On the road to a green energy UK: Integrated gas & electricity networks support the journey

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WALES&WEST UTILITIES

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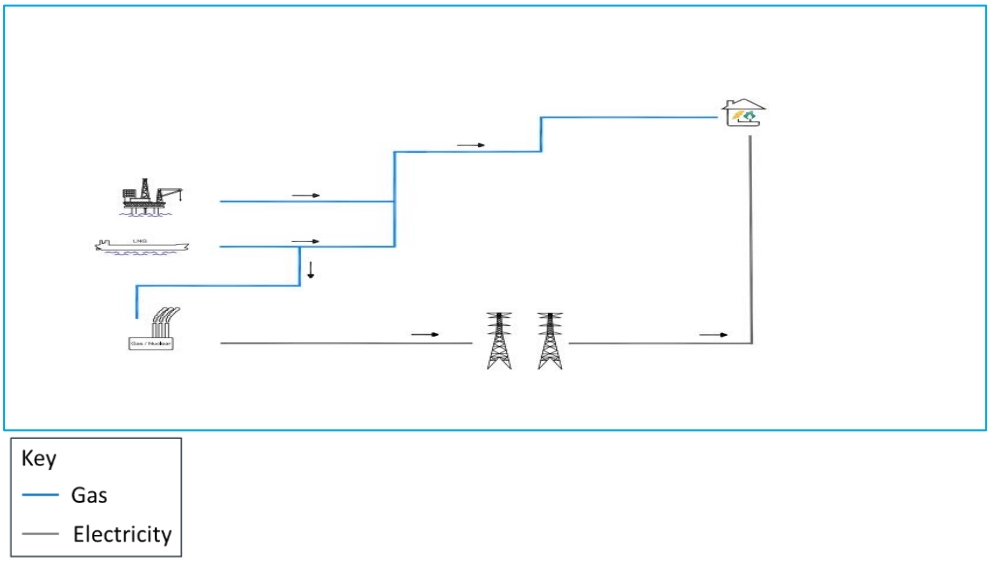
1.0 Background

There has been a shift change in the interaction between the gas and electricity networks – which is set to continue in the move to create a dynamic, flexible, integrated energy system to support a green energy UK.

Here we examine a new analytical model that simulates energy supply and demand balance and looks at how new hybrid heating systems offer cost effective, low carbon ways to keep homes and businesses warm.This research has been commissioned by Wales & West Utilities, the gas emergency and pipeline service operating across Wales & the south west of England.

2.0 Energy distribution systems – changing relationships

For decades, gas and electricity transmission and distribution systems have operated independently, with gas providing the heat source for most homes and businesses and electricity generation relying on nuclear, coal and gas.

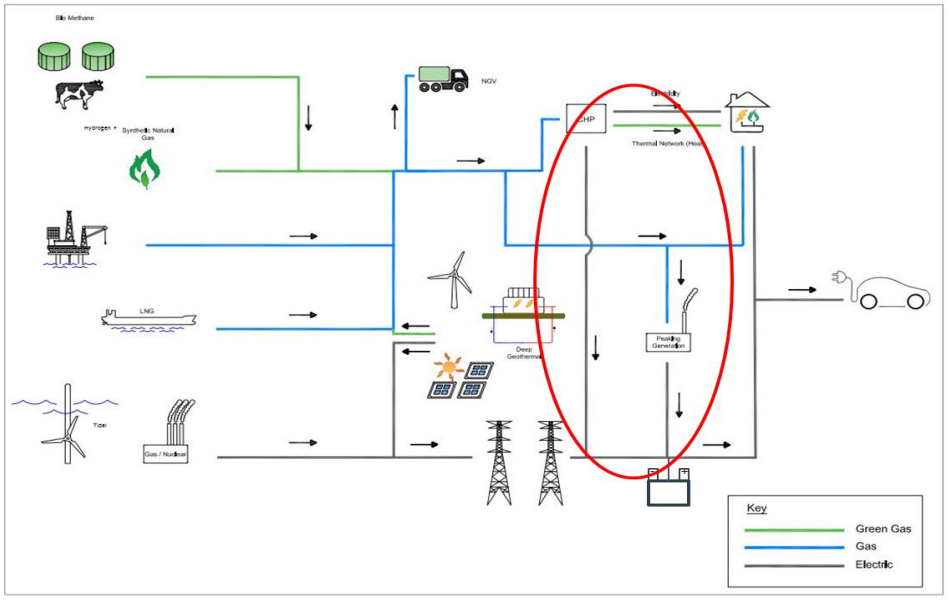


This has become more complex over the last decade, with the introduction of renewable sources of energy connecting to both networks - biomethane to the gas grid and wind & solar to the electricity grid.

