious of the moral integrity of their work, (Hesse-Biber, 2010). Ethical considerations are the responsibility of the researcher to recognise and protect the rights of the participants if the study, (Wisker, 2008)

Ethics plays a role throughout the entire research process, and all researchers must be vigilant in checking themselves at every stage of their investigation, (Hesse-Biber, 2010). Self-monitoring one’s ethical standpoint is critical regarding mixed-methods research projects, as these projects are more likely to contain thorny ethical issues that arise only after the project is underway, (Hesse-Biber, 2010). A researcher needs to explain carefully to anyone they intend to interview precisely what the researcher will do with the interview material, (Wisker,
2008). In conducting any research, there is an ethical responsibility to do the work honestly and with integrity, (Adams et al., 2013). The researcher ensured that informed consent was received from all participants of the quantitative and qualitative aspects of this study. This consent outlined the data that would be collected as part of this study and how it would be used and stored. The participants were informed of the voluntary nature of the study, informed that they could withdraw from the study at any time, for any reason and then asked for their consent to proceed.

3.5.6.1 – Informed Consent

According to Adams et al. (2013), if research involves humans as subjects in experiments or as cases in a survey, informed consent must be obtained. Adams et al. (2013), further detail that research participants need to be informed about the research, what the researcher hopes to achieve, how they will be affected and ensure that they understand. Ethical guidelines insist that researchers should not do physical or psychological harm and that participants should give their fully informed consent before taking part, (Wisker, 2008). For the quantitative portion of the study, the first survey question asked participants to agree to participate within the study and have their data processed; an extract is shown in Figure 7 below.

1. By undertaking this survey, I agree to participate in the research process. I understand that this survey is anonymous, and no personally identifiable information is gathered. I understand that I can withdraw from the study at any time. I grant permission for the data generated from this survey to be used in the researcher's publication(s) on this topic.

  - I agree
  - I disagree

*Figure 7 - Quantitative Survey Consent Question*
For this study's quantitative portion, the researcher produced a dedicated consent form that each participant read and agreed to. An example of the consent form is available in Appendix 1. Due to the remote nature of this study, with interviews being carried out via Zoom, the consent form was provided to the participants, and their verbal agreement was deemed appropriate. As the researcher's employer is mentioned occasionally within this study, ethical clearance was received from Gas Networks Ireland, a copy of which is available in Appendix 3.

3.5.6.2 – Privacy, Confidentiality and General Data Protection Regulations (GDPR)

There is an obligation on researchers to ensure privacy and confidentiality; this can relate to the information collected, individuals involved, the setting and how the research data and findings are stored and disseminated, (Adams et al., 2013). Simply and profoundly, privacy should be respected because people should be respected; privacy is widely valued as a core human need and condition for living life with dignity, (Lowrance, 2012).

In order to ensure privacy, confidentiality and adherence to GDPR, (General Data Protection Regulation), the researcher carried out several steps. Firstly, all files that potentially contained sensitive information were password-protected, with all physical copies destroyed immediately after a digital copy was created. Recordings and transcripts were also stored electronically and password protected. Additionally, all participants were assigned a number in the process of barrage double to ensure they were not identifiable. Research materials will be held, password protected, to ensure it is available if requested. If no request is received for research material by Q2 2022, the data will be deleted in line with the requirements of GDPR.

3.5.7 – Limitations

A limitation of a study design or instrument is a systematic bias that the researcher did not or could not control and which could inappropriately affect the results, (Price & Murnan, 2004).
As this research was self-funded and undertaken while the researcher was in full-time employment, time constraints were a limitation of this study. An essential aspect of public perceptions is how they may vary over time; this study serves as a snapshot in time and was not carried out over a long-term period. Regardless of this limitation, the researcher sought to produce a study that contributes to knowledge in a comprehensive and well-researched way.

There are limitations associated with the design of the study. As outlined within chapter 3.5.5, bias may have been introduced into the study by circulating the quantitative survey on LinkedIn. The survey may underrepresent those without college educations and may have reached more of those who work in a technical field, as the researcher works as an engineer of a utility company and is connected with people in similar professions. The non-representative nature of this study must be acknowledged due to the relatively small sample for such a broad-reaching research subject; nevertheless, the data provides informative insights into the concerns and perceptions of the participants concerning hydrogen as a domestic energy vector in the Republic of Ireland.

3.5.8 – Conclusion

This chapter has outlined how the research question was explored and presented the research methodologies that the researcher implemented in an effort to answer the research question. This chapter discussed the research journey, the reasoning for selecting the final mixed methods research methodology and the observed limitations of the chosen research methodology. The following chapter presents the findings of the research.
4.0 Research Findings

4.1 – Introduction

This chapter will present the data gathered during the research process. This data was gathered from an online survey and eight virtual face-to-face interviews. The first section will present the quantitative survey findings; the second section will present the qualitative empirical data gathered from the eight face-to-face semi-structured interviews.

4.2 – Quantitative Survey Data

This section presents the quantitative survey findings, which received 127 responses, 115 of which were deemed valid. The quantitative survey found that 75% of respondents indicated they were aware of uses for hydrogen. In addition, respondents were aware that hydrogen can be used as a fuel and are aware of its potentially dangerous properties. Interestingly, the word “water” was one of the most frequent responses, indicating a working knowledge of hydrogen production and combustion lifecycle.

With regards to the safety of hydrogen, no consensus was achieved in this study when the respondents were asked if they associated hydrogen with danger; however, an interesting finding is that 64% of respondents believed hydrogen delivered via the gas network would be safe with only 3% believing it would be unsafe. The remaining 33% provided a neutral/undecided response.

65% of respondents associated the use of hydrogen with positive environmental performance, with 34% undecided. The environmental impact of a fuel was ranked as the least important consideration among the respondents when choosing a fuel for the home; cost ranked as most important. The respondents demonstrated a level of understanding of the environmental benefits of blending hydrogen within the gas network; however, 52% of respondents were
undecided. The quantitative survey found that 82% of respondents trusted that they would be provided accurate and trustworthy information before any transition to hydrogen.

4.2.1 – Survey Demographics

The overall gender balance of the survey respondents was found to be 65% male, 34% female, as can be seen in Figure 8. As outlined within section 3.5.2.2 – Research Data Collection, the researcher believes this gender demographic results from the method used to circulate the survey for response. Over 94% of respondents identified as being from the Munster and Leinster provinces of the Republic of Ireland.

![Survey Gender Balance](image)

The survey received responses from a wide range of ages; however, the over 65 age bracket is underrepresented; the researcher believes this results from the online survey method used, resulting in lower buy-in from the over 65 demographic.
4.2.2 Theme – Awareness of Hydrogen

To gauge the general level of awareness of hydrogen among the respondents, the survey asked an open-ended question, “When you hear the word hydrogen, what is the first word that comes to mind?”. The words “fuel”, “water”, “explosion”, and “peroxide” were the most popular responses to the online survey. Responses relating to danger such as bomb, flammable, explode, also occurred frequently.
The survey also asked respondents if they were aware of some uses for hydrogen; close to 75% of respondents indicated that they were, in fact aware, see Figure 11. Some respondents also provided examples of uses for hydrogen that they were aware of, see Figure 12. The most common responses are related to fuel cells, cars and rocket fuel.

Figure 11 – “Are you aware of some uses for hydrogen?”
4.2.3 Theme – Perceived Safety of Hydrogen

To gain insight into the respondent’s perception of hydrogen as a fuel, the survey asked respondents to rank their responses to statements on a Likert scale. In response to the question “I associate the use of hydrogen fuel with danger”, no consensus was achieved. Responses received were 35% positive, 30% neutral and 35% negative.

![Figure 12 - Word cloud of open detailed responses to “Are you aware of some uses for hydrogen?”](image)

![Figure 13 - Responses to survey question “I associate the use of hydrogen as a fuel with danger”.](image)
Interestingly, when the survey asked, “I believe hydrogen, supplied via the gas network to my home, will be safe”, 64% of responses agreed. 34% of responses were undecided, possibly indicating the need for more information before arriving at a firm decision. An outcome of this question is that only 2% of respondents disagreed with the above statement and believed hydrogen delivered via the gas network would be unsafe.

An indicative finding of this study is that no consensus could be reached regarding the perceived danger of hydrogen on its own; however, while hydrogen is delivered via the gas network, 64% of respondents perceived hydrogen as safe.

4.2.4 Theme – Hydrogen Blending

To gauge the respondents understanding of the environmental benefits of blending hydrogen with natural gas in the network, the survey asked the following question “Blending hydrogen with natural gas within the gas network will make natural gas more environmentally friendly”. Most responses received were undecided at 52%, with 43% agreeing with the statement; interestingly, only 5% of the respondents disagreed with the statement.
4.2.5 Theme – Acceptance of Hydrogen in the home

When responding to the statement “I would accept the use of pure hydrogen as a fuel in my home”, 58% of respondents agreed, and 35% were undecided, with only 7% disagreeing. This indicates that currently, there is not a high level of opposition to the use of hydrogen within the home and a high level of acceptance based on the respondent’s current level of knowledge, the portion of respondents that would need further information before arriving at a firm decision remains prevalent.

Figure 15 - “Blending hydrogen with natural gas within the gas network will make natural gas more environmentally friendly.”

Figure 16 - “I would accept the use of pure hydrogen as a fuel in my home”
4.2.6 Theme – Hydrogen’s Environmental Performance

This study found that 60% of respondents associated the use of hydrogen with positive environmental performance, with 7% disagreeing. It is worth noting that 33% of the respondents indicated a neutral/undecided response indicating the lack of a strong opinion.

4.2.7 Theme – Environmental Considerations

The survey respondents were asked to rank four considerations in order of importance when choosing a fuel to heat their home. The results of the survey indicated that the respondents viewed cost and safety as the most important considerations. The impactful finding is that the environmental impact of a home heating fuel was considered the least important consideration of those surveyed.

![Figure 17 - Responses to fuel considerations ranking question](image)

4.2.8 Theme – Willingness to Pay

As hydrogen is not naturally occurring and needs to be produced, it is believed that it may be more expensive than fossil fuels for a time. To ascertain the public's willingness to bear the possible extra expense, the online survey included targeted questions surrounding cost. Firstly, half of the respondents believed that using hydrogen would be more expensive than their current fuel of choice, indicating a level of awareness of the cost issues regarding the production and use of hydrogen. Some 36% of respondents had an undecided response, indicating that a high proportion of respondents would need additional information before
arriving at a firm decision. Secondly, the survey asked if the respondent would be willing to pay more for a more environmentally friendly fuel. While 43% of respondents agreed with this statement, a high proportion of respondents disagreed at 33%. The level of undecided responses to the question was 24%, again highlighting that a portion of the public require more information to help them arrive at a firm decision.

![Figure 18 - Responses to “I am willing to pay more for an environmentally friendly fuel”](image)

4.2.6.1 Sub Theme - Appliance Replacement Burden & Grants

It is believed that a conversion of the natural gas network to supply hydrogen would require the replacement of domestic gas boilers and hobs for appliances designed to run on hydrogen. As the replacement of natural gas appliances would burden consumers with additional costs, this study sought to examine the impact of the appliance replacement burden on the acceptability of hydrogen among consumers. The respondents were asked to rank if they agreed or disagreed with the following on the Likert scale: “The need to replace my gas appliances would discourage me from accepting hydrogen as a fuel in my home”. The survey results showed that 44% of respondents either agreed or strongly agreed, reinforcing that
consumers are sensitive to cost over environmental considerations. A total of 25% of respondents indicated a neutral stance on the above statement, with 31% indicating that the need to replace gas appliances would not discourage them from accepting hydrogen as a fuel in their homes. Interestingly, 90% of respondents indicated that the availability of grants/subsidies to offset the cost of replacing appliances would make them more likely to accept hydrogen as a fuel in the home.

![Bar chart showing gender comparison on hydrogen acceptance](image)

*Figure 19 - “The availability of grants/subsidies to offset the conversion cost would make it more likely for me to accept hydrogen as a fuel in my home”*

### 4.2.9 Theme – Information and trust

82% of respondents to the online survey believed that they would be provided with accurate information and all their questions would be answered before a hydrogen rollout. In addition to this finding, 82% of respondents indicated that they also believed that the source of information regarding the use of hydrogen as a domestic fuel would be trustworthy
4.3 – Qualitative Data

This section presents the outcomes of eight semi-structured interviews with a ratio of 50% female interviewees and 50% male interviewees, drawn from respondents to the quantitative survey that indicated their willingness to interview. The interviews were carried out in May 2021. As COVID-19 restrictions remained in place at the time, all interviews were carried out remotely via Zoom. The purpose of the interviews was to gain further insight into the research question and findings of the quantitative data.
4.3.1 Theme – Willingness to Convert to Hydrogen

In terms of willingness to take part in a changeover from natural gas to hydrogen, this study found that overall, 87% of interviewees demonstrated a willingness to use hydrogen in a domestic setting.

The first contributor outlined that they would be willing to take part in a changeover:

*I would be willing to take part in a changeover to hydrogen.*

[Participant 1, Preschool Teacher].

The next participant outlined their willingness to use hydrogen while detailing some technical challenges that needed to be overcome:

*I have absolutely no issue transferring to hydrogen. I am comfortable enough to transition to hydrogen, but there is a lot to be proven. To my knowledge, they have not figured out the smell or the visual, whatever chemical component, to give it a bit of colour so that you can see the flame and smell the gas. Once those things are bottomed out as fuel, I have no issue with it; if it burns and heats great, I am all for it.*

[Participant 2, Electrical Engineer].

The following interviewee also demonstrated a willingness to use hydrogen as a domestic fuel:

*Yes, I would be willing to take part in a changeover to hydrogen; I would be open to switching over.*

[Participant 3, Soldier].

The next contributor agrees with the previous contributor, viewing a changeover to hydrogen in a positive light:

*Yes, I would be willing to convert to hydrogen because we will never get anywhere if people don’t take part.*

[Participant 5, Safety Assurance Lead].

The following interviewee also expressed a willingness to use hydrogen if proven safe.

*I would be absolutely willing to give it a go if it is proven to be safe.*

[Participant 6, Shift Supervisor].
The next contributor also viewed the use of hydrogen as beneficial and expressed a willingness to changeover:

*Absolutely, yes, if it's going to be environmentally friendly, obviously that has a big bonus. I would be very concerned for the environment, and hydrogen sounds like a good option.*

[Participant 8, Homemaker].

The next participant outlined that they would consider converting to hydrogen if natural gas was no longer an option:

*Yes, I would use hydrogen. If natural gas is no longer an option and hydrogen is a viable alternative, I would consider changing.*

[Participant 7, Quality Engineer].

A contrary view was outlined by the next interviewee, stating that they would not be interested in using hydrogen as a domestic fuel:

*If I must spend money to upgrade my existing boiler and I get nothing in return, and it's all to reduce greenhouse gases, I wouldn't be interested, definitely not.*

[Participant 4, Manager].

4.3.2 Theme – Attitude Strength and Acceptance

Concerning strength of opinion and acceptance, this study found that where a contributor indicated that they would accept or reject hydrogen as a fuel in their home, they also indicated that they had a firm opinion and were unlikely to change their minds. Interestingly, where a contributor indicated an undecided opinion of hydrogen, they indicated their opinion was weak and could easily change.

The following interviewee indicated a strong opinion and outlined that they would need to be convinced to not take part in a changeover to hydrogen:

*It would take a lot to convince me, yes. It would take a lot to convince me not to take part because if people don't take part, then they're never going to learn what's involved in changing over. So, to facilitate learning, then people must partake in the changeover.*

[Participant 5, Safety Assurance Lead].
The following contributor indicated a strong opinion and would be unlikely to change their mind:

*It's more eco-friendly; therefore, I don't think it would be easy to dissuade me from using hydrogen.*

[Participant 7, Quality Engineer].

The next interviewee felt strongly about their opinion and did not believe they would change their mind easily:

*I wouldn't change my mind because I think hydrogen will be the way things are going to go in the future. It might not happen immediately, but I do think it could happen, and I wouldn't change my mind about it, then I'd be happy to go ahead.*

[Participant 8, Homemaker].

The following participant indicated a lack of a strong opinion but remained willing to accept hydrogen as a domestic fuel:

*I don't have a very strong opinion on a changeover to hydrogen; my concerns would not point-blank stop me from changing over at the moment; however, I could very easily change my mind.*

[Participant 1, Preschool Teacher].

The next interviewee also indicated that they did not have a strong opinion and could easily change their view:

*To change my mind and become against a hydrogen changeover, like anything, I could quite easily change my mind in a sense, and that's just the way it is with anything. It's new; I don't have a history of trust in it or built up a reputation over ten years or grown up with it. To be honest, if it was introduced on a test scale and there was a calamitous explosion or something, I'm sure very quickly you could go against something new like that, and I think that's true with anything new. Smart cars are beginning to come in, and I am all for it, but if one was to plough into a building, I'm sure I would go against it very quickly. I'm quite for a changeover to hydrogen; however, I could go quite against it very easily.*

[Participant 2, Electrical Engineer].

The following interviewee, having previously expressed an unwillingness to accept hydrogen, outlined that they felt strongly and would need to be convinced before becoming willing to accept hydrogen as a domestic fuel:
It will take an awful lot of convincing to change my mind. I like data; I like facts; I would like to see all of these reviewed and peer-reviewed before I would even consider changing my mind.

[Participant 4, Manager].

4.3.3 Theme – Hydrogen Blending

In terms of accepting a blend of twenty per cent hydrogen and eighty per cent natural gas fed into their home via the gas network, 75% of interviewees indicated their willingness. Some interviewees indicated that their acceptance was dependant on cost and safety. Interestingly, participant 5 believes hydrogen blending was only a short-term solution and indicated a preference for pure hydrogen from the outset.

