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Heating in Great Britain: An incumbent discourse coalition resists an electrifying future

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ABSTRACT

The power of incumbent actors to affect sustainability transitions is increasingly recognised as a central issue associated with systemic change. However, incumbent's approaches and the outcome of their influence is rarely examined in academic literature. Using a novel approach which combines the lens of 'discourse coalitions' with an explicitly critical discursive stance, in which the coalition's storyline is scrutinised, this interdisciplinary analysis investigates a pro-gas, incumbent led coalition present in the Great Britain (GB) energy system. In response to the threat of electrification, the coalition presents decarbonising the gas grid with replacement gases as the optimal route for heat decarbonisation. However, much analysis suggests a significant need for heat electrification and our review highlights major uncertainties with a decarbonised gas pathway. Incumbents are over-selling 'green-gas' to policy makers in order to protect their interests and detract from the importance and value of electrification. Policy and research recommendations are made.

1. Introduction

The transitions of systems from unsustainability to sustainability are likely to challenge existing regime interests who may resist change (Geels, 2014). The required transformation[1] of the global energy system to zero carbon, in line with the Paris Agreement, appears particularly radical in both speed and scope (IPCC, 2018). The most radical transformations may be particularly at risk of attempts at subversion and '*aims in social science*' should act '*strongly to resist the shaping of knowledge by incumbent interests*' (Stirling, 2014, p91).

This article investigates attempts by incumbent interests to shape GB heat decarbonisation policy and questions the validity of their proposed storyline. We use a critical discursive approach, and borrow the lens of 'discourse coalitions' (DCs) in order to take a highly policy relevant analytical methodology which takes into account the state of the art analysis around UK heat decarbonisation

Abbreviations: AD, Anaerobic digestion; ADA, Argumentative discourse analysis; BEIS, Department for Business, Energy and Industrial Strategy; CCC, Committee on Climate Change; CCS, Carbon capture and storage; CDA, Critical discourse analysis; DC, Discourse coalition; DECC, Department of Energy and Climate Change; ENA, Energy Networks Association; GHG, Greenhouse gas; GB, Great Britain; LPG, Liquefied petroleum gas; MLP, Multi-level perspective; NGO, Non-governmental organisation; SNG, Synthetic natural gas; UK, United Kingdom

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[1] While much of the literature on sustainable change uses the term 'transition', when considering the radical changes required for the global and Great Britain heat system we use to term 'transformation' to emphasize the speed and breadth of the required changes.

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pathways.

While this study focuses on GB, heat decarbonisation is a global challenge and many socio-technical issues associated with GB's heat transition may be reflected in other countries, in particular those with large penetrations of fossil gas heating. This article may therefore have particular value for scholars interested in the heat transitions in the Netherlands, Italy and certain US states. In California, popular media is already reporting corporate resistance against heat electrification (LA Times, 2019) and at a US-wide level, recent analysis by environmental NGOs has highlighted the promotion of 'Renewable Natural Gas' in response to ideas of electrification (Earth Justice and The Sierra Club, 2020).

1.1. Heating in the United Kingdom (UK) and its future

Greenhouse gas (GHG) emissions from space heating and hot water production in the UK[2] make up a fifth of emissions (Committee on Climate Change, 2016) with 79 % of this energy provided by the combustion of fossil fuels (BEIS, 2018a). Net zero GHG emission targets imply total elimination of these emissions requiring the replacement of all fossil fuel heating systems with something else alongside reductions in heat demand (Committee on Climate Change, 2019a).

Techno-economic analysis by academia, the UK Government and its advisors has repeatedly suggested that electrification of much heat demand, primarily using heat pumps alongside the reduction in heat demand, represents the lowest cost pathway to near fully decarbonised heating (Committee on Climate Change, 2010; DECC, 2013, 2012, 2010; Element Energy and AEA, 2012; UKERC, 2009). Despite some uncertainty, there are common messages for the future of UK heating:

- 'Energy demand reduction is essential for meeting emission targets'
- 'A substantial level of electrification of heating (via heat pumps) is expected'
- 'District heating will play an important role in heat supply decarbonisation'

(Chaudry et al., 2015, p268).

The UK's statutory climate advisor 'The Committee on Climate Change' (CCC) sees 19 million electrically powered heat pumps (including air source, ground source and hybrids) installed in UK homes in 2050 in its 'further ambition' scenario which aims towards net zero emissions; this growth in heat pump systems is expected to come alongside growth in heat networks, reductions in heat demand through energy efficiency measures (Committee on Climate Change, 2019a). Recent analysis has shown that heat pumps already out-compete fossil fuel heating based on carbon intensity in the majority of situations globally (Knobloch et al., 2020) and that the potential for decarbonisation of heat using heat pumps across Europe would provide significant and immediate carbon benefits (Rosenow and Lowes, 2020).

The heat electrification transformation would have significant impacts on incumbents in the UK's heat sector who may no longer be able to sell gas boilers or may own stranded assets such as gas infrastructure (Lowes et al., 2018a). Some response by incumbents therefore seems likely.

1.2. Increasing complexity

Despite the expected importance of electrification, converting the UK's gas system to run on low carbon gases including hydrogen and biomethane (often referred to as 'green gases') has recently and rapidly emerged as a key technology option considered by policy makers to decarbonise heating in the UK (Committee on Climate Change, 2018a; HM Government, 2017). This gas-based pathway has emerged in the UK heat policy discourse at the same time as strong promotion of this technological approach by the gas industry suggesting the gas industry may have had some political success.