There is a continuing rise in the number of businesses generating their own heat & power requirements, with the gas network providing increased amounts of gas to supply both power and heat requirements. Very recently there has been a sharp increase in enquiries from developers looking to connect gas-powered peaking plants to the gas distribution system.

Wales & West Utilities received over 300 enquiries in 2016, with 20 plants now connected or in progress.

With enquiries to utilise excess generation by feeding electrolysed hydrogen into the gas distribution system (power to gas), plus ever increasing gas and electrical transport, the networks have never been so connected, or indeed reliant on each other - on a cold winters' day, 80% of heat and power energy starting life traveling through the gas grid.



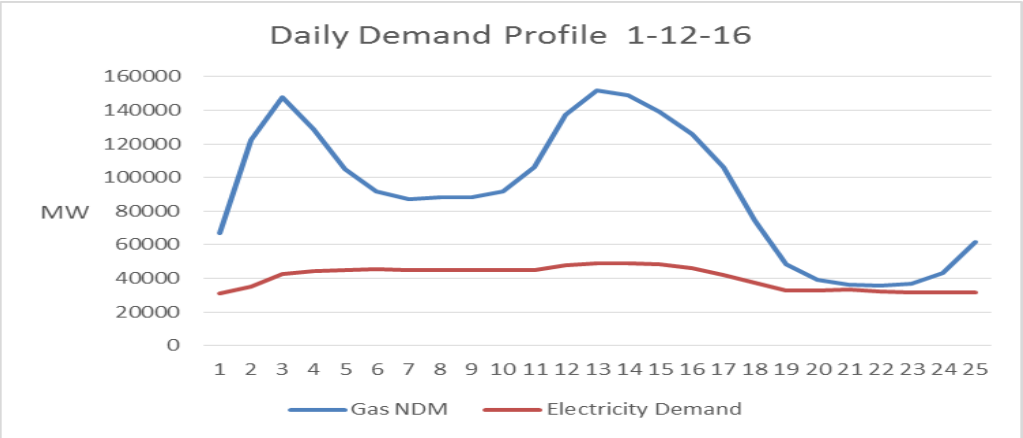
The 2020's – an integrated gas/electric energy network

As the networks continue to integrate, variation of demand and supply on the electricity network will have immediate impacts on the gas network. For example, where more electric vehicles are charged with intermittently-generated renewables, this creates larger demand swings on the electricity network, affecting demand on the gas distribution system as gas peaking plants respond to maintain capacity on the electricity network.

3.0 Modelling heat and power together – the Wales & West Utilities simulator

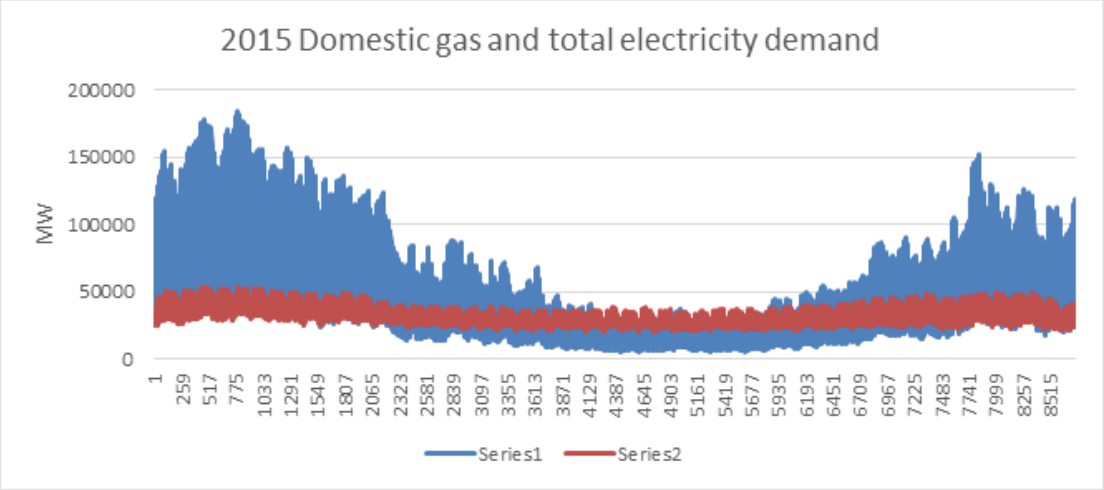
Recognising the current and future impact of the complex system emerging, Wales & West Utilities commissioned research to assess the operation of such a system, and subsequently developed the concept into a heat and power supply/demand simulator.