The following participant indicated they would accept a blend of hydrogen and natural gas if technically feasible and outlined that they believed it would be safer:

*I don’t think I’d have an issue with hydrogen blending, assuming that they can mix and blend safely. I don’t know much about hydrogen at the moment. I believe I know enough about natural gas, and I know the dangers of natural gas. In my opinion, hydrogen would be slightly safer than gas. So, therefore, I think having less gas coming in with the mixture of hydrogen would be of benefit.*

[Participant 1, Preschool Teacher].

The next contributor, agrees outlining that they would be in favour of a natural gas and hydrogen blend provided it was technically feasible and added that it appeared to be a sensible option when seeking to reduce carbon emissions:

*If it can be proven to work, I’m all for it; I have no issue. If there is no impact like changing appliances, I think that blending hydrogen with natural gas would be quite simple; it doesn't matter what we are burning, whether it's the bio methane, natural gas, or a hydrogen blend. As a consumer, I’m just happy that I'm turning on the boiler and my house is heating up, I turn on the cooker, and my food is cooking, so no issue with it. From a technical perspective, I am very curious about how it's going to work and how the tests turn out. My understanding is that hydrogen is a very small molecule compared to natural gas. You blended it and push it into the pipe; how does it not have a detrimental impact? I'm not a chemist or an expert in it but, it seems there may be challenges to overcome. I am sure if they have proven it is safe in technical studies, then I would take that research as gospel, and I'd be happy. To answer the question straight, I have no issue with hydrogen blended into my local gas network. I have heard comments from different engineering industries like Engineers, Ireland. Hydrogen is the hot topic; you’d be living under a rock to not see all the different communication’s*
about how it's a good thing with no emissions, and basically, it's the way forward if we are going to have a sustainable planet. My opinion on why I would be for it is because it seems to be the most sensible option to transition to a more sustainable world where we can use a combustible substance that doesn't have the issues of carbon and greenhouse gas emissions. So that's why I have no issue with hydrogen blending and transitioning to hydrogen in principle.

[Participant 2, Electrical Engineer].

The following interviewee states that they would accept a blend of natural gas and hydrogen, acknowledging the environmental benefits however stipulating that it must be proven to be safe and not require major works to their home:

*I'd be happy with hydrogen blended with natural gas as long as it is safe. With anything to do with flammable gas, safety is my main concern. A second concern is if any groundworks needed to be done in the area near my residence to facilitate a changeover, I wouldn’t be too happy in that case. Other than that, I'd be happy to change over. If it’s all gearing towards a maintainable, cleaner fuel that benefits the environment, I'm all for it if it can be done economically.*

[Participant 3, Soldier].

The following contributor outlined that they would be willing to accept a blend of natural gas and hydrogen. Interestingly, the contributor believed that a blend of hydrogen would be beneficial as it would be more familiar than converting to pure hydrogen:

*If you only have a blend, you could keep the appliances you have already in your home, so I'd be ok with having blended gas and hydrogen, provided our supplier was prepared to do a blend. I'd be happy with us doing that. You have the security of the natural gas, and you’ve just a little bit of the hydrogen, so it would be more familiar than going pure hydrogen straight away.*

[Participant 8, Homemaker].

The next interviewee indicated that their willingness to accept blended hydrogen was dependent on the cost:

*As long as a local supplier does public and transparent things, they can demonstrate to me the benefits also in terms of cost. Am I paying more for less? But I would be willing to use it.*

[Participant 6, Shift Supervisor].

A contrary view was outlined by the next interviewee, stating that blending hydrogen with natural gas would need to provide a benefit for them other than reducing greenhouse gas
emissions while stating that they believed the risk would be reduced to an acceptable level by the network operator:

*What's in it for me? What benefit am I getting, if any? Is it going to be cheaper for me, or is it going to reduce greenhouse gases? Does it work out better for my family and me? If we are now going to a four to one ratio of hydrogen in natural gas, is my risk level increasing with that? I would assume the network provider would do all of those assessments and provide relevant data and facts and figures to say that it's as safe as natural gas on its own and that the network supplier would have done as much as reasonably practicable to make sure that it's safe coming into my house along with everybody else's.*

[Participant 4, Manager].

The following contributor indicted that they viewed hydrogen blending as a short-term solution and would prefer to see a roll-out of pure hydrogen:

*This sounds a bit messier. I'd rather one or the other. I don't understand the whole blending process very well, but I'd rather one or the other. I'd rather one or the other and not be messing with blending. Is blending likely to be a long-term product? No, I don't think so. It's all or nothing.*

[Participant 5, Safety Assurance Lead].

The next participant indicated that they would question the safety of hydrogen blended with natural gas due to a lack of knowledge; the participant goes on to detail that if the information was available, they would be open to accepting hydrogen blended with natural gas:

*The first question would be, would there be a safety risk, especially for things like a gas cooker? Is it safe to cook with? If it is, I don’t think. I have any questions. I lack knowledge on blending hydrogen; not many people know about hydrogen as a fuel at the moment, so that’s where the safety concern would be a question for me. If more information was available on hydrogen being mixed with gas or replacing gas and that it was readily used everywhere and people have no problems with this, I wouldn’t have any concerns. But I think it’s just the lack of information at the moment. It still seems to be quite an out-there theory.*

[Participant 7, Quality Engineer].

4.3.4 Theme – Hydrogen Production

Interestingly, this study has found a consistent preference for green hydrogen among the participants as it is produced from renewable sources. 25% of participants indicated that they
would tolerate the use of brown hydrogen for a period as a means of rolling out green hydrogen; however, 75% of participants outlined their opposition to using brown hydrogen as it is generated from fossil fuels. Fascinatingly, 100% of the participants outlined a preference for green hydrogen if a transition to hydrogen was to occur.

The following contributor indicated a willingness to use brown hydrogen as means to rolling out green hydrogen. They stipulated that the period brown hydrogen could be used should be limited and indicated a preference for green hydrogen from the outset:

*If brown hydrogen was used starting out as a means to get hydrogen up and running in the country, I don't think I'd have a huge issue with it. It would need to be clarified that it would transition into the green hydrogen by a certain date. Ideally, using green hydrogen from the outset would be better. I don't think using brown hydrogen would change my opinion of hydrogen coming into the household.*

[Participant 1, Preschool Teacher].

The next interviewee agreed with Participant 1 by outlining a willingness to use brown hydrogen for a limited timeframe. The interviewee caveated that the transition from brown to green hydrogen should be clearly laid out and outlined a preference for green hydrogen from the outset:

*You would want a clear roadmap on moving from brown hydrogen to green hydrogen because otherwise, you are, in my opinion, just adding cost by producing hydrogen with no saving in carbon emissions. I wouldn't be against the idea of using brown hydrogen, but it would need to be a very limited time frame. I am for it almost as the next step in a trial to show that hydrogen can be blended, delivered safely to the customer; all the appliances are still going to work. But again, it would have to be time-limited to make it work, all because there's no point moving from natural gas to hydrogen if you are getting the hydrogen from natural gas and adding all the costs involved in extracting hydrogen from the natural gas. So as a proof of concept, I'm for it but only in a limited timeframe. If green hydrogen is used from the outset, it would be best. You're displacing the fossil fuel; you're displacing the carbon emissions and any other greenhouse gases in a complete product. It just comes down to the actual technical ability to do it.*

[Participant 2, Electrical Engineer].

The following contributor viewed brown hydrogen as the same as natural gas and questioned the reasoning for its use without expressing outright opposition to brown hydrogen. The contributor preferred the use of green hydrogen from the outset:

*Essentially, brown hydrogen is the same product as natural gas. If you're using fossil fuels to make it, then why just not use gas in the first place? Are you using so much less fossil fuel to make the hydrogen than you would be if you were using just using natural*
gas? I wouldn't have an issue with it, but my preference would be green hydrogen from the outset. The whole point of changing over the hydrogen is to stop using fossil fuels; if your aim is to no longer use fossil fuels and use green fuel sources, you want to hurry up and get there.

[Participant 7, Quality Engineer].

The next contributor also believed that the use of brown hydrogen, given its harm to the environment, should be time-limited, in line with the beliefs of the two previous contributors while expressing a preference for green hydrogen from the outset:

There is no benefit to going to brown hydrogen, only to find out that the infrastructure to switch to green hydrogen is decades down the line; having a time limit would be my only caveat to being supportive of brown hydrogen initially. Brown hydrogen is still harmful to the environment. Why not go carbon neutral from day one with green hydrogen? That is the aim of the game nowadays to be as environmentally friendly as they possibly can.

[Participant 3, Soldier].

The following contributor indicated opposition to the use of brown hydrogen, citing the damage it would cause to the environment and believed there would be a negative perception among the general public if brown hydrogen is used longer than expected. The contributor went on to detail that green hydrogen rolled out from the outset was preferred.

It's kind of being a bit ironic, isn't it? Starting with brown hydrogen, which damages the environment, when they're trying to be cleaner and more environmentally friendly. The political and public perception of a company trying to do this would be bad. They would need to have very good people when it comes to marketing to convince the public that it's the right way to go. I'm assuming that there's going to be a benefit to everybody in X amount of years, and that's in the form of a reduction in greenhouse gas emissions. I don't think time should be the limiting factor in swapping from brown hydrogen to green hydrogen. I think the data should be the limiting factor. I don't know all the facts and figures, obviously, but the data should point to whether a changeover is possible, is sustainable, is cost-effective. Is it reducing harmful emissions? The problem is when you give figures, i.e. we'll have it swapped over to green hydrogen in two years or three years, the public will hold you to that. If you go over that, I won't say you failed, but the perception will be that you failed. I would like to see it driven by the data and the facts and figures to drive the changeover. Let the data tell you, let people know it's an evolving story and build it that way.

[Participant 4, Manager].

The next interviewee indicated opposition to the use of brown hydrogen, citing a preference for green hydrogen:
I don’t like the brown hydrogen idea. I mean, why would we? I appreciate that hydrogen is the cleaner gas, hydrogen is the way we need to go, and it's the gas that we need to be working with. To get there is going to be as environmentally damaging as everything else if we use brown hydrogen. So, the gain isn’t enough. Why can't we go more quickly and use renewable energy to produce green hydrogen in the first place? Forget about the brown and go straight to the green. Why would we phase in the green hydrogen? Surely, we should go straight to the green? Why would we use fossil fuels to produce hydrogen when we can just use wind farms and solar farms to get to the green hydrogen? Why would we bother with the brown? Green hydrogen has to be used from the outset; there should be no brown. We should have green because we have surely got enough wind farms? Forget about brown.

[Participant 5, Safety Assurance Lead].

The following contributor also viewed the use of brown hydrogen negatively, citing that the use of brown hydrogen is a waste while indicating a preference for green hydrogen use from the outset:

*It doesn’t make sense to me why you would use brown hydrogen. The process of how brown hydrogen is made, it's just wasting gas. Currently, gas is considered the cleaner of fossil fuels. It's still a fossil fuel, but it's a lot cleaner than coal. So why would you waste it to make something else to burn? Green hydrogen is made by taking hydrogen out of the water and refining it; you're not purposely wasting anything else. The thing with natural gas is that going forward; they want to leave it in the ground, not burn it. So, if you can make hydrogen while leaving the gas in the ground, that can only be a good thing. That would be the method that, going forward, I would prefer to see explored.*

[Participant 6, Shift Supervisor].

The final participant also indicated a preference for green hydrogen from the outset of a changeover:

*I don't like to idea of brown hydrogen because you're letting gasses out into the environment to produce it, I suppose. The green seems to be the way to go to me; it sounds better for the environment. I don't think I'd be happy with brown hydrogen. If I had a choice of the two, I think the green would be the way to go for me; I'd prefer the green hydrogen.*

[Participant 8, Homemaker].

4.3.5 Theme – Safety

This study found that safety was the overarching theme of acceptance of hydrogen among the participants; overall, the word “safety” had over fifty mentions across the eight interviewees.
It was found that 75% of contributors to this study believed that hydrogen delivered via the natural gas network to homes and businesses would be safe. While many contributors outlined that the safety of hydrogen was a consideration, the majority trusted that hydrogen would be deemed safe by the appropriate authority before being used in homes and businesses. 25% of participants indicated that they believed hydrogen delivered via the gas network would be unsafe and that they were opposed to a transition based on their current knowledge. These contributors would like to see the safety of hydrogen demonstrated to them before they would deem it safe and accept it in their home.

The following participant believes that hydrogen would be safe if rolled out and indicated they would be unlikely to change their mind and deem it unsafe:

*I presume that they have engineers that will be checking and making sure that it is safe. It's the same as natural gas; you have people looking after the pipes and the network. I would assume that hydrogen would be the same, and it would be looked after by professionals. If it was coming in, I wouldn't likely change my mind; I would accept that hydrogen was coming in. If it was done safely, I'd be happy to go with that.*

[Participant 8, Homemaker].

The next interviewee outlines that while they have safety concerns regarding the use of hydrogen in the home, they wouldn’t stop them from using hydrogen. The interviewee believes that it is safer than natural gas and details that if there were accidents involving hydrogen, they may deem it unsafe and withdraw support:

*I don't know much about hydrogen, but I know, for one, it's odourless. It's kind of drilled into us that if you smell gas, you act quickly. I would be a little bit nervous about safety; if you couldn't smell hydrogen, how would you detect a leak? But then, I assume that if it is being pumped into households and coming through appliances, there is a way of determining if there is a leak. My concerns at the moment wouldn't stop me from bringing hydrogen into my home. I would consider hydrogen to be safer than gas, and I know little about it. Something drastic would have to happen for me to become opposed to having hydrogen in my home. If I heard of more explosions in households and households going up in flames because of hydrogen, I would change my mind.*

[Participant 1, Preschool Teacher].

The next contributor outlines that they would be comfortable using hydrogen in their home if it was deemed safe by the appropriate body and goes on to outline that the evidence from future trials will dictate their future perception of hydrogen. The contributor goes on to state
that they have no qualms with the safety of hydrogen and trusts that it will not be introduced into homes and businesses if there are any safety issues:

If it is proven by an expert authority such as IGEM, Gas Networks Ireland or National grid. If they come back after testing and say it can be done safely, I'd be very comfortable to go with it. Currently, there seem to be many different trials going on, and things seem to be pointing in the right direction. Once those trials have been conclusively bottomed out, I have no issue whatsoever with hydrogen. I have seen a study where they pumped hydrogen into a building in an attempt to make it explode. They found it very difficult because, unlike natural gas, which is a heavier gas and goes into pockets and becomes potentially explosive, hydrogen was dispersing rapidly because it is so light and finding its way out of the house. From what I saw in that study, it was not conclusive; it may be even harder to get hydrogen to gather in pockets than natural gas, therefore, making it safer. If other studies show that it is indeed safer, I'd be very comfortable with all the safety aspects of it. You can put me down as quite happy at the moment with safety. I'm evidence-based, and if the evidence tells me something else, I'll change my mind. If the evidence is inconclusive, I'll sit on the fence and stay comfortable with it. If there is a test to show that hydrogen is unsafe or there's an incident in society where it's trailed, and something comes up, then I'll change very quickly. Unless something definitive comes up, I'll stay quite comfortable with the safety of it. I have no qualms with safety or anything like that, I think there's a lot of work that needs to be done to bottom out things like adding a smell to hydrogen similar to gas, and I think the flame is clear and almost invisible to the eye. I know hydrogen has a higher explosive range, so it could potentially combust if there was a leak. Hydrogen will not be introduced at high risk, I would imagine; it will be introduced once it's gone through the Q&A and testing; I am very comfortable.

[Participant 2, Electrical Engineer].

The following participant outlines that they are aware of technical issues such as a smell needing to be added to hydrogen but details that he believes the engineers involved would ensure hydrogen is safe:

Safety aspects such as the smell that natural gas currently has needs to be added to hydrogen as it is a very volatile gas and odourless. I don't know much on what modifications, if any, would be needed to the pipelines, but I'm sure the engineers would be all over that. In the gas game, safety is paramount.

[Participant 3, Soldier].

The next contributor outlined that while hydrogen is highly explosive, they view the risk as equal to the risk associated with natural gas, provided hydrogen is appropriately regulated. The contributor also stated that they believed that adequate safety measures would be in place prior to hydrogen being fed into homes, and they would be comfortable with the safety level:
I don't know. Hydrogen is highly explosive, but then so is natural gas. Is it more explosive than natural gas? In my mind, it doesn't matter. Natural gas going to cause damage in an explosion, and so would hydrogen. Once it's regulated properly the way we do currently with natural gas, then the risk is the same. They're both highly flammable, I think. They're both explosive, I think, so the risk is the same. I think that I know enough about the two gases to know that they are equally flammable. Gas providers would have the proper safety measures in place to ensure that it is safe to pipe that to your kitchen. So, I would be comfortable with that.

[Participant 5, Safety Assurance Lead].

The following interviewee outlined that while they view hydrogen as safer than natural gas, they would have concerns regarding converting the gas network and natural gas appliances.

The interviewee went on to outline that they felt it would be difficult to change their opinion:

Considering the only output of hydrogen when it is burned is water, I would think it would be relatively safe. Obviously, the risk of natural gas in the house is that carbon monoxide is a safety concern, which would no longer be there on hydrogen. It would depend on the work needed to integrate hydrogen into the current gas network; that would be probably my safety concern. Unless you're changing out your current appliances, how do the old ones change over to using hydrogen instead? As for using hydrogen, no problem, but the changeover would be a concern. I would be fairly firm in my opinion; I wouldn't change my mind easily.

[Participant 7, Quality Engineer].