However, it may also be that genuine concerns over the required increase in electricity system capacity which would result from heat electrification (which have not just been highlighted by incumbents e.g. Maclean et al., 2016 have led to his complexity. In general, heat decarbonisation pathways in the UK have become more complex with pathways which now include full electrification, full conversion to hydrogen, hybrid pathways and pathways with geographical variation (Lowes et al., 2018a; Winskel et al., 2016).

Electrifying the heat currently provided by gas would have an impact on the electricity system with analysis suggesting that if 20 % of homes had heat pumps, electricity system peak demand could increase by 14 % (Love et al., 2017). However, while electrifying heat would clearly increase electricity system throughput, recent analysis suggests these 'peak heat' concerns may be less of an issue than was previously believed (Watson et al., 2019). Others have also added that reductions in heat demand alongside 'smart' heat load shifting approaches can reduce system impacts further (Rosenow and Lowes, 2020). It may of course also be that increasing GB electricity capacity is simply a requirement of heat decarbonisation.

Recent analysis suggested the most cost effective GB heat pathway to net-zero may be one where much heat demand is electrified but this is supported by hybrid systems which top up heat pumps with gas[3] based heating (Strbac et al., 2018). These hybrids work at

[2] The UK (The United Kingdom of Great Britain and Northern Ireland) includes Northern Ireland and the Isle of Man. Energy governance for the UK and GB is connected and while we discuss the UK throughout this paper where relevant, for example in relation to analysis or system change, the empirical focus of this work is GB.

[3] This would need to be some form of low carbon gas with hydrogen seen as the vector. This hybrid model would therefore require the deployment of heat pumps at scale and the conversion of the gas distribution networks to hydrogen alongside the use of boilers suitable for hydrogen.

a building level requiring the maintenance of much gas infrastructure and the need for two appliances. It has also been suggested that because costs between technological pathways may be similar, low carbon heat solutions may vary by location depending on, for example, available resources and infrastructure (Committee on Climate Change, 2018a). Nonetheless, because of limited deployment and a lack of practical experience, significant uncertainty remains over the potential of low carbon gas.

In light of the apparent uncertainty over the optimal pathway, the UK government is not expecting to make strategic decisions on the future of heating, particularly for houses on the gas grid, until the evidence around options, electrification or hydrogen, provides greater clarity on the optimum solution (HM Government, 2017). Meanwhile, the deployment of energy efficiency and heat pumps in the UK is below indicator levels set by the CCC for decarbonisation (Committee on Climate Change, 2019b). Recent analysis has also shown that heat policy makers in GB perceive technological approaches for heat decarbonisation as both disruptive, but particularly important for this analysis, uncertain (Lowes and Woodman, 2020).

The lack of progress around heating and uncertainty over future technology suggests goals for decarbonisation may be at risk. This article is interested in the potential role of incumbents in causing this risk.

1.3. Research focus

This article considers the behaviour of incumbents[4] threatened by heat decarbonisation, through the examination of the green gas discourse, which they are promoting.

Fundamentally, this article is interested in the shape and practices of the incumbent coalition as well as the discursive storyline that is being promoted. Through a critical discursive approach, this interdisciplinary investigation considers the ‘green gas’ storyline and its proponents alongside technical analysis associated with so-called ‘green gas’ and heat decarbonisation pathways.

Specifically, we investigate:

1 Can a DC be identified and what practices are being used to promote the storyline?
2 How does the proposed storyline compare to relevant and recent analysis on UK heat decarbonisation pathways and the potential role for gas?
3 What are the transition and policy implications of the efforts of incumbents?

Section 2 explores the theory of incumbency, discourse coalitions and critical discourse analysis. Section 3 explains research materials and methods. Section 4 considers the presentation of the GB ‘green gas’ DC. Based on a state of-the-art evidence review, section 5 critiques the ‘green gas’ storyline employed by the discourse coalition. Section 6 considers the potential impacts of the approaches of the incumbent discourse coalition on GB heat decarbonisation. Section 7 concludes the paper and highlights the implications for policy.

2. Power, incumbency and critical discourse approaches

The power of actors to affect the transitions of large socio-technical systems, such as the UK heat transformation, is widely regarded as significant (Avelino and Rotmans, 2011, 2009; Geels, 2014, 2010; Kern, 2011; Smith et al., 2005) and the literature investigating issues of power and sustainable change is rapidly growing. However while the concept of power is a ‘*core concept*’ in the social sciences, it is ‘*arguably one of the most difficult concepts to make sense of*’ (Clegg and Haugaard, 2009, p1).

A lack of a definitive characterisation of power and the complexity of the issue means that it ‘*seems as if any student of power designs his or her approach*’ (Arts, 2000, p112). This article takes an ‘interests’ based approach whereby actors are expected to behave in a way which maximises ‘personal utility’ (Kern, 2011, p1120) and for the purpose of this article, power can be considered as the ability of an actor to affect the transition to sustainable heating. If actors are able to have power to affect the UK’s heat transformation, this could have implications for the speed and direction of change.

