KPMG

# Ervia

## Decarbonising Domestic Heating in Ireland

June 2018

# Important notice

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We have not verified the reliability or accuracy of any information obtained in the course of our work, other than in the limited circumstances set out in our Engagement Letter with Ervia.

# Contents

# 1 Executive summary

**Scope of this Report**

Ervia, the parent company of Gas Networks Ireland, commissioned KPMG to develop and evaluate a number of scenarios for the decarbonisation of the one million Irish residential homes currently connected, or within close proximity, to the existing gas network.

## 1.1 Context

Ireland has an ambitious vision to transform into a low carbon society and economy by 2050. While significant progress has been made to date in the decarbonisation of industrial energy and electricity generation, there is a recognition that more can, and must be done to address other areas such as heating and transport, which also generate significant volumes of greenhouse gases. This report focuses on one of these areas, namely the decarbonisation of the residential heating sector.

The methodology employed in this report is similar to that employed in a 2015 study by KPMG commissioned by the Energy Networks Association ("ENA") on future alternative 2050 scenarios for energy decarbonisation in the UK[1].

We have developed a series of high level decarbonisation scenarios and have made an assessment of the feasibility and cost of each one. The costs of transitioning to these scenarios are measured against a "Do Nothing" baseline, where the energy system continues in largely the same form as today. Our approach to developing an evidence base has been to use the assumptions developed for the UK study, unless an Ireland specific source exists.

While there are two million residential homes in Ireland[2], this report is specifically focussed on the circa 700,000 currently connected to the gas network and the 300,000 homes within close proximity to it. The scope of this analysis excludes the circa one million homes which cannot be connected to the network without significant network expansion, and on which a separate decarbonisation strategy will have to be considered.

### 1.1.1 Scenarios for analysis

We have selected three potential scenarios to show how domestic heat demand from the one million properties either currently connected to or in close proximity to the gas network can be significantly decarbonised by 2050. The scenarios are described in Table 1.1 below.

**Table 1.1: Description of scenarios**

| Scenario | Description |
|---|---|
| **Gas Decarbonisation (Biomethane)** | Current gas network extended to 300,000 homes (nearly all of which currently use oil heating) within close proximity of the network so that the total number of connections reaches one million.<br>Renewable gas replaces natural gas from 2018, with material quantities available from 2025 onwards. |
| **Gas Decarbonisation (Biomethane & Hydrogen)** | Current gas network extended to an additional 300,000 homes within close proximity to the network, so that the total number of connections reaches one million.<br>Renewable gas gradually replaces natural gas from 2025 on most of the network. In the Cork area, 100,000 households receive hydrogen - this conversion takes place |

[1] http://www.energynetworks.org/gas/futures/the-uk-gas-networks-role-in-a-2050-whole-energy-system.html

[2] Central Statistics Office, 2016

| Scenario | Description |
|---|---|
| | between 2035 and 2040. Hydrogen is produced through Steam Methane Reformers (“SMRs”). The $CO_2$ produced is captured and stored in the depleted Kinsale gas field. |
| **Electrification of Heat** | Heating systems in homes are electrified from 2025 onwards, with the electricity sourced from new renewable electrical generation. Domestic demand for natural gas declines and the gas distribution network is decommissioned. |

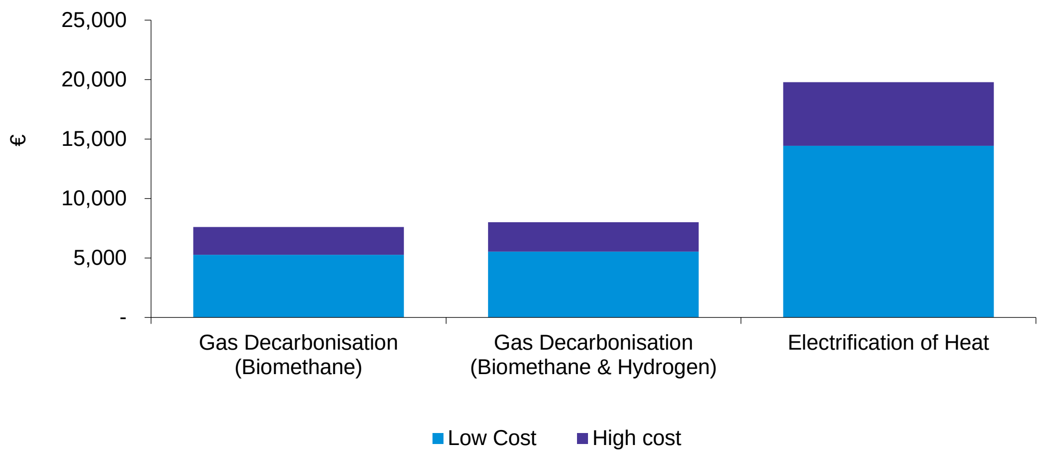
### Table 1.2: Summary analysis

| Scenario | Technologies Deployed | Financial Impact per Household | $CO_2$ Emissions Mitigated (‘000 tns per annum) | Summary of Feasibility Assessment |
|---|---|---|---|---|
| **1. Gas Decarbonisation (Biomethane)** | Biomethane produced by AD as a principal low carbon alternative to natural gas | €5,300 - €7,600* <br> ** Average discounted cost per household between now and 2050 including combination of capex and increased energy costs.* | 2,690 (93%)* <br> ** including GHG savings within the biomethane, as well as savings with the agricultural sector.* <br> *Excludes further savings from displacement of synthetic fertiliser, which would provide additional GHG savings* <br> *Refers to percentage saving Vs today’s baseline GHG emissions.* | Proven technology, with no change required at consumer or network level compared to existing natural gas usage. <br> Meeting the heat demand of one million homes with biomethane will require considerable waste and grass silage resources that are complimentary with agri-food production (e.g. slurries, crop residues, rotation/catch crops) or increase utilisation of lower productivity grass-land. <br> Significant new AD plant construction and a policy support mechanism would likely be required. <br> Able to meet all current & expected EU GHG efficiency requirements. |
| **2. Gas Decarbonisation (Biomethane & Hydrogen)** | Biomethane produced by AD and hydrogen through SMR as principal low carbon alternatives to natural gas. | €5,500 - €8,000* <br> ** Average discounted cost per household between now and 2050 including combination of capex and increased energy costs.* | 2,706 (93%)* <br> ** including GHG savings within the biomethane, as well as savings with the agricultural sector.* <br> *Excludes further savings from displacement of synthetic fertiliser, which would provide additional GHG savings.* <br> *Refers to percentage saving Vs today’s baseline GHG emissions.* | Hydrogen is not yet proven at a mass market level so gradual roll-out and testing would be required. The same would apply to a large CCS facility. Consumers using hydrogen would also need new appliances. However, no additional space would be required because current boilers will be replaced with gas appliances which are compatible with hydrogen. <br> New plant to produce biomethane would be required at scale, as well as |

| Scenario | Technologies Deployed | Financial Impact per Household | $CO_2$ Emissions Mitigated ('000 tns per annum) | Summary of Feasibility Assessment |
|---|---|---|---|---|
| | | | | a new policy support mechanism. |
| **3. Electrification of Heat** | Homes currently supplied with gas for heating will instead have heat pumps supplied with electricity. | €14,350 - €19,600*<br><br>** Average discounted cost per household between now and 2050 including combination of capex and increased energy costs.* | 2,861 (99%)*<br><br>** Assumes all electricity comes from renewable sources. Given intermittent nature of wind and solar, significant battery storage would be required to achieve this without baseload fossil backup. This report does not include the cost of battery storage, which could be very significant.* | Proven technology. Subject to sufficient investment in additional renewable electrical generation, able to provide significant reduction in GHG emissions. Achievable under current regulations.<br><br>Requires expensive, deep retrofit of houses to achieve energy efficiency levels required for heat pump technology. Additional space requirements for the technology may prohibit smaller properties.<br><br>Consumer acceptance challenges since low heat output.<br><br>Increased peak demand would require significant electricity network investment, along with electricity storage, smart meters or alternative smart grid solutions, which would require significant investment. |

The costs per household are also summarised in the chart below:

**Cost per household (€), total costs (capital investment and fuel) to 2050, discounted, current prices**



## 1.2 Conclusions

Our analysis draws the following main conclusions:

**Decarbonising the domestic heating sector will incur significant consumer cost, regardless of approach or technology**

Any decarbonisation pathway for domestic heat will create costs relative to a 'Do Nothing' scenario, where heat demand continues to be met by fossil fuels. Each of our three decarbonisation scenarios incur significant cost, which will ultimately be borne by consumers through higher renewable levies, higher energy prices or upfront capital investment in generating infrastructure and housing energy efficiency conversions.

Policy makers will have to demonstrate the rationale and benefit to consumers of accepting these higher costs to ensure sufficient public support and acceptance.

**Utilising low carbon biomethane within the existing gas network is the lowest cost way of decarbonising heat for homes connected to or in close proximity to the gas network**

Of our three scenarios, utilising low carbon biomethane within the existing gas network represents a lower cost alternative to either electrification or a biomethane / hydrogen mix.

Furthermore, our analysis also suggests that extending the gas network to the c.300,000 homes in close proximity to the existing gas network ('network infilling') represents a lower cost option than electrification for these homes. Our estimate of the cost per household of creating a low-carbon gas distribution network serving one million customers is roughly one-third of converting these properties to electric heat. This is before we consider energy storage which is likely to be required for electrification and which would add considerable expense.

**Low-carbon gas is the least disruptive way of decarbonising domestic heating**

Consumer acceptance is an important consideration in selecting a decarbonisation technology or scenario. At a household level, low carbon gas does not require the 'deep retrofit' needed to convert properties to electric heat (e.g. installation of underfloor heating / high levels of insulation), nor are new appliances or internal infrastructure required. Although a deep retrofit is not needed, Ervia and KPMG are including significant energy reduction measures in all houses connected to the network. Furthermore, the low carbon gas scenario does not require extensive network reinforcement to meet peak demand.

**Meeting heat demand through low-carbon gas will require extensive use of Ireland's natural resources and a very ambitious deployment of anaerobic digestion technology**

Producing the requisite quantities of renewable gas to meet domestic heating requirements will require the use of considerable quantities of grass silage feedstocks and agricultural wastes, as well as construction of significant AD processing facilities. While studies suggest we can source the required volumes without impacting current land use, Ireland's energy and food needs will need to be considered holistically to ensure the correct balance in land use.

**Low-carbon gas can be a highly secure decarbonised heat supply**

Ireland's gas networks are highly reliable, even in severe weather conditions where there can be a loss of electricity supply. Renewable gas, in particular biomethane, can provide an indigenous source of energy for the country at scale. Furthermore, the costs presented in this report do not reflect the value of the inherent flexibility of gas, nor the costs of ensuring that electricity supply is sufficiently flexible to provide heat on demand. With high levels of intermittent renewables being proposed for and implemented in Ireland, sources of reliable supply will be required to meet domestic heat demand.

**Hydrogen holds potential, but remains a developing technology**

While it holds significant potential to provide decarbonised gas, there are also considerable challenges to deploying low-carbon hydrogen as a heating fuel. The lowest cost method of producing hydrogen is through the SMR process. However, this produces $CO_2$ as a by-product, meaning that SMR units must be fitted with Carbon Capture kit and connected to a $CO_2$ transport and storage network. CCS networks are complex projects, with a range of risks that are difficult to manage. As a result of these complexities, there has been limited development of CCS projects globally to date.

**Development of the sector will bring significant societal benefit**

As well as assisting in the decarbonisation of the economy, the development of an indigenous anaerobic digestion industry has potential to transform large parts of Ireland's rural economy. Not only will it stimulate high value infrastructure investment across a decentralised and geographically disbursed rural area, it will also create and support significant construction and engineering roles within the wider economy.

**Policy Implications & Recommendations**

1. Recognition that the decarbonisation of heat in Ireland represents an important element of Ireland's overall decarbonisation strategy, and that appropriate policy support is introduced to support its implementation;
2. Adoption of a joined up approach across government to deliver biomethane decarbonisation including appropriate energy policy, planning policy, waste management policy and appropriate financial support mechanisms;
3. Ring fence the carbon tax on natural gas to support production of renewable gas;
4. Base Irish energy policy on total system costs to the consumer (including impact on consumer bills, consumer capital expenditure and the exchequer), rather than solely on costs to the Exchequer, as is currently the case;
5. Adopt the same approach to financially support the production of renewable gas as electricity by introducing a gas PSO levy. Alternatively, introduce support for biomethane grid injection within a renewable heat incentive scheme.

# 2 Decarbonising heat in Ireland

## 2.1 Introduction

Ireland has an ambitious vision to transform into a low carbon society and economy by 2050. While significant progress has been made to date in decarbonisation, particularly in industrial energy usage and electricity generation, there is a recognition that more can and must be done to address other areas such as heating and transport, which also generates significant volumes of greenhouse gases. Failure to meet Ireland's ambitious long term decarbonisation targets would result in significant financial penalties which means that a 'Do Nothing' approach is not an option.