Energy demand follows a predictable daily profile, with both gas and electricity grids experiencing a morning and evening peak - even on a mild winters' day. However, when looked at together, electricity demand appears flat due to the scale of heat demand.



Demand profile on a mild winters day - 65% of 1:20 day

Seasonal demand is quite different, with electricity demand being near constant, but gas demand showing a very significant seasonal swing, in addition to the daily variance (above).



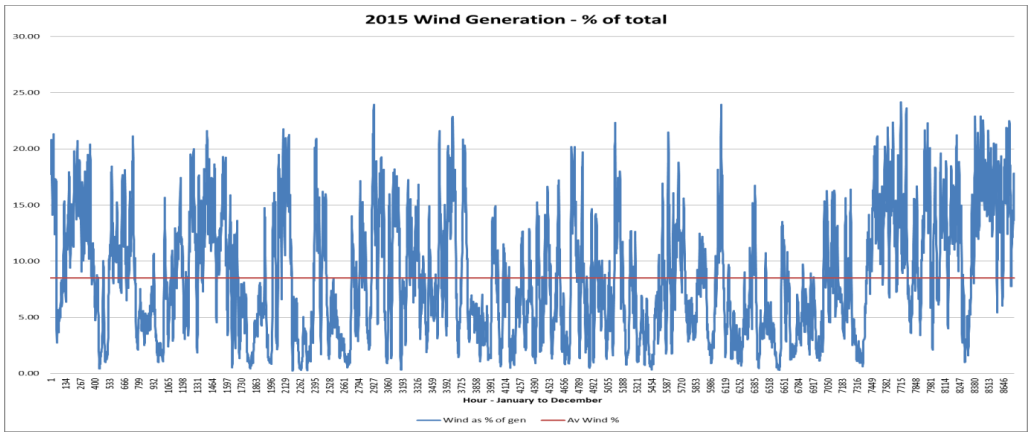
Domestic gas (blue) and electricity (red) for a mild year.

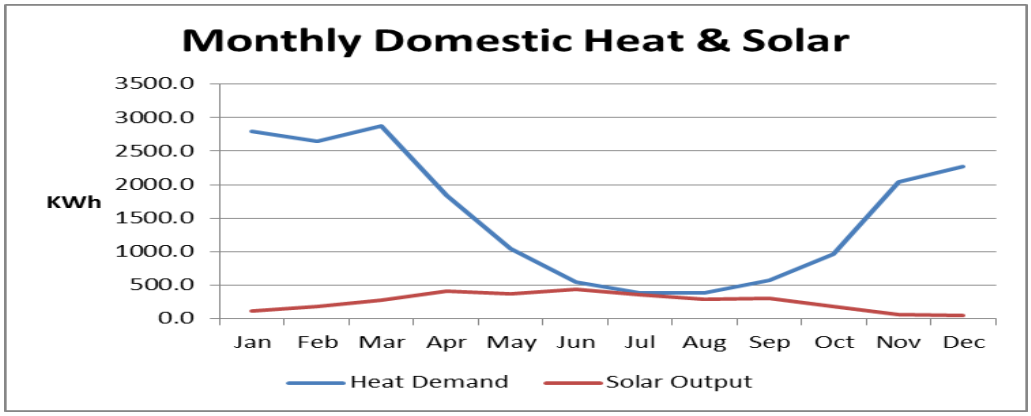
The energy system in the UK achieves security of supply by the utilisation of huge storage reserves in the gas pipe network to balance daily swing and seasonal storage and variable beach supplies (such as LNG).

Whilst demand is relatively straightforward, supply characteristics are now far more complex due to the decarbonisation of electricity utilising intermittent sources, such as solar PV and wind.

For example, the UK wind profile for 2015 provides a year round supply of energy - but its wide range of output creates challenges for energy balancing.

