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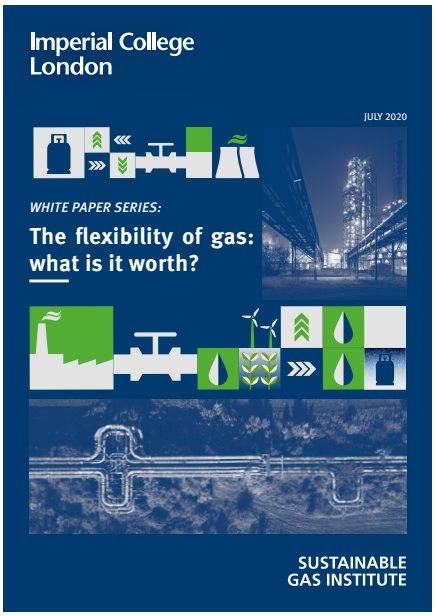
The flexibility of gas: what is it worth?



The aim of the white paper is to investigate the evidence surrounding the flexibility provided by gas and gas networks and the cost of, and value provided by gas to the future energy system.

There is an increasing debate regarding the use of gas networks in providing support for the decarbonisation of energy systems. The perceived value of gas "vectors" – encompassing natural gas, hydrogen and biomethane – is that they may provide flexibility, helping to support daily and seasonal variation in energy demand, and increasingly intermittent electricity supply as renewable electricity generation increases as a proportion of the electricity mix.

Arguments in support of gas suggest that electricity systems will find it difficult to maintain flexibility on their own, whilst also reducing greenhouse gas emissions and increasing production to meet new demand for heating and transport. Gas, on the other hand, is expected to provide flexibility at relatively low cost, and may be produced and used with relatively low greenhouse gas emissions.

The gas network provides flexibility in a number of different ways, including the ability to shift the timing of supply over short timescales through flexibility in pipelines (linepack) and short-term storage; as well as the ability to move supplies over longer timescales through seasonal gas storage, as well as imports from other countries through interconnector pipelines or LNG markets.

If we are to maintain gas networks in the future, their design will fundamentally change in order to meet climate change targets. These changes will develop over time and will have a changing and fundamental impact on flexibility provision. Understanding these changes and their impact on flexibility and value is important to future emissions reduction and the development of robust systems with which to deliver it.

Key findings

1 Gases such as natural gas, hydrogen and biomethane are inherently storable and transportable energy carriers and can be a valuable component of a flexible future energy system.

- Natural gas has delivered seasonal energy demand at an additional cost of less than 0.5 p/kWh in the UK, Europe and the United States between 2015 and 2020.
- The value of linepack in managing daily flexibility needs is highlighted in modelling studies, potentially providing profits or savings for both gas producers and consumers.
- There is a significant opportunity for gas networks to contribute to flexibility in the future, though changes to networks will be necessary.
- The value of operating gas and electricity networks as an integrated energy infrastructure could help provide an opportunity to deliver on climate commitments and mismatched energy supply and demand conditions.

2 Natural gas and gas networks provide flexibility for daily and seasonal variation in demand, and increasingly electricity supply, to deliver energy to consumers when needed.

- This includes flexibility in gas production, flexible gas electricity generation, gas network linepack, natural gas storage and gas imports through pipeline and LNG (liquefied natural gas) terminals.
- In the future, new types of flexibility provided by gas could become increasingly important, such as power to gas to maximise the utilisation of renewable energy generators and hybridisation of end-use between electricity and low carbon gas, to reduce peak demand on the increasingly burdened electricity system.

3 The cost of providing gas network flexibility reduces as the networks become more interconnected with other countries through pipelines, LNG infrastructure or flexible domestic production.

- Summer-winter price spreads (an indicator of the cost of shifting gas to meet seasonal energy demand patterns) appear to be reducing in the UK, Europe and the United States. Between 2005 and 2020 UK summer-winter price spreads reduced by 70%.
- Interconnection and LNG trade has increased in the UK and Europe, and this is a significant driver of the reduction in summer-winter price spreads. For the US, increased domestic gas production has contributed to reduced price spreads.
- Gas storage capacity appears to be reducing in many regions as international gas markets become more connected, thus providing competition to provide the inter-seasonal flexibility in the delivery of primary energy.

4 The future gas network will change to meet climate change targets, fundamentally changing its role in providing flexibility to the energy system.

- Climate targets will result in forced changes to gas networks. Estimates for gas use in Europe suggest that achieving 100% reduction in emissions might result in a 30% to 45% reduction in gas use by 2050, with

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For further information on this subject please contact us at SGI@Imperial.ac.uk
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hydrogen and other low carbon gases making up 75% to 80% of all gas use.