The following interviewee details that they would be very concerned with the risk associated with using hydrogen if it was not managed correctly. The interviewee outlines that they currently have limited knowledge of the technical aspects of a changeover to hydrogen and would need to be convinced that the risks have been mitigated:

I'm not a hydrogen expert, but I have heard how flammable or explosive hydrogen can be. Therefore, I would need to make sure that it's not going to be more dangerous than the natural gas currently coming into my house, so understanding natural gas is dangerous, but if hydrogen was five or tenfold more dangerous, I would need to assess it. We hear of many incidents throughout the world of gas leaks, gas explosions, not so much in this country, but in other countries. If hydrogen had lower explosive limits than natural gas mixtures, etc., then I would be very concerned about the risk associated with it if it wasn't managed correctly. With the public in mind, it would probably end up being voted against if it came to a vote. If it wasn't a vote and it was a private company or a semi-state pushing a changeover, I would imagine there would be the likes of protests. Things like this would end up happening. Then on the other side, you'll end up having the other side of the protesters who want this. But from a safety point of view, I would need to see the data. Is our system capable? Do pipes have to be replaced? Do flanges, do pumps, compressors? We're adding smells to natural gas; do we have to do all of that to the hydrogen? All of it would need to be painted clearly for me. Right now, from my limited knowledge of hydrogen, I would have concerns about

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having it piped into my house as it is. It wouldn’t take much for me to change my mind providing the was available. So, like an earlier question, I said you would take an awful lot to convince me. Yes, but if you had all the data and the facts and figures and risk assessments and could show me that that company has done as much as possible and the risk is brought ALARP. You could convince me if you had all of this data. If you don’t have the data, how do you know it’s safe?

[Participant 4, Manager].

The next participant detailed that they view hydrogen as unsafe and that they did not believe the gas network could transport hydrogen leak-free. The participant would like to see the safety of hydrogen demonstrated and proven to be safe before accepting hydrogen in the home:

My experience would say that if hydrogen is exposed to air, it can become combustible, unstable in fact. I would see it currently as unsafe. I don’t think the network would be a hundred per cent free of leaks. What will the plan be to upgrade the existing network before the transition over to hydrogen gas? I would like to see a significant reduction in leaks to make transportation of hydrogen gas to my home actually safe. It would need to be demonstrated that the works are ongoing to future proof the existing network, and it is safe before I would change my mind. If I was to change over to using hydrogen in my home, it would need to be demonstrated that it’s safe to do so. I’m currently unaware of how you would incorporate it into a household, but if you could prove that it’s safe, I would be willing to participate.

[Participant 6, Shift Supervisor].

4.3.6 Theme – Environmental Citizenship

This study found that 62% of the participants demonstrated environmental citizenship; these participants believed that the environmental benefits of hydrogen were enough of a motivation to warrant its use, even in the absence of any other benefit. The remaining participants indicated opposition to the use of hydrogen unless it could provide another tangible benefit such as lower cost etc.

The following interviewee viewed the environmental benefit of hydrogen as enough of a benefit to warrant using it in the home:

Well, if there is a benefit for the environment, I’d feel very happy with it. If it made me richer simultaneously, brilliant, but the fact that using hydrogen is displacing fossil fuel alone would be enough of a win for me to be very positive about it. I don’t need anything else for me to be very much behind it.
The following participant agreed, believing that the environmental benefits of hydrogen were enough of a motivation to warrant its use:

*I'd be happy with that at the end of the day, what we do to the environment, now is what affects our kids in the future, but we need to be realistic about it at the same time, just because someone is comfortable with their current fuel doesn't mean you shouldn't change it for something that works effectively and is cleaner for the environment.*

[Participant 3, Soldier].

The next contributor saw the environmental benefits of hydrogen as hugely beneficial:

*Well, being more environmentally friendly is hugely important. One is more environmentally friendly than the other so, hydrogen all the way. Hydrogen is the more environmentally friendly option, so I would feel more excited about hydrogen.*

[Participant 5, Safety Assurance Lead].

The following participant also viewed the environmental benefits of using hydrogen as a motivation to changeover:

*It's still better for the environment in multiple ways, really, so I'd be happy to change over. It sounds like it's a win-win; it is better for the environment. Why wouldn't you change?*

[Participant 7, Quality Engineer].

The next contributor indicated that hydrogen’s environmental credentials were enough of a motivation to changeover from natural gas:

*I would feel the same about a new hydrogen supply as I do with my current gas supply. If hydrogen is better for the environment and nothing more when compared to natural gas, that's good enough for me.*

[Participant 8, Homemaker].

A subsequent interviewee expressed no opposition but caveated that their lack of opposition depended on hydrogen costing the same and being as safe as natural gas. Indicating that the environmental benefits of hydrogen alone were not enough of a motivation to warrant its use in the interviewee’s opinion:
I would have no opposition if the cost was the same; if it worked the same was safe, I'd have no opposition.

[Participant 6, Shift Supervisor].

The following contributor outlined that hydrogen being more environmentally friendly was not enough of a motivation to use hydrogen over natural gas and that they would stick with natural gas unless there was an additional benefit:

I would assume that if I am changing to hydrogen, that I would need to get new appliances. So, there would be, as we said before, a cost issue. Then, to not have any benefit after changing all those appliances such as a cost-saving or energy saving. I don’t think I’d change just for the environmental factor; I think I’d just stick with natural gas in that case. You want some incentive to change; if the only benefit was environmental, I would not see the point in changing. I don't think I'd be very happy if I was forced to pay for new appliances, just for the environmental factor.

[Participant 1, Preschool Teacher].

The next interviewee outlined that they were not interested in using hydrogen unless it could provide a tangible benefit other than being better for the environment. The interviewee also outlined that they believed that any reduction in greenhouse gas emissions in the Republic of Ireland would be minor compared to potential reductions in other countries. The interviewee believed that hydrogen would be acceptable if it behaved in the same manner as natural gas, citing that if it did not, they would wish to stay with natural gas:

I would go back say, what's in it for me? I'm not interested, no, thank you, I don't want it. We are a small population; there are other superpowers out there, North Americans, Indians, Chinese, Brazilians, Russians, putting enough pollutants into the air. If they manage to do something, one per cent of what we could do, it will make things an awful lot better. Therefore, if there's nothing else in it for me, especially not a cost reduction, I would not be interested. I would imagine that most other people would feel the same in that scenario; there's nothing in it for them, so why would they bother? If I am getting a fuel that performs the same as the current natural gas, so my heat output, my BTU’s is all identical, and there are no safety concerns, and it's the same cost, and it could be reducing CO2 emissions, no problem. Ideally, I would like the cost to be cheaper, but if the cost was the same and we're saving the environment, fine, I would take it, but it would need to be guaranteed, written in stone, proven. If there was any slight risk or chance that it might
not work, please keep me on the exact natural gas supply that's coming into my home right now.

[Participant 4, Manager].

4.3.7 Theme – Consumer Choice

Due to the nature of the gas network, it is believed that entire areas may need to be changed over to hydrogen at once in the event of a changeover. This possibility was presented to the participants as such a scenario could create an issue with consumer choice. This study has found that 50% of the participants would not have an issue if a changeover to hydrogen was not their choice, while 37% indicated that they would oppose a changeover to hydrogen if it was not their choice. The remaining 13% were undecided:

The following interviewee did not see an issue with not being given a choice between natural gas and hydrogen once the fuel is available:

I would say that that would be no problem, so long as there is always one or other gas coming to my cooker and I can cook.

[Participant 5, Safety Assurance Lead].

The next participant also did not have a problem with not being given a choice regarding a hydrogen changeover, outlining that they felt it would be good for the area:

If the whole area was going to be changed over, I'd be happy to go with that. I don't think not being given a choice would affect me because I feel everyone else is getting it done in the area, so it will benefit the area. I'd be happy to go with that. It wouldn't bother me that I wasn't given a choice.

[Participant 8, Homemaker].

The next participant believed they would understand the need to changeover large portions of the gas network to hydrogen as they would be cognisant of the bigger picture. However, they didn’t believe that most consumers would be as understanding:

Because I'm in the engineering industry, I'm very understanding of the technical difficulties with something like this. If you didn't realise your estate might be one of the first to change over to hydrogen and you had bought your gas boiler only four years ago, now you'll have to change before it reaches the end of its life, while inconvenient, I think I'd be very understanding of it. There is a danger that not everyone would be as
understanding. I'd be quite cognisant of the bigger picture here rather than my own little world. So, I would be very understanding of it.

[Participant 2, Electrical Engineer].

The following contributor detailed that they would not have an issue with not being given a choice on a hydrogen changeover; however, they caveated that their acceptance was dependent on cost and function. The participant also outlined that they did not believe those who did not choose to have hydrogen should pay for it:

*I would be ok with it if it works. If all your appliances are all the same, no problem; if there’s a cost implication for someone who didn’t want to change over to retrofit your appliances accordingly, then I think that should be government-funded. For everybody, not just the people who do want to change, but I think it would be unfair to force a change and then expect people to pay for that.*

[Participant 7, Quality Engineer].

The next contributor was largely undecided and would like to understand the benefits of hydrogen before expressing a firm opinion:

*Having choice is nice, obviously. It would have to be explained to me the benefits of hydrogen.*

[Participant 6, Shift Supervisor].

The following contributor outlined that they would like a changeover to hydrogen to be their choice:

*I don't think I’d have much of a say if the whole estate is changing. This would happen over time, and I don't think I’d have an issue with hydrogen in my home, but I would like it to be my choice.*

[Participant 1, Preschool Teacher].

The below interviewee expressed that choice was important to them, and they would not be happy if they were not given a choice in a changeover to hydrogen:

*I wouldn't be too happy about it, especially if it wasn’t my choice and I didn't have the finances at the time to switch all my appliances to something that would now work with hydrogen.*

[Participant 3, Soldier].
The next participant indicated that they would not be happy if they were not given a choice on a changeover to hydrogen and believed others would feel the same way. The participant believed that if they were not given a choice between natural gas and hydrogen, they would source an alternative fuel for their home:

>You would have a very unhappy customer. The important thing is choice, so we live in a country that gives us a choice and allows us to make decisions without being dictated to. I understand that the gas network may have to go this way in the future, providing it was an absolute last resort. If it was the case that we’re going to do it because we’re going to potentially reduce greenhouse gases, I definitely wouldn’t like that, and I think it will be a similar uproar to what happened with the likes of Irish Water. It was something the people didn't want. If a changeover to hydrogen was to be mandated, I think there would be disruption. If that’s how a changeover would go, then I would seriously need to consider other means of heating my house.

[Participant 4, Manager].

4.3.8 Theme – Appliance Replacement

In order to operate on pure hydrogen, current natural gas appliances may need to be replaced with hydrogen ready appliances. This study found that 62% of participants would be opposed to replacing their appliances to facilitate a hydrogen changeover if they had to burden the cost of the new appliance. In addition, 87% of participants believed some form of grant or financial assistance should be made available to offset the cost of appliance replacement while being given as much notice as possible to plan for the future.

The following contributor believes that the need to change appliances would not stop them from taking part in a hydrogen changeover; however, they felt the availability of grants would help them changeover faster and went on to outline that advanced notice of a changeover to prepare would be valuable:

>I wouldn't be totally against changing appliances; if there were incentives, I would do it in a heartbeat. The need to change appliances would not put me off changing over to hydrogen. I don't think that having to change the hob and change all the other appliances would be an issue. Suppose there was some form of a grant from the government to change all the appliances in the house; I would change over a little bit faster than if there was no incentive. If I got a few years to think about it and prepare for it to come, I don't think I’d have an issue with changing over the appliances. Many of the houses where I am living would be slightly older, and appliances only last a matter of years anyway. If I was given a few years to think, okay, by this date, this year, we’re going to have to change, everything is going to hydrogen. It’s just moving with
the times. If I had reassurance and had been given the date for a changeover, then I'd be fine with it.

[Participant 1, Preschool Teacher].

The below interviewee detailed that once the new appliances were not prohibitively expensive, they would have no problem replacing their existing appliances to facilitate a new hydrogen supply. The interviewee adds that they believe people have shown to be willing to pay more for less carbon-intensive heat sources while detailing that being provided with adequate notice of a changeover would help them to feel more positively about replacing an appliance:

*The only thing to be determined, in my view, is if the new hydrogen appliances were affordable. As this is a new technology, you must accept it will be more expensive than an existing, well established mass-produced technology. Whether they must do it through grants or tax incentives, if the appliances are not completely unaffordable, I have no issue changing the appliances to welcoming in a new, more environmentally friendly solution. It's similar right now: people are paying seven to ten thousand euro for heat pumps when they could pay probably two thousand for an oil boiler. People have already shown they are willing to pay extra for new, less carbon-intensive heat sources. Long story short, I have no issue paying more for the benefit of the environment. A few years notice of a changeover would make my view more positive because I would accept the bigger picture. If I had invested in a gas appliance and then only fifty per cent into its lifecycle had to replace it, I'd be understanding the situation, but if I had the five years notice, I would completely accept the new appliance. As much notice as possible that you are changing over would allow you to make your choices on your appliances. The more time, the more comfortable I am with the technology or with the changeover, period.*

[Participant 2, Electrical Engineer].

The next participant indicated no opposition to changing appliances but believed that some form of subsidy or grant would help them feel more positively about the need to change over appliances. The participant also outlined that vulnerable members of society may not have the means to change appliances:

*I still think it'd be worth it, just as I mentioned before, to help the older generation that might be surviving on their pension switch over, there would need to be some sort of scrappage scheme to help fund the switch over. Appliances aren't cheap when one of them goes down, never mind when you must replace that and the heating system at once. Government incentive and scrappage scheme of some sort would help me feel more positively about it, especially if you are being backed into a corner where you have to switch. There would need to be safeguards to ensure that you aren't going to be
left without an appliance because you can’t afford it and the government just said you need to have it.

[Participant 3, Soldier].

The next interviewee outlined that they would not be happy changing appliances if they were costly. Interestingly, the interviewee believed that being given more time to plan for the expense would improve their view:

*Obviously, there will be a cost if you must replace your appliances, but how much of a cost is there going to be? It’s not going to be cheap to change over, but if it’s very expensive, of course, you’re not going to be happy about that. If it’s a thing that’s being done all over, you would have to incur the expense, I suppose. If you’ve been given time to do it, that is an advantage. If you have plenty of time to plan what it’s going to cost you, that would be better.*

[Participant 8, Homemaker].

The below contributor outlined their opposition to changing appliances to facilitate hydrogen as they would not be willing to pay for the appliances. The contributor detailed that they expected the network operator to factor in the cost of new appliances to the overall network conversion cost stating that, requiring the people to pay would damage the reputation of the network operator and result in customers seeking alternative fuels:

*If I’m paying for it, no, thank you, I am not interested. What I have works, it’s three years old, and I have a ten-year warranty, I’m not interested in replacing it. When I purchased that unit downstairs, I purchased an all stainless internal because I was told it would be solid for ten years. There was no mention of hydrogen three years ago. At that time, I spent additional finances for the top of the range model to give me peace of mind for ten years. Now, if you’re coming in in the middle of this telling me I need to change, and I need to pay for it, no, thank you. I would not be happy, and I would expect and hope that the network providers would be building this into the case for switching from natural gas to hydrogen. Build this in so X amount of houses times two thousand euro an appliance and factor all that in and somehow manage it that way. If the network provider decided it isn’t worth it and decide that the people should pay, then they will damage their reputation and lose customers*  

[Participant 4, Manager].

The following participant also agrees that the network operator should allow for the cost of new appliances or provide financial assistance with the changeover:

*The supplier would have to allow for the requirement for new appliances and either provide the new appliance or at least provide and some sort of a financial subsidy towards the new appliances.*
The next interviewee indicated that they would not be happy changing out appliances to facilitate a hydrogen changeover, and financial aid would be beneficial. Interestingly, the interviewee also detailed that the lack of financial aid would not prevent them from changing appliances:

*I'd be very annoyed if I had to change out my boiler. I'd be hoping that whenever that happens, there would be some sort of grant available. It wouldn't be a game-changer and prevent me from changing over, but I would be annoyed about having to get a new boiler. A grant or some sort of incentive being available would make me feel more positive about it.*

[Participant 5, Shift Supervisor].

Intriguingly, the next participant believed that if a changeover was an individual’s choice, they should expect to pay additional costs. The participant further stated that if the consumer did not choose a changeover, grants should be available. The participant also believed that consumer willingness to accept hydrogen was dependent on the age of existing appliances:

*I think it depends; if you had, for instance, just built a new house and bought all gas-related appliances, they were brand new, and you expected to get ten years out of them. Changing them would be a hard hit to take. But if you had ageing appliances that needed to be replaced possibly in the next year or two anyway, not as difficult to take. Again, I suppose it depends if the decision is forced on you to change over to hydrogen or not; if you're choosing to change over to hydrogen, you would expect some cost implication. If it's being forced onto you by a rollout in your area, then I think there should be an incentive for it. If you were voluntarily switching over, that's different. Not many appliances will be gas specific, maybe a gas cooker and maybe a gas boiler, nothing else I can think of offhand, but it shouldn't be that much of a hit to take, especially if you had sought out changing over to hydrogen.*

[Participant 7, Quality Engineer].

4.3.8.1 – Sub Theme: Hydrogen Ready Appliances

A hydrogen ready appliance is capable of burning either natural gas or pure hydrogen. This study found that 87% of participants would favour the phase-in of hydrogen ready appliances and phase-out of traditional single fuel appliances in anticipation of a changeover to pure hydrogen sometime in the future. Many viewed this option as an ideal way to future proof their appliances as they came to the end of their life cycle.
The following contributor outlined that they viewed the rollout of hydrogen ready boilers favourably while outlining that they viewed the use of hydrogen favourably regardless:

*I don't think I would have an issue with that; I think that would be good. It is the same with cars; if you're going to buy a car and there are no diesel cars to buy, you're automatically going to buy a petrol or electric car. I think it's the same with the appliances. If you have a couple of different hydrogen ready options, you can pick the best one to suit you and go from there. It wouldn't change my opinion on anything. I think I'd be happy enough to go pure hydrogen regardless.*

[Participant 1, Preschool Teacher].