Smith et al. (2010) suggest that ‘*opening the black-box of public policy*’ may have particular value for scholars interested in how power can affect transitions because the policy process may be a particuarly important location of power struggles. They go on to explain that ‘*there are long-standing literatures on regulatory capture, government-industry relations, clientelism, iron triangles, policy networks, and discourse coalitions that can help us ensure analysis of socio-technical regimes and public policies are more deeply intertwined*’ (p446). This paper makes a contribution to opening the policy black-box through its critique on the practices of a specific discourse coalition.

The relationships between system transitions and power have been considered previously. Investigations have considered the power of discourses and ideas (Castán Broto, 2015; Späth and Rohracher, 2010), the power associated with historical regimes (Arapostathis et al., 2013), the power associated with institutions (Fuenfschilling and Truffer, 2014) and a whole special issue of this journal has been dedicated to the ‘*politics of innovation spaces for low-carbon energy*’ (Raven et al., 2016). Lowes et al. (2019) specifically considered the power of actors to affect historic GB heat transformation policy development.

[4] Lowes et al., (2017) develop a working definition of the term incumbency on which the view of incumbency in this paper is based. They ‘*…define incumbency in the context of sustainable transformations as the presence of existing actors within a specific socio-technical system. An incumbent will be currently active in the socio-technical system or a part thereof and therefore likely to be or have been involved in unsustainable practices. Incumbents have the economic, social or technological capacity to influence system change*’.

2.1. Incumbency

Markard (2018) suggested that the politics of transitions and specifically issues with incumbents attempting to slow down transitions will be a key area for energy transition research and has called for the adoption of political science concepts and approaches by transition scholars. Ideas of 'incumbency' and 'incumbents' have featured widely within the literature on power and sustainability transitions and the key issue for analysis of incumbents is whether incumbents have power to drive, slow or shape transitions.

Incumbency is widely seen as an issue which can slow or inhibit change (Johnstone et al., 2017; Roberts et al., 2018; Stirling, 2014; Unruh, 2000). This may however not always be the case with evidence existing of incumbents driving sustainability practices (Geels, 2011; Stenzel and Frenzel, 2008) and incumbents from neighbouring systems able to support change beyond their own regime (Turnheim and Geels, 2019).

Incumbent responses are also likely to depend on relative landscape pressures (Roberts et al., 2018), after all, why would an incumbent with a product or service that supports (normative) change attempt to block a transition? Indeed, some have suggested that the urgency of decarbonisation means that where incumbent regimes can support transitions, supportive management may be warranted (Winskel and Radcliffe, 2014). Overall, while incumbents appear to be important and powerful, their responses may vary.

Evidence on the actual impacts of the power of incumbent actors in response to transitions is limited. Smith et al. (2005) recognised the ability of regime actors to shape visions and expectations of transformations. Dutch transitions management approaches to energy system change have seen a dominance of so called transition arenas by incumbent interests (Hendriks and Grin, 2007; Kemp et al., 2007; Kern and Smith, 2008). Recently, Lockwood et al. (2020) have shown that the development of the UK's capacity market for electricity appears to have been influenced, by, and for the benefit of, incumbent electricity generation interests and have proposed more independent and transparent regulation of this sector. There appears to be little, if any, research into incumbency associated with sustainable heat transformations, a gap we fill.

2.2. Critical discursive approaches

Stirling (2014) explictly states that energy social science research must '*strongly resist the shaping of knowledge by incumbent interests*' (p91).

Future visions of socio-technical systems may be an important element of transitions providing some sort of guide or story for actors to coalesce around (Avelino, 2009; Kenis et al., 2016; Turnheim and Geels, 2019). However, power relations and existing structures can limit or alter visions, potentially leading to long term transition impacts (Smith et al., 2005; Stirling, 2014). If incumbents can capture and therefore shape visions, impacts could be significant. Scholars have recently highlighted the use of 'discourses of delay' to reduce support for climate policies (Lamb et al., 2020).

Discursive approaches focus on how the social world is constructed through social elements including language, texts and the media (Burnham et al., 2008). So-called 'critical discourse analysis' (CDA) looks in part to understand how discourse relates to and potentially maintains inequality in power relations (Van Dijk, 1993a, 1993b). CDA may therefore have value for the consideration of large, systemically embedded incumbents (such as those within socio-technical (energy) systems) and how they are shaping visions and debates.

Even as a subset of wider approaches to discourse, CDA is a large research field however some general characteristics of CDA have been suggested:

1 It is not just analysis of discourse but is part of a more systematic transdisciplinary analysis of relations between discourse and other social elements.
2 It is not just a commentary on discourse but it includes some from of discursive analysis.
3 It is not just descriptive but it is also normative, addressing social wrongs in discursive form and suggesting possible ways to approach those wrongs.

(Fairclough, 2010)

Others agree that CDA is a broad approach but one which is 'problem oriented' while being focused on dominace and inequality in power relations (Van Dijk, 1993a, 1993b; Van Dijk, 1995). Van Dijk (2001) explains: '*CDA focuses on the ways discourse structures enact, confirm, legitimate, reproduce, or challenge relations of power and dominance in society*' (p353) and also highlights the idea of using power to '*control the acts and minds of (members of) other groups*' (p355). Taking this even further, Van Dijk (1993a, 1993b) suggests that CDA is a truly action oriented endeavour: '*Ultimately, its success is measured by its effectiveness and relevance, that is, by its contribution to change*' (p253).