Against this backdrop, KPMG has been commissioned by Ervia to develop and evaluate a number of scenarios for the decarbonisation of one of these key emission areas, namely the residential heating market. Ervia is the commercial semi-state multi-utility company responsible for Ireland's national gas infrastructure through Gas Networks Ireland. Specifically, Ervia has asked KPMG to focus on the one million Irish residential homes currently connected (circa 700,000), or within close proximity (300,000)[3], to the existing gas network. The scope of this analysis therefore excludes the circa one million homes which cannot be connected to the network without significant network expansion, and on which a separate decarbonisation strategy will have to be considered.

In 2015, KPMG prepared a report for the UK's Energy Networks Association ("ENA") on future alternative 2050 scenarios for energy decarbonisation in the UK, with a particular focus on gas. The report concluded that regardless of the technology, significant investment would be required to decarbonise the residential heat sector, but continuing to use the gas network offers significant savings versus alternative heating sources. The report further concluded that careful consideration must also be given to any alternative heating sources to ensure any changes are embraced by consumers.

The methodology employed in this report is similar to that employed in the 2015 UK study noted above. We have developed a series of high level decarbonisation scenarios and have made an assessment of the feasibility and cost of each scenario. The costs of transitioning to these scenarios are measured against a "Do Nothing" baseline, where the energy system continues in largely the same form as today. Our approach has been to use the assumptions developed for the UK study, unless an Ireland specific source exists, as the UK assumptions are expected to remain relevant and appropriate when used in an Irish context.

We recognise that in reality the energy system is highly unlikely to develop according to one particular scenario that we can set out today. The purpose of having these scenarios is to show a range of possibilities, and to this end we have deliberately chosen contrasting scenarios. Real world experience is likely to see a combination of scenarios in varying proportions.

### 2.1.1 Exclusions

We would draw attention to a number of exclusions within the scope of this study:

— We have only considered emissions of $CO_2$ in this study, which accounts for the majority of greenhouse gas emissions. We assume that other greenhouse gas emissions are proportionality reduced but we have not investigated this further.

— While we have set out the relative costs of decarbonisation under the various scenarios, we have not offered an opinion or analysis on the societal value for money of such decarbonisation options. Given the significant costs involved under any scenario, such an assessment will need to be made at community and political level.

[3] Source: Gas Networks Ireland

- We have not considered the additional cost of electricity storage in our assessment of electrification of heat.
- While we discuss a number of decarbonisation technologies, including electrification and decarbonised gas, we have not undertaken primary research on the feasibility of each technology and have instead utilised existing research and reports which are clearly identified within this report.

This chapter sets the context for the report by providing an overview of the Irish gas network, Ireland's decarbonisation targets and the current status of greenhouse gas emissions ("GHG") in Ireland.

## 2.2 The Irish Gas Network

**Figure 2.1: Gas Networks Ireland Map**


Since the scope of this report focuses on the one million homes on or within close proximity to the Irish gas network, it is helpful to provide a summary of the existing gas network and its geographic location.

Both the gas transmission and distribution pipelines across Ireland are owned and managed by Gas Networks Ireland, a subsidiary company of Ervia.

Currently, gas plays a key role in Ireland's energy system, providing approximately 27% of the country's primary energy needs[4]. It provides an effective source of heat for households and businesses which are connected to the gas network, and is safe and modern by global standards[5].

As outlined above, this report is focused on two geographies, being areas connected to the gas network and areas located in close proximity to the gas network. Gas Networks Ireland currently serve approximately 688,000 customers in Ireland. In addition it is estimated that 200,000 homes are on streets where gas is available and another 100,000 homes are in estates near to a gas supply. When considering decarbonisation scenarios, this report therefore assumes that a total of one million homes in the Republic of Ireland are connected to the gas network to allow for moderate growth, for ease of explanation and to simplify the analysis.

Residential heating currently comprises around half of Ireland's overall heat demand[6]. Approximately 97% of households in Ireland were centrally heated as of 2011, with oil and gas being the dominant fuels for providing heating[7]. Ireland's gas networks have grown, particularly in urban areas, with approximately 39% of Irish households now connected to the gas grid as of 2014[8]. By contrast, electric central heating is relatively uncommon in Ireland with just 9% of households using electrical storage heating[9].

[4] Page 12, SEAI, Energy in Ireland 1990-2015.

[5] For example, in 2016, Ervia reported a consistently high safety performance on its distribution network, with only 1 gas in building event, 3 unplanned outages and no gas supply emergencies

[6] Energy Institute, 'The Story of Heating in Ireland', http://ireland2050.ie/past/heat/.

[7] Energy Institute, 'The Story of Heating in Ireland', http://ireland2050.ie/past/heat/.

[8] Houses of the Oireachtas, Written Answers 282-300, 1 July 2014, http://oireachtasdebates.oireachtas.ie/debates%20authoring/debateswebpack.nsf/takes/dail2014070100064.

[9] http://ireland2050.ie/past/heat/.

## 2.3 Ireland's Decarbonisation Targets

Ireland has ambitious long term decarbonisation targets which have been developed in the context of the significant role played by both Global and European institutions in determining energy policy, markets and regulation.

On a Global scale, Ireland is a party to the United Nations Framework Convention on Climate Change ("UNFCCC") and to the Paris Agreement, which provide the international legal framework for addressing climate change at a global level. The ultimate objective of UNFCCC is the "stabilisation of global GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system"[10].

Within the EU context, the 2020 climate & energy package has set a binding EU wide target of a 20% reduction in GHG emissions from 1990 levels. This target is increased to 40% by 2030 under the 2030 climate and energy framework of October 2014. The European Commission has also developed a low-carbon economy roadmap which suggests the EU should cut greenhouse gas emissions by 80% below 1990 levels. The EU's Effort Sharing Decision also set 2020 targets for EU Member States in relation to GHG emissions from sectors not included in the EU Emissions Trading Scheme ("ETS") (i.e. agriculture, transport, the built environment, waste and non-energy intensive industry). Ireland has a 2020 target to achieve a 20% reduction of such non-ETS sector emissions on 2005 levels.

The Global and EU objectives have been implemented in Ireland though the National Policy Position on Climate Action and Low Carbon Development 2014 and the Action and Low Carbon Development Act 2015. The National Policy Position establishes the fundamental national objective of achieving transition to a low carbon, climate resilient and environmentally sustainable economy to 2050, and envisages a reduction in GHG emissions from the energy sector by at least 80% compared to 1990 levels. The Climate Action and Low Carbon Development Act 2015 provides the statutory basis for Ireland's transition.

## 2.4 Greenhouse Gas Emissions

As noted above, Ireland has made significant progress in decarbonisation in recent years, particularly in industrial energy usage and electricity generation. Between 2005 and 2014, Ireland reduced total GHG emissions by more than 17%[11]. However, it is estimated that non-ETS sector emissions are projected to be only 4% - 6% below 2005 levels by 2020[12], substantially below the 2020 target of 20% set by the EU.

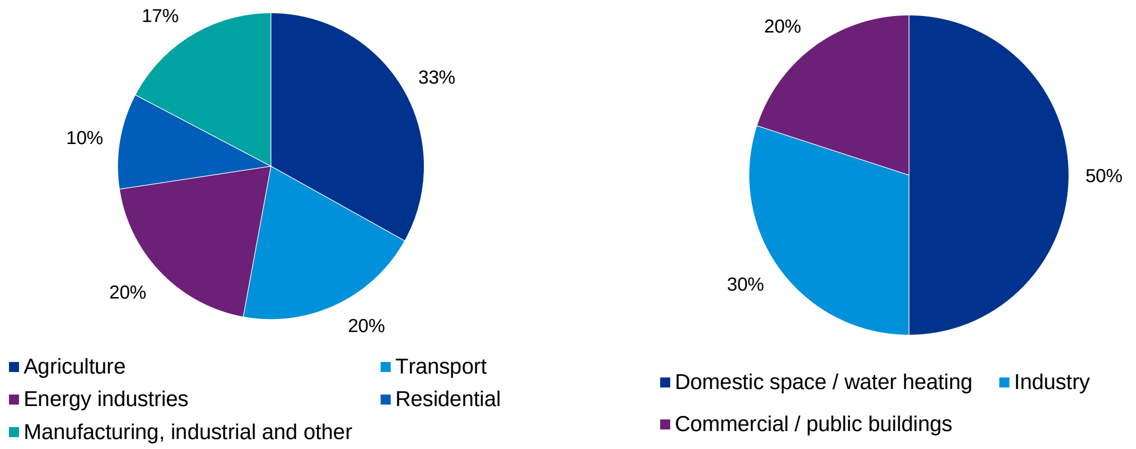
The main sources of Ireland's GHG emissions and the sources of heat demand are illustrated below:

[10] Article 2, The United Nations Framework Convention on Climate Change

[11] http://www.cso.ie/en/releasesandpublications/ep/p-eii/eii2016/ggcc/.

[12] Environmental Protection Agency: Ireland's Greenhouse Gas Emission Projections 2016 – 2035, April 2017

**Figure 2.2: Greenhouse gases by Sector[13] and Heat Demand[14]**




Energy related emissions comprise more than 60% of total emissions and include energy industries, transport, residential, manufacturing, industry and commercial sectors. The majority of the non-energy emissions are from the agriculture sector.

The "Residential" sector contributed c.10% of total GHG emissions, and so there is scope for significant further reductions in GHG emissions through the decarbonisation of residential energy use.

The "Residential" sector includes the greenhouse gases related to combustion for domestic space and hot water heating (using gas and other fuels), and so the transition to decarbonised residential heating would need to consider the impact of changes required in each home that will need to face the cost and disruption associated with substitution of energy sources.

## 2.5 Chapter Summary

- Residential heating currently comprises around half of Ireland's overall heat demand. The "Residential" sector contributed to c.10% of Ireland's GHG emissions in 2015.
- Approximately 39% of Irish households are connected to the gas grid as of 2014. This report assumes a total of one million homes are connected for the purposes of considering decarbonisation scenarios.
- Ireland is targeting a reduction in GHG emissions from the energy sector by at least 80% compared to 1990 levels by 2050.
- Between 2005 and 2014, Ireland reduced total GHG emissions by more than 17%. However, non-ETS sector emissions are projected to be only 4% - 6% below 2005 levels by 2020, substantially below the 2020 target of 20% set by the EU.

[13] Environment Protection Agency: Ireland's Final Greenhouse Gas Emissions in 2015, 13 April 2017

[14] Percentage shares approximate, based on text in Energy Institute, 'The Story of Heating in Ireland', http://ireland2050.ie/past/heat/.

# 3 Scenarios for residential decarbonisation

In this section of the report we describe the basis of the scenarios we have evaluated for the future decarbonisation of domestic heating. This section is structured as follows:

- Section 3.1 sets out the principal technology options for decarbonising domestic heat in Ireland;
- Section 3.2 sets out the rationale for the scenarios analysed in this report; and
- Section 3.3 provides detail for each of the scenarios.

## 3.1 Technology options for decarbonising heat

Prior to the development of specific scenarios to be assessed within this report, it was necessary to undertake an assessment of the wide range of heat technologies which are available to assist in the decarbonisation of the residential heating sector. These technologies can be split in to four key groupings as follows:

### 3.1.1 Demand reduction

One of the most effective and proven decarbonisation strategies is to reduce energy demand at source, through effective insulation, energy efficiency device deployment (e.g. low energy bulbs, smart heating systems) and consumer education.

Under each of our scenarios we have assumed a base level of demand reduction (20% - 40%), incorporating a range of technologies. While this is effective in moving towards the GHG targets, on its own it is unable to achieve the ambitious targets and therefore needs to be combined with other solutions.

### 3.1.2 Electrification

There are a number of electrification of heat technologies, including traditional resistive heaters and heat pumps. Based on our review of the technology options available, we have concluded that heat pumps[15] (ground and air source) provide the most realistic and effective electrification technology and so this has formed the basis on our electrification scenario. Resistive heating, while proven, has been discounted due to its high cost and inefficiency.

### 3.1.3 Decarbonised gas

Decarbonised gas refers to a range of gases which can be produced as a replacement for the existing natural gas utilised within the residential gas network. Depending on the specific gas produced, it can be compatible with existing infrastructure and appliances, but may require adaptions.