The below interviewee viewed the rollout of hydrogen ready appliances positively as it would enable the public to purchase a future-proofed appliance if their current natural gas appliances reach end of life:

*That's the ideal solution for the short term. If you were coming to the end of the life cycle of your boiler and you get a message to say there is a likelihood that you could be getting hydrogen in the next one to five years, rather than trying to keep an end of life boiler going, you could purchase a new efficient boiler that could run on hydrogen and natural gas. That would be an excellent solution, the best solution you could come up with in reality because it allows you to stick with what you have now and future proof.*

[Participant 2, Electrical Engineer].

The following participant believed that the rollout of dual-fuel hydrogen ready appliances was a better option than single fuel appliances:

*That's a good alternative; you can get a new appliance that can work on hydrogen, and you can use it from day one. Better than saying it's one or the other and be damned if you can’t do it. If your new appliance can run on dual fuel, it's the better option.*

[Participant 3, Soldier].

The next contributor detailed that they had no issue with the rollout of hydrogen ready appliances while detailing that it is the way forward:

*Sure, that must be the way it's going to go eventually because they're going to have to move completely to one. It's like anything that you eventually can't buy in the shops anymore. You can't buy the old, inefficient bulbs anymore; they have forced us to buy the energy-efficient bulbs. That's the way it must be. That's the way you must enforce it going forward. So, yeah, I have no issue with that.*
Similarly, the following participant indicated they viewed hydrogen ready appliances positively as it enabled the future-proofing of homes:

Yeah, I have no problem changing over. To be honest, if it works the same, it's not interfering with the way your house currently works and you're future-proofing. No problem, that's probably the best of both worlds.

[Participant 7, Quality Engineer].

The following interviewee detailed that once hydrogen ready appliances were similar to existing gas boilers in terms of cost, efficiency etc., they would not see an issue:

If the appliances are as efficient and maybe even more efficient, they cost the same to run, and they serve the same purpose. I wouldn't see an issue with it.

[Participant 6, Shift Supervisor].

The following contributor outlined that once hydrogen ready appliances were not overly complicated; they would be willing to accept dual fuel appliances:

That would be ok, as long as it's safe and that you're not going to have any issues with the appliance. Having an appliance compatible with the two different gasses may overcomplicate things. If there were no issues with the appliances, I would be happy to go with that.

[Participant 8, Homemaker].

The following interviewee detailed that they would be concerned that hydrogen ready appliances would be more expensive than traditional natural gas appliances and the impact the additional costs may have. They also outlined that if a changeover to hydrogen was coming and the technology was already in place, it would be beneficial:

If we go for something that now needs to be capable of running on two separate fuel sources, I believe there would be additional costs. I'm sure greenhouse gasses is one thing, but we don't want to push people below the breadline. If the overall appliances are cheaper, brilliant, bring it in. I'm assuming that functionality, throughput efficiencies, that all of that is the same. If we swapped to the hydrogen in X amount of years and we have the technology in place, great.

[Participant 4, Manager].
4.3.9 Theme – Cost

The qualitative portion of this study found that 75% of participants indicated that they were willing to tolerate increased costs in the short to medium term with the belief that the cost of hydrogen would fall over time. All the participants indicated that increased cost over the long term would result in them becoming unsupportive of a changeover to hydrogen.

The first participant outlines that while they believed hydrogen would be more expensive than natural gas, they didn’t believe the additional cost would dissuade them from changing over to hydrogen. The participant added if the cost of hydrogen came down over time, it would be an incentive the changeover to hydrogen:

> When you're changing over to something like that, there is going to be costs involved. I believe that it will be expensive going from natural gas to hydrogen, but I think over time, if the cost came down, that would be a huge incentive. I don't think the cost would stop me from having hydrogen, but the cost is a big concern.

[Participant 1, Preschool Teacher].

The next interviewee accepted that using emerging technologies such as hydrogen would cost more than traditional technologies for the short to medium term. The interviewee outlined that they hoped the price of hydrogen would fall as the technology became more established while stating they were willing to tolerate higher costs initially:

> I think my view is that with any technology or innovation, you're going to have to accept that it will be a higher cost, to begin with, and probably for the short to medium term until it becomes established. Whether you are talking about hydrogen or a mobile phone. The first mobile phones that came along were exorbitant prices, and the mobile phone price has come down now. I think hydrogen is bound to be more expensive than gas, to begin with. Hopefully, as the technology improves and the efficiency of extracting hydrogen from our environment improves, then the price will come down in line with that. I completely understand higher costs to begin with.

[Participant 2, Electrical Engineer].

The below contributor believed that eventually, the cost of hydrogen would either level out with carbon-based fuels or even become cheaper. The contributor expressed a willingness to tolerate the increased cost of hydrogen for a time in the hope that the cost would reduce in the future while caveating that they were still sensitive to cost, outlining that a major cost would dissuade them from using hydrogen:
We're getting carbon tax increases nearly every budget as it is. Theoretically, the hydrogen fuel should level out overtime to possibly be even less than carbon-based fuels. An initial impact on the finances wouldn't be too bad. Hydrogen could become more stable over time where it shouldn't be going up year on year like all other carbon fuels are. I'd be happy to take the hit at the start for a later reward. The only thing that would make me unwilling to take part in a hydrogen changeover is if there was a major cost to switch over, especially on the heating side of things. There would have to be a good incentive there to do as well, kind of like a scrappage scheme that was on cars a couple of years ago.

[Participant 3, Soldier].

The following participant believed that cost would be a major factor in deciding whether they would accept hydrogen as a fuel in their home. The participant outlined that if the additional cost was a few euros a month extra, they would be willing to accept hydrogen due to their view of the environmental and safety benefits of hydrogen:

I think the main factor would be if it turned out to be extremely expensive to change over. The cost consideration of converting over appliances, boilers, cookers, etc., would be a concern. Another question would be, is it more expensive per unit? If it was more expensive, but also, it's green and safe. It's potentially a lot safer in your house for your family. If paying an extra couple of euros a month was the cost of a greener and safer fuel, then I'd be ok with it.

[Participant 7, Quality Engineer].

The following contributor outlines that they hope the price of hydrogen would come down in the long term and that the saving would be passed on to the customer. The contributor detailed that they would not be happy with the increased cost in the short term and believed there would be opposition to hydrogen as a result:

No one likes having to spend the extra money, and I am no different. Suppose you take how expensive a battery pack for an electric car was a few years ago. The price has come down exponentially, and those cars are getting cheaper to make. The hope would be that long term, hydrogen will be the same, and the process of making it will become a lot cheaper, a lot more efficient, and that fall in price would be passed on to the customer. Short term, I still wouldn't like to be taking a hit in the pocket. No one does; if that was the consequence of an initial roll out there would be a lot of kickback, especially from lower-income families.

[Participant 6, Shift Supervisor].
The below participant believed that they would accept a higher cost for a time but would not be happy if hydrogen was more expensive than natural gas indefinitely. Interestingly, the participant was willing to accept higher costs if it benefitted the environment:

*You could take a hit for a little while, I'd imagine, but after that, I suppose there's not a lot we can do. If it's going to be something that's coming in, you're going to have to heat your home, and you must cook. Just have to take the hit, I suppose. You're not going to be happy if it's going to be astronomically expensive, but if it's good for the environment, I suppose that's ok.*

[Participant 8, Homemaker].

The following participant would prefer to not see additional costs arising from a changeover to hydrogen while conceding that additional costs are likely. Surprisingly, the participant was not generally in favour of a subsidy as they felt this would be an indirect cost to themselves most likely collected through increased taxation. The participant felt that a clear and binding roadmap of future costs combined with when it was believed costs would reduce would be useful:

*I would hope; ideally, there wouldn't be additional costs. We're all about cost improvements; we all want to bring costs down. I don't want my bills going up the same as you don't. If you were to tell me, my bill would go up through no fault of my own. Not ideal, but I understand that additional technologies, additional research, people, and resources etc., costs money. To go from nothing to a ramp-up and pay for all this cost's capital. I would say to you some people might expect it to be subsidised by our government. The only thing is, if I don't pay it on my hydrogen bill, I'm going to pay it some other way; the tax rates are going to go up. They're going to increase taxes on other carbon-based fuels, "they" being the government. They will "catch me" some other way. So, let's make it open and honest, call it out up front. A unit of natural gas costs X, a unit of hydrogen costs Y. We expect that by year Z the costs will be equal and thereafter reduce. That would almost need to be written in stone and signed in blood. The country got burned with USC, it was brought in for a short time, and now we're all still paying it. So short term, higher cost, medium-term, even cost, long term the cost comes down. Short term pain. Long term gain.*

[Participant 4, Manager].

The next interviewee believed that if their bills were to double, they would become unsupportive of a changeover to hydrogen, and the prospect of increased cost is not exciting. The interviewee believed that the initial cost of hydrogen would be substantial and like to see government support to make it affordable, further stating that they would be disappointed by any additional cost:
It would depend on how much it would cost. There's nothing cheap at the moment, even as it is, if it's going to double in price I would probably not be as worried about the environment. If my bills were to double, I wouldn't be impressed. There's talk that it would be quite a substantial amount higher, isn't there? Initially, anyway, at least. That's not exciting; that wouldn't excite me. The government will surely have to row in if we are going to meet twenty fifty targets. No, I wouldn't be excited to think that it might be more expensive. I'd be disappointed.

[Participant 5, Safety Assurance Lead].

4.3.9.1 – Sub Theme: Tolerable Cost Increase

This study indicates that the maximum tolerable increase in cost among the interviewees varied from 5% to 30%, with the average tolerable increase being 13%.

The below contributor believed that a 20% cost increase would be the maximum they could tolerate:

   I'd imagine twenty per cent would be my max. That would be a lot, but that would be what I would tolerate.

[Participant 8, Homemaker].

The following participant believed a 20–30% increase in the cost of their bills would be tolerable:

   I’d say twenty or thirty per cent would be the highest I would tolerate; ideally, it would be much lower than that.

[Participant 1, Preschool Teacher].

The next interviewee found that a 5–10% increase in their bills would be tolerable:

   I would tolerate maybe five per cent, ten per cent max.

[Participant 3, Soldier].

The below participant believed a 10% increase in the cost of the bills would be tolerable:

   Ten per cent, maybe.

[Participant 7, Quality Engineer].
The next contributor would tolerate an increase no higher than 5% in their bill:

*I think that all the utility bills are climbing up all the time anyway. So, if it was to go up a few per cent, that would be ok, three, four or five per cent—no higher than that.*

[Participant 5, Safety Assurance Lead].

The following participant expressed unease at any increase beyond 10% in the cost of their bills but outlined that an increase over this would not necessarily lead them to oppose a changeover to hydrogen:

*Five to ten per cent, I would be uneasy with any increase above that but not necessarily in opposition.*

[Participant 6, Shift Supervisor].

The next interviewee detailed that they would find an increase of between 10% and 20% in the long term would be tolerated by the public. The interviewee believed that if the cost of production was greater than 10%, a long-term view would need to be taken to ensure fuel poverty isn’t created:

*That’s a very difficult one to put a number on. I’m sure in the short term, it would want to be managed whether that's through kind of a PSO charge similar to electricity, the cost stays mostly the same you just pay an extra five or ten euro a year. You couldn’t be dealing with multiples, that's for sure. Probably somewhere between ten and twenty per cent is the max that would be acceptable to the public, probably closer to ten per cent and do it over a long period of time. Even if the cost of production was more than ten per cent, there would have to be a long-term view taken by both the regulator and the provider, the shipper and the supplier. You have to think of fuel poverty and all that; every given household is different.*

[Participant 2, Electrical Engineer].

4.3.10 Theme – Trust

Regarding which sources of information the participants would find trustworthy on a future transition to hydrogen, this study finds that 62% of participants would trust government departments and the gas network operator, Gas Networks Ireland. Other participants added that they would trust independent sources such as academia and professional engineering bodies. Interestingly, a single participant believed they would not trust government members but would still trust government departments.
The participants indicated a distrust of online sources, individual opinions, and some media outlets. It was suggested that if a source of information was deemed untrustworthy, that information would not impact their perceptions and would be discarded. Interestingly, a participant stated that they would also not trust companies that could profit from a hydrogen transition as they believed such companies had a vested interest in the transition being successful.

The following contributor outlined that they would trust information from a Government Department or Gas Networks Ireland concerning a transition to hydrogen. The contributor goes on to detail that they would not be happy to consume hydrogen in the home if they did not trust the body providing information on hydrogen:

*I would trust information coming from a government body or Gas Networks. They always clarify that if you are out and about and smell gas, whom do you ring? I would want the same level of expertise from somebody when it comes to hydrogen and a changeover. Somebody who is in a position of trust, knows what they're talking about, has researched how safe it is and has done the research into the appliances. I would not trust someone who is not familiar with hydrogen. I would not be happy to bring hydrogen to my home if I didn’t trust the person giving me information about it. Like I've said already, a government body or Gas Networks would be the only people I'd really trust.*

[Participant 1, Preschool Teacher].

The next interviewee echoes the first, stating that they would trust information coming from a government body or Gas Networks Ireland. Interestingly, the interviewee outlined that they would trust some independent commentators while distrusting members of government:

*Whatever government agency takes over a changeover, be it Gas Networks Ireland or another, I’d be happy to trust that. I would also find independent commentators trustworthy, depending on how much I was aware of them beforehand. If I don’t trust a source of information, however, I generally believe the opposite of what they're telling me. I will not trust most politicians if I am honest.*

[Participant 3, Soldier].

The below participant detailed that they would trust Gas Networks Ireland when it came to information regarding a transition to hydrogen:

*I would tend to trust whoever is converting the network to hydrogen, such as Gas Networks.*

[Participant 8, Homemaker].
The below contributor detailed that they would trust information coming from the government, Gas Networks Ireland or another well-advised source concerning a transition to hydrogen. The contributor goes on to detail that they would not necessarily trust online content from social media sites or companies that they are not familiar with:

Something official from the Irish government, Gas Networks Ireland or whoever will be the people supplying it. People get a lot of false information online these days, but if the information was coming from the government or a well-advised source, then you’re more likely to believe it and trust the information you’re being given has been vetted, it’s been tested, it’s safe to use, the costs that they’re saying is accurate. You would believe it more. I think false information could scare people off. I can’t necessarily say Facebook or the likes would be untrustworthy sources of information because even the government has a Facebook page. I suppose if you just hear from companies that you’ve never heard of before, brand new, like hydrogen.ie or something, you wouldn’t trust them. Unlike Gas Networks Ireland, which everybody in Ireland knows. I think it needs to be a company that everybody’s aware of and or a government-related source outside of that you’re not going to trust it.

[Participant 7, Quality Engineer].

The next participant detailed that they would trust information coming from the government and mainstream media concerning a transition to hydrogen. The participant outlines that while they would trust these sources of information, they would still seek multiple sources of information to gain a complete picture. The participant also outlined that they did not trust some media outlets and individuals on social media for information relating to hydrogen, citing that such sources would not impact their opinion of hydrogen:

I would tend to trust government sources and mainstream media. If the government did an information campaign in the same way as they do before every kind of a referendum, to familiarise people with what’s going to happen, how it’s going to work, how long it’s going to take to roll out, and the benefits to society and also individuals. I wouldn’t be taking my conclusions from just one source, though; I’d have to get a few. I’d take the information I find trustworthy on board, but it wouldn’t be the one thing that influences whether I would use hydrogen in my home or not. If I didn’t trust a source of information, I’d have to look for alternative sources on whatever question I was looking for an answer to. For example, how the burner would work compared to how my current burner works is a very simple example. If I knew a source of information was not trustworthy, such as Fox News or Joe Bloggs on Facebook, I wouldn’t be listening to that source; it wouldn’t impact my perception of hydrogen at all. What you’re talking about is hearsay, and even though that’s how most of the world decisions are made right now, it’s not really how I would make my decisions.

[Participant 6, Shift Supervisor].
The following interviewee believed that the Department of Environment and SEAI would be trustworthy but also believed they could be biased in favour of a transition to hydrogen; the interviewee goes on to outline that they believed reliable sources from abroad or universities would be most trustworthy. The interviewee also details that they would not trust the opinions of individuals but would rather hear facts. The interviewee concludes that they would not trust information from media such as RTE concerning a hydrogen transition:

It would need to come from a nonbiased body; the Department of the Environment and the SEAI would be a little bit biased in my mind. So while it would be useful to hear from the likes of the Department of the Environment and the SEAI, their opinion will be wanting green, wanting green, wanting green, where I’m going to want to know the facts. We can surely learn from countries that are doing this already—Reliable sources from abroad. I don’t know yet what the reliable sources here would be, universities, those sorts of things. I’d be cautious of biased media and reading from sources that want you to believe a certain way. I would trust the environmental bodies here; however, I would not fully trust them because of the bias. It’s not fair to say that I outright wouldn’t trust them. I would not trust silly radio interviews with professors of nothing. I would not trust opinions; it must be based on facts. Then, where do we get the facts? I’m not entirely sure, but I would not trust opinion-based resources. At the moment, I do not trust RTE, and I would not trust them with this.

[Participant 5, Safety Assurance Lead].