Methodologically, CDA approaches are diverse and foci can range from education to racism and also include political discourse and ideology (Blommaert and Bulcaen, 2000). In the case of public policy, these approaces focus on how discourse is shaped by social practice (Hewitt, 2009) and how discourses may dominate and show stability or instability (Fairclough, 2013). While not generally the key cause of policy changes, policy discourses are recognised as being be an influential factor (Hajer, 1995). With both limited progress, a lack of significant policy and governance support for low carbon heat and the perception of various and competing options for heat decarbonsation technologies in the UK, a CDA approach may have great value.

2.3. Discourse coalitions

CDA appears likely to have significant value for the study of incumbency associated with energy system change yet beyond the use of textual and interview analysis, there are no firm methodlogical approaches. In order to support this analysis with a relevant discursive lens, we borrow an approach based around the idea of discourse coalitions (DC).

DC approaches are often associated with argumentative discourse analytical (ADA) approaches whereby various DCs are considered to form a discursive space (Leifeld and Haunss, 2012). Discursive struggles take place with DCs competing to reach some form of hegemony or ideological dominance (Hajer, 2002). ADA approaches do not typically focus on a single discourse coalition or group of actors (such as incumbents) but there may be merit in combining the 'discourse coalitions' element of ADA with critical discursive approaches. This combined approach can provide focus on a particular group of organised actors while simultaneously unpicking the story that group is promoting and may have particular value for those investigating incumbent resistance.

According to Hajer (1995, p146):

'*Discourse should be understood as a specific ensemble of ideas, concepts and categorizations that is produced, reproduced and transformed in a particular set of practices and through which meaning is given to physical and social realities. Discourse coalitions' refers to the way in which a particular discourse gets its social power. Here the term 'coalition' is meant to underline that this is not necessarily a matter of concerted and strategically negotiated action but might be the result of far more pragmatic, incidental alliances that shape up around specific 'story-lines*''.

Hajer (1993) links the DC approach to issues associated with the mobilisation of bias and the so-called 'second face of power', an element of power associated with the ability of actors to set political agendas[5] .

Storylines have elsewhere been described as the '*intentional mobilisation of resource*' as a means of influencing policy change (Smith and Kern, 2009, p2001). Bulkeley (2000) suggests that in the case of DCs, despite consistent storylines, members may not necessarily share similar world views but the actors '*coalesce around certain storylines in order to advance oppositon to the dominant coaliton*' (p745). Lovell et al. (2009) agree, suggesting that storylines may be used by whoever they have value for.

DC approaches have frequently been used to consider large system dynamics. This incudes around wind energy policy (Szarka, 2004) and developments (Jessup, 2010), sustaianble housing (Lovell, 2008), the emergence of 'transition' ideas in Dutch policy making (Smith and Kern, 2009), shale gas (Cotton et al., 2014) and more recently around ideas of responsibility for food waste (Welch et al., 2018).

2.4. Theoretical synthesis

CDA and DC approaches appear to have significant value for investigating and framing the behaviours of incumbents in response to systemic transitions. CDA approaches encourage normatively critical approaches to discourse and DC approaches provide a lens to consider how actors can coalesce to attempt to dominate (Bulkeley, 2000).

A recent review highlighted the increase in the use of discursive approaches to consider energy transitions; this review showed the frequent use of argumentative discourse analysis but also showed the use of CDA (Isoaho and Karhunmaa, 2019). Analysis of Isoaho and Karhunmaa's (2019) data set shows five[6] energy transition articles employing some form of 'critical' discursive approach. All of these articles which had a clear methodology used some form of text and/or interview based analysis.

These articles highlighted some key risks associated with policy discourses including potential overly-generous political support for bio-energy (Chaliganti and Müller, 2016), faith in technological developments to negate sustainability issues with bio-energy (Levidow and Papaioannou, 2013), politically challenging EU and USA discourses around the Chinese solar energy strategy (Caprotti, 2015) and competing views on geoengineering (Anshelm and Hansson, 2014).

In these articles, actual critique of the discourses under study appears often only superficial. Chaliganti and Müller (2016) went some way to highlight the way institutionalised discourses may crowd out other valuable approaches, echoing ideas of the importance of combining CDA methods with (new) institutional approaches as suggested by Genus (2014). Levidow and Papaioannou (2013) suggested real concerns over sustainability may be unheeded because of discursive ideas of 'future innovation' (p47). Overall however, only slight attention appears to have been paid to critique of the discourses under investigation.

With regards to DC approaches, Späth and Rohracher (2010) suggest that this approach has already been fruitfully linked with the 'multi-level perspective (MLP) on transition processes' (p252). However, the examples proided by Späth and Rohracher (2010) show in some cases only limited connections between the two approaches; for example, Smith et al. (2005) do not actually used the term 'discourse coalition' and Smith and Kern (2009) consider the DC associated with Dutch transitions approaches rather than considering DCs in approaches to sustainability transitions in general. And while Lovell et al. (2009) do consider ideas of transitions, they do not refer to the so called 'multi-level perspective'. So while there has been some cross-over between the approaches of transitions and DCs, this cross-over actually appears quite limited.