While solar output is less intermittent, it poses a great challenge in any heat scenario due to its low winter output, being around 100 times less on a typical winter day to that of a typical summer day in 2015 in south west England.





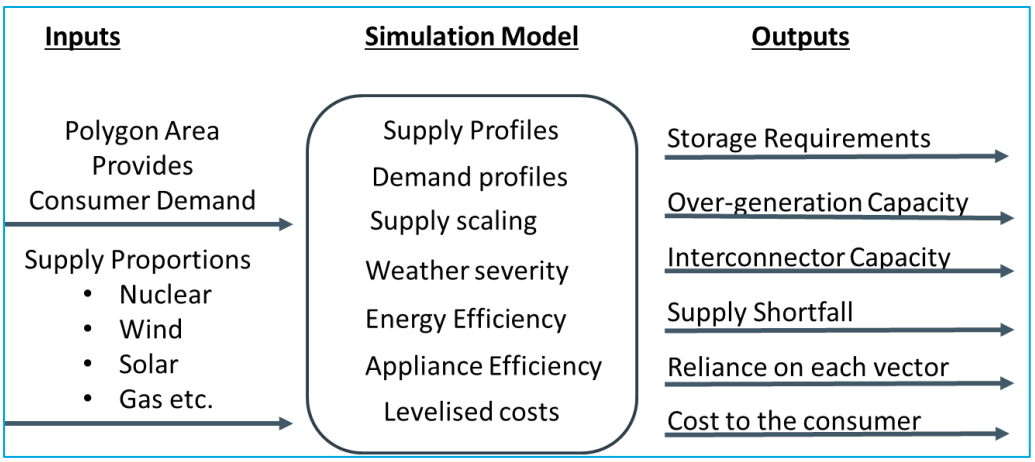
The challenge therefore is a model that:

- Adds heat and power demand together by hour/day/month
- Balances against the full range of supply options – wind, solar, nuclear, and gas.
- Determines interconnection requirements - storage or demand side response (interruption), to address in-balance.
- Is scalable i.e. can model a house, a town, a county, or a country.

The principle equation in the model is hourly demand minus hourly supply = imbalance, e.g.

- heat + power demand – wind – solar – nuclear = storage in/out

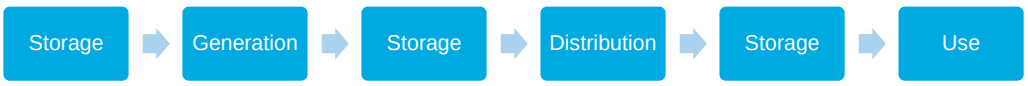
Peak identification indicates capacity (in GW) of interconnection, storage or demand side response, whilst a cumulative calculation indicates the size of storage if used in GWh.



The Wales & West Utilities/DeltaEE simulator

3.1. Cost Model

To assess the costs and investment required, a cost model was developed to assess the whole system cost, not just individual elements.



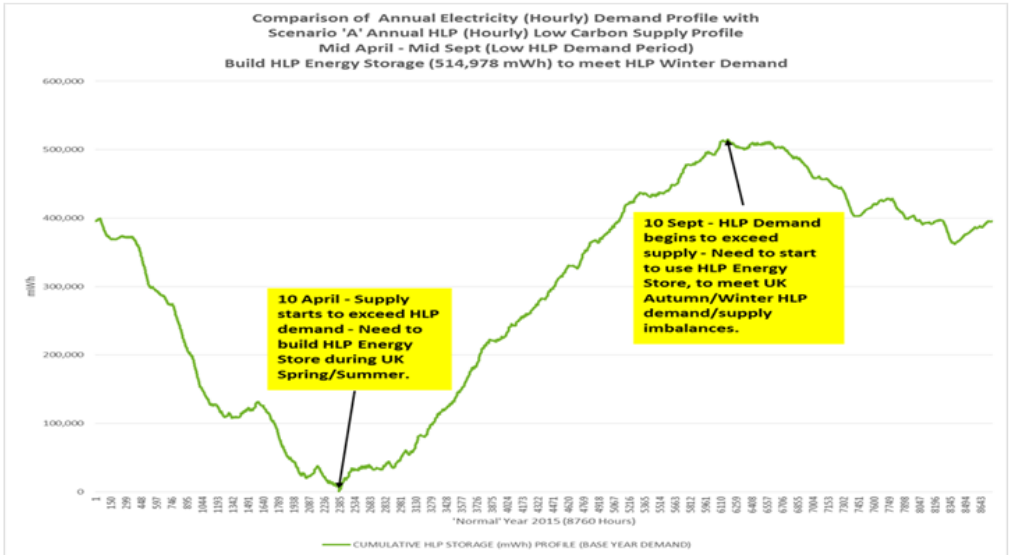
In this way, the cost to the consumer could be estimated, along with the cost per tonne of carbon abated.