The below contributor believed that they would trust information from professional bodies such as Engineers Ireland on a transition to hydrogen. The contributor further outlined that they are very careful about how much credence they give sources of information, detailing that they would not find some newspapers trustworthy. Interestingly, the contributor specifies the difference between deliberately misleading information, which they believed was potentially harmful, and information that is incorrect which they believed could be part of the scientific process:

I would trust information from IGEM, IET, Engineers Ireland. I have great confidence in the reputation and the standard of people and studies that they circulate to their members. You have to take everything with a little pinch of salt in that you can’t just assume that if it is Engineers Ireland telling you it has to be true, it gives you a great starting point to have confidence in what you are being told is likely to be true. The more engineering-based information is how I like to learn about new technologies or innovation. It’s particularly harmful having untrustworthy sources of information out there. I’m very careful as to how much credence I give sources of information. If I saw information on hydrogen in the daily newspaper, The Sun, for example, that wouldn’t hurt hydrogen’s stance to me one way or the other because I don’t trust anything a newspaper like that would say. If a credible source was to put forward information on hydrogen that I later found out to be misleading in particular,
if it's incorrect and found to be so in later studies, that's part of how science works. However, if I learned that something was misleading or that they knew false, then that would set back anything in my mind, including hydrogen.

[Participant 2, Electrical Engineer].

The next participant outlined that in order to trust the information on a hydrogen transition, it would need to be from an independent source, and it would need to not be manipulated in any form. The participant further stressed the importance of independent sources of information, citing the lack of awareness of hydrogen in society. The participant also believed that they would not trust companies selling hydrogen as they believed the company would be biased, concluding that they would seek out alternative sources of information if they did not trust the information available on a transition to hydrogen.

To trust future information on hydrogen, I would like to see information from separate, independent companies, people, countries. Another source I would trust is academia and independent people that provide data. It would need to be not manipulated in any shape or form. I would not trust the information if it came from the people who are selling it unless it has been backed up by somebody independent. If it's from company A and company B, who may be their competitor, they should be able to provide the same data, and everything should correlate. If it's a pure business move and the companies rolling out a changeover or selling hydrogen are not scrutinised, controlled, and managed independently. That's not a good way to go. This is only because we as a society don't know enough about the transmission of hydrogen; well, I don't. Therefore, we would need independence. I would be a little bit cautious if the information was coming from a company with an interest in a hydrogen rollout, and I would potentially look elsewhere for data to back up the claims. In the same way, as the government is supposed to be for the people and it's supposed to be totally independent, but there are sometimes where people will still go elsewhere other than governmental agencies for information. I would not trust an information campaign if the wrong people were involved, such as the sellers. If the seller is telling me this is the best thing since the sliced pan, take it, and it'll only cost you X. I would be a little bit cautious, and I would look to go and verify what that company or he or she has told me.

[Participant 4, Manager].

4.3.11 Theme – Environmental Awareness

Regarding the participants' environmental awareness, a finding of this study is that 37% of respondents indicated that they believed they were very informed of current environmental
and energy issues while 37% indicated they had average knowledge. The remainder believed that they had low knowledge of current environmental and energy issues.

The following participant indicated that they believed that they were quite informed of energy and environmental issues, citing an interest in the area:

\[ I \text{ would consider myself quite informed of energy and environmental issues. I have a definite interest in the area; when opportunities for webinars or CPD or even relevant articles come up, I am very interested in them. I'd like to consider myself informed without being overly studious in the area.} \]

[Participant 2, Electrical Engineer].

The next interviewee viewed themselves as very environmentally aware, detailing their efforts to be more environmentally friendly at home and outlining where they are aware of where they can improve:

\[ I \text{ would say I'm very environmentally aware. I'm very paranoid about the overuse of plastic; I'm all about reduce, reuse, recycle, handing on toys, not buying disposable clothes. I worry about the landfills, and I worry about our waste production. I worry about my consumption in the house. It would be really uncommon that anything would go out of date in my fridge because I'd be very conscious of keeping everything right and using things before they go out of date. I am very conscious while working from home to put a blanket over my legs, not to put on the heat. I would say very environmentally aware, but I still drive a diesel car. While I might be very aware, I know where I could improve, but if I was to have an electric car, I'd probably struggle to get in and out of work every day. While I'm aware, I can improve.} \]

[Participant 5, Safety Assurance Lead].

The following contributor viewed themselves as very up to date with environmental issues nationally:

\[ I'd \text{ be very up to date, nationally, anyway. Worldwide, to a certain extent.} \]

[Participant 6, Shift Supervisor].

The next participant believed that they had average knowledge of energy and environmental issues:
I would have an average knowledge of energy and environmental issues. I'm not doing a severe amount of research into it, but it is everywhere now, and I'm picking up bits and pieces.

[Participant 3, Soldier].

The following interviewee detailed that they were aware of environmental issues while admitting that they were not very knowledgeable in the area:

I'm aware of environmental issues; I'm not very knowledgeable and lack detail. That's because it's not something that I really need to know right now. What I mean by that is we're on this little island; I look outside, I see lovely blue skies. Do I read and research on all of this? No. Do I get annoyed when I see rubbish at the side of the road? Absolutely. I've been to the US and see all the big coal-burning stations there with big stacks pumping pollution into the air. When I think about pollution and the negative side of things. We have our little one litre cars here; the average size in the US, I think, is three-point six-litre cars. They don't care about the environment. I believe there are three hundred and sixty million people in the US, one point three billion in China. That's just two countries. We have four and a half million people. I won't say it's not my problem, but I sit back and think, if the other countries did just a little bit more, we wouldn't even need to be thinking about this.

[Participant 4, Manager].

The next contributor outlined that they had a middling knowledge of current environmental issues:

Middling, I suppose. I am aware that we have other sources of energy like wind farms and solar-PV panels and all that, but I think the incentive in Ireland to install those or go down those routes isn't there.

[Participant 7, Quality Engineer].

The final participant believed that they lacked knowledge of current environmental issues at the moment:

Currently, I wouldn't know an awful lot about anything other than what we have in our home at the moment. I wouldn't count myself as terribly up to date, absolutely not.

[Participant 8, Homemaker].
4.3.12 Theme – Cost Trumping Environmental Considerations

This study sought to gain further insight into the findings of the quantitative survey by presenting the findings of Chapter 4.2.7 Theme – Environmental Considerations, where it was found that, among the respondents to the online quantitative survey, the environmental impact of their fuel of choice was the least important consideration, cost being indicatively found as the most critical consideration.

This study found that 72% of interviewees agreed with the quantitative study findings, which indicatively found that cost was the most important consideration when choosing a fuel for the home. Among the interviewees that agreed with the quantitative survey findings, two potential reasons for this point of view became apparent. The interviewees believed that people are generally concerned with their quality of life, and increased fuel costs would erode their quality of life by increasing the cost of living. An interesting parallel theme of the responses for the interviewees was the perceived visibility of cost compared to environmental impact. The interviewees outlined that cost is a noticeable impact of fuel use that consumers are reminded of often through bills. The environmental impact of fuel is far more challenging to quantify and is far less visible.

The following interviewee agreed with the findings of the quantitative survey. The interviewee believed that the responses received ranking cost as the most important consideration was a sincere response from the survey respondents. The interviewee further believed that when it comes down to the wellbeing of one’s family, the bigger picture becomes less critical. The interviewee outlined that when faced with a possible reduction in quality of life resulting from increased costs, most would deprioritise environmental considerations. The interviewee also outlined that they believed costs should be carefully managed to avoid creating fuel poverty:

*I'm not surprised; I think it's a very honest answer to say the environment is the least important consideration when choosing a fuel. I think it's a paradox because a question put another way would result in environmental sustainability being top of the list. I think in a very real sense, when it comes down to your family, your home and your own affordability; you're always thinking about maximising living standards, opportunities for your children and everything like that. I can see why the bigger picture becomes less important when you are thinking about, the smaller picture, which is basically the family and providing for them. That's why it comes back to my own view that if hydrogen is twice as expensive as gas, the industry would have to, for the greater good, swallow those costs and drag them out over the long term rather than double people's gas bills because people just won't accept that. I think that there would be too many complications around fuel poverty. I think that it's a very personal*
thing, people want to look out for themselves and their family, which you could describe as selfish, but I think that is a very cold way to think of it. It's just everyone innate instinct to survive, and if fuel is expensive, quality of life is obviously going to reduce for the family and people close to you. When faced with a reduction in quality of life, you're obviously going to put the environment probably down a peg in your priorities in favour of affordability. It's the quandary with anything new, things are going to be a little bit more expensive at the start, and you have to manage that cost so people can actually still afford it.

[Participant 2, Electrical Engineer].

The next participant agrees with the finding of the quantitative survey outlining that they believe most of society leans towards the lowest cost option when choosing a fuel to heat their home as people generally watch what they spend:

*It just comes down to how much it takes to heat your house; it's something that already costs a lot per unit. Usually, you are going to choose a fuel that costs the least per unit. If oil and gas gave out the same heat per unit, but oil was half the price of gas, you'd be more likely to lean towards oil just because nobody in broader society has money to burn. Everyone wants to watch what they're spending; it just comes down to that.*

[Participant 3, Soldier].

The following contributor agrees with the findings of the quantitative survey. The contributor also believed that, for the average person, cost is one of their principal daily concerns and directly impacts the quality of their daily lives. The contributor believed that if a transition to hydrogen reduced people’s disposable income, they would not be happy about it.

*We all don't get up in the morning and go out to work and say, I love my job, and I don't care how much I get paid, there are very few people out there that do that, and they are typically people on the big, big money where slight changes make no difference to them. For the average person, in the Republic of Ireland, we go to work, and it's a means to an end, bringing in financial reward to look after family and home. You may hear that money doesn't make the world go round, but it does. The world is built on the dollar, the euro, the yen and the British pound; it's as simple as that. You asked why was money number one and the atmosphere last? Money is the thing that I would imagine most people discuss, argue and fight about on a daily basis; it's everything. For the average worker, we care about money. Why do they care about money? Because it is what keeps them above board. I'm glad you said it; you found most people on the survey valued the cost of fuel over the environmental impact. People are thinking with their heads, not with their hearts. They are thinking it costs me more, so I am not interested. I need to fend for now and look after my family. It's disposable cash at the end of the day; if hydrogen energy reduces disposable income, people aren't going to be happy.*
The next participant agreed with the findings of the quantitative survey, stating that cost trumps environmental concerns because cost affects people’s everyday lives in a visible way. The participant further details that they believe most people are only concerned with their own needs rather than environmental needs. The participant concludes that further information on the environmental credentials of hydrogen may help them change their view:

[I believe cost trumps environmental concerns because the cost is something that affects people every day, a lot more than environmental concerns. Most people are only concerned with their own needs rather than environmental needs. I suppose you could say it is people being people if you use natural gas as an example. You know, the breakdown that if you burn that what is emitted as carbon. I guess if you showed me the breakdown. How clean hydrogen burns might be something that could convince me that the environmental aspect is more important than cost. More information about how it burns, what's given off and in what percentages, and I believe most of its water.

[Participant 6, Shift Supervisor].

The following contributor believed that the quantitative survey found that the environmental impact of fuel was the least important consideration among the respondents because people cannot immediately see the environmental impact of their fuel of choice but can see the cost. The contributor also outlined that people may not believe that the environmental impact of their fuel may not become apparent in their lifetime. The contributor concluded that they believe scare tactics regarding the environmental impact of fuel may help change opinions and persuade people to rank the environmental impact of their fuel of choice as the most important consideration:

People can't immediately see the environmental impact of their fuels; it's not in your face. With regards to the cost, you get a bill every month, and you know exactly how much it hurts your pocket. We're only now becoming aware of the implications of using fossil fuels through the damage it's done, and even then, I don't think people think the damage it's doing is going to happen fast enough to actually impact them. It might impact their kids or grandkids, but they don't think it's going to impact them, and they don't particularly care all that much. Care a little bit, but not enough to pay above beyond for it. Probably want to tell me that the world was going to implode tomorrow, for me to view the environmental impact of a fuel as more important than cost, to be honest, or at least in my lifetime. There would want to be serious scare
tactics to make the environment the most important factor over cost—serious scare tactics.

[Participant 7, Quality Engineer].

The next interviewee disagreed with the findings of the quantitative survey detailing that they believed that the environmental impact of fuel was of equal importance as the cost to them:

*That's strange. I would have assumed the environment would be equally important as the cost, but I can understand if something is going to be very expensive, people are going to be concerned. I think they're both important, but obviously, if it's going to be extremely costly, that will be a big concern. To me, cost and environmental impact are both equal.*

[Participant 8, Homemaker].

The next interviewee disagreed with the finding of the quantitative survey, stating that the environmental impact of a fuel is the most important consideration for them. Interestingly, the interviewee outlined that this consideration was in itself cost-sensitive, believing that if their existing bills were to double as a result of a hydrogen transition that the environmental impact of fuel would no longer be their first consideration:

*I don't think the cost is the most important consideration. I think that the environmental piece is the most important; however, knowing that it's the most important and supporting it are two different things. While I might know that the environmental piece is the most important piece, if it is going to cost me twice as much, my mindset has changed then because I might not be willing to pay twice as much. It needs to be either fully or almost cost-neutral. Of course, if it was cheaper, that would be even better, but that's not likely. It would need to be cost-neutral, but I think I'd be willing to pay a small bit more.*

[Participant 5, Safety Assurance Lead].

4.3.13 Theme – Information on Hydrogen

Regarding a future information campaign on a transition to hydrogen, this study finds that 50% of the contributors believed that the public would need to be brought around gently to the idea of transitioning to hydrogen. They detailed that failing to do so could create opposition to a future transition among the public. The participants also believe that an information campaign should focus on the benefits of a transition to hydrogen while outlining the safety and cost aspects of the transition.
The following interviewee believed that most of the public would be willing to accept hydrogen in their home if there was a large-scale information campaign detailing the benefits of using hydrogen in the domestic setting. The interviewee believed just telling people the change was coming would risk a panic among the public.

*I think a lot of people hear hydrogen don’t know what it is, myself included. The only thing I know, in my opinion, is that it is likely safer, but I’m only one person. I think if before it was rolled out and there was a large campaign on how safe it is, how it can benefit your home, family life, it would be beneficial. I think a lot more people would be more open and willing to accept hydrogen into their households if there was a large information campaign rather than just being told we are changing over and risking people panicking.*

[Participant 1, Preschool Teacher].

The following participant believed that a future information campaign on a hydrogen transition would need to present a very positive message while presenting the benefits to consumers citing that they believe people are tired of environmentally friendly information. Interestingly, the participant believes that the public will need to be brought around to the idea of a transition to hydrogen gently, the participant believed not doing so risked creating opposition among the public:

*It's going to need to have the most positive slant that it can possibly have because it is the way forward, in my opinion. It’s going to have to be colourful and bright and so that it becomes second nature to us all. It is going to cost billions to try to persuade people to take this on board. I think people get a bit worn out from the whole green thing, and they need to know what wins they have out of it. Telling people this is what’s happening will make it unsuccessful; people will need to be brought along, brought around to this. If it's treated like the water charges, then we're all in big trouble. It'll have to be a softly, softly nice and easy approach with benefits in there for people, not just the environment. They could go wrong by telling people that this is what has to happen. Then people kick back straightaway.*

[Participant 5, Safety Assurance Lead].

The following contributor believes that a future information campaign on a transition to hydrogen should highlight the benefits to consumers, address the safety of hydrogen and outline how the process will work. Interestingly, the contributor also believes that the public would need to be brought around gently to the idea of a hydrogen transition:

*Obviously, one that highlights the pros. One that is focused on the safety of the process and an overview of how it works because people tend to be very scared of*
what they don't understand. You need to be able to give people a very basic overview of how the process works without confusing them. I would see an unsuccessful information campaign as one that the consumer is just told that it's happening and there's nothing you can do about it—tough tomatoes.

[Participant 6, Shift Supervisor].

The next interviewee believes that a future information campaign on a transition to hydrogen should outline the benefits, safety and cost of a hydrogen transition. The interviewee believes forcing a transition and making consumers pay for it would make the public unwilling to accept a transition to hydrogen.

An information campaign would need to highlight the safety and benefits of the changeover. If you were changing over from gas and carbon monoxide poisoning is no longer a risk would be good. The campaign should give an idea of the cost of changing over your appliances, the cost of powering your house in the future, the time frame for a changeover and how much of a choice it actually is. If it's going to be rolled out in some areas, some people could be forced into it. Letting people know it could be coming, whether you want it or not, definitely needs to be made clear. Probably just telling people it's coming, suck it up, and you're going to be paying for everything would result in an unsuccessful campaign, in my opinion. People like having a choice. I think a lot of people are more aware of the environment and that hydrogen will be a better, greener, more eco-friendly choice that would help it succeed. If it doesn't hit their pockets too much, I think people will be willing to go for hydrogen but probably not if it's forced upon them without a financial incentive to do it.

[Participant 7, Quality Engineer].

The next participant believed that an information campaign on hydrogen would need to be very visible and digestible, given the complex message. The participant further outlined that focusing on the big wins rather than the details would aid messaging.

Any information campaign would need to be very visible and digestible for the consumer. This is a complex message. You really have to look at it from the wider public acceptance angle. I think focusing on the big wins, the big deliverables rather than the how to's is key to get the message across to the public.

[Participant 2, Electrical Engineer].

The following contributor believed that an information campaign on hydrogen would need to be delivered across digital and traditional platforms to gain exposure to each age demographic; failing to do so could risk leaving some people out of the loops on a changeover.
An information campaign would need to get the message across over a couple of different fronts. With the younger generation, everything's gone digital, and they consume information through whatever social media platforms are popular at the time. For the older generation, they would probably need a leaflet and television ad campaign, just to make sure you're hitting every demographic that needs to be hit. If you target a purely digital campaign, you will miss the elderly generation that wouldn't be on the computer. They wouldn't be getting the ads and wouldn't know what is coming down the line. The risk with that is that someday the changeover could come, and they could just have an appliance in their house that doesn't work because they never switched over. Leaving a whole generation out of the loop would definitely be a failure of an advertising campaign.