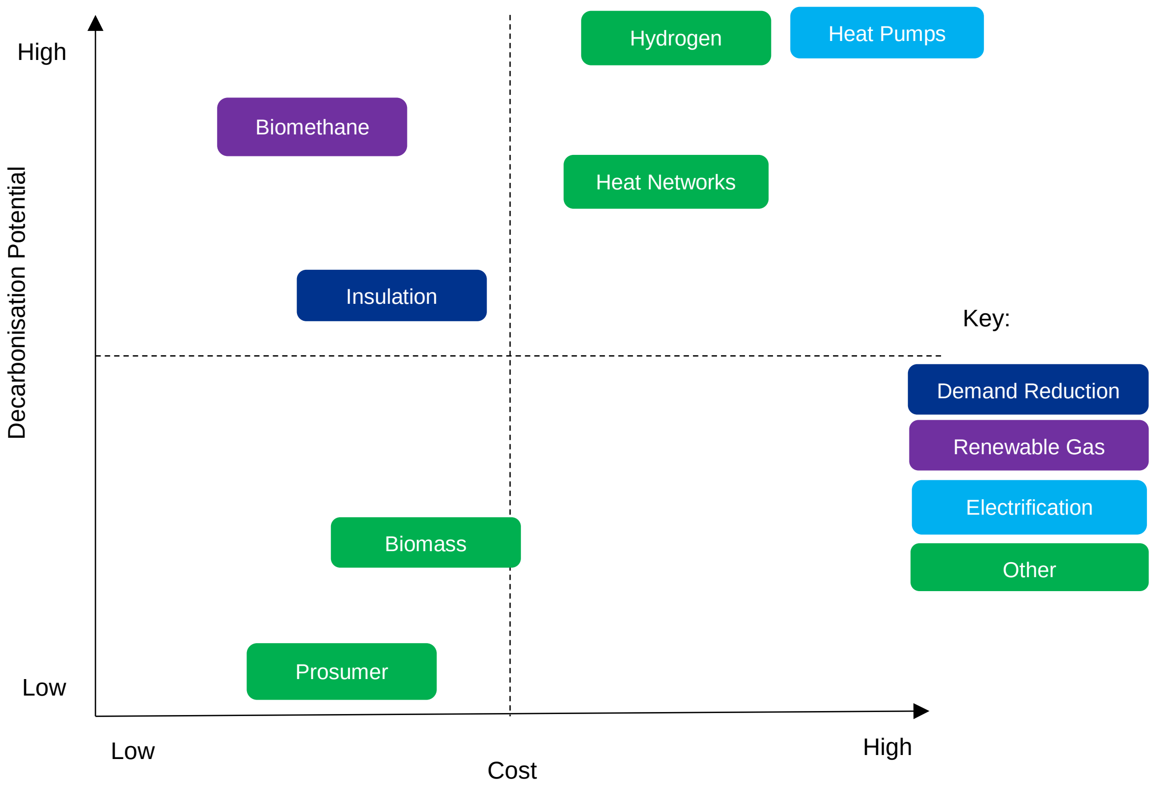
### 3.1.4 Other (Incl. Heat Networks & Biomass)

There are a range of other technologies which were considered as part of this report, including biomass heating and heat networks. While we consider these technologies to hold potential within specific circumstances, low density housing and space constraints mean these are unlikely to have widespread impact on decarbonisation in Ireland, and have therefore been excluded from our scenario analysis.

[15] We have assumed heat pump with a COP of 3 as per Part L Building Control Regulations

Our assessment and selection of technologies included consideration of their decarbonisation potential, capital and operational costs, impact on consumers, network impact and peak demand capability as illustrated below.

**Figure 3.1: Assessment of future heating technologies**




The key characteristics of each technology are set out in Table 3.1 below.

**Table 3.1: Technologies available for the decarbonisation of domestic heat**

| | Description | Carbon Emissions | Potential in Ireland | Current status |
|---|---|---|---|---|
| **Hydrogen** | Hydrogen is a gas that may be used in a similar manner to natural gas. Appliance replacement would be necessary, but the central heating system would be retained.<br><br>Hydrogen can be transported using the majority of the existing gas distribution networks which are modern polyethylene. | No $CO_2$ emissions created at the point of use.<br><br>Hydrogen can be produced via electrolysis using renewable electricity to be carbon free. It can also be derived from natural gas using the SMR process. The SMR process creates $CO_2$ emissions, which must be captured and stored (for example with CCS if the hydrogen produced in this way is to be considered low-carbon). | Ireland's existing gas infrastructure can supply the natural gas needed for the steam methane reformation to produce hydrogen. In addition, there may be suitable offshore storage sites for the $CO_2$ by-product in the Head of Kinsale gas field off the coast near Cork. | At present hydrogen is not used as a heating fuel in Ireland. In the UK, Northern Gas Networks' 'H21 Leeds City Gate' network innovation project has reported that creating a hydrogen network in Leeds using the SMR process is feasible and economic[16]. |

[16] Page 8, Northern Gas Networks, 'H21 report'.

| | Description | Carbon Emissions | Potential in Ireland | Current status |
|---|---|---|---|---|
| **Biomethane** | Biomethane is a renewable gas.<br><br>It has similar properties to natural gas and can be transported using the existing gas network, and used by existing gas appliances.<br><br>It can be produced using AD and by (not yet mature) gasification technologies. | Does produce $CO_2$ emissions but at a significantly lower level than natural gas[17].<br><br>Based on a feedstock mix primarily consisting of grass silage and slurry, a recent study suggests biomethane could reduce $CO_2$ emissions by more than 77% compared to the 'do nothing' counterfactual. | The main consideration in Ireland is feedstock availability.<br><br>Producing biomethane in the quantities required to meet domestic heat demand will require the use of a considerable proportion of Ireland's waste and land resources, albeit a number of recent studies have concluded that it is possible to source sufficient feedstock to meet the scenario demand without impacting current land and feedstock usage. | Limited existing deployment in Ireland, however proven in Northern Ireland and worldwide.<br><br>GNI is constructing the first Gas Grid Entry Hub in Cush, Co. Kildare, which will facilitate gas collection from up to 6 remote biogas AD facilities for central injection from 2018. It is progressing plans for the next grid entry hub in Mitchelstown Co. Cork at one (of 55) strategic grid stations which will have a design capacity to accommodate between 24 to 36 remote AD facilities within a 90km radius[18].<br><br>Although there are currently less than 10 operational AD plants in Ireland, there is significant pent up demand in the rural economy, which will facilitate the introduction of significant additional capacity. |
| **Biomass** | Heat generated through a range of biofuels including wood pellets, animal, food or industrial waste or high energy crops such as maize. | Burning biomass still produces $CO_2$, but when it is produced sustainably it is deemed carbon neutral. Particulates are an issue for biomass. | While SEAI analysis suggests that planned renewable energy output from bioenergy could be fuelled entirely from domestic sources[19], its widespread application at residential level is challenging.<br><br>For this reason this technology has been excluded from this report. | By 2015, biomass met around 5% of heat energy demand in Ireland[20]. |
| **Heat networks** | A network of hot water pipes supplying a number of buildings from central sources. This source could be industrial waste heat, biomass plants or a conventional gas boiler or an electric heat source. | This will depend on the source of the heat (low/no $CO_2$ emissions for some sources). | Limited - heat networks are most effective in high-density housing areas e.g. apartment developments, which may limit the scope for application in Ireland.<br><br>For this reason, this technology was excluded from this report. | Ireland has one of the lowest shares of district heating in Europe, at less than 1% of heat demand compared to a European average of 10%[21]. |

[17] To comply with the EU Renewable Energy Directive 2 (currently in draft) biomethane emissions must be 70% lower than natural gas by 2026, and 75% thereafter. Biomethane emissions can be reduced by flexing the amount of slurry used in anaerobic digestion processes. Source: IERC Repot "Certification of Renewable Gas in Ireland" May 2018

[18] Information provided by GNI.

[19] http://www.energyireland.ie/the-dark-horse-of-irelands-renewable-transition/.

[20] Page 34, SEAI, 'Energy in Ireland 1990-2015'.

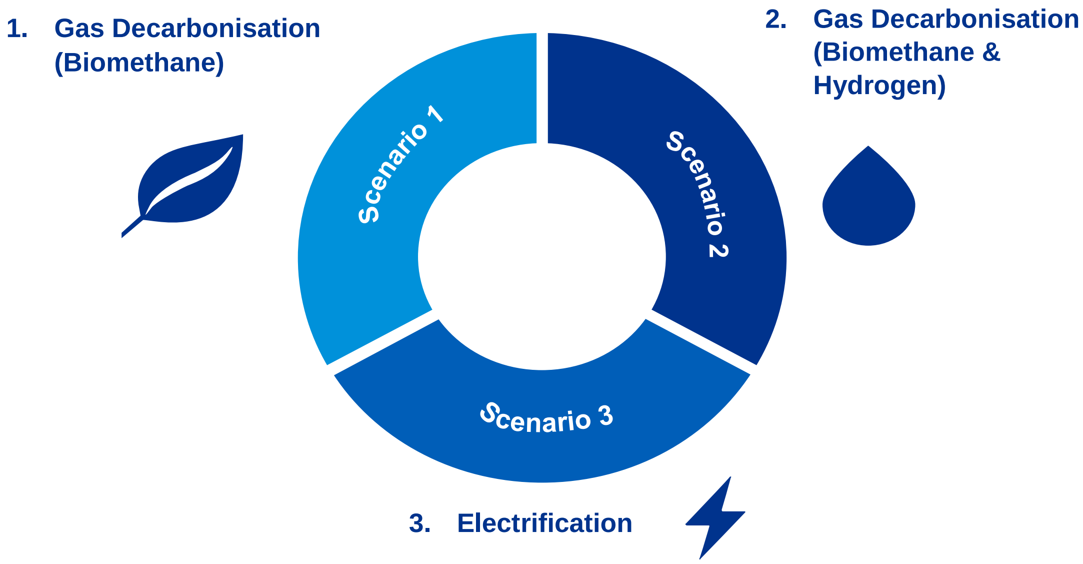
[21] http://www.energyireland.ie/developing-district-heating-in-ireland/.

| | Description | Carbon Emissions | Potential in Ireland | Current status |
|---|---|---|---|---|
| **Heat pumps** | Powered by mains electricity, these absorb heat from the outside air or ground, which is then transferred to and used in the property. The energy output is multiples greater than the input electrical energy. Based on the nature of the heat delivered by this technology, it is also necessary to undertake significant installation and insulation works in retrofit homes, which has been factored into our analysis. | Depends on the source of the electricity. The heat they extract from the air or ground is natural and renewable. | The main limitation on the deployment of ground source heat pumps is space - they require a significant amount of ground space.<br><br>Air source heat pumps are typically the size of a washing machine[22], and are located on the outside of a property[23]. | Geothermal / ambient sources (including heat pumps) met around 1% of Irish energy demand in Ireland in 2015.[24.] |
| **Prosumer** | Customers with the ability to generate and store their own heating energy via a number of different technologies, reducing energy taken from the grid substantially. The full cost of maintaining an electricity grid connection would have to be recovered should this approach gain traction. | Prosumer technologies use solar powered heat pumps and solar air collectors. | No specific estimates have been made of the potential for prosumer heating in Ireland.<br><br>Given the likely low penetration potential for this technology, it was excluded from this report. | Solar technologies are becoming more widespread, but a fully 'prosumer heating' property is generally still at experimental stage. These technologies all inherently require space, ideally within the property, which may limit how widely they can be applied.<br><br>Connections to electricity and gas networks may still be needed as 'back-up'. |
| **Insulation** | Use of insulation in residential buildings will reduce the requirement for domestic heating. Common examples of residential insulation include attic / roof insulation, cavity wall insulation and internal / external wall insulation. | The reduction in demand for heat as a result of insulation will in turn reduce energy consumption and associated $CO_2$ emissions.<br><br>We assume a level of insulation under all scenarios we are modelling, with 20% assumed under the gas decarbonisation, and 40% under the more intensive, deep retrofit required for electrification. | SEAI identified that energy savings potential is largest in the residential buildings sector at 13.5TWh[25]. Over 250,000 households have delivered an upgrade with government support through SEAI grants, but it is estimated that over 1 million homes need improving[26]. There is an inherent difficulty in achieving a high level of insulation in older homes. | Insulation is common in buildings across Ireland, particularly for new properties, with homes built from 2006 onwards constructed to the 2003 Building Regulations. Grants are available through SEAI for homes that were built and occupied before 2006[27]. |

22 https://www.evergreenenergy.co.uk/heat-pumps/how-much-space-do-i-need-for-a-heat-pump/.
23 http://www.yougen.co.uk/blog-entry/1679/How+%2728%2726+where%2729+to+position+your+air+source+heat+pump/.
24 Page 34, SEAI, *ibid*.
25 SEAI, 2015, Unlocking the Energy Efficiency Opportunity
26 SEAI, Behavioural insights on energy efficiency in the residential sector
27 https://www.seai.ie/grants/home-grants/better-energy-homes/insulation-grants/

## 3.2 Scenario Development

Following consideration of the technologies, KPMG has developed three core scenarios for this report as follows:




While there are a wide range of technologies available to assist in decarbonisation, our assessment of available options suggests that the key technologies which have the most potential in Ireland are electrification and low carbon gases. Accordingly, we have adopted scenarios comparing 100% electrification with 100% gas decarbonisation, along with a third scenario showing the impact of supplying 10% of the decarbonised gas volume using the more ambitious hydrogen gas (equivalent to the entire population of Cork).

As outlined in section 2 of this report, there are approximately 700,000 homes which are currently connected to the gas distribution network. Gas Networks Ireland have identified a further 300,000 properties not currently connected to the gas network (and which currently rely on other fuels such as oil) but are within close proximity and could be connected to the gas network without major cost and disruption. This is known as "infilling" and would give a total number of homes in scope of the analysis of one million. The Decarbonised Gas Scenarios (1 & 2) therefore assume that infilling of the gas network occurs and one million homes in total are connected to the gas network.

We have considered the time period from now until 2050 (as also used in the UK study). Deployment of low-carbon technologies in the domestic heat sector in Ireland to date has been limited[28] with, for example, the first injections of renewable gas into the Irish grid only expected to occur in 2018. We have therefore assumed that deployment of low-carbon heat technologies does not begin at scale until the 2020s.

An overview of the three scenarios above is provided below.

### 3.2.1 Scenario 1: Gas Decarbonisation (Biomethane)

In the first scenario it is assumed that renewable gas, transported through the existing gas infrastructure and utilising existing appliances, is used to provide residential heating to the households connected to (or in close proximity to) the gas network.