- Possible changes will include the fragmenting and shrinking of gas networks as other low carbon vectors are preferred, the introduction of low carbon gases to the gas network and the isolation of gas networks until international trade in low carbon gases is developed.
- These changes are likely to place an increasing burden on linepack and gas storage as the flexibility mechanisms in the initial transition to low carbon gas networks.

5 Gas networks provide low cost flexibility in studies that examine future costs and emissions in whole energy systems.

- In UK modelling studies, whole system costs in hydrogen, electricity, and hybridisation-focussed scenarios are found to be similar, though cost benefits appear possible when electricity and gas infrastructures are more integrated and hybridising opportunities are included.
- A similar story exists in Europe, where studies show gas playing an important role in providing flexibility to support the increased penetration of renewables and providing peaking energy to heat in the domestic sector to support electricity and heat pumps.
- In global modelling studies, increasing penetration of intermittent renewable energy technologies is linked to a decrease in the use of gas, and the reduction in systems costs for the same emissions outcome.

6 Gas networks can deliver flexibility with relatively low greenhouse gas (GHG) emissions, though a more important contribution could come from carrying low-carbon gasses like hydrogen or biomethane.

- The gas network provides flexibility at a relatively small energy penalty and therefore GHG cost. The gas networks own use of gas increases between summer and winter leading to additional GHG emissions in the order of 1-2 $gCO_{2\text{-eq}}$/kWh, though this is declining over time. This can be compared to the combustion emission of natural gas of 184 gCO_2/kWh.

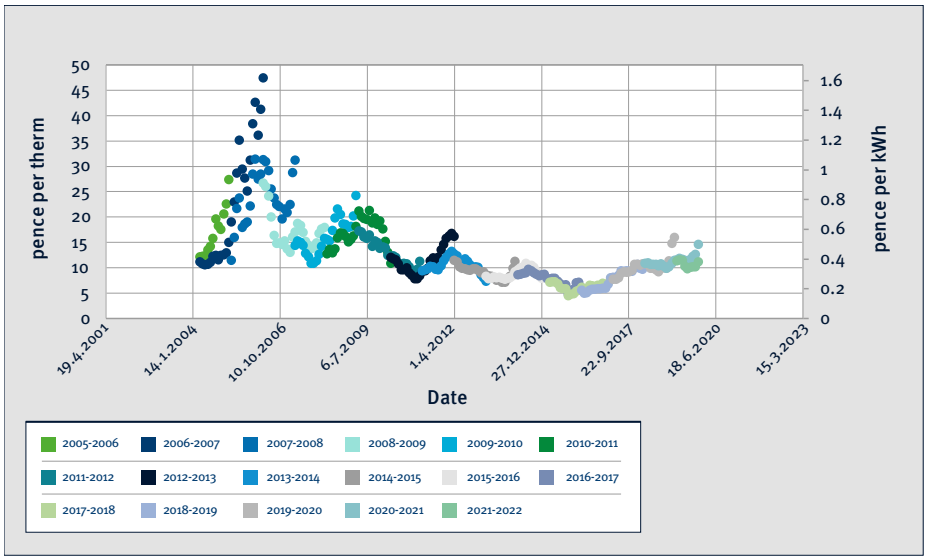
7 Opportunities in developing gas markets such as Brazil exist but are limited by the extent of existing infrastructure.

- Currently, gas has a limited role in Brazil due to the relative lack of existing pipeline infrastructure particularly with domestic and commercial consumers and with energy supply dominated by low carbon hydroelectric power generation.
- However there is a role for flexible gas power generation to support hydroelectric stations and the increasing penetration of intermittent renewable electricity generation.
- There is a significant potential for biogas and biomethane to play a role in this decarbonisation given the biomass potential in the sugarcane industry. However, increased infrastructure will be necessary to connect these plants to existing gas networks.
- The significant challenge for countries like Brazil with low-carbon electricity already prevalent in the electricity system is how to utilise the flexibility value of gas without significantly increasing emissions and endangering climate commitments.
- There are a number of opportunities for future research into the value of gas network flexibility in the future energy system.

8 The emerging demonstration of various aspects of future gas networks provides significant opportunities for research in flexibility provision and costs resulting from these fundamentally different gas systems. Research should be pursued to keep abreast of emerging data and keep policy makers informed of those developments and their implications for decision making. Research opportunities include the following:

- Research to help understand the spatial and consumer aspects of different scenarios that include gas networks, including natural gas, hydrogen and hybrid scenarios. challenges.
- The impact of changing linepack and storage energy density on costs of delivering flexibility.
- Better understanding of the costs of operating gas networks with relatively low gas flows.
- An examination of what is lost in the value of gas network flexibility by moving to smaller, fragmented networks.

FIGURE ES1
Gas summer-winter spreads at the National Balancing Point (NBP)



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