[Participant 3, Soldier].

The next interviewee detailed that they would like to see an information campaign on hydrogen headed up by an independent body with lessons learned from other countries implemented. The interviewee believes open; two-way communication would be a vital component of a future information campaign to ensure concerns can be addressed. The interviewee also believes that future information would need to paint a realistic picture of a hydrogen transition:

An independent body number one that is not guided directed steered, influenced by the particular body or company that's trying to implement this, so it needs to be completely independent, and then, we need to look at what other similar companies and/or countries throughout the world have done, assuming we're not the first. I would imagine we are not going to be the first, and other countries are looking at or will have implemented it. What have they done? How did they do it? Get the campaign to paint a real picture and a true picture. Sometimes we're told what we want to be told, and sometimes we have to understand that; however, when it comes to what I would say is a substantial change and potentially substantial risk to human life, the campaign would need to be independent, overseen by independent parties and include relevant experts. Have all of that upfront, paint the picture and then produce the data and the facts and figures. Make it open, so that it's not one-way communication, that there is a two-way street so people can revert to somebody, whether that's per county, per major city or whatever, and that all gets fed back up. Two-way communication would be absolutely amazing. Let's just make sure, as a consumer, if somebody's voice needs to be heard, then it can be heard somehow. It may be as simple as; an email address or social media, phone or an old fashioned P.O. box.

[Participant 4, Manager].

The following participant believes that not having enough information available leaving people confused or concerned would result in an unsuccessful information campaign:
Televised ads, social media, door to door leaflets, I'd imagine all of that. There would have to be a lot of information handed out to make a successful information campaign. If there wasn't enough information being put out there and people were confused and concerned, the campaign would have failed. All the information would need to be out there for people to not be concerned about it.

[Participant 8, Homemaker].
Chapter 5.0 Main findings, Recommendations & Conclusions

5.1 – Introduction

This study was carried out to provide insight into public perceptions of hydrogen as an energy vector in the Republic of Ireland. The researcher identified several emerging themes and aimed to provide exploratory findings that can be used as a foundation for future work. The researcher views this study as timely, mainly as testing of hydrogen for use in the gas network in the Republic of Ireland commenced this year, (O’ Halloran, 2020). An interpretive approach employing a sequential mixed methods design combined with triangulation was utilised. Secondary data was gathered and analysed, followed by a quantitative survey that achieved 115 valid responses and qualitative interviews with eight participants. The findings of the secondary and primary data are triangulated within this chapter, and conclusions are drawn. This study has identified several themes, a summary of which is presented in Table 1 below, with an analysis of findings presented further within this chapter.
5.2 – Summary of Empirical Findings

<table>
<thead>
<tr>
<th>Theme</th>
<th>Quantitative Data</th>
<th>Qualitative Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness of hydrogen</td>
<td>75% of respondents were aware of uses for hydrogen</td>
<td>100% of participants were aware of uses for hydrogen.</td>
</tr>
<tr>
<td>Acceptance of hydrogen as a domestic fuel</td>
<td>58% of respondents would accept the use of hydrogen within the home, 35% were undecided.</td>
<td>87% of interviewees demonstrated a willingness to use hydrogen in a domestic setting.</td>
</tr>
<tr>
<td>Perceived Safety of hydrogen delivered via the Gas Network.</td>
<td>64% of respondents agreed it would be safe, 3% believed it would be unsafe.</td>
<td>75% of contributors believed that hydrogen would be safe.</td>
</tr>
<tr>
<td>Hydrogen Blending</td>
<td>52% of respondents believed blending hydrogen with natural gas would be good for the environment.</td>
<td>75% of contributors were willing to accept natural gas blended with hydrogen in their homes.</td>
</tr>
<tr>
<td>Hydrogen’s Environmental Performance</td>
<td>65% of respondents associated the use of hydrogen with positive environmental performance.</td>
<td>100% of participants expressed a preference for Green hydrogen over other forms.</td>
</tr>
<tr>
<td>Environmental Considerations</td>
<td>Respondents viewed cost and safety as the most important considerations when choosing a fuel for the home. The environmental impact of a fuel was the least important consideration.</td>
<td>72% of interviewees agreed that cost was the most important consideration and trumped environmental considerations when choosing a fuel for the home.</td>
</tr>
<tr>
<td>Cost</td>
<td>43% of respondents were willing to pay more for an environmentally friendly fuel, 33% were unwilling.</td>
<td>75% of participants were willing to tolerate increased costs in short to medium term. The average tolerable cost increase among the participants is 13%.</td>
</tr>
<tr>
<td>Information</td>
<td>82% of respondents believe that they will be provided with</td>
<td>50% of contributors believe the public will need to be gently introduced to the</td>
</tr>
<tr>
<td><strong>Trust</strong></td>
<td>82% of respondents believe that the source of information on a hydrogen transition will be trustworthy.</td>
<td>62% of participants indicated that they trust information from Government Departments &amp; Gas Networks Ireland concerning hydrogen.</td>
</tr>
<tr>
<td><strong>Appliance Replacement Burden</strong></td>
<td>43% of respondents believed the need to replace appliances would discourage them from accepting hydrogen as a fuel in the home.</td>
<td>62% of participants are opposed to replacing their appliances to facilitate a hydrogen changeover if they had to burden the cost of the new appliance.</td>
</tr>
<tr>
<td><strong>Financial Assistance</strong></td>
<td>90% of respondents believed the availability of grants/subsidies would make them more likely to accept hydrogen as a fuel in the home.</td>
<td>100% of participants believe some form of financial assistance should be made available to offset the cost of transitioning to hydrogen.</td>
</tr>
<tr>
<td><strong>Hydrogen Production</strong></td>
<td>This theme was identified from the results of the quantitative survey.</td>
<td>75% of participants are opposed to the use of Grey hydrogen, with 100% of participants preferring Green hydrogen.</td>
</tr>
<tr>
<td><strong>Consumer Choice</strong></td>
<td>This theme was identified from the results of the quantitative survey.</td>
<td>50% of participants would not have an issue if a changeover to hydrogen was not their choice, while 37% indicated that they would oppose a changeover to hydrogen if it was not their choice.</td>
</tr>
</tbody>
</table>

**Table 1 - Summary of Empirical Findings**

5.2 – Review of Main Findings

The main findings section of this study will examine the key themes derived from the quantitative and qualitative data outlined in Chapter 4. The key themes will be summarised and presented with their consistency to previous studies discussed.
5.21 – Public Awareness of Hydrogen

Public awareness of hydrogen as a fuel is low (Ricci *et al.*, 2010; Flynn *et al.*, 2013; Scott & Powells, 2019; Fylan *et al.*, 2020). Interestingly, the quantitative portion of this study is not consistent with the literature as 75% of respondents indicated an awareness of hydrogen, with the word “Fuel” being one of the most popular responses to the first word projected technique question asking, “When you hear the word hydrogen, what is the first word that comes to mind?” (Chapter 4, p.62). Responses relating to danger such as “explosion, bomb, flammable” also occurred frequently, (Chapter 4, p.62), indicating that the respondents were aware of the potentially dangerous properties of hydrogen. Surprisingly, the word “water” was also one of the most popular responses, (Chapter 4, p.62). The researcher concludes that this implies a working knowledge among some of the respondents that hydrogen can be produced through the electrolysis of water and/or knowledge that the by-product of burning hydrogen is water. Some respondents not only demonstrated a basic knowledge of hydrogen but also responded with words such as “green, wind, clean”, and “energy”. These responses suggest that a proportion of the respondents demonstrated knowledge of the lifecycle of green hydrogen, a clean energy source generated using wind farms and electrolysers.

This study is consistent with the literature that outlines that opinions of hydrogen energy are not hostile with widespread support evident, (Flynn *et al.*, 2013; Ricci *et al.*, 2007; Ricci *et al.*, 2010). The qualitative aspect of this study found that 87% of participants were willing to use hydrogen energy in a domestic setting, with one interviewee stating, “I have absolutely no issue transferring to hydrogen”, (Chapter 4, p.71).

Previous studies outlined that high environmental awareness appeared to influence attitudes to hydrogen more than technical knowledge, Schulte *et al.*, (2003). This study is consistent with the literature. Participants that demonstrated positive opinions of hydrogen also demonstrated high environmental awareness; as an example, participant 5 states, “Yes, I
would be willing to convert to hydrogen”, (Chapter 4, p.72) and “I am very environmentally aware”, (Chapter 4, p.103) while participant 4 believes that “if it is all to reduce greenhouse gasses….I would not be interested”, (Chapter 4, p.86) and “I am not very knowledgeable [of environmental issues] and lack detail”, (Chapter 4, p.104).

5.22 – Public Acceptance of Hydrogen

Studies have found that the public is generally supportive of hydrogen, (Achterberg et al., 2010; Iribarren et al., 2016); however, other studies concluded that public opinion regarding hydrogen was generally neutral (Ricci et al., 2008; Fylan et al., 2020; Lambert & Ashworth, 2018). The quantitative element of this study is consistent with the literature outlining that the public is generally supportive of hydrogen, revealing that 58% of respondents believed that they would accept the use of hydrogen within the home while 35% were undecided and 7% would not accept the use of hydrogen in the home. The qualitative element of this study is also consistent with the literature, which concludes that the general public is generally supportive. The qualitative element of this study found that there is currently a high level of acceptance of hydrogen among the public; however, the proportion of undecided responses is notable. The qualitative element of the study reveals that 87% of interviewees are willing to accept the use of hydrogen in the home. Participant 2 details that they would have “absolutely no issue transferring to hydrogen”, (Chapter 4, p.71). Interestingly, this study also finds that that, while low, there was some opposition to hydrogen, with participant 4 detailing that, “if I must spend money….and it is all to reduce greenhouse gasses, I would not be interested”, (Chapter 4, p.85). This finding is consistent with the literature outlining that some of the public would reject a conversion to hydrogen, (Fylan et al., 2020).

Surprisingly, the qualitative aspect of this study finds that when a contributor indicated that they would either accept or reject the use of hydrogen in the home, they also expressed that their opinion was strong, and they were unlikely to change their minds. For example,
participant 4 detailed that “it will take an awful lot of convincing to change my mind”, (Chapter 4, p. 74). Where a participant outlined that they were undecided, they indicated that the strength of their opinion was weak; this was evident with participant 1, who outlines that they “do not have a strong opinion…. I could very easily change my mind” (Chapter 4, p.73).

5.23 – Safety

Previous studies found that safety is the number one concern of the public surrounding the use of hydrogen (Lambert & Ashworth, 2018; Dodds & Demoullin, 2013; Chaube et al., 2020; Ricci et al., 2008; Scott & Powells, 2019; Flynn et al., 2013) however, the quantitative element of this study differs. No consensus could be achieved among the respondents to the quantitative element of this study when asked if they associated the use of hydrogen as a fuel with danger, with 35% of respondents deeming it dangerous while 35% were undecided, (Chapter 4, p.64). Intriguingly, the qualitative aspect of this study is consistent with the literature, with safety being mentioned by all participants across numerous aspects of a transition from natural gas. Participant 8 echoes the feelings of other interviewees, outlining that their acceptance of hydrogen depended on “If it can be done safely”, (Chapter 4, p.80). Fascinatingly, this study aligns with previous studies, detailing that, while safety is a concern among the public, the public trusted that hydrogen would be deemed safe before being supplied to the home, (Fylan et al., 2020; Lambert & Ashworth, 2018; Ricci et al., 2008; Scott & Powells, 2019; Flynn et al., 2013). The quantitative portion of this study found that respondents viewed hydrogen safety when delivered via the Gas Network favourably, with 64% of respondents perceiving it as safe, (Chapter 4, p.65). The qualitative aspect of this study is also consistent with the literature, finding that the public trusted hydrogen would be delivered to their homes safely. Participant 5 summarises this theme, stating, “gas providers will have the proper safety measures in place… I would be comfortable with that”, (Chapter 4, p.82).
5.22 - Hydrogen Blending

Literature regarding the public perception of blending hydrogen with natural gas is scant. Studies examined hydrogen blending from an environmental, technical and economic perspective, (Pellegrini et al. 2020; European Commission, 2020; Kouchachvili & Entchev 2018; Gas Networks Ireland 2019); however, they neglected to examine public perceptions of hydrogen blending. The quantitative aspect of this study found that 43% of respondents believe that blending hydrogen with natural gas within the gas network will make natural gas more environmentally friendly, (Chapter 4, p.66). Surprisingly, 52% of respondents were undecided, signifying that while most respondents would accept the use of pure hydrogen as a fuel, the majority of respondents were not convinced of the environmental credentials of blending hydrogen with natural gas, (Chapter 4, p.66). Interestingly, the qualitative portion of this study found that 75% of interviewees are willing to accept a blend of hydrogen and natural gas fed into their home via the gas network, (Chapter 4, p.76); however, this expressed acceptance was often conditional on cost and safety. Participant 1 outlines that “I do not think I would have an issue with hydrogen blending, assuming they can mix and blend safely”, (Chapter 4, p.74). Participant 3 echoes this conditional acceptance specifying that “I would be happy with hydrogen blended with natural gas, as long as it is safe”, (Chapter 4, p.75). Surprisingly, the environmental benefits of blended hydrogen were not enough of a tangible benefit for participant 4, who detailed “What is in it for me? What benefit am I getting, if any?”, (Chapter 4, p.76). Intriguingly, participant 5 of the qualitative portion of this study viewed hydrogen blended with natural gas as a short-term solution stating that they would “rather one or the other and not be messing with blending… it is all [pure hydrogen] or nothing” (Chapter 4, p.76).
5.23 – Hydrogen Production

Studies have found that green hydrogen is favoured by the public, (Ricci et al. 2010; Zimmer & Welke 2012; Cherryman et al., 2008). The qualitative portion of this study is consistent with the literature as 100% of interviewees expressed a preference for green hydrogen if a transition was to occur, (Chapter 4, p.77). Interestingly, participant 2 outlines that “green hydrogen used from the outset would be best, you are displacing fossil fuels, carbon emissions and any other greenhouse gasses in a complete product”, (Chapter 4, p.78). The qualitative portion of this study also found that 25% of interviewees indicated tolerance for the use of non-renewable hydrogen, with participant 2 detailing that a clear roadmap from non-renewable to green hydrogen would be required in such circumstance as “otherwise, you are just adding cost by producing hydrogen with no saving in carbon emissions”, (Chapter 4, p.77). The use of non-renewable hydrogen was generally refuted, with participant 7 stating that non-renewable hydrogen “is the same product as natural gas, if you are using fossil fuels to make it, then why just not use natural gas in the first place”, (Chapter 4, p.78).

5.24 – Cost

Studies have found that the public is concerned about costs to them as consumers as a result of using hydrogen (Scott & Powells 2019; Flynn et al., 2013). The quantitative portion of this study is consistent with the literature, finding that 47% of respondents believe that hydrogen would be more expensive than their current fuel of choice. Notably, 36% of respondents were undecided, indicating that a high proportion of respondents need additional information before arriving at a decision. Previous studies found that cost was of paramount importance to consumers when considering hydrogen, even in light of environmental considerations, (Cherryman et al., 2008; Lambert & Ashworth 2018). The quantitative and qualitative portions of this study are consistent with the literature. The quantitative aspect of this study found that cost was ranked as the most critical consideration to most respondents when
choosing a fuel for their home, environmental impact was ranked as the least important consideration, (Chapter 4, p.67). Surprisingly, the quantitative section of this study also found that, while 43% of respondents were willing to pay more for an environmentally friendly fuel, 33% of respondents disagreed, indicating that they were not willing to pay more for an environmentally friendly fuel. The level of undecided responses to this question were notable at 24% indicating that a large portion of consumers require more information to help them develop an opinion, (Chapter 4, p.68).

Intriguingly, the qualitative portion of this study partially aligns with the literature, finding that 75% of participants were willing to tolerate increased costs but only in the short to medium term with the belief that the cost of hydrogen would fall over time. All the participants of the qualitative portion of this study indicated that increased cost over the long term would result in them rejecting a changeover to hydrogen, (Chapter 4, p.94). Notably, participant 5 of the qualitative portion of this study added that, “If my bills were to double, I would probably not be as worried about the environment. I would not be excited to think that hydrogen might be more expensive; I would be disappointed”, (Chapter 4, p.97).

Studies have found that most consumers were unwilling to pay more for hydrogen than they currently spend on energy bills, (Scott & Powells 2019; Lambert & Ashworth 2018). Surprisingly, the qualitative portion of this study is not consistent with the literature, finding that all interviewees were sensitive to the cost of hydrogen as a fuel, but to differing degrees. 75% of interviewees outlined that they were willing to tolerate potentially higher costs associated with the use of hydrogen for short to medium term, with participant 2 stating that “hydrogen is bound to be more expensive than gas to begin with, hopefully; as the efficiency of extracting hydrogen from our environment improves, then the price will come down in line with that”, (Chapter 4, p.95). The expressed cost tolerance is based on the belief that the cost
of hydrogen would fall long term, “the hope would be that long term, hydrogen, and the process of making it will become a lot cheaper”, (Chapter 4, p.96).