[28] Most renewable heat deployment has been due to solid biomass consumption in the wood products and food sectors of the economy. Source: Page 34, SEAI (2016), 'Energy in Ireland 1990-2015'.

Renewable gas (also referred to as biomethane, "green gas" or "biogas") is currently produced in small quantities in Ireland by AD of organic materials such as bio-waste, animal manure and grass silage which is sourced from Ireland's agricultural sector. Renewable gas can be upgraded using a proven technology to give performance that is identical to natural gas and so can therefore be injected into the gas network and used by standard gas appliances. As well as providing domestic heat, renewable gas can also be used in transport and in power generation.

In assessing the feasibility of deploying AD in Ireland, we have considered a number of reports including the European Commission Report: *"Optimal use of biogas from waste streams, An assessment of the potential of biogas from digestion in the EU beyond 2020"*, SEAI's 2017 report *"Assessment of Cost and Benefits of Biogas and Biomethane in Ireland",* which undertook a detailed analysis of the potential for AD deployment based on specific land and feedstock availability in Ireland, and a 2016 study by Ricardo Energy and Environmental *"Bioenergy Supply in Ireland 2015 – 2035"*.

While the SEAI report considered a number of AD scenarios, KPMG has principally considered its "All AD feedstock" scenario, which assumes Ireland maximises both waste and agricultural inputs available for AD. Under this scenario, the SEAI considers it feasible that 1,044ktoe of biomethane energy could be generated in Ireland, equivalent to 28% of natural gas usage today. This would be more than sufficient to provide 100% of the gas requirements of the one million residential homes considered within this report, which have an estimated heat demand of 946ktoe[29] annually (which is assumed to reduce by 20% in this report to 757ktoe by 2050, due to increased insulation and energy efficiency).

This conclusion is further supported by the Ricardo study[30] which states that Ireland has sufficient under-utilised land to produce sufficient grass silage to generate the required level of biogas to supply the one million homes considered in this study, without impacting existing land use for food or animal purposes.

Other studies have estimated a higher biogas resource in Ireland. Indeed, a European Commission report estimates that Ireland has the highest biogas potential in the whole of Europe, such that 20% of Ireland's gas demand could be sourced from organic wastes (together with power to gas and algae sources) by 2030, with the potential for Ireland to become an exporter of renewable gas in the future[31]. Given this potential, renewable gas plays a major role in scenarios 1 and 2 in this report where the gas network continues to meet heat demand.

We have assumed a cost of €75/MWh for biomethane produced through AD, based on SEAI analysis[32].

### 3.2.2 Scenario 2: Gas Decarbonisation (Biomethane and Hydrogen)

Under the second scenario in this report it is assumed that the gas network transitions to use both biomethane gas (as outlined above) and, for 10% of the homes, hydrogen gas. While in the future hydrogen could in theory be rolled out to all homes, this scenario only seeks to demonstrate the impact of converting a city the size of Cork to hydrogen in the first instance.

Hydrogen can be produced from natural gas through SMR or through electrolysis of water. SMR is currently the most economic and widespread method of production. A by-product of the SMR process is $CO_2$, which needs to be captured and stored in order for the hydrogen produced to be

[29] CER determination of average Irish household energy use of 11,000kWh per annum

[30] Ricardo Energy and Environmental "Bioenergy Supply in Ireland 2015 – 2035

[31] CE Delft (2017), 'Optimal use of renewable gas from waste streams, An assessment of the potential of renewable gas from digestion in the EU beyond 2020'.

[32] SEAI, 'Costs and benefits of biogas and biomethane in Ireland'. Figure 4.7 shows a range of 30-100 €/MWh for biomethane produced via AD, depending on feedstock and technology. Based on this, Ervia have estimated that biomethane producers will require a price of 75 €/MWh to be economically viable.

considered low-carbon. The deployment of CCS technologies will also be crucial for Ireland's power sector to capture the $CO_2$ produced by energy production.

Hydrogen produced by SMR is by definition more expensive than natural gas, as natural gas and energy are inputs into the SMR process. To be economic, the price of hydrogen must also cover the cost of the SMR facility itself. The availability of low cost renewable electricity (for example excess wind output at times when demand is low) could facilitate the production of hydrogen through electrolysis, which is carbon free. In the long run, production through electrolysis could potentially complement or displace SMR production depending on the relative economics of each technology[33].

Ireland has potential offshore storage sites for $CO_2$ in the Kinsale Head gas field, off the Cork coast. As well as providing storage for $CO_2$ produced in the production of hydrogen, the location of the Kinsale field means that it could also store $CO_2$ produced by two combined cycle gas turbine ("CCGT") plants (Whitegate and Aghada)[34]. Indeed, the presence of multiple users of a $CO_2$ transport and storage network will be crucial to ensuring the financeability of the network[35]. To reflect this, natural gas is replaced with hydrogen in the Cork area in scenario 2 over the 2035 to 2040 period, with 100,000 properties then using hydrogen to meet their domestic heating needs.

### 3.2.3 Scenario 3: Electrification

The third and final scenario is the use of electricity generated from renewable sources to power low-carbon domestic heating for the same one million homes considered in the previous scenarios. This scenario assumes that homes currently supplied with gas for heating move to the use of heat pumps supplied with electricity, and that sufficient new renewable electricity generating assets (primarily onshore and offshore wind) are deployed to meet this increased demand.

Given that gas network penetration in Ireland is relatively low at 39% of households and that a major gas network expansion programme would be required to supply rural, off-grid properties, other renewable fuels (bio-LPG, biomass etc) or electrification is likely to have a major role to play in the decarbonisation of heat in rural Ireland.

There is a range of electric heating technologies available today, from 'traditional' resistive heaters to newer technologies such as ground source and air source heat pumps.

Many households use individual electric heaters as a complement to their main heating source (so called 'secondary heating') to heat a small space for a limited time[36]. However, they are a costly way of heating whole properties (unit rates for electricity are several times higher than for gas) and if they were used in this way on a large scale, the increase in peak demand has the potential to create considerable strain on the Irish electricity network, and create the need for a substantial increase in generation capacity.

Heat pumps require less electricity to heat a property, and are therefore favoured as the lead technology option for the electrification of heat[37]. However, heat pumps do require more fundamental changes to household heating systems and to the fabric of the house than low-carbon gas. In addition, they give off low levels of heat relative to gas, and high levels of insulation / energy efficiency are therefore required. Although heat pumps use less power than other electric heating options, they will still be required to meet peak heat demand in the same way gas does today. This represents a significant challenge as levels of intermittent wind generation increase.

[33] Historically, the cost of production for hydrogen via SMR has been around one quarter to one third of the cost of electrolysis. See Arnold, 'The lowdown on hydrogen part 2- production' http://energypost.eu/the-lowdown-on-hydrogen-part-2-production/.

[34] http://www.powerengineeringint.com/articles/2017/10/cork-for-carbon-capture-and-storage.html.

[35] A larger number of users reduces the counterparty risk for investors in a CCS network, i.e. the impact of the failure of one network user on the network operator's revenues will be proportionally less.

[36] See http://www.energysavingtrust.org.uk/home-energy-efficiency/heating-and-hot-water.

[37] For example, see Peter O'Shea (ESB), 16th January 2018 - Joint Oireachtas Committee on Communications, Climate Action and Environment: 'Heat pumps with insulation and air tightness are the leading candidate to replace oil'.

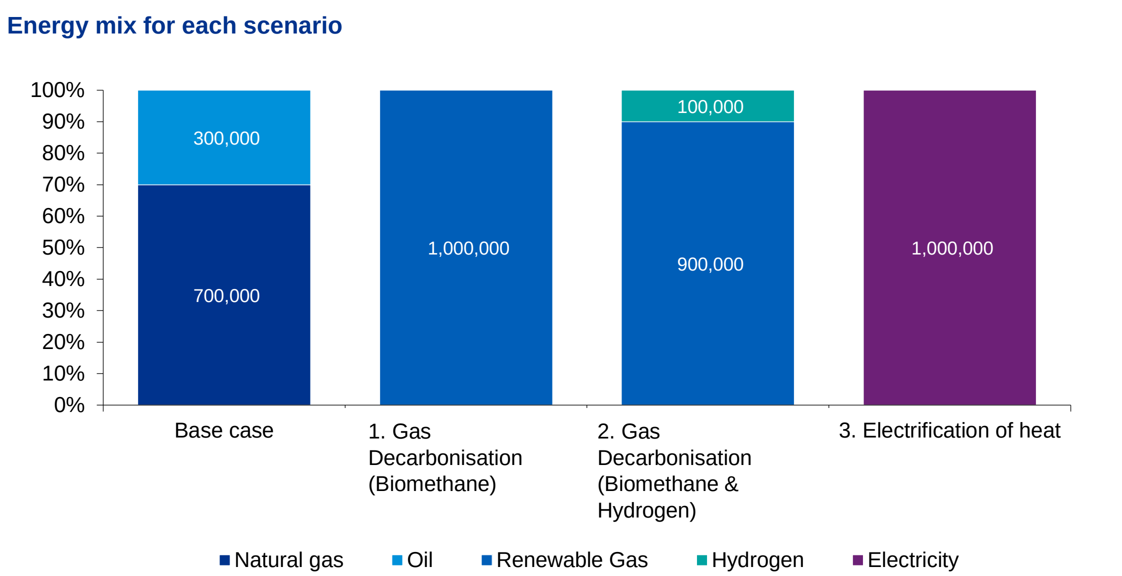
Given these issues, 'hybrid' technologies may become prevalent, which use heat pumps to meet baseload demand, coupled with a boiler to provide heat at peak times. However, for the purposes of this study, as a counterpoint to the gas evolution scenarios, we consider a single technology electrification scenario, where the gas distribution network is entirely decommissioned, and the homes on it are fitted with heat pumps to meet their heating needs.

### 3.2.4 2050 energy mix

The 2050 energy mix for each of the three scenarios is set out in the chart below. The 'Base Case' (or 'Do Nothing') acts as a comparator showing how heat demand is currently met.

**Figure 3.1: Summary of energy mix in potential scenarios**

**Energy mix for each scenario (1 million households)**




The scenarios are 'snapshots' of what an energy system in Ireland in 2050 may look like. They are not intended to be accurate predictions, rather they are meant to show a range of potential options in order to compare the costs of transitioning to decarbonised technologies. We recognise that the energy system is unlikely to develop according to one particular scenario and a mixture of potential scenarios is likely to emerge. We are not accounting for population or housing stock growth so the energy demand being estimated is for existing housing stock.

The precise costs of these decarbonisation pathways are uncertain at this stage, as many low-carbon technologies have yet to be rolled out at scale. We therefore present low-high ranges of costs for each scenario, rather than a single central estimate.

## 3.3 Our scenarios: the specifics

On the following pages we provide a description of each of the three scenarios we have evaluated for this study. Full details of the assumptions we have used can be found in Appendix 1. When we come to compare the scenarios it is necessary for us to make some common assumptions about the energy market.

We assume domestic heat demand falls between now and 2050 in all scenarios. These reductions reflect continuing improvements in the efficiency of appliances and insulation, and increased uptake of energy efficiency measures as households replace their current appliances and systems with low carbon emission ones.

We assume a larger reduction in domestic heat demand out to 2050 in the electrification scenarios (40% versus 20% in scenarios where gas networks continue to be used[38]), since households converting to electric heating would require a 'deep retrofit' of energy efficiency measures to ensure that heat pumps can operate efficiently.

Although total domestic heat demand is lower with electrification, we have assumed a smaller reduction in peak heat demand in these scenarios, reflecting the fact that electricity networks will need to have sufficient capacity to provide dispatchable energy at peak in the way that gas does today.

### Table 3.2: Summary description of scenarios

| Scenario | Description | Homes using each fuel in 2050 | | |
|---|---|---|---|---|
| | | Renewable Gas | Hydrogen | Electricity |
| **Gas Decarbonisation (Biomethane)** | Current gas network extended to 300,000 homes within close proximity so that the total number of connections reaches one million homes.<br>Renewable gas gradually replaces natural gas from 2025. | 1,000,000 | 0 | 0 |
| **Gas Decarbonisation (Biomethane & Hydrogen)** | Current gas network extended to an additional 300,000 homes within close proximity to the network, so that total number of connections reaches one million.<br>Renewable gas gradually replaces natural gas from 2025 on most of the network. In the Cork area, 100,000 households receive hydrogen with this conversion taking place between 2035 and 2040. The hydrogen is produced through Steam Methane Reformers and the $CO_2$ produced is captured and stored in the Kinsale gas field. | 900,000 | 100,000 | 0 |
| **Electrification of heat** | Following deep retrofit, heating systems in homes are replaced with heat pumps from 2025 onwards. Domestic demand for natural gas declines and the gas distribution network is decommissioned. | 0 | 0 | 1,000,000 |

For each scenario, we have considered the key influences affecting the development of energy systems through to 2050. We have looked at:

- **New energy infrastructure requirements:** We have estimated the costs of the additional infrastructure required for the supply of low-carbon heat. This includes the costs of AD facilities to produce and transport renewable gas, and the SMRs and CCS network that will be needed to produce hydrogen, and store the $CO_2$ created as a by-product.
- **The implications for gas and electricity networks:** We consider how we will have enough capacity in the networks to deliver energy at peak times, i.e. 7pm on a cold winter's day. We

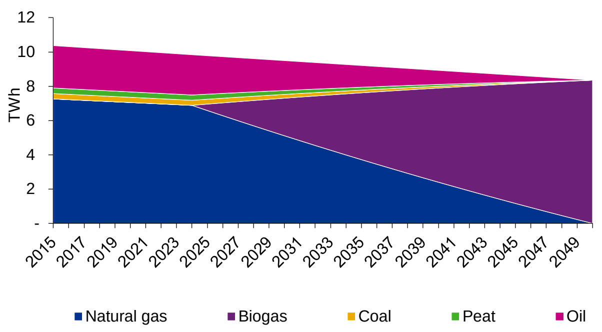
[38] The 20% reduction in energy demand as a result of continuing improvements in efficiency is considered a conservative estimate. The SEAI suggests that a home's heating costs could be reduced by 20% simply by upgrading heating controls and that a home can lose 30% of its heat through poorly insulated walls. See: https://www.seai.ie/grants/home-grants/better-energy-homes/.

also consider the costs of increasing the reach of gas networks (‘network infilling’) and decommissioning when there is a switch away from gas to electricity.