In order to build on this existing literature, and overcome some of the limits of previous research, a combination of CDA and DC

[5] The 'faces of power' approach is one approach to consider power. Lukes describes 3 faces (Lukes, 2005) although others have suggested there are four faces to power, essentially the three faces of Lukes plus post-structural approaches to power (which include Foucauldian approaches) (Haugaard, 2012).

[6] The original research article suggested seven articles were based on CDA but on review, not all were. Discounted articles include Lassen (2016) who focuses on 'genre' and (Schmid, 2004) who very briefly mentions CDA.

approaches may provide a useful approach to critically investigate the the behaviour of incumbents in response to threat of energy system change.

Our approaches uses CDA as a basis but augments this with DC approaches where we specifically consider the make-up of the coalition and the story lines being promoted. The critical element of our analysis combines the storyline(s) being promoted with state of the art analysis around heat system decarbonisation and 'low carbon gas'. This multi-disciplinary analysis has been enabled by collaborative working across institutions in order to build on expertise around both incumbency and technical challenges associated with heat decarbonisation.

3. Materials and methods

All apart from one of the articles into DCs discussed in the previous section used a combination of interviews and grey literature analysis (Bulkeley, 2000; Cotton et al., 2014; Jessup, 2010; Lovell, 2008; Smith and Kern, 2009; Szarka, 2004; Welch et al., 2018) with Welch et al. (2018) also using workshops. Separately, Leifeld and Haunss (2012) used quantitative social network approaches.

This analysis is based on a wider exploratory study which considered the issue of incumbency in the GB heat sector. This study was based around in-depth interviews which took places across 2017 and a review of grey literature, both of which have value for CDA and DC approaches.

Interviewees included individuals from the private sector, third sector and public sector, all with an interest in and knowledge of heat decarbonisation and the role of industry. A previous review highlighted key business sectors and large businesses operating in the GB heat sector (Lowes et al., 2018a). This mapping allowed targeting of interviews in order to gain representation across the GB heat sector. Those involved in policy development were also identified from the research team's existing network. A snowballing approach was used to reach further relevant interviewees. This interview data was coded into themes using NVivo software.

This paper takes an ex-post approach to analysis of the DC based on findings from the wider research. Based on interview data from 30 interviews[7] and with the inclusion of relevant grey data, the results describe the DC storyline, the associated members and the practices used to attempt to give power to the discourse. Following the emergence of a storyline, we critically asses the storyline based around the best available data and analysis on heat decarbonisation in the UK.

Hajer (2006) also suggests that DCs can be considered to be dominant if central actors are forced to accept the new discourse and the discourse is reflected in relevant political institutions. While we don't focus on the dominance of the incumbent storyline, we pay close attention to the requirement for further careful analysis, and the policy implications of our findings.

All interviews have been anonymised, however where quotations are used, the type of interviewee may be included, if relevant. Annex 1 contains a list of interviewees detailing the type of interviewee and date of interview.

4. The discourse coalition

In building on Hajer's approaches and like Welch et al. (2018), this section considers the DC and its central storyline taking account of the key incumbent actors, the storyline being presented, and the practices used to reproduce the storyline.

4.1. Actors and the coalition

Interviews and grey literature analysis highlighted a group of actors promoting a heat future in which the combustion of gas forms the central tenet of a future low carbon heat system. This coalition was formed primarily of incumbent businesses with an interest in the GB gas sector. Key actors which emerged were gas boiler manufacturers, gas distribution networks and associated lobby groups.

A number of interviewees suggested the idea of converting the gas grid to 100 % hydrogen to replace 100 % of heat demand in buildings, was being promoted primarily by the gas network owners (four interviewees). The role of the gas appliance (boiler) manufactures in promoting the low carbon gas storyline was also suggested (four interviewees). There was also a recognition among a number of interviewees that the idea of converting the gas grid to 100 % hydrogen had emerged fairly recently (four interviewees).

Interviews also highlighted that the off-grid liquefied petroleum gas (LPG) industry was another group of actors promoting 'green gas' (2 interviews) with one heat pump interest suggesting that this was to protect LPG from being replaced by electric heat pumps in rural areas. A 2017 publication from the UKLPG trade body supports 'bio-propane' as an off gas grid green gas solution (UK LPG, 2017).

The presence of a self-identifying coalition which refers to itself as the 'decarbonised gas alliance' also emerged from interviews (three interviews). A presentation given to The UK Department for Business, Energy and Industrial Strategy (BEIS) by the alliance which was shared by an interviewee showed that this alliance includes specific hydrogen interests, upstream gas producers, consultants and researchers as well as the previously mentioned gas appliance manufacturers and networks incumbents. The categories and their members as shown in this presentation (available on request) are listed below:

- Hydrogen, including transport and end use: ITM Power, Worcester Bosch Group, Kiwa, Providence Policy, ULEMco.
- CCUS: Carbon Capture and Storage Association, Cambridge Carbon Capture, Pale Blue Dot, Summit Power.
- Gas networks, energy trade associations: Northern Gas Networks, National Grid, SGN, Wales and West Utilities, Energy Networks

[7] From a wider set of 51 interviews. The interviews not included did not contain data relevant to the research questions.