4.0 Simulator Results

The simulator has been programmed and run for three scenarios, to date.

4.1. A renewable Cornwall

The energy simulator developed was used to evaluate proposals to create a totally renewable Cornwall, a project published as ‘The Cornwall Energy Island’. The research (previously explained in Gas International and published by Wales & West Utilities) highlighted that the use of renewable energy sources to providing heating, particularly solar energy, requires very large seasonal storage. Using a mix dominated by wind (50%) and solar (25%) required storage for Cornwall alone of 500 Gigawatt hours.



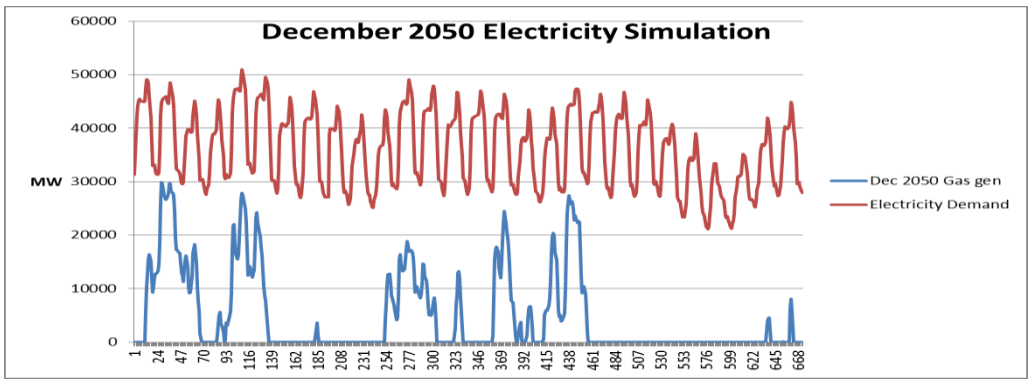
In summary, the evidence shows that the aptly named energy trilemma, of delivering energy in an affordable, secure and sustainable way, cannot be met by the electrification of heat.

4.2. Secure electricity generation into the future

During 2016 records were set for renewable generation - welcome news on the road to decarbonisation. Analysis of the data and projecting forward along an electricity generation decarbonisation pathway reveals that, whilst the volume of gas generation reduces substantially, the reliance on gas generation remains.

In December 2016, despite being the greenest Christmas Day, renewables (wind, hydro and solar) provided 11.5% of generation, nuclear 22.3% and gas, 47%. The remainder included interconnectors and coal was still utilised every day. The peak gas use (on 16th December) saw generation rely on gas for 61% of capacity.

In December 2050, even scaling up wind to 80GW of capacity sees the reliance on gas only dropping to 67%, due to the lack of solar output and the intermittency of wind, even across all locations of the UK.



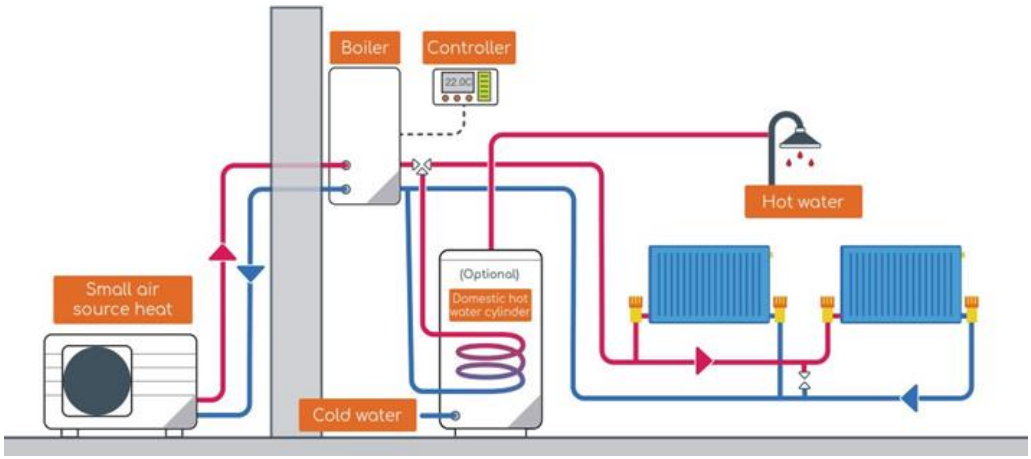
Simulation of 2050 with December 2016 weather