— **The cost implications of change at a household level:** We consider how converting the appliances in individual homes is a key driver of overall costs. We look at the costs of the different transitions households may be required to make to move to low carbon heating e.g. from natural gas to renewable gas, from oil to electric heating, or from natural gas to electric heating.

The gas decarbonisation (biomethane) scenario is outlined in table 3.3 below.

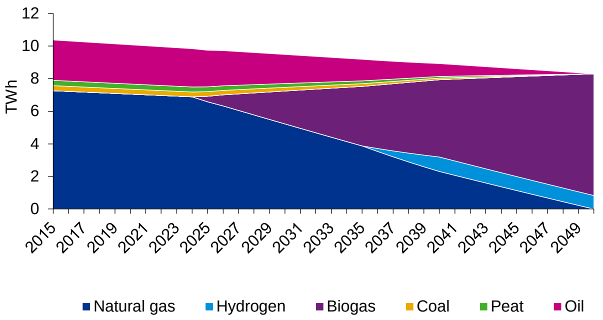
### Table 3.3: Gas Decarbonisation (Biomethane)

<table>
<tr><td>Scenario Name</td><td colspan="2">Gas Decarbonisation (Biomethane)</td></tr>
<tr><td>Description</td><td>This scenario assumes the gas network is expanded so it reaches 300,000 off-grid homes, giving a total of one million homes on the gas network.<br><br>The entire network is assumed to be converted to renewable gas from the 2020s, following the first injections of renewable gas into the Irish grid in 2018.</td><td>Total consumption by fuel<br>
</td></tr>
<tr><td>Number of homes</td><td colspan="2">1 million</td></tr>
<tr><td rowspan="5">Summary of impacts</td><td>Fuel use</td><td>▪ Renewable gas is introduced and natural gas use in homes gradually declines to zero from 2025 onwards.<br>▪ Use of other fossil fuels (coal, peat and oil) declines to 2050 as more off-grid homes are connected to the gas network.</td></tr>
<tr><td>Gas networks</td><td>▪ Infilling of gas network to reach 300,000 additional homes by 2050.</td></tr>
<tr><td>Electricity networks</td><td>▪ Minimal impact (no additional capacity required to meet heat demand).</td></tr>
<tr><td>Investment in energy production</td><td>▪ Investment in AD plants to produce biomethane.</td></tr>
<tr><td>Household conversion</td><td>▪ The existing natural gas appliances are used so no additional cost occurs.</td></tr>
</table>

The Gas Decarbonisation (Biomethane & Hydrogen) scenario is outlined in table 3.4 below.

### Table 3.4: Gas Decarbonisation (Biomethane & Hydrogen)

<table>
<tr><td>Scenario Name</td><td colspan="2">Gas Decarbonisation (Biomethane & Hydrogen)</td></tr>
<tr><td>Description</td><td>In this scenario, the gas network is expanded so it reaches a further 300,000 homes, giving a total of one million homes on the network. In the Cork area, 100,000 homes switch to hydrogen as their principal source of heat (a new boiler is installed, but heating system remains) and the necessary infrastructure (steam methane reformers, carbon capture and storage) is developed. The conversion to hydrogen is assumed to take place over a shorter period (2035 to 2040). On the rest of the network, natural gas is gradually replaced by renewable gas from 2025 onwards.</td><td>Total consumption by fuel



</td></tr>
<tr><td>Number of homes</td><td colspan="2">1 million</td></tr>
<tr><td>Summary of impacts</td><td>Fuel use</td><td>

- Renewable gas is introduced and natural gas use in homes gradually declines to zero from 2025 onwards, although it is used as an input into the production of hydrogen (from 2035).
- Hydrogen is used by consumers in the Cork area.
- Use of other fossil fuels (coal, peat and oil) declines to 2050 as more homes are connected to the gas network.
</td></tr>
<tr><td></td><td>Gas networks</td><td>

- Infilling of gas network to reach 300,000 additional homes by 2050.
- Natural gas continues to be supplied (via the transmission network) as an input into the SMR process to produce hydrogen.
</td></tr>
<tr><td></td><td>Electricity networks</td><td>

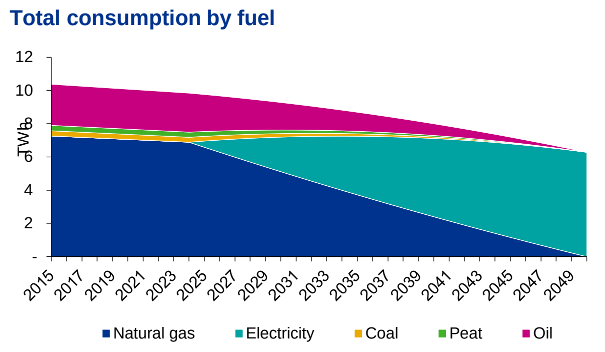
- Minimal impact (no additional capacity required to meet heat demand).
</td></tr>
<tr><td></td><td>Investment in energy production</td><td>

- Investment in anaerobic digestion plants to produce biomethane.
- Investment in hydrogen production (with CCS) in Cork area.
</td></tr>
<tr><td></td><td>Household conversion</td><td>

- No change in the 900,000 renewable gas homes and appliances (boiler, fire, cooker). Replacement in the 100,000 hydrogen homes.
</td></tr>
</table>

The electrification of heat scenario is outlined in table 3.5 below.

### Table 3.5: Electrification of heat

| | | |
|---|---|---|
| **Scenario Name** | Electrification of heat | |
| **Description** | Under this scenario, the current gas distribution network is decommissioned and households meet their heating needs through electricity. Households close to the current gas network (which are assumed to be connected in scenarios 1 and 2) also convert to electric heating. |  |
| **Number of homes** | 1 million | |
| **Summary of impacts** | **Fuel use** | ▪ Natural gas use in homes gradually declines to zero from 2025 onwards.<br>▪ Use of other fossil fuels (coal, peat and oil) declines to 2050 as more off-grid homes switch to electric heating. |
| | **Gas networks** | ▪ Gas distribution networks are gradually decommissioned from 2025 onwards. |
| | **Electricity networks** | ▪ Additional network capacity is required to meet increased peak demand. |
| | **Investment in energy production** | ▪ Additional electricity generation capacity is required to meet increased demand. Significant high cost additional electrical storage required to meet peak heat demand. |
| | **Household conversion** | ▪ Investment in additional electricity generation to meet demand. There are high costs and disturbance associated with heat pump installation and retrofit. |

## 3.4 Chapter Summary

- The key technologies available for decarbonising the residential heating sector in Ireland include hydrogen conversion, biomethane, biomass, heat networks, heat pumps, prosumer heating and insulation.
- Our assessment considers three scenarios including 100% gas decarbonisation using biomethane only, 100% gas decarbonisation using 90% biomethane and 10% hydrogen, and 100% electrification.
- The energy system is unlikely to develop according to one particular scenario and a mixture of potential scenarios is likely to emerge.
- Each scenario assumes a total of one million homes, including circa 700,000 homes currently connected to the gas network and 300,000 within close proximity that could be connected without major cost and disruption.
- For each scenario we have considered the key influences affecting the development of energy systems through to 2050, including new energy infrastructure requirements, the implications for gas and electricity networks and the cost implications at a household level.

# 4 Approach

We have analysed the scenarios based on an assessment of cost and feasibility. The key elements of the approach are set out below.

## 4.1 Our approach to cost assessment

We have estimated the net impacts of each scenario against a ‘Do Nothing’ baseline, where Ireland continues to meet domestic heat demand using a mix of energy sources prevalent today. We have measured and costed the following impacts:

- **Changes in fuel use:** Demand for fossil fuels for heat falls to zero by 2050, replaced by low carbon alternatives (renewable gas, hydrogen and electricity from low-carbon sources);
- **Gas networks infilling / decommissioning:** This estimates the costs of connection of homes in close proximity to the current network, or of the required safe distribution network decommissioning as households transition to electricity to meet their heating needs;
- **Electricity networks reinforcement:** Increases in network capacity will be required to meet peak demand in electrification of heat scenarios;
- **Investment in energy production:** The following low-carbon sources are deployed across our scenarios: AD, hydrogen production (via Steam Methane Reformers), CCS and low-carbon electricity; and
- **Household conversion costs:** when switching over to low-carbon heat, households will incur costs. These costs include buying new appliances, household re-wiring, and other energy efficiency measures. Given uncertainty around the exact level of these costs, we have developed high and low ranges for the household costs of conversion, rather than a set of point estimates. We have excluded costs for the introduction of electricity storage in the home to accommodate peak heat demand, however note this could add a very significant additional cost.

Our study is not a comprehensive ‘bottom-up’ study of costs but rather a ‘top down’ high level approach, using existing data and estimates (particularly from KPMG’s ‘2050 Energy Scenarios’ report).

Details of the key assumptions we have used are outlined in Appendix 1.

## 4.2 Our approach to feasibility assessment

In addition to estimating the costs of each scenario versus a ‘Do Nothing’ baseline, we have made a qualitative ‘feasibility assessment’ of each scenario which looks at the main technical and societal challenges of moving away from the current situation. The key parameters of the feasibility assessment are set out in Table 4.1 below.

**Table 4.1: Parameters of feasibility assessment**

| Theme | Area | Description |
|---|---|---|
| **Technical feasibility** | Technical feasibility | ▪ Have the technologies been deployed?<br>▪ Have the technologies been demonstrated at scale?<br>▪ Can the supply chain provide components and appliances on a commercial basis?<br>▪ Is there sufficient technical potential to meet demand? |
| | Meeting peak demand | ▪ Can the network meet winter peak demand? |

| Theme | Area | Description |
|---|---|---|
| **Customer acceptance** | Disruption of changeover | ▪ What level of disruption and inconvenience will consumers face in transition? |
| | Functionality | ▪ Do consumers perceive that heating methods will provide the functionality they need?<br>▪ Is the heat available on-demand? |
| | Space impacts | ▪ Will heating technologies take up a large amount of space in the home? |
| | Financeability | ▪ What investment will customers need to make? |
| **Societal and political acceptance** | New infrastructure | ▪ Will significant levels of infrastructure need to be built? |
| | Regulatory and market change | ▪ What changes to the market and the regulatory arrangements will be required? |

Our findings are summarised in Section 5 of this report.

## 4.3 Chapter summary

- We have analysed each scenario based on an assessment of cost and feasibility.
- The cost assessment considers the impact of changes in fuel use, gas networks infilling / decommissioning, electricity networks reinforcement, investment in energy production and household conversion costs.
- The feasibility assessment considers the challenges of moving away from the current situation under the parameters of technical feasibility, customer acceptance and societal and political acceptance.

# 5 Findings

In this section we set out the results of our cost and feasibility assessments for each scenario. This is ordered as follows:

- **Section 5.1:** Gas Decarbonisation (Biomethane);
- **Section 5.2:** Gas Decarbonisation (Biomethane & Hydrogen); and
- **Section 5.3:** Electrification of Heat.

Costs are presented on both a total and per household basis. Each area of the feasibility assessment is given a red/amber/green rating, with red indicating significant concerns and green indicating little/no concerns.

## 5.1 Gas Decarbonisation (Biomethane)

### 5.1.1 Cost assessment

In this scenario, AD biomethane production facilities are developed to produce low-carbon gas for injection into the gas network and use of natural gas declines out to 2050. Additional costs are incurred to extend the gas network to 300,000 additional homes. The costs of building and operating AD facilities more than outweigh the savings from reduced natural gas use (reducing to zero over time), reflecting the higher cost of renewable gas. Household adaptation costs are low in this scenario, reflecting the compatibility of renewable gas with current appliances and systems running off natural gas. The cost assessment also includes energy efficiency measures (insulation) installed at the time of conversion.