Association, EUA, Energy UK, UKOOG, East of England Energy Group.
- Industrial, scientific: Johnson Matthey, BOC, Ineos, Chemical Industries Association, Peel.
- Engineering, standards, consulting: Arup, Institution of Mechanical Engineers, IGEM, DNV-GL.
- Local government: Tees Valley Combined Authority.
- Energy companies: Total, Shell, Spirit Energy.
- Academia, research: GERG - The European Gas Research Group, Sustainable Gas Institute, University of Strathclyde Oil and Gas Institute, Energy Research Accelerator, Birmingham Energy Institute, The Tony Davies High Voltage Laboratory, University of Chester, Powerful Women.

This relatively organised coalition previously had no publicly available profile or website. In the presentation to BEIS, in order to increase policy support to levels perceived to be being given to the renewable energy sector, the group explain: '*We believe that the ambition for the decarbonisation of the gas system should match the ambition for the continuing development of renewables*' (Decarbonised Gas Alliance, 2018).

The organisation now has a website which explains that it represents companies including Shell, Total, Equinor and the bodies which represent UK gas network owners and gas heating appliance manufacturers and is run by company DNV GL (Decarbonised Gas Alliance, 2020). The website also highlights the organisation's interests in biogas and hydrogen.

It is apparent that a clear coalition, part of which appears to have formalised, promoting the green gas storyline, exists. This coalition includes not just incumbent business interests but wider interests who appear to have coalesced around the green gas story line. This reflects Szarka's (2004) and Bulkeley's (2000) observations that DC members may not necessarily share world views but become a coalition around a storyline.

Two interviewees explained that the shale gas lobby group 'UK Onshore Oil and Gas' originally convened the Decarbonised Gas Alliance but the group is now run by consultants DNV GL. Following a request, DNV GL did not provide any further information on the group (corresponding author, personal communication, 5/2/18).

4.2. The storyline

The 'green gas' storyline is fundamentally based on the principle that the gas currently used for heating in GB can be replaced with a lower carbon gas. Under this storyline, in a decarbonised world, the gas grid in GB is maintained and gas connected households continue to combust gas in boilers in a similar way as they do today.

Interviews highlighted the potential for a number of different low carbon gas options:

- Converting the gas grid to run on 100 % hydrogen (seven interviewees);
- Blending a percentage of hydrogen into the fossil gas grid (two interviewees);
- Using synthetic natural gas produced from solid fuels (two interviewees);
- Replace fossil gas and liquefied petroleum gas with gas from bioenergy sources (biomethane or bio liquefied petroleum gas) (four interviewees).

A key element of the storyline is that the green gas option represents continuity for consumers who would not need new types of appliances whereas for non-gas technology options, new appliances such as heat pumps would be needed (four interviewees).

For consumers, green gas was suggested by a firm involved in manufacturing gas boilers to represent '*business-as-usual, because they can relate to a boiler, they can understand it, they know how it works*'. One interviewee from the third sector explained that the use of this idea of consumer continuity allowed incumbents to '*make their case* [for the green gas storyline] *via consumer interest*'.

This idea of minimising disruption is also visible in industry produced grey literature. For example industry analysis into converting the Leeds gas system to run on hydrogen explains:

'*The process will involve minimal disruption for the customer (domestic or commercial) and require no large scale modifications to their property*' (Northern Gas Networks et al., 2016, p1).

According to a GB boiler manufacturer's lobbying strategy shared with the author, green gas is:

'*the most cost effective and pragmatic way of decarbonising the UK's heat supply, whilst simultaneously delivering a solution that will be most acceptable and cause the least disruption to consumers*'.

In a consultation response, The Energy Networks Association (ENA) which represents gas and electricity network owners explains that '*injecting green gas such as hydrogen into the grid, offers significant cost savings against alternative low carbon heating sources. It is also shown to be the most practical scenario in terms of technical feasibility and, importantly, acceptance from customers and society*' (ENA, 2017).

Overall, the low carbon gas storyline maintains the gas system and is framed around representing continuity and minimal disruption for consumers.

4.3. Practices

The practices of the green gas DC highlighted from interview data appear primarily related to influencing energy policy and future heat system visions. These key practices identified were associated with engagement with policy makers and the publication of reports supportive of green gas pathways.

One civil servant explained:

'*It's [the gas industry] a huge industry; they are very powerful companies and all powerful companies particularly in a highly regulated market have a huge government lobbying and influencing role to protect their position for the future. I mean, clearly they are having a big influence the whole time*'.

4.3.1. Engagement with policy makers

Interviewees, including those from incumbent firms, described engagement with Government by gas and oil boiler manufacturers both directly (three interviewees) and also through trade associations (six interviewees) with the goal of promoting green gas options and protecting interests. A large number of interviewees also referred to lobbying and regulatory pressure associated with the gas network companies (six interviewees). This lobbying was suggested to be linked to concerns over the potential for decarbonisation to reduce the requirement for gas infrastructure (6) with one interviewee explaining '*they've got terrified that the gas networks are going to become redundant*' as a result of heat electrification.

One interviewee from a large gas and oil boiler manufacturer explained: '*we do try hard to influence departments, obviously BEIS now and ministers*' and provided the interviewer with a document described as the company's 'Heat lobbying strategy'. This strategy proposed focusing on converting the gas grid to run on low carbon gas and using bio-energy for homes not connected to the gas grid.