The simulation does calculate alternatives such as battery storage. For the UK – it requires 1,500,649 MWh of Storage, calculated at an investment cost of £1.65Tn. The storage would be required for at least four days, ruling out short term storage and, for example, using the batteries of electric vehicles.

4.3. Hybrid Heating

The third scenario simulated is a unique project jointly sponsored by Western Power Distribution and Wales & West Utilities by PassivSystems. This £5m innovation project will address market barriers to hybrid heating system adoption and is titled project FREEDOM.

There are a number of types of hybrid heating, with project FREEDOM utilising one of the simplest forms - a small electrical heat pump linked to an existing domestic gas central heating system. This has the advantage of a much lower installation cost compared to fully electrical heat pumps and utilises the gas infrastructure in its most effective mode – meeting peak heat demand.



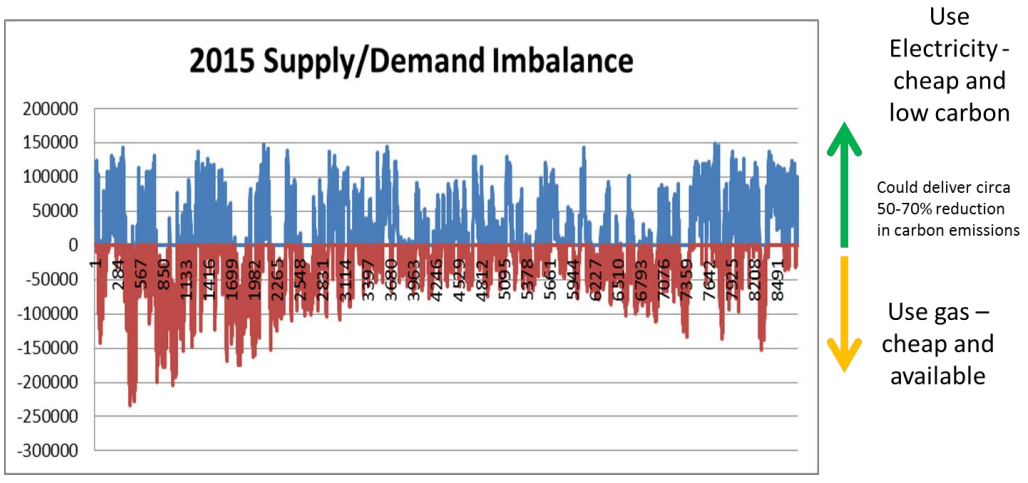
Typical hybrid heating system

The following project objectives have been identified and will be analysed by installing around 75 installations in a variety of homes in south Wales:

- Use the ability of the hybrid system to switch between gas and electric load
- Demonstrate the consumer, network, carbon and energy system benefits
- Address the elements of the energy trilemma.

In simple terms the system will enable the future use of excess renewable generation for heating, but having the back up of gas heating when renewables are absent, for example in typical winter anticyclonic weather conditions.

The Wales & West Utilities energy simulator has provided an early indication of how the system could work. It identified that in future with the forecasted renewable generation mix, if electricity was used for background heating when generation was both green and cheap, and gas was used the rest of the time, a carbon reduction of 50% could be achieved.