**Table 5.1: Gas Decarbonisation (Biomethane) – costs (total and per household), discounted, current prices**

| Incremental Costs | Costs (€ million in 2016) | | Household Costs (€ in 2016) | |
|---|---|---|---|---|
| | **High** | **Low** | **High** | **Low** |
| **Energy Production - capital expenditure** | | | | |
| Electricity generation | - | - | - | - |
| Hydrogen SMR facilities | - | - | - | - |
| Biomethane facilities | 1,200 | 1,200 | 1,200 | 1,200 |
| **Energy Production - operational expenditure** | | | - | - |
| Natural gas usage (including in SMRs) | (1,000) | (1,000) | (1,000) | (1,000) |
| Electricity generation | - | - | - | - |
| Biomethane facilities | 3,100 | 3,100 | 3,100 | 3,100 |
| ***Net consumer cost change from change in energy production*** | **3,300** | **3,300** | **3,300** | **3,300** |
| **Networks** | | | | |
| Gas networks infilling | 400 | 400 | 400 | 400 |
| Gas networks decommissioning | - | - | - | - |
| Electricity networks | - | - | - | - |
| **Household and commercial adaptations** | 3,900 | 1,600 | 3,900 | 1,600 |
| **Total** | **7,600** | **5,300** | **7,600** | **5,300** |

*The table above outlines the incremental costs of Scenario 1 compared to a Base Case scenario where Ireland continues to meet heat demand with the fuels it uses today. We have distinguished between three types of cost: 1) costs due to changes in energy production; 2) costs due to changes in network use; 3) costs for households to switch to new heat technologies.*

*All category 2) and 3) costs in the Scenario are additional to Do Nothing, since Do Nothing involves no changes to how networks are used or to the heat technologies households use. In category 1 there is a mixture of costs and savings versus Do Nothing: while building and running energy production facilities to produce low-carbon heat will involve costs which will be passed on to consumers through bills, they will no longer need to purchase natural gas as they do today. The Net consumer cost line shows the cost to consumers from changes in energy production, net of the savings from lower natural gas use.*

### 5.1.2 Feasibility assessment

The table below sets out the main considerations for this scenario:

**Table 5.1: Gas Decarbonisation (Biomethane) - feasibility assessment**

| Area | Consideration | Observations |
|---|---|---|
| **Technical** | Feasibility of fuels | ▪ Biomethane production from anaerobic digestion is considered a proven technology, with significant deployment across Europe, as well as a number of large scale plants already operational in Ireland and Northern Ireland.<br>▪ While Ireland has yet to inject biomethane into the gas network, this is a proven technique. GNI is currently constructing the first Gas Grid Entry Hub in Cush Co. Kildare, which will facilitate gas collection from up to six remote biomethane AD facilities for central injection.<br>▪ The principal feedstock for AD plants in Ireland will be grass silage and agricultural wastes. Ervia is treating the EU's post-2020 Renewable Energy Directive as mandatory and as such, plants will have to ensure they meet the required blend between virgin crops and waste materials.<br>▪ Meeting the heat demand of homes on the network with biomethane will require the utilisation of a considerable quantity of grass silage and other agricultural feedstocks and wastes, which must be considered within the wider food and land use debate. |
| | Meeting peak demand | ▪ Gas networks can continue to meet peak demand as they do today. |
| **Customer acceptance** | Change over | ▪ Appliances that use natural gas can also use biomethane. |
| | Functionality | ▪ Appliances running off biomethane will offer the same flexibility. |
| | Space impacts | ▪ No additional space required. |
| | Financeability | ▪ While this is the lowest cost scenario considered, with the lowest cost conversion at a household level, the biomethane produced via AD remains a more expensive fuel than natural gas. Accordingly government subsidy will be required, or the public must accept higher gas costs as part of the transition to a low-carbon system. |
| **Societal/ political** | New infrastructure | ▪ New plants to produce biomethane will be required at scale. These plants will require large amounts of feedstock, principally wastes and grass silage. There is uncertainty around whether the supply of these feedstocks will be sufficient to produce enough biomethane to meet Ireland's heat demand[39]. Alternative feedstocks such as wood pellets and energy crops may be required in order to produce sufficient biomethane to meet Irish heat demand. Extensive use of energy crops in particular could lead to pressure on Ireland's arable resources, and see land potentially diverted away from food production. |
| | Changes to regulatory/market arrangements | ▪ A policy support mechanism (e.g. PSO or similar to the RHI in UK / Northern Ireland) will be required to encourage the use of biomethane, given it is not yet cost competitive with natural gas. |

[39] See SEAI, (2017), 'Assessment of costs and benefits of biogas and biomethane in Ireland'.

## 5.2 Gas Decarbonisation (Biomethane & Hydrogen)

### 5.2.1 Cost assessment

Natural gas use declines in this scenario, although it is still used in the production of hydrogen. Additional costs are incurred to extend the gas network to 300,000 additional homes, construct facilities to produce renewable gas and hydrogen, and to store the $CO_2$ by-product of the hydrogen production process. Household adaptation costs are higher than in our other gas scenario (see 5.1), reflecting the additional costs of installing new hydrogen appliances.

**Table 5.3: Gas Decarbonisation (Biomethane & Hydrogen) - costs (total and per household), discounted, current prices**

| Incremental Costs | Costs (€ million in 2016) | | Household Costs (€ in 2016) | |
|---|---|---|---|---|
| | High | Low | High | Low |
| **Energy Production - capital expenditure** | | | | |
| Electricity generation | - | - | - | - |
| Hydrogen SMR facilities | 400 | 300 | 400 | 300 |
| Biomethane facilities | 1,100 | 1,100 | 1,100 | 1,100 |
| **Energy Production - operational expenditure** | | | | |
| Natural gas usage (including in SMRs) | (800) | (800) | (800) | (800) |
| Electricity generation | - | - | - | - |
| Biomethane facilities | 2,700 | 2,700 | 2,700 | 2,700 |
| ***Net consumer cost change from changes in energy production*** | **3,400** | **3,300** | **3,400** | **3,300** |
| **Networks** | | | | |
| Gas networks infilling | 400 | 400 | 400 | 400 |
| Gas networks decommissioning | - | - | - | - |
| Electricity networks | - | - | - | - |
| **Household and commercial adaptations** | 4,200 | 1,800 | 4,200 | 1,800 |
| **Total** | **8,000** | **5,500** | **8,000** | **5,500** |

*The table above outlines the incremental costs compared against that of the base case scenario. These costs have been split between capex, opex, network costs and costs of household adaption. Electricity generation has 0 operating expenditure, due to the use of low operational cost renewables. Natural gas usage is a net benefit, due to decreased use of fuel against that of the base case scenario. The costs of Hydrogen SMR facilities is included in that of natural gas usage.*

## Feasibility assessment

The table below sets out the main considerations for this scenario:

### Table 5.4: Gas Decarbonisation (Biomethane & Hydrogen) - feasibility assessment

| Area | Consideration | Observations |
|---|---|---|
| **Technical** | Feasibility of fuels | ▪ The feasibility of biomethane is as per Table 5.2 above for scenario 1.<br>▪ Hydrogen is not yet proven at a mass market level. Gradual roll-out and testing will need to be conducted before it is rolled-out at scale. All of the components needed for Hydrogen conversion can be competitively sourced from a substantial variety of suppliers based within the EU. This ranges across both gas production and use.<br>▪ Large CCS facilities needed to store the carbon produced by the steam methane reformer process are not currently widely used. However experience is growing with over 17 projects already constructed worldwide and a further four under construction[40]. Hydrogen production by SMR is an established technology in worldwide use. |
| | Meeting peak demand | ▪ Gas networks can continue to meet peak demand as they do today. |
| **Customer acceptance** | Change over | ▪ Appliances that use natural gas can also use biomethane. A new boiler will be required to use hydrogen. |
| | Functionality | ▪ Appliances running off biomethane or hydrogen will offer the same flexibility as current appliances. |
| | Space impacts | ▪ No additional space required. |
| | Financeability | ▪ Consumers using hydrogen will need to replace their existing boilers and gas appliances, which will involve a relatively modest upfront cost. Nevertheless even this modest conversion cost will be a challenge for many lower income customers. In the UK, it has been suggested to socialise the costs in relation to the potential conversion of Leeds to hydrogen heating across all UK users[41]. |
| **Societal/ political** | New infrastructure | ▪ The infrastructure required for biomethane is as per Table 5.2 above for scenario 1.<br>▪ Much of the difficulty and disruption of building new network infrastructure, particularly digging up urban streets, is avoided.<br>▪ New SMR plants fitted with CCS, or electrolysis plants, will be needed to produce low-carbon hydrogen. A $CO_2$ transport and storage network in particular is a complex technical and commercial undertaking which will require a number of $CO_2$ emitters (it is unlikely to be financeable if it is servicing only the SMR facility). |
| | Changes to regulatory/market arrangements | ▪ A new regulatory model will be required to finance / operate a CCS network.<br>▪ A policy support mechanism (similar to the RHI in UK/Northern Ireland) will be required to encourage the use of biomethane and hydrogen, given they are not yet competitive with natural gas. |

[40] https://www.globalccsinstitute.com/projects/large-scale-ccs-projects.

[41] Page 251, Northern Gas Networks, 'H21 Report'.

## 5.3 Electrification of heat

### 5.3.1 Cost assessment

Increased demand for electricity requires additional generation capacity, as well as investment in the electricity network, in order to ensure peak demand can be met. Natural gas declines to zero in this scenario and there are costs associated with the decommissioning of the gas distribution network as electricity becomes the principal source of domestic heat. Household adaptation costs are higher than in scenarios where gas continues to be used for heating. This reflects the extensive adaptation required to convert homes that currently use gas to electric heating.

**Table 5.5: Electrification of heat - costs (total and per household), discounted, current prices**

| Incremental Costs | Costs (€ million in 2016) | | Household Costs (€ in 2016) | |
|---|---|---|---|---|
| | **High** | **Low** | **High** | **Low** |
| **Energy Production - capital expenditure** | | | | |
| Electricity generation | 1,800 | 1,800 | 1,800 | 1,800 |
| Hydrogen SMR facilities | - | - | - | - |
| Biomethane facilities | - | - | - | - |
| **Energy Production - operational expenditure** | | | | |
| Natural gas usage (including in SMRs) | (1,000) | (1,000) | (1,000) | (1,000) |
| Electricity generation | - | - | - | - |
| Biomethane facilities | - | - | - | - |
| ***Net consumer cost change from changes in energy production*** | **800** | **800** | **800** | **800** |
| **Networks** | | | | |
| Gas networks infilling | - | - | - | - |
| Gas networks decommissioning | 300 | 250 | 300 | 250 |
| Electricity networks | 600 | 500 | 600 | 500 |
| **Household and commercial adaptations** | 17,900 | 12,800 | 17,900 | 12,800 |
| **Check** | | | | |
| **Total** | **19,600** | **14,350** | **19,600** | **14,350** |

*The table above outlines the incremental costs compared against that of the base case scenario. These costs have been split between capex, opex, network costs and costs of household adaption. Electricity generation has 0 operating expenditure, due to the use of low operational cost renewables. Natural gas usage is a net benefit, due to decreased use of fuel against that of the base case scenario. The costs of Hydrogen SMR facilities is included in that of natural gas usage.*

### 5.3.2 Feasibility assessment

The table below sets out the main considerations for this scenario:

**Table 5.6: Electrification of heat- feasibility assessment**

| Area | Consideration | Observations |
|---|---|---|
| **Technical** | Feasibility of fuels | ▪ Electric heating technologies are all technically proven, albeit there can be significant shortfalls in actual annual efficiency versus laboratory tests.<br>▪ Given this technology requires electricity to operate, its decarbonisation potential will be impacted by the extent to which the incoming electricity has been produced from renewable sources. |
| | Meeting peak demand | ▪ New electricity capacity will be required to meet peak demand. This is especially challenging since both most likely renewable sources, wind and solar, are intermittent.<br>▪ Electrical storage provides an option, but is an expensive means of inter-seasonal storage and is not currently deployed at scale in Ireland. |

| Area | Consideration | Observations |
| --- | --- | --- |
| **Customer acceptance** | Change over | ▪ Change to electric heating will require new appliances and rewiring, as well as significant upgrades to household insulation and efficiency levels.<br>▪ Many smaller properties may not have room for an Air Source Heat Pump.<br>▪ Transition in an area can be gradual - gas network can be maintained until final properties are converted - although costs of gas network will be met by a diminishing number of consumers. |
| | Functionality | ▪ Air source heat pumps are effective continuous sources of heating but do not offer the same instantaneous 'on demand' heat as a gas boiler and are less effective in particularly cold temperatures. This leads to continuous heating rather than 'morning and evening' bimodal heating. This increases average internal temperatures and thus overall energy demand. Hot water supply is limited by tank size, thereby limiting 'on demand' hot water. |
| | Space impacts | ▪ Heat pumps will require a certain amount of space (e.g. a small outside space or garden) to operate efficiently. A sufficient size DHW tank will also require significant space. The average property may not have the space available, particularly in more urban areas. |
| | Financeability | ▪ The cost of switching to electrical heating appliances is significant, and will provide an upfront financing challenge. Some kind of subsidy and assistance is likely to be required, particularly for vulnerable and / or fuel poor customers.<br>▪ As well as the financial cost, this will involve substantial disruption for consumers. Works may take up to six weeks, involve a number of different sub-contractors onsite and require replacement and re-decoration around vents and windows[42]. |
| **Societal/ political** | New infrastructure | ▪ Increased peak demand will require substantial investment in electricity networks. This will involve significant amounts of work in built up areas, and consequent disruption. |
| | Changes to regulatory/market arrangements | ▪ This can be delivered under current regulatory arrangements. |

[42] http://tippenergy.ie/wp-content/uploads/2017/05/Fact-Sheet-Deep-Retrofit.pdf.