The gas networks were described by an energy researcher from an independent research organisation as '*lobbying, very, very, very hard*' on hydrogen with another interviewee from a large energy supplier explaining '*I mean it's often the gas networks who are leading this charge for quite obvious reasons*'. One interviewee from a gas network company explained that they actively lobby Ofgem, the GB network regulator, who controls investment in the gas grid, to show a need for continued investment. In their own words:

'*for them [Ofgem] to sanction kind of eight years' worth of investment in the gas distribution network, and the gas transmission network, what we need to be doing is justifying to our independent regulator that actually that investment is going to deliver value for money, for users. So all the work that we're doing now, is building the story to show this is why you should invest in the gas networks, because that will actually be a valuable investment, on the path to 2050'*.

Two interviewees from gas networks also explained that as well as trying to influence regulator Ofgem, they also attempt to influence central Government departments. One gas network interviewee explained:

'*Our aim has got to be to influence the regulator to support the investments. But actually the policy makers are BEIS and DECC* (The Department of Energy and Climate Change which has now been replace by BEIS) - *was DECC, now BEIS - so what we're aiming to do is develop the objective, independent evidence; provide them with the understanding that actually you shouldn't be ruling out the gas network or selecting this pathway at the minute because we don't really know what the solution is*'.

Details of civil service meetings with external organisations are not recorded however the Department for Business, Energy and Industrial Strategy does publish data on ministerial meetings. Although this data set is not complete, for the period from July 2017 to July 2018 this data includes three meetings attended by the 'Energy and Utilities Alliance' trade body (BEIS, 2018b).

These meetings were:

- A meeting on the 16th October 2016 along with other attendees to discuss '*domestic heat and energy efficiency*';
- A meeting alongside other attendees on 11th January 2018 to discuss '*oil and gas*'
- A meeting alongside other attendees on 7th March 2018 to '*discuss the hydrogen economy*'

The EUA represents a number of gas interests including some gas networks and gas boiler manufacturers. It is seen to be a particularly active pro-hydrogen lobby group according to an interviewee from a heating appliance manufacturer which produced both fossil fuel and low carbon heating systems.

The 11th January meeting was also attended by the ENA which represents UK gas networks owners[8] who appear to be part of the green gas DC. The ENA has recently announced a new cross-network initiative 'Gas Goes Green' to promote and support the decarbonisation of the gas, suggesting their mission can deliver '*net zero in the most cost effective and least disruptive way possible*' (ENA, 2020).

One interviewee from an energy consultancy firm explained that the EUA trade body had employed an ex-Member of Parliament to promote the industry: '*the guy who was the MP, I can't remember his name*' referring to the organisation's chief executive. The concept of the 'revolving door' whereby individuals move between Government and lobbying firms has been discussed elsewhere and is a phenomenon which allows individuals to take contacts and expertise from Government to other sectors to support influencing activities (Vidal et al., 2012).

The EUA released a manifesto in 2017 in which they explained: '*the UK has the world's leading gas grid infrastructure in place, directly supplying the energy to heat 85 per cent of UK homes. It would be a travesty not to use this existing infrastructure as part of the solution to the trilemma, and "green" gas could be the key*.' (EUA, 2017). The EUA continues, on a video on their website that: '*Using a range of green gases, we can offer a cost effective way of meeting our 2050 carbon reduction targets*' (EUA, 2019).

The website of the EUA makes clear that it does respond to Government consultations and, the twitter account of the Heating and Hot Water Industry Council, part of the EUA explains in a tweet on 11th June 2018 '*Green gas is the best means to #decarbonise #heat and tackle the #energy trilemma. Read why in our response to @beisgovuk' call for evidence 'a future framework for heat in buildings' which can be found here* -https://goo.gl/vCaZyc'. While the consultation focused on homes off the gas grid, the 'Heating and Hot Water

[8] ENA also represents electricity network owners.

Industry Council' explain that they responded to BEIS, '*informing them that decarbonising the gas grid, using green gas offers the most pragmatic, practical and cost effective solution to the energy trilemma'* (HHIC, 2018).

Our analysis has also highlighted the response to consultations by the previously identified Decarbonised Gas Alliance. Specifically, the DGA responded to a call for evidence from the UK's CCC on reaching a zero carbon economy. In their response, the DGA promoted the role of hydrogen for buildings currently connected to the gas-grid and biogas (bio-LPG) for buildings in off-gas grid areas (Committee on Climate Change, 2019c).

It has also emerged that a network of gas interests which includes GB's four regulated gas distribution networks and the EUA trade association have worked together to develop an 'All Party Parliamentary Group on hydrogen' led by public affairs consultancy Connect PA (Connect Public Affairs, 2018). All Party Parliamentary Groups are not official parliamentary bodies but provide a forum for engagement on particular issues and are open to all members of parliament and peers (Parliament, 2018).

4.3.2. Funding reports and analysis

An important element of practices to promote the green gas storyline appears to be through the production of reports which contain visions of the future heat system where an important role of gas is emphasised.