While 25% of interviewees were not willing to tolerate higher costs, an understanding of why there would be additional costs was apparent among the participants of this study, with one participant summarising, “ideally, there would not be additional costs, if my bill was to go up, not ideal…but I would understand”, (Chapter 4, p.96). Interestingly, participant 4 indicated that while opposed to additional costs, they aligned with previous interviewees who indicated they would tolerate higher costs in the short to medium term, “short term, higher cost, medium-term, even cost, long term the cost comes down. Short term pain. Long term gain”, (Chapter 4, p.97). Research defining the maximum tolerable cost increase amongst consumers due to a transition to hydrogen is scant. However, the qualitative portion of this study found that the maximum tolerable cost increase as a result of transitioning to hydrogen varied among the interviewees from “five per cent”, (Chapter 4, p.98) to “thirty per cent”, (Chapter 4, p.98). The average tolerable increase being 13%. Intriguingly, participant 2 outlines that they believed a long-term view of additional costs should be taken “even if the cost of [hydrogen] production was higher than ten per cent… a long-term view would need to be taken by the regulator…you need to consider fuel poverty”, (Chapter 4, p.99).

The findings of the qualitative and quantitative portions of this study lead the researcher to conclude that cost is a major influencing factor to consumers when choosing a domestic fuel and could potentially result in a broad rejection of the use of hydrogen as a domestic fuel among the public if not kept within expressed tolerable limits.

5.25 – Appliance Replacement Burden

It is currently believed that in order to operate on pure hydrogen, a large proportion of domestic gas boilers and appliances would require replacement in favour of appliances
designed to operate on hydrogen. Research regarding the public perception of needing to replace appliances to facilitate a transition to hydrogen is scant. The quantitative aspect of this study found that 44% of respondents would be discouraged from accepting hydrogen as a fuel in the home if it required replacing existing natural gas appliances, (Chapter 4, p.69). Notably, 25% of respondents indicated a neutral response, (Chapter 4, p.69). The qualitative portion of this study found that 62% of participants would be opposed to replacing their appliances to facilitate a transition to hydrogen as fuel if the cost was born by them, (Chapter 4, p.88). Participant 4 outlines that “if I am paying for it, no thank you, I am not interested. The boiler I have works, it is three years old, and I am not interested in replacing it”, (Chapter 4, p.91).

Expectantly, 90% of respondents to the quantitative aspect of this study indicated that the availability of grants/subsidies to offset the cost of replacing appliances would make them more likely to accept hydrogen as a fuel in the home, (Chapter 4, p.69). The qualitative portion of this study aligns with the findings of the quantitative portion, with 87% of interviewees mentioning grants or financial subsidies when discussing appliance replacement to facilitate a transition to hydrogen, (Chapter 4, p.88). Participant 1 outlines that they “would not be totally against changing appliances, but if there were incentives, I would do it in a heartbeat”, (Chapter 4, p.89), a view echoed by participant 3, who believes that a grant “wouldn’t be a game-changer and prevent me from changing over, however, a grant or incentive would make me feel more positively about it”, (Chapter 4, p.90).

The qualitative portion of this study found that 87% of interviewees favour the phase-in of hydrogen ready appliances and the phase-out of traditional single fuel appliances in anticipation of a changeover to pure hydrogen in the future. Participant 2 viewed this option as “an excellent solution, it allows you to stick with what you have now and future proof”, (Chapter 4, p.92), a view detailed by participant 3, who viewed the phase-out of traditional...
single fuel appliances as “a good alternative, you can get a new appliance that will work on hydrogen in the future”, (Chapter 4, p.92). It is worth noting that, even when discussing the phase-in of hydrogen ready appliances, cost and safety are still the overarching themes, with participant 4 detailing that, “if we go for something that now needs to be capable of running on two fuel sources, I believe there would be additional costs” (Chapter 4, p.94). While participant 8 believes that “it would be ok, as long as it is safe”, (Chapter 4, p.93).

5.26 – Environmental Citizenship

Previous studies have found little evidence of environmental citizenship or concern for the broader public good among consumers, with cost being the primary consideration (Schulte et al., 2003; Ricci et al., 2008; Flynn et al., 2008). The quantitative portion of this study is consistent with the literature, finding that survey respondents ranked the environmental impact of their fuel of choice as the least important consideration, with cost being the most important consideration, (Chapter 4, p.67).

Surprisingly, the qualitative portion of this study is not consistent with the literature or quantitative aspect of this study, finding that 72% of participants demonstrated environmental citizenship, detailing that they believed that the environmental benefits of using hydrogen warranted its use, even in the absence of any other benefit, (Chapter 4, p.105). Participant 2 outlines that “the fact that using hydrogen is displacing fossil fuels would be enough of a win for me; I do not need anything else for me to be very in favour of it” (Chapter 4, p.84). Interestingly, participant 8 details that “if hydrogen is better for the environment, that is good enough for me”, (Chapter 4, p.85). Curiously, while environmental citizenship was evident among the majority of interviewees, the remaining participants held views in line with the literature, with participant 1 stating that “if the only benefit was environmental, I would not see the point in changing… I would stick with natural gas in that case”, (Chapter 4, p.85) and
participant 4 stating “if there is nothing else in it for me, I would not be interested…why bother”, (Chapter 4, p.86).

Studies have found that consumers are more likely to change their behaviour in an environmentally friendly way when the cost burden is small, (Von Borgstede et al., 2013). The qualitative aspect of this study is consistent with the literature, finding that where interviewees detailed that the environmental benefits of hydrogen were not enough of a benefit to warrant a transition cost was mentioned as an incentive. Participant 1 outlines that they would like “some incentive to change…I would not be happy if I had to pay more”, (Chapter 4, p.85). Participant 4 echoed this view who would like hydrogen to “cost less than natural gas” (Chapter 4, p.86).

5.27 – Trust

Studies have found that distrust by the public was a factor in the acceptance of hydrogen as a fuel, (Flynn et al. 2008; Zimmer & Welke 2012; Williams et al. 2018). This study is consistent with the literature. The quantitative aspect of this study found that 82% of respondents trusted that they would be provided accurate information and their questions would be answered before a transition to hydrogen, (Chapter 4, p.70). In addition, the quantitative portion of this study found that 82% of respondents indicated that they believed that the source of information regarding the use of hydrogen as a domestic fuel would be trustworthy, (Chapter 4, p.70). The qualitative portion of this study found that 62% of interviewees viewed government departments and the gas network operator, Gas Networks Ireland, as trustworthy sources of information on a transition to hydrogen, (Chapter 4, p.99). Participant 1 details that “a government body or Gas Networks would be the only people I would really trust”, (Chapter 4, p.99). Participants added that they would also trust independent commentators, academia, and professional bodies, (Chapter 4, p.100).
The qualitative portion of this study also found that the interviewees distrusted online sources, individual opinions and some media outlets. It was suggested that if a source of information was deemed untrustworthy, it would not impact their perceptions and would be disregarded, as outlined by participant 6, who believed that “if I know a source of information was not trustworthy, it will not impact my perception of hydrogen at all”, (Chapter 4, p.101). Notably, participant 4 outlined that they would not trust any company or organisation that could potentially profit from a transition to hydrogen as they believed that they have a vested interest in a transition being successful; the interviewee further detailed that they “would be a little bit cautious if information was coming from a company with an interest in a hydrogen rollout. I would not trust an information campaign if they were involved and would look for data elsewhere”, (Chapter 4, p.103). Surprisingly, participant 3 outlined that while they would trust whatever “government agency takes over a transition to hydrogen”, they caveated that they “would not trust most politicians”, (Chapter 4, p.100). Notably, participant 7 outlined that “while it would be useful to hear from government departments… I would not fully trust them as they may be biased”, (Chapter 4, p.101).

Intriguingly, participant 7 also detailed that they believed “false information could scare people off hydrogen”, (Chapter 4, p.100). While participant 1 highlighted the importance of trustworthy sources of information on hydrogen by stating that they “would not be happy to bring hydrogen into my home if I did not trust the source of information on it”, (Chapter 4, p.99).

This study has found that consumers currently believe that information on a transition to hydrogen will be accurate and from a trustworthy source. Predictably, another finding of this study is that trust is critical to a transition to hydrogen, finding that if the public does not trust a source of information on hydrogen, they may reject the transition altogether. Trust is also an essential aspect of the transition as it is a significant factor in the safety aspect of a
transition. As previously mentioned in section 5.23 – Safety, most consumers trust that hydrogen will be safe before being supplied to homes. This expressed trust must be nurtured as progress is made towards a transition.

5.28 – Information on Hydrogen

Previous studies outline that educating the public on hydrogen will be a crucial challenge (Cherryman et al., 2008; Williams et al., 2018; Scott & Powells, 2019). Surprisingly, the qualitative portion of this study is only partially consistent with the literature, with 50% of interviewees believing that the public needs to be gently introduced to the idea of transitioning to hydrogen as a domestic fuel, further detailing that failing to do so could potentially create opposition to a transition, (Chapter 4, p.109).

Studies have found that marketing has the potential to improve attitudes towards hydrogen, (Schulte et al., 2003; Cherryman et al., 2008). This study is consistent with the literature; interestingly, there was consensus among the interviewees regarding how the message should be communicated to the public. Participant 5 details that “just telling people this is happening will make it unsuccessful, people will need to be brought around to this. It will need to be a nice and easy approach with benefits there for people, not just the environment”, (Chapter 4, p.110). A point echoed by participant 6, who detailed that they would deem an information campaign unsuccessful if it “just told the consumer that this is happening and there is nothing you can do about it”, (Chapter 4, p.110). Participant 4 also believes that an information campaign should be “open so that it is not one-way communication to consumers, there should be a two-way street”, (Chapter 4, p.112). Interestingly, participant 6 outlines that “people tend to be scared of what they don’t understand, so you would need to give them an overview of the process without confusing them”, (Chapter 4, p.110). This point was also touched on by participant 2, who believed that an information campaign would need to be “digestible for the consumer, as this is a complex message. Looking at it from the wider
public acceptance angle, focusing on the big wins and deliverables rather than the how to’s is key to getting the message across to the public”, (Chapter 4, p.111).

5.3 – Recommendations for the Future Practice

The recommendations within this study are aimed at policymakers, gas network operators, gas suppliers and significant stakeholders in the Republic of Ireland. Based on the findings of this study, the following recommendations for practice are proposed:

5.3.1 Increase Public Awareness

This study has found that, in general, opinions of hydrogen are not hostile, with widespread support evident. Surprisingly, this study found that the level of awareness of hydrogen’s potential use as a fuel was higher than expected. It is worth pointing out that throughout this study, the level of undecided responses was notable, possibly indicating a lack of adequate knowledge to form an opinion on a transition to hydrogen among some of the respondents. As undecided respondents reported having weak opinions, efforts should be made to inform the public of the benefits of a transition to hydrogen as soon as possible. Failing to engage with the public at an early stage could result in a missed opportunity to easily convert respondents with undecided opinions to supportive opinions. This study has found that those who were undecided expressed weak opinions that could easily change once provided with correct and transparent information.

Interestingly, those who had made up their minds, be it in favour or against a transition to hydrogen, expressed strong opinions that would be difficult to change. This study concludes that if the undecided portion of consumers is provided with clear information, they can make an informed choice about a conversion to hydrogen. The public should be engaged early to ensure that consumers have clear and accurate information regarding a transition to hydrogen.
Educating the public will be a crucial challenge as a hydrogen transition can be quite complex. Long term engagement beginning with the communication of the basic principles of a transition, advancing to more and more complex aspects over time would be a wise investment. Genuine engagement with the public will help to ameliorate concerns and foster buy-in.

5.32 – Phase in Hydrogen Ready Appliances

This study has found that the respondents are broadly in favour of phasing in hydrogen ready appliances and the phase-out of traditional natural gas-fired appliances; this was viewed as an attractive way of future-proofing appliances as they reach end of life and require replacement. Action number 60 of the 2019 climate action plan seeks to “effectively ban the installation of gas boilers from 2025 in new dwellings through the introduction of new regulatory standards for home heating systems”, (Government of Ireland, 2019, p.82). This study recommends that, in addition to banning the installation of natural gas boilers for new dwellings, the climate action plan should include the phasing out of natural gas only appliances for sale in the Republic of Ireland in favour of hydrogen ready appliances. Such a move would ensure that existing natural gas appliances installed in the existing housing stock would gradually be replaced with appliances capable of operating on hydrogen as a fuel.

The phase-in of hydrogen ready appliances would enable the future decarbonisation of the existing housing stock in the least disruptive manner compared to the deep retrofits to housing and electrical grid reinforcements required to install heat pumps. This study found that the burden of replacing functioning natural gas appliances in favour of hydrogen ready appliances to facilitate a transition was not viewed favourably by the participants. Given the documented sensitivity consumers have to additional costs, the gradual phase-out of old inefficient appliances that have reached end of life in favour of hydrogen ready appliances is viewed as the most efficient and economical pathway to enabling a conversion to hydrogen in
the future with little perceived additional costs to the consumer. Such a move was broadly welcomed by the participants of this study and viewed as future-proofing new appliances as they are replaced.

5.33 – Financial Impact on Consumers

One of the overarching themes of this study is cost, with the word “cost” mentioned over 234 times within this document. This study has found that all participants are sensitive to cost to differing degrees, with a 13% cost increase found to be the average tolerable among the participants over the short to medium term. Interestingly, even when aware of the environmental benefits of a transition to hydrogen, many of the participants accepted or rejected a transition based on the costs they would be required to bear, a finding that is consistent with the literature. While the environmental benefits of hydrogen were beneficial, they were not viewed as enough of a win to justify increased costs long term. As such, this study concludes that the success of any transition to hydrogen as an energy vector in the future hinges on to what degree costs will be passed on to consumers, what the consumers appetite for the increased cost is at the time and how reasons for the increased cost is communicated to the public. While a transition to hydrogen would be better for the environment, this benefit is not clear to the consumer. In the absence of a clear benefit, consumers are reluctant to burden themselves with additional costs.

As the cost an individual household may have to bear to enable a transition to hydrogen is undefinable with any significant level of accuracy currently, this study recommends that the wider public is introduced to the benefits of hydrogen as an energy vector. Currently, consumers are aware of the benefits of hydrogen but cannot translate this benefit into how it will impact their daily lives. In comparison, additional costs are imagined very clearly with an associated perceived detrimental impact on consumers quality of life. A campaign to define the benefit of a conversion to hydrogen will aid consumers in the future; such work

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will help consumers weigh up the cost vs benefit of a transition to hydrogen. In addition to defining a benefit to consumers, any future programme to roll out hydrogen as an energy vector should seek to not only define the costs to consumers but should also examine avenues for minimising costs and diverting costs away from consumers as much as reasonably practicable. This approach will aid the establishment of a green industry with increased acceptance among consumers.

5.34 – Nurture Public Trust

This study has found that trust is a vital aspect of a transition to hydrogen, with distrust having the potential to lead to a broad rejection of a transition among the public. This study has found that trust concerning a transition to hydrogen has two distinct strands:

1. Trust of Safety
2. Trust of Information

Firstly, safety was one of the most critical considerations alongside cost among all participants of this study when considering a transition to hydrogen. The safety of hydrogen delivered to domestic homes was questioned by all participants, with all participants requesting reassurance that a transition will not increase the risk they are exposed to within their homes. The safety of hydrogen was viewed as a prerequisite to a transition that the participants trusted would be considered in detail by a competent authority and demonstrated to be safe long before hydrogen is introduced to the gas network and homes.

The second strand of trust was trust in the information provided regarding a transition to hydrogen. This study found that 82% of respondents to the quantitative survey trusted that they would receive accurate and trustworthy information concerning a hydrogen transition. Additionally, there is a high level of trust in information originating from government.
departments and the transmission system operator, Gas Networks Ireland, on a transition to hydrogen as a domestic fuel.

Given the pivotal role trust has regarding safety and information regarding a transition to hydrogen, the researcher concludes that existing trust must be protected, nurtured, and built further to enable the success of a transition. This is especially important given the prevalence of “fake news” and misinformation in recent times. A trustworthy organisation responsible for a transition to hydrogen such as Gas Networks Ireland or a government department should engage with the public through all available channels such as social media, advertising, leafleting and public information sessions. Doing so will broaden the organisations' reach and allow the public to receive trustworthy information first-hand from an organisation they trust. Building a presence with the public online will also serve as an outlet to respond to misinformation if it emerges through direct, clear clarifications and corrections quickly, thereby limiting the spread of misinformation.

Additionally, consistent transparency should be maintained at every stage of a transition from building a strategy to implementing physical changes on the gas network as it is essential to building and maintaining trust amongst the public throughout what could be for some a quite worrying transition if they are not adequately informed. Finally, the organisation responsible for the transition should be reachable by the public. This study has found that an information campaign on a future transition to hydrogen should incorporate two-way communication between the public and the entity responsible for the transition. Incorporating avenues for the public to ask questions and seek information will aid transparency and build trust. Participants of this study felt that failing to incorporate two-way communication with the public may cause some to feel “dictated to”, thereby fostering opposition to the transition.
5.35 – Repeat the study

As this study encompasses a relatively small sample size with a potentially narrow demographic, it is recommended that the study is repeated with a greater sample size over as wide of a demographic as possible in order to ascertain a truly accurate representation of public perceptions of hydrogen as a domestic fuel in the Republic of Ireland.

5.4 – Recommendations for Future Research

As outlined previously within this study, much research is underway regarding the technical aspects of a transition to hydrogen as a domestic fuel; however, research into the public perceptions of a transition to hydrogen is lacking, especially in the Republic of Ireland. Given the relatively small sample of this study, the researcher recommends that a further study is carried out with a larger sample into public perceptions of hydrogen as an energy vector in the Republic of Ireland that can be statistically validated.

The researcher believes that the phase-in of hydrogen ready appliances is vital to the success of a transition to hydrogen in the future and how to best do so warrants further investigation. A cost-benefit analysis study could provide valuable insight into the costs of hydrogen ready appliances at scale that could then be used to inform consumers and industry further.