## 5.4 Chapter summary

**Scenario 1: Gas Decarbonisation (100% Biomethane)**

- Biomethane production using AD is a proven technology but will require AD plants to be built at scale and a considerable proportion of Ireland's waste and grass silage will be required as feedstock.
- The costs of building and operating AD facilities more than outweigh the savings from reduced natural gas use. The higher cost of biomethane must be borne by consumers.
- Minimal household adaption is required, with appliances that use natural gas also compatible with biomethane.
- A policy support mechanism will be required to encourage the use of biomethane.

**Scenario 2: Gas Decarbonisation (90% Biomethane & 10% Hydrogen)**

- Hydrogen is not yet proven at mass market level and large CCS facilities for $CO_2$ storage are not currently widely used.
- Additional costs will be incurred to produce renewable gas and hydrogen and to store the $CO_2$ by-product of the hydrogen production process.
- Higher household adaptation costs will be incurred to install new hydrogen appliances.
- A policy support mechanism will be required to encourage the use of biomethane and hydrogen.

**Scenario 3: Electrification of heat**

- Electric heating technologies are all technically proven. However the decarbonisation potential of electrification will depend on the extent to which electricity is from renewable sources.
- Increased demand for electricity will require additional generation capacity and investment in the electricity network. Costs will also be incurred with the decommissioning of the gas distribution network.
- Extensive adaption will be required to convert homes from gas to electric heating, including rewiring and insulation. Heat pumps will also require additional space.
- A subsidy will likely be required to assist with upfront financing costs.

# 6 Conclusions

## 6.1 Scenario comparison

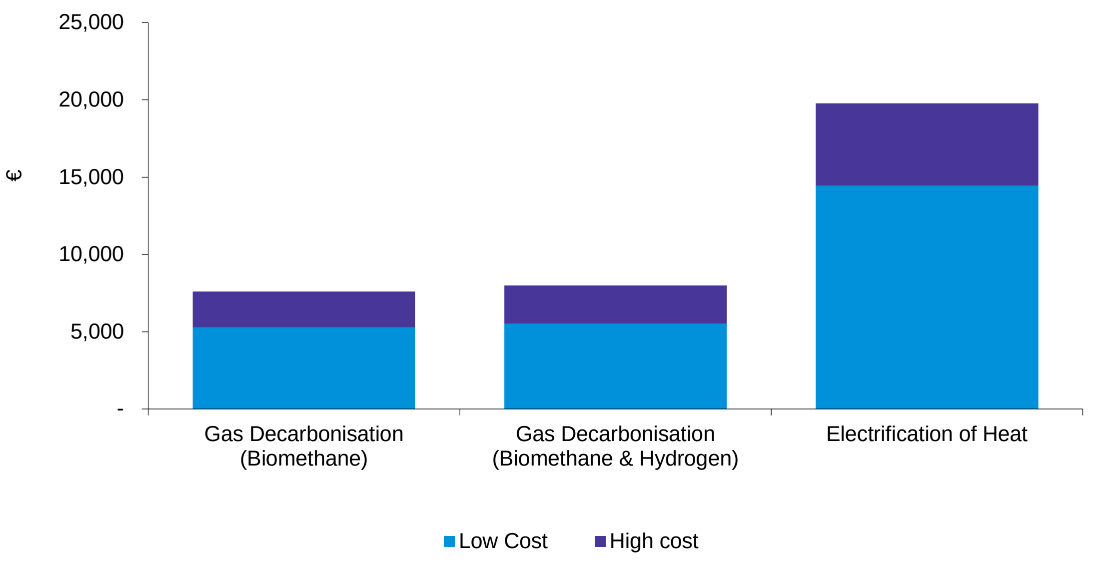
### 6.1.1 Cost

The chart below summarises how the scenarios compare in terms of net overall cost per household. How much of this cost is ultimately borne by the householder will depend on how the decarbonisation strategies are implemented by the Irish Government.

It is clear that the scenarios where renewable gas is used for heating are significantly lower cost than the electrification of heat scenario, with a per household cost of roughly one-quarter to one-third of that of the electrification of heat scenarios.

**Figure 6.1: Cost comparison between scenarios**

**Cost per household (€), total costs (capital investment and fuel) to 2050, discounted, current prices**

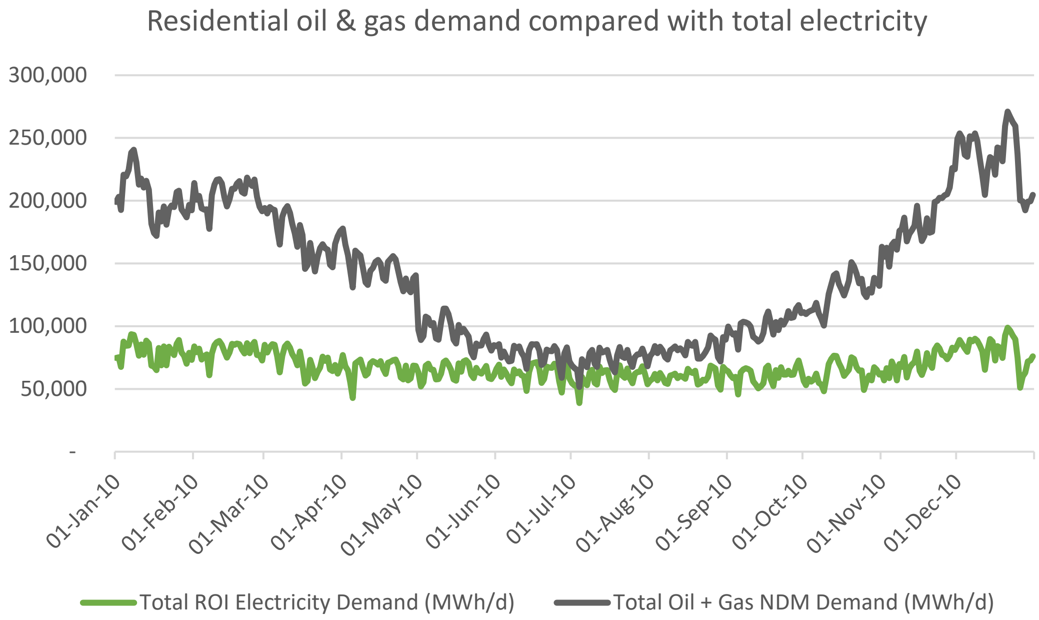



There are two major factors that contribute to the higher cost for the electrification of heat scenario.

1. **Peak Demand**

The electrification scenario includes costs for a significant amount of additional grid capacity on the electricity network in order to help meet increased peak demand.

As outlined on the graph below, while annual electricity demand is fairly consistent, there is very significant peak heating requirements in the heating sector which, while currently addressed by gas heating, will be very expensive to accommodate using electricity capacity or storage.




Source: GNI

Furthermore, since heat demand cannot be shifted (it is needed at peak times and when the weather is cold), an energy system with a high level of intermittent renewables penetration (as is being implemented in Ireland[43]), will require sources of flexibility. Our scenario does not explicitly factor in all potential additional costs of providing the required flexibility e.g. investment in electricity storage, smart meters or alternative smart grid solutions and investment in flexible low-carbon generation sources such as Combined Cycle Gas Turbines (CCGT) with CCS.

### 2. Household Adaptions

The costs of household adaptation for electrification are much higher than the low-carbon gas scenarios. Whereas decarbonised gases are typically compatible with the gas boilers and heating systems used today, electric heating will require new appliances (in particular heat pumps) and extensive re-wiring. In addition, heat pumps require highly energy efficient homes to maximise their effectiveness, which necessitates additional significant investment in insulation on top of appliances and rewiring. The necessary investment at a household level raises issues of affordability, particularly for lower-income households with limited access to capital.

[43] Government policy requires 40% of Ireland's electricity to come from renewable sources, principally wind, by 2020 in order to meet its EU-mandated renewable energy target.

## 6.2 Comparative feasibility assessment

The table below summarises the level of feasibility concerns across the different scenarios.

**Table 6.1: Comparative feasibility assessment of the scenarios**

| Area | Consideration | 1. Gas Decarbonisation (Biomethane) | 2.Gas Decarbonisation (Biomethane & hydrogen) | 3. Electrification of Heat |
|---|---|---|---|---|
| **Technical** | Feasibility of fuels | | | |
| | Meeting peak demand | | | |
| **Customer acceptance** | Change over | | | |
| | Functionality | | | |
| | Space impacts | | | |
| | Financeability | | | |
| **Societal/ political** | New infrastructure | | | |
| | Regulatory Changes | | | |

Firstly, the gas network currently provides an effective way of meeting peak demand. If the gas distribution network was decommissioned, this ability to provide dispatchable energy at peak would have to be replicated by electricity networks. Major reinforcement of electricity networks would be a major infrastructure undertaking, and would involve significant disruption, including in built up urban areas. In addition, new sources of flexibility e.g. batteries, would need to be integrated into the system to ensure heat demand can always be met in a system with high levels of renewables penetration.

Secondly, at a household level, converting to electric heating involves a considerably greater level of disruption than moving from one gas source to another. Converting to electric heating will require a fundamental re-working of household energy systems. A complete deep retrofit of each home will be required, including stripping back all fixtures and fittings, rewiring the home, installing air tight insulation and underfloor heating, and installation of new appliances. This change will be disruptive, with a current estimate of conversion time of six weeks[44].

However, the gas scenarios are not without concerns from a feasibility perspective. Changing fully from natural gas to renewable gas / hydrogen will require major investment in technologies that are currently marginal or not present in Ireland (Anaerobic Digestion, Steam Methane Reformers, Electrolysis, Carbon Capture and Storage). In particular, there is uncertainty as to whether a sufficient level of Ireland's waste streams can be channelled into use as feedstocks by AD plants. In order to bring AD to commercial deployment at scale, the Irish Government will have to provide a level of funding commitment in the same way it does with renewable electricity technologies. Furthermore, the development of networks to transport and store the $CO_2$ emitted in the production of hydrogen by SMR plant will require new regulatory arrangements, as well as a significant degree of underwriting by the Irish Government[45].

[44] See http://tippenergy.ie/wp-content/uploads/2017/05/Fact-Sheet-Deep-Retrofit.pdf.

[45] This applies particularly to the storage element of projects, where liabilities will persist beyond the longest timeframes of private sector companies. Under the EU CCS Directive long term storage liability will be passed on to governments when 'all available evidence' suggests the $CO_2$ will be permanently contained. See ETI, 'Carbon capture and storage- mobilising private sector finance in the UK'

## 6.3 Overall conclusions

Our analysis suggests that gas networks can have a major role in providing reliable and affordable energy supplies for domestic heat to Irish consumers as the economy decarbonises. The use of low-carbon alternatives to natural gas means that consumers can continue to enjoy the flexibility and convenience that gas provides, whilst avoiding some of the costs and disruption that a switch over to electric heating would entail. However, there are significant challenges involved in the transition to low-carbon gas.

Our key conclusions are:

**Decarbonising the domestic heating sector will incur significant consumer cost, regardless of approach or technology**

Any decarbonisation pathway for domestic heat will create costs relative to a 'Do Nothing' scenario, where heat demand continues to be met by fossil fuels. Each of our three decarbonisation scenarios incur significant cost, which will ultimately be borne by consumers through higher renewable levies, higher energy prices or upfront capital investment in generating infrastructure and housing energy efficiency conversions.

Policy makers will have to demonstrate the rationale and benefit to consumers of accepting these higher costs to ensure sufficient public support and acceptance.

**Utilising low carbon biomethane within the existing gas network is the lowest cost way of decarbonising heat for homes connected to or in close proximity to the gas network**

Of our three scenarios, utilising low carbon biomethane within the existing gas network represents a lower cost alternative to either electrification or a biomethane / hydrogen mix.

Furthermore, our analysis also suggests that extending the gas network to the c.300,000 homes in close proximity to the existing gas network ('network infilling') represents a lower cost option than electrification for these homes. Our estimate of the cost per household of creating a low-carbon gas distribution network serving one million customers is roughly one-third of converting these properties to electric heat. This is before we consider energy storage which is likely to be required for electrification and which would add considerable expense.

**Low-carbon gas is the least disruptive way of decarbonising domestic heating**

Consumer acceptance is an important consideration in selecting a decarbonisation technology or scenario. At a household level, low carbon gas does not require the 'deep retrofit' needed to convert properties to electric heat (e.g. installation of underfloor heating / high levels of insulation), nor are new appliances or internal infrastructure required. Although a deep retrofit is not needed, Ervia and KPMG are including significant energy reduction measures in all houses connected to the network. Furthermore, the low carbon gas scenario does not require extensive network reinforcement to meet peak demand.

**Meeting heat demand through low-carbon gas will require extensive use of Ireland's natural resources and a very ambitious deployment of anaerobic digestion technology**

Producing the requisite quantities of renewable gas to meet domestic heating requirements will require the use of considerable quantities of grass silage feedstocks and agricultural wastes, as well as construction of significant AD processing facilities. While studies suggest we can source the required volumes without impacting current land use, Ireland's energy and food needs will need to be considered holistically to ensure the correct balance in land use.