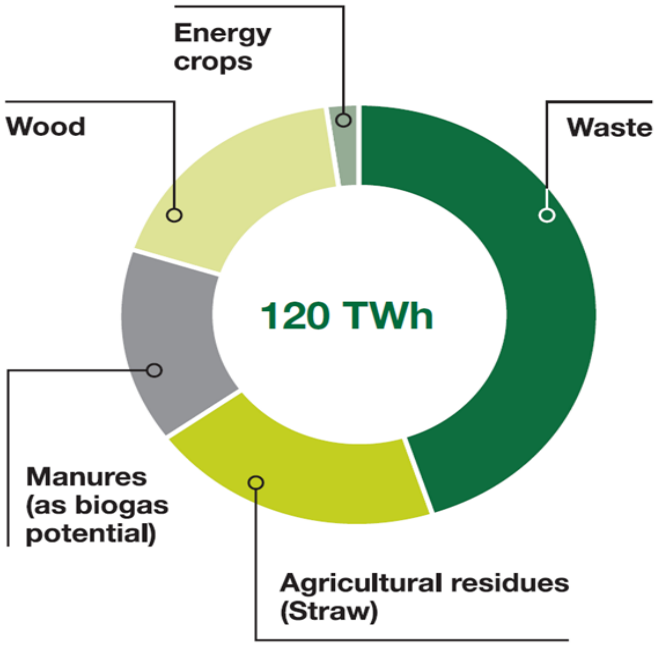


Hybrid heating simulation

5.0 Next Steps

5.1. Green gas – bioSNG

A key feature for future modelling is the availability of green gas, previously thought to be limited by feedstock supply, and this is where another innovative project by National Grid Gas Distribution is featuring practical decarbonisation. BioSNG is methane produced from domestic waste, overcoming the limitation of feedstock that could restrict the production of biomethane via anaerobic digestion.



UK Feedstock potential – National Grid

The £25m project, with Advanced Plasma Power and Progressive Energy, will see a commercial facility that will be the world's first grid-connected full chain waste to SNG facility operating under commercial conditions. In another innovative

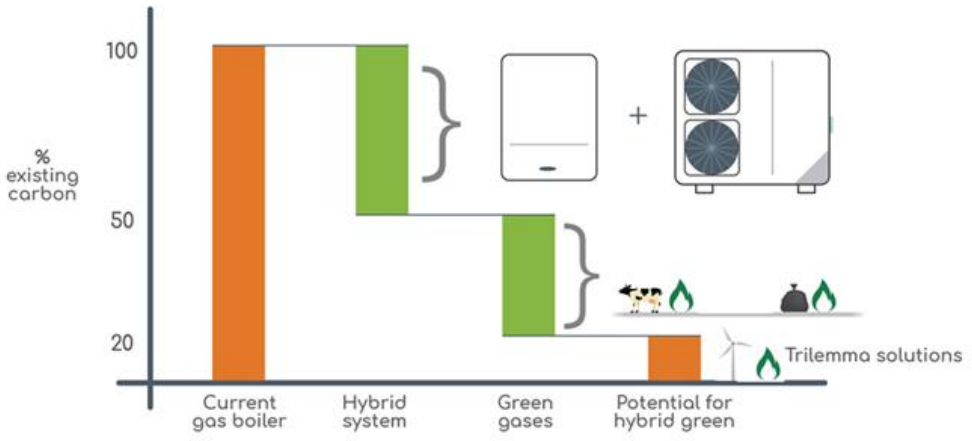
move, the gas will be used to help decarbonise transport with a local haulage firm who will be converting HGV's to compressed natural gas. The latest phase will produce enough gas to power 75 freight vehicles.

With access to waste as a feedstock, in addition to other bio waste feedstocks, National Grid has estimated that 120 TWh of gas could be produced per annum, sufficient to meet 33% of domestic demand by bioSNG and biomethane.

6.0 The future of heat

A vision of the future is emerging - if the full electrification of heat comes with excessive cost, could a comb ination of hybrid heating with green gases, including hydrogen, be the solution that no one has published? This could complement potential hydrogen cities such as Leeds, which is being investigated by Northern Gas Networks, supported by Wales & West Utilities, to demonstrate how hydrogen could heat and power major cities across the UK.

Imagine the 2030's, when newly built renewable electricity generation at times exceeds demand and an all PE gas network transports low carbon gases to homes which have hybrid heating systems. This low operational cost gas network utilises the best of both energy vectors. The hybrid heating system reduces the carbon intensity of heating homes when too much renewable generation is produced, and the green gases further reduce the carbon footprint to deliver secure and affordable energy when renewable electricity fails.



Hybrid Green – potential 80% carbon reduction

The same gas network supports intermittent renewable electricity, by providing standby power generation, and hence the gas network is responsible for ‘keeping the lights on’, just as it is now. This leads to the conclusion that the network of the future is not a gas grid and an electricity network, but an integrated energy system, working in tandem meeting the energy trilemma.

The model is currently being further developed to consider the impacts of decarbonising transport along with new renewables such as tidal lagoons.

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A Hybrid Hydrogen future

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