Another topic that would merit further research is the perception of small and medium enterprises (SME’s) of a transition to hydrogen. These businesses operate within a sector deemed difficult to decarbonise and often use natural gas for heating, cooking etc. Therefore, they would also be part of a transition to hydrogen, should it occur. A qualitative study into the perceptions of SMEs of a transition to hydrogen is not widely researched and would provide valuable data.
This study has found that all participants favour green hydrogen when compared to other means of production. As such, the availability of adequate levels of green hydrogen production infrastructure is key to a successful transition. The researcher recommends that research is carried out into how to encourage the construction of green hydrogen production facilities with sufficient capacity to maintain supplies year-round as part of a transition to hydrogen.

5.5 – Conclusions

This research study examined public perceptions of hydrogen as an energy vector and aid to decarbonisation in the Republic of Ireland. This study adopted an interpretive approach employing a sequential mixed methods design combined with triangulation to address the aims and objectives of the study set out in chapter 1. Several prominent themes were identified by this study regarding cost, safety, awareness, acceptance, trust and sources of information.

A detailed review of pertinent literature was carried out with a specific focus on public perceptions of hydrogen as an energy vector. The literature revealed that public acceptance of hydrogen as an energy vector was vital to its future success; however, this aspect of a transition lacked research, especially regarding the Republic of Ireland. Surprisingly, public awareness of hydrogen was found to be much greater than expected, leading the researcher to adapt the research design to take advantage of these findings. As expected, opinions of hydrogen as an energy source are not hostile, with broad support evident.

Curiously, the qualitative aspect of this study did not reveal a majority regarding acceptance or rejection of hydrogen as a fuel within the home; however, the qualitative aspect of this study revealed a high acceptance rate of 87%. This disparity may be due to the semi-structured nature of the interviews where interviewees were provided with some brief
background information prior to being asked a question or may be due to the small sample size. Fascinatingly, this study finds that public acceptance of hydrogen is dependent on the production method, with all participants of this study expressing a preference for green hydrogen with limited tolerance expressed for hydrogen generated by other means.

Understandably, the two overarching themes of this study are cost and safety. Current research outlines that while safety is a concern among the public when considering a transition to hydrogen, the public trusted that hydrogen would be deemed safe before being supplied to the public. This study aligns with previous research finding that the public views safety as a prerequisite to a transition to hydrogen and believes that no transition will occur unless hydrogen safety is proven.

Studies have found that cost is paramount to consumers when considering a transition to hydrogen from fossil fuels, even trumping environmental considerations. This study aligns with the findings of previous studies finding cost is the primary concern often over the environmental impact of a fuel. This study examined this theme further, finding that most consumers are willing to tolerate increased costs in the short to medium term but would expect the costs to be comparable to their current expenditure in the long term. Additionally, all participants of this study indicated that increased costs over the long term would lead to a comprehensive rejection of a transition to hydrogen from fossil fuels. Given that cost is a significant consideration of consumers, this study recommends that traditional gas appliances are phased out in favour of hydrogen ready appliances, which was widely welcomed by the participants of this study who viewed such a move as futureproofing.

Fascinatingly, trust was found to be a prevalent theme of this study. Trust is vital to a transition to hydrogen as it is a critical aspect of two parts of a transition: safety and information. This study finds that if the public does not trust a source of information, they
may reject a transition. Additionally, it was found that the public trusts that hydrogen will be supplied safely by a competent authority; without this expressed trust, hydrogen may be deemed unsafe by the public leading to a broad rejection of a transition. Given the critical role of public trust when considering a transition to hydrogen, this study recommends that existing trust is protected, nurtured, and built to ensure a successful transition.

It is noteworthy that the level of undecided responses within this study was high; however, this was expected given the nature of the research question. This study concludes that the undecided responses indicate that a large proportion of the population needs more information before arriving at a firm opinion regarding hydrogen. Intriguingly, this study found that when a participant expressed an opinion regarding the acceptance or rejection of hydrogen as a fuel, they detailed that their opinion was firm and unlikely to change easily. This study recommends that the public is engaged at the earliest opportunity regarding a transition to hydrogen. Genuine engagement with the public in an effort to educate them on what can be a complex message will help those who are undecided arrive at a decision, ameliorate concerns, reduce the risk of opposition, and foster buy-in.

Although this study is not statistically validated or structured with a relatively small sample size, it has provided insight into public perceptions of hydrogen in the Republic of Ireland and provides exploratory findings that can be used as a foundation for future work in the area.

WORD COUNT: 48,196.
References


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European Parliament. (2018). Sector Coupling: How can it be enhanced in the EU to foster grid stability and decarbonise?


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Appendix 1 – Interview Written Consent Form
CONSENT FORM

Master of Business Administration - Strategy
Public perceptions of Hydrogen as an energy vector in the Republic of Ireland
Munster Technological University

Student: Colm Delaney
Supervisor: Dr Angela Wright

I ________________________________ consent to be interviewed for the purpose of the research named above. The details of the research explained to me and I am happy that my quotes can be used for the purpose of the research and any conference publications if successful. I understand that I can ask for clarification about the research at any stage. I understand that I can withdraw (opt out) from the process at any stage.

I understand that my data will be stored in line with MTU GDPR regulations and policy.

Signed:

____________________________

Date

____________________________
Appendix 2 – Qualitative Interview Guide
Introduction
Thank you for taking the time out for this interview. As you are aware, the purpose of this interview is to gather your opinions on the research topic "Public perceptions of Hydrogen as an energy vector and aid to decarbonisation in the Republic of Ireland".

The data collected as part of this interview will be used for research purposes only in completing my studies in MTU and may be used in a conference publication if successful. In order to keep a record, this interview will be recorded. I will go through the consent form to ensure you are happy to proceed with the interview.

Q1. Hydrogen
As you know, Hydrogen is a naturally occurring element and is seen as a potentially environmentally friendly alternative to natural gas and many other fuels. Hydrogen is not extracted from the earth like fossil fuels but can be generated by environmentally friendly means.

When Hydrogen is burned in our gas appliances, it produces only water with no damaging emissions. Given its potential, supplying Hydrogen to homes and businesses is currently being examined as a means of decarbonising society.

It is believed that people who currently use natural gas for cooking and heating will use Hydrogen in the same way; however, a switchover to Hydrogen may require the modification/replacement of existing gas appliances.

Question: How do you view using Hydrogen as domestic fuel to cook and heat your home with? Do you feel you would be willing to take part in a changeover from natural gas to Hydrogen?

Follow up question: How strongly do you feel? In your opinion, would it take much convincing to change your mind and become unwilling/willing to take part in a changeover?

Q2. Hydrogen Blending
In some countries, the blending of Hydrogen into the gas network is currently being trialled. It is believed that this will take place prior to any switch to pure Hydrogen. This would allow a mix of up to 20% Hydrogen and 80% Natural Gas in the network with no need to replace or adapt existing equipment.

Question: If your local gas network was switching to a blend of Hydrogen and Natural gas, which would then be fed into your home, what would your views be?

Researcher Prompt: Undecided

Follow up question: In your view, what would help you arrive at a firm decision?

Researcher Prompt: Positive Response

Follow up question: Can you detail what you believe has informed your view that blending Hydrogen within the gas network would be a positive move?
Colm Delaney – Hydrogen Perceptions in ROI

**Researcher Prompt: Negative Response**

**Follow up question:** You have outlined that you would view Hydrogen's blending within the gas network in a negative light. In your view, what has helped inform your views/concerns?

For the researcher: High level of undecided responses to Hydrogen blending on the survey, try to arrive at reasons for being undecided.

**Q3. Hydrogen Production**

Hydrogen, in its pure form, is an invisible, odourless gas that’s lighter than air. However, Hydrogen is not naturally found in this state; unlike natural gas, which is extracted from underground, Hydrogen needs to be produced. There are several ways to do this; some methods require fossil fuels, others do not.

Brown Hydrogen = Produced from fossil fuels such as natural gas, not carbon neutral.

Green Hydrogen = Produced from renewable electricity such as wind farms, carbon neutral.

**Researcher Question:** What would your views be if brown Hydrogen was initially used within the gas network with green Hydrogen phased in overtime?

**Follow up question:** In your opinion, do you believe there should be a time limit on a phase-in from brown Hydrogen to green Hydrogen?

**Follow up question:** How would you feel if green Hydrogen was used from the outset?

For the researcher: Literature show that the only benefit of Hydrogen is its green credentials; consumers will not accept brown Hydrogen.

**Q4. Safety**

**Researcher question:** What is your view of the safety of Hydrogen delivered via the gas network for use in homes and businesses?

**Follow up question:** In your opinion, how firmly do you feel? Do you believe it would take much convincing for you to change your mind?

For the researcher: A large proportion of survey respondents associate Hydrogen with danger, but there is a significant proportion undecided as to whether it will be safe if delivered by the gas network.

**Q5. Consumer Benefit/ Environmental citizenship**

**Question:** A new hydrogen supply to your home may be carbon neutral and better for the environment. If the new hydrogen supply did not provide any other benefit and worked much like your current gas supply, how would you feel?
Follow up question: In your opinion, if you were given the opportunity to air your questions with someone knowledgeable in the area before the change, how would you feel?

Follow up question: Due to the nature of the gas network, it is believed that entire areas would be changed over to Hydrogen at once. It may not be possible to switch individual houses over to Hydrogen and keep others on natural gas. This would create difficulty when it came to consumer choice. Could you please discuss how you would feel if your entire area was switching to Hydrogen by a certain date and you were not given a choice in the matter?

For the researcher: Literature & survey showing that there appears to be little support for Hydrogen if there is no tangible consumer benefit, e.g. lower bills greater convenience. Reasons why?

Q6. Appliance Replacement

Question: In order to operate on pure Hydrogen, current natural gas appliances may need to be replaced with Hydrogen ready appliances. If this was the case, how would this affect your view on using Hydrogen as a domestic fuel?

Follow up question: In your opinion, what would help you to feel more positively about it?

Follow up question: In your view, if you were given a few years notice of a changeover and the need for a hydrogen ready appliance to be installed, would it change your view? If so, why? If not, why not.

Follow up question: If natural gas boilers were gradually phased out and replaced with hydrogen ready appliances that could run on both natural gas and hydrogen in anticipation of a changeover. Could you discuss your thoughts?

Follow up question: How would you feel if you were given a few years notice of a hydrogen changeover and you had already swapped out your appliances for Hydrogen ready ones?

For the researcher: Literature & survey showing that replacement burden would dissuade a large portion of the population.

Q7. Cost

Question: As Hydrogen needs to be produced rather than extracted from underground, it believed it might be more expensive than natural gas for a time. As a consumer, what would your views be in relation to additional costs?

Follow up question: As a consumer, how would you feel if your monthly gas bill increased because of a hydrogen changeover?

Positive Response Follow up: What percentage increase in the cost of your bills do you believe would be tolerable?

Follow up question: If the additional cost was subsidised in some form, what impact would it have on your viewpoint?

Follow up question: If it was believed that the cost of Hydrogen would become less expensive than natural gas over time, how would you feel as a consumer?
Q8. Information

Using Hydrogen to replace natural gas is a relatively new concept. It is believed a large-scale information campaign would be required to inform consumers.

**Question:** In your opinion, as a consumer, what would make a successful information campaign about a changeover to Hydrogen?

**Follow up question:** In your opinion, what would an unsuccessful information campaign about Hydrogen consist of?

**Follow up question:** How comfortable do you believe you would be in asking questions regarding a hydrogen changeover?

**Follow up question:** In your view, would witnessing Hydrogen being used in a domestic home would impact your decision making? If so, please give details.

Q9. Trust

**Question:** What sources of information on a potential Hydrogen roll out, in your view, would you find most trustworthy?

**Follow up question:** In your view, if you believe a source of information on Hydrogen is trustworthy, how would this impact your decision making? Please give details.

**Follow up question:** In your view, if you believe a source of information on Hydrogen is not trustworthy, how would this impact your decision making? Please give details.

**Follow up question:** In your view, what would be an untrustworthy source of information on a Hydrogen changeover?

*For the researcher: Literature suggesting that the public may not trust the information provided.*

Q10. Environmental & Sustainability

**Question:** How would you rate your awareness of broader energy and environmental issues currently?

In an effort to inform this study, a survey was circulated, which received 127 responses. One of the interesting findings from the survey was that the respondents ranked the environmental impact of their fuel of choice as the least important consideration when choosing a fuel for their home. The cost of a particular fuel was found to be the most important consideration.

**Follow up question:** In your opinion as a consumer, why do you believe cost is the most important consideration when choosing a fuel for your home?

**Follow up question:** In your opinion as a consumer, what do you feel would encourage you to view the environmental impact of a fuel as the most important consideration?

*For the researcher: Literature suggesting that people aware of broader energy and environmental issues will also have an increasing interest in Hydrogen. The survey found the cost was the most important consideration among survey respondents, seek to understand why*
Conclusion

*Question: In conclusion, do you have any further thoughts, observations or concerns that would help further inform this study?*
Appendix 3 – Ethical Written Consent Form
Research Ethical Consent Form

Master of Business Administration – Strategy.

Title of Research: Public Perceptions of Hydrogen as an aid to decarbonisation in the Republic of Ireland.

Munster Technological University.

Date: 02/03/2021.

Name of student: Colm Delaney.

Name of Supervisor: Dr Angela Wright.

I [Delancy], on behalf of Gas Networks Ireland (GNI), consent to Colm Delaney carrying out research on the above-mentioned topic. I consent to Gas Networks Ireland (GNI) being named within research documentation on the above-named subject.

I understand that the above-mentioned research will be carried out in line with the requirements of GDPR and no GNI Staff will be named without their written permission.

I understand that I can ask for clarification about the research at any stage and can withdraw permission. The research is being carried out by Colm Delaney is in conjunction with Munster Technological University and all participants will be made aware of this.

I understand that Colm Delaney will present a draft of the research for my review and I can request changes/redactions/omissions prior to publication.

I understand that all data will be stored in line with MTU GDPR regulations and policy.

Signed:

Date: 16-03-2021
Appendix 4 – Reflective Journal
Appendix 5 – Online Survey Questions Sample

1. By undertaking this survey, I agree to participate in the research process. I understand that this survey is anonymous, and no personally identifiable information is gathered. I understand that I can withdraw from the study at any time. I grant permission for the data generated from this survey to be used in the researcher’s publication(s) on this topic. *

   ○ I agree
   ○ I disagree

2. I identify as:
   ○ Male
   ○ Female
   ○ Prefer not to say
   ○ Other

3. Do you live in the Republic of Ireland? *
   ○ Yes
   ○ No
4. Which area best describes where you currently live? *
   - Munster
   - Leinster
   - Connaught
   - Ulster

5. Please select your age *
   - Under 18
   - 18 - 29
   - 30 - 45
   - 46 - 65
   - Over 65

6. Please rank the following in order of importance when it comes to heating your home. (1 being most important, 4 being least important)

   - Convenience
   - Low Cost
   - Safe to use
   - Environmental impact

7. What is the primary heat source in your home?
   - Natural Gas
   - Oil
   - Electricity
   - Open Fire/ Stove
   - Heat Pump
   - Other
8. When you hear the word "Hydrogen", what is the first word that comes to mind?

Enter your answer

9. Are you aware of some uses for Hydrogen

Enter your answer

10. Please rank how you feel about the following statements:

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly agree</th>
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</thead>
<tbody>
<tr>
<td>&quot;I associate the use of Hydrogen as a fuel with positive environmental performance&quot;.</td>
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<tr>
<td>&quot;I associate the use of Hydrogen as a fuel with danger&quot;</td>
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<td>&quot;I believe the use of Hydrogen as a fuel would be more expensive than my current fuel of choice&quot;</td>
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<td>&quot;I am willing to pay more for environmentally friendly fuel&quot;</td>
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<td>&quot;I believe that Hydrogen, supplied via the gas network to my home, will be safe&quot;.</td>
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<tr>
<td>&quot;Blending Hydrogen with Natural Gas within the gas network will make Natural Gas more environmentally friendly&quot;</td>
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<td>Statement</td>
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<tr>
<td>&quot;I would accept the use of pure Hydrogen as a fuel in my home&quot;</td>
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<td>&quot;I believe that I will be provided with accurate information and my</td>
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<td>questions will be answered in advance of Hydrogen becoming available as</td>
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<td>a domestic fuel&quot;</td>
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<td>&quot;I believe that the information provided regarding the use of Hydrogen</td>
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<td>as a fuel will be accurate and trustworthy&quot;</td>
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<td>&quot;The need to replace my gas appliances would discourage me from</td>
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<td>accepting Hydrogen as a fuel in my home&quot;</td>
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<td>&quot;The availability of grants/subsidies to offset conversion costs would</td>
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<td>make it more likely for me to accept Hydrogen as a fuel in my home&quot;</td>
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</tbody>
</table>
11. If your local gas network was used to deliver Hydrogen to your home as fuel, how would you feel?

Enter your answer

12. If incentives were available to aid the conversion to Hydrogen as a domestic fuel, which would be most appealing?

- Free installation of Hydrogen ready equipment.
- Tax incentives to purchase Hydrogen ready equipment.
- Interest free financing to spread the cost
- Lower monthly bills for a specified period of time.
- Other

13. Do you have any further observations or concerns regards Hydrogen

Enter your answer

14. Would you be willing to participate in a focus group to discuss your thoughts on Hydrogen as a domestic fuel? *

- Yes
- No

15. Thank you, please provide your email address and you will be contacted with more information.

Note: All answers/information gathered as part of the focus group will be held anonymously in line with the requirements of GDPR. *

Enter your answer
Appendix 6 – Snapshot of Survey Responses