**Low-carbon gas can be a highly secure decarbonised heat supply**

Ireland's gas networks are highly reliable, even in severe weather conditions where there can be a loss of electricity supply. Renewable gas, in particular biomethane, can provide an indigenous source of energy for the country at scale. Furthermore, the costs presented in this report do not reflect the value of the inherent flexibility of gas, nor the costs of ensuring that electricity supply is sufficiently flexible to provide heat on demand. With high levels of intermittent renewables being proposed for and implemented in Ireland, sources of reliable supply will be required to meet domestic heat demand.

**Hydrogen holds potential, but remains a developing technology**

While it holds significant potential to provide decarbonised gas, there are also considerable challenges to deploying low-carbon hydrogen as a heating fuel. The lowest cost method of producing hydrogen is through the SMR process. However, this produces $CO_2$ as a by-product, meaning that SMR units must be fitted with Carbon Capture kit and connected to a $CO_2$ transport and storage network. CCS networks are complex projects, with a range of risks that are difficult to manage. As a result of these complexities, there has been limited development of CCS projects globally to date.

**Development of the sector will bring significant societal benefit**

As well as assisting in the decarbonisation of the economy, the development of an indigenous anaerobic digestion industry has potential to transform large parts of Ireland's rural economy. Not only will it stimulate high value infrastructure investment across a decentralised and geographically disbursed rural area, it will also create and support significant construction and engineering roles within the wider economy.

**Policy Implications & Recommendations**

1. Recognition that the decarbonisation of heat in Ireland represents an important element of Ireland's overall decarbonisation strategy, and that appropriate policy support is introduced to support its implementation;

2. Adoption of a joined up approach across government to deliver biomethane decarbonisation including appropriate energy policy, planning policy, waste management policy and appropriate financial support mechanisms;

3. Ring fence the carbon tax on natural gas and use to support production of renewable gas;

4. Base Irish energy policy on total system costs to the consumer (including impact on consumer bills, consumer capital expenditure and the exchequer), rather than solely on costs to the Exchequer, as is currently the case;

5. Adopt the same approach to financially support the production of renewable gas as electricity by introducing a gas PSO levy. Alternatively, introduce biomethane grid injection within a renewable heat incentive scheme.

# Appendix 1 – Assumptions

| Assumption | Source |
|---|---|
| Per GW cost of new electricity transmission network capacity<br>High case: €317m/GW<br>Low case: €259m/GW | ▪ As in KPMG (2016) for ENA, '2050 energy scenarios' ('the UK study').<br>▪ Took the combined Regulated Asset Values (RAV) for each Transmission company for 2021 (last year of current price control) of Ofgem, RIIO-ET1 Price Controls Financial Model (PCFM).<br>▪ Divided this RAV by the peak electricity demand in 2021 according to the FES2015 Gone Green scenario forecast.<br>▪ Use this per GW figure to show costs of incremental investment in transmission network in each scenario. |
| Per GW cost of new electricity distribution network capacity<br>High case: €756m/GW<br>Low case: €619m/GW | ▪ As in the UK study.<br>▪ This is the sum of a) the incremental cost of reinforcing the electricity distribution network and b) the cost of reinforcing connections to properties.<br>▪ For a) we took the combined RAV for each distribution company for 2023 (the last year of current price control) from Ofgem's RIIO-ED1 PCFM.<br>▪ Divided this RAV by the peak electricity demand in 2023 according to the FES2015 Gone Green scenario forecast to give per GW figure.<br>▪ For b) we estimated connection reinforcement costs for residential and commercial properties informed by connection cost information published by Northern Power Grid and UKPN. We took a conservative approach and used figures at the lower end.<br>▪ We multiplied these reinforcement costs by the total number of residential and commercial properties in GB respectively.<br>▪ We divided this number by the peak electricity demand in 2014. This gives a cost per GW of peak of reinforcing connections. |
| Cost of gas networks in-filling<br>€805m | ▪ Provided by Ervia. |
| Cost of decommissioning the gas distribution network<br>High case: €467m<br>Low case: €382m | ▪ Based on the UK study and scaled down to reflect the smaller size of Ireland's gas networks.<br>▪ Estimated cost of decommissioning the distribution networks according to National Grid. Our high case and low case figures are 10% more and less than National Grid's figure.<br>▪ In scenarios where gas is no longer used, the cost of decommissioning part of the network is calculated as the fraction of this overall decommissioning cost. |
| Cost of biomethane energy from AD<br>€75/MWh | ▪ Levelised cost of energy produced by agricultural AD plants primarily utilising grass silage and slurry, and using road tankers to transport gas from the AD plant to gas injection facilities. Source: GNI estimate based on SEAI Report |
| Cost of additional electricity generation | ▪ Based on Department of Energy and Climate Change's (DECC) wholesale electricity price projection. |

| Assumption | Source |
|---|---|
| Time series data average approximately €70/MWh | ▪ These costs do not account for any additional costs to address the intermittency of renewable electricity sources e.g. batteries. |
| Cost of constructing natural gas to hydrogen SMR facilities<br><br>High case: €1,802m/GW<br><br>Low case: €1,474m/GW | ▪ As in the UK study.<br>▪ This figure is from research by Kiwa. It encompasses the full costs, including the costs of transporting the $CO_2$ produced by SMR facilities to storage facilities.<br>▪ This is used as the cost of producing hydrogen for use as a heating and cooking fuel in properties. (It does not include hydrogen for transport.). |
| Commodities cost (natural gas)<br><br>Time series data average c. €22/MWh | ▪ Based on BEIS natural gas price projection (https://www.gov.uk/government/collections/energy-and-emissions-projections). |
| Appliance change costs to electricity<br><br>High case: €35,000 per property<br><br>Low case: €25,000 per property | ▪ Based on SEAI/Tipperary Energy Agency study.[46] |
| Appliance change costs to hydrogen<br><br>High case: €14,135 per property<br><br>Low case: €8,465 per property | ▪ As in the UK study.<br>▪ A KPMG estimate of the average total cost of converting appliances to run off hydrogen instead of natural gas.<br>▪ Added to the cost of converting local networks.<br>▪ Additional energy efficiency costs of €3,200-7,700 added based on SEAI estimates: these cover attic and wall insulation and energy efficient heating controls. |
| Appliance change costs to bio-gas (from natural gas)<br><br>€3,200-7,700 per property | ▪ We assume that homes converting to renewable gas will install energy efficiency measures at the time of conversion (as per hydrogen conversion). |
| Energy efficiency change costs to bio-gas (from oil/peat/coal)<br><br>High case: €7,700 per property<br><br>Low case: €3,200 per property | ▪ Assumed that energy efficiency measures will be installed at the time of the conversion<br>▪ Cost of adapting appliances included in Network Infilling costs above |
| $CO_2$ Saving Calculations | ▪ Average Household consumes 11,000kWh per annum[(1)]<br>▪ Current household $CO_2$ emissions = 2.91m tns[(2)]<br>▪ AD[(3)] $CO_2$ emissions = 82.8 x 9,240 = 795k tn $CO_2$ (assuming 20% reduction in demand (excluding water heating) due to higher energy efficiency) |

[46] ESB Innovation and Tipperary Energy Agency (2016), 'Near zero energy residential buildings- how and why'.

| Assumption | Source |
|---|---|
| | ▪ Wind(4 & 5) $CO_2$ emissions = 13.5 x 2,904 = 39k tn $CO_2$ (assuming 40% reduction in demand (excluding water heating) due to higher energy efficiency<br><br>(1) Source: CRU "Review of Typical Domestic Consumption Values for Electricity and Gas Customers, 2017"<br>(2) Source: Energy in the Residential Sector 2018<br>(3) Ervia feedstock mix: 78% grass silage, 8% slurry, 11% waste, 3% crops (% of total biomethane by feedstock, giving $CO_2$ level of 82.8g $CO_2$/kWh<br>(4) Source: ClimateXchange "Lifecycle costs and carbon emissions of wind power", 2015, Av 13.5g $CO_2$/kWhe<br>(5) Using an air source heat pump, assumes 1Kwh electricity to produce 3kWh of heat kWh (Part L Building Control Regulations) |

# Glossary

| Term | Definition |
|---|---|
| **Anaerobic Digestion** | A biological process where organic matter is processed in the absence of oxygen to produce biomethane. |
| **Biogas** | Gas produced by anaerobic digestion. |
| **Biomethane** | Biogas which has been cleaned or purified to produce almost pure methane. |
| **Biomass** | Organic matter used as a fuel to produce energy. |
| **Carbon Capture and Storage** | The process by which waste carbon dioxide is captured from large point sources, transported to storage sites and deposited safely so it does not enter the atmosphere. |
| **Carbon Dioxide** | The main greenhouse gas, the majority of which is generated from the burning of fossil fuels such as coal, oil and gas. |
| **Combined Cycle Gas Turbine** | A system that uses both a gas and a steam turbine together to produce electricity. Waste heat from the gas turbine is routed to the nearby steam turbine, which generates extra power. |
| **Committee on Climate Change** | An independent, statutory body established under the Climate Change Act 2008 to advise the UK Government on emissions targets and preparing for climate change. |
| **Decarbonisation** | The reduction of greenhouse gas emissions produced as a result of energy use. |
| **Department for Business, Energy and Industrial Strategy** | A UK Government Department created in 2016 as the result of a merger between the Department of Energy and Climate Change and the Department for Business, Innovation and Skills. |
| **Electrification** | The use of electricity to produce heat. |
| **Electrolysis** | The process of chemical decomposition by passing an electric current through a liquid or solution containing ions. |
| **Energy Networks Association** | An organisation which represents the UK’s gas and electricity networks. |
| **Emissions Trading Scheme** | A scheme operated by the EU which sets a carbon price for emissions from large industry, power generation and energy intensive and civil aviation sectors. It works on a “cap and trade” principle, with a cap set on the total amount of certain greenhouse gases that can be emitted. Each participant can trade emission allowances and must surrender enough allowances each year to cover all of its emissions, otherwise fines are applied. |
| **Ervia** | The commercial semi-state multi-utility company responsible for Ireland’s national gas infrastructure through Gas Networks Ireland. |
| **Gasification** | The process of producing gas. |
| **Gas Networks Ireland** | A subsidiary company of Ervia that owns and operates the natural gas network in Ireland. |
| **Greenhouse Gas** | A variety of gases that contributes to global warming by absorbing infrared radiation. |
| **Heat Network** | A system of hot water pipes supplying heat to a building or buildings from a central source (this can be industrial heat, biomass or conventional oil and gas). |
| **Heat pump** | A device that absorbs heat from outside air or from the ground, which is then used in a property. |
| **Hydrogen** | A colourless, odourless and highly flammable gas. |
| **Natural gas** | A naturally occurring hydrocarbon gas mixture consisting primarily of methane. |
| **Network infilling** | The connection of homes (approximately 300,000 in Ireland) in close proximity to the existing gas network. |

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| **Office of Gas and Electricity Markets** | A non-ministerial government department and an independent National Regulatory Authority with the principal objective of protecting the interests of existing and future electricity and gas consumers in the UK. |
| **Photovoltaic** | The conversion of light into electricity |
| **Prosumer** | The production and use of heat energy by the one party. |
| **Renewable gas** | A biogas which has been upgraded to a quality similar to fossil natural gas. Renewable gas refers to a range of decarbonised gases which can be produced as a replacement for the existing natural gas utilised within the residential gas network |
| **Renewable Heat Incentive** | A UK Government scheme set up to encourage uptake of renewable heat technologies amongst energy users through financial incentives. |
| **Steam Methane Reformer** | A system that reacts steam at high temperature with a fossil fuel to produce hydrogen. |
| **Sustainable Energy Authority of Ireland** | Ireland's national energy authority established by the Government in 2002. |
| **United Nations Framework Convention on Climate Change** | An international environmental treaty adopted in 1992 as a framework for international cooperation to combat climate change. There are currently 197 parties to the convention. |

# Abbreviations

| Term | Definition |
|---|---|
| **AD** | Anaerobic Digestion |
| **BEIS** | The Department for Business, Energy and Industrial Strategy |
| **CCC** | The Committee on Climate Change |
| **CCGT** | Combined cycle gas turbine |
| **CCS** | Carbon Capture and Storage |
| **$CO_2$** | Carbon Dioxide |
| **COP** | Coefficient of Performance |
| **DECC** | Department of Energy and Climate Change (UK) |
| **DHW** | Domestic Hot Water |
| **ENA** | Energy Networks Association |
| **ETS** | Emissions Trading Scheme |
| **EU** | European Union |
| **GHG** | Greenhouse Gas |
| **GNI** | Gas Networks Ireland |
| **GW** | Gigawatt |
| **km** | kilometre |
| **ktoe** | Thousand tonnes of oil equivalent |
| **kW** | Kilowatt |
| **m** | million |
| **MWh** | Megawatt hour |
| **OFGEM** | Office of Gas and Electricity Markets |
| **PCFM** | Price controls financial model |
| **PV** | Photovoltaic |
| **RAV** | Regulated asset values |
| **RHI** | Renewable Heat Incentive |
| **SEAI** | Sustainable Energy Authority of Ireland |
| **SMR** | Steam Methane Reformer |
| **TWh** | Terrawatt hours |
| **UK** | United Kingdom |
| **UNFCCC** | United Nations Framework Convention on Climate Change |

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