Five such reports were discovered. These were:

- '2050 Energy Scenarios: The UK Gas Networks role in a 2050 whole energy system', carried out by consultants KPMG and funded by the ENA (KPMG, 2016). This report suggested that an 'evolution of gas' scenario which saw no growth in electric heating but with much fossil gas supply replace by hydrogen and biomethane had lower practical obstacles and would be significantly cheaper that technology options which contained a greater proportion of heat electrification. Funders the ENA explain the report shows that '*Making use of the UK's gas network infrastructure offers a practical and affordable solution to the future challenge of heat decarbonisation'* (ENA, 2016);
- 'The Green Gas Book' published by the Parliamentary Labour Party but funded by the ENA with contributions from various gas industry interests. This book suggested that '*green gas has the potential to help us pragmatically solve the immense energy and climate challenges we face. It deserves our full support*' (The Parliamentary Labour Party Energy and Climate Change Committee, 2016, p8);
- 'Too hot to handle' produced by think tank Policy Exchange and funded by the EUA and Calor Gas which called for a '*more balanced set of priorities and technologies–incorporating substantial improvements in energy efficiency, more efficient gas appliances, greener forms of gas…*' (Policy Exchange, 2016, p7);
- 'Next steps for the gas grid' produced by think tank Carbon Connect and funded by the Institute of Gas Engineers and Managers which concluded that '*the gas grid could play a vital role in transitioning to a low carbon energy system through the widespread use of low carbon gas*' (Carbon Connect, 2017, p9);
- 'Energy from gas: taking a whole system perspective' produced by the Institute of Mechanical Engineers with contributions from The Institute of Gas Engineers and Managers, the ENA and gas network owner Wales & West Utilities which called for investment and further research into hydrogen (Institute of Mechanical Engineers, 2018);

5. Critical analysis and the uncertainty of 'green gas'

This section critiques the green gas storyline being presented by the incumbent led coalition. This critical approach is based on available evidence around low carbon gases as well as a recognised need for rapid decarbonisation and an analytical position based on existing evidence that electrification is important for heat decarbonisation. As highlighted in section 1.1, much analysis and indeed meta-analysis has suggested that a significant degree of heat electrification is needed for decarbonisation in the UK. While we don't suggest that electrification ever had hegemonic status in the UK heat decarbonisation discourse, clearly it appears to be an important element.

The socio-political relevance of this critique is that our prior analysis has shown the development of an organised and incumbent led coalition promoting a solely low carbon gas pathway in spite of the recognised need for significant electrification. The discourse coalition may be over-selling the potential for 'green' gas while at the same time sitting in a privileged discursive position, linked to incumbent capacity and institutional integration.

The following sections primarily critique the technological pathways promoted by the discourse coalition. Attention is also paid to ideas of continuity for consumers, reduced disruption and lower costs, all elements which have been suggested to be associated with low carbon gas options.

5.1. Converting the gas grid to 100 % hydrogen

Converting the UK's gas grid to hydrogen was the key approach suggested by the DC to achieve significant levels of carbon reduction in heating for areas with gas grid infrastructure. This approach generally sees hydrogen being produced from fossil gas using reforming processes with the carbon content of the gas captured and stored with carbon capture and storage (CCS) technologies (HM Government, 2017; Northern Gas Networks et al., 2016). Hydrogen is then generally expected to be burnt in suitable boilers which operate in a similar way to gas boilers but new appliances would be required; as would some sort of programme which converts certain geographical areas from fossil gas to hydrogen at different times (Northern Gas Networks et al., 2016).

Despite the promotion of this option, a gas system has never been converted to low carbon hydrogen anywhere in the world and there are major uncertainties around potential carbon reduction, costs and technical feasibility. The uncertainties are expanded in the following sub-sections.

5.1.1. Carbon reduction potential

In order to be a suitable option for heat decarbonisation, levels of GHG emissions from a hydrogen system must be minimal. This is a fundamental point, yet hydrogen production may have significant associated emissions.

The Leeds Citygate research project, delivered by a UK gas network, suggested that the conversion of Leeds to hydrogen would result in carbon reductions of only 60 % compared to fossil gas due to emissions from the hydrogen production and carbon capture process (Northern Gas Networks et al., 2016). Peer reviewed analysis investigating the carbon credentials of hydrogen suggests that the lifecycle GHG emissions of hydrogen produced using fossil gas with CCS for heating can vary significantly from 23 to 150 gCO_2eq/kWh; fossil gas lifecycle emissions for heating are around 230–318 gCO2eq/kWh (Balcombe et al., 2018).

The potential carbon intensity of hydrogen produced from CCS is uncertain. Based on the previous figures, the most optimistic GHG reduction potential of hydrogen compared to fossil gas (from 318 gCO2eq/kW reduced to 23gCO2eq/kW) is 93 % though the most pessimistic is a reduction of 35 % (from 230 gCO2eq/kW reduced to 150gCO2eq/kW). If extremely low carbon hydrogen cannot be produced, it is not clear what role it can have in a net-zero world. Even if a 93 % reduction in the emissions from fossil gas could be achieved with hydrogen, the remaining emissions would need to somehow be offset.

While theoretically, near zero levels of carbon emissions could be achieved by producing hydrogen from renewable and low carbon electricity using electrolysis, techno-economic analysis has suggested this would cost significantly more than a more direct electrification route where electricity is used directly for heat in buildings (Strbac et al., 2018).

A fundamental question remains over whether hydrogen, produced from methane alongside CCS, can reduce emissions in line with carbon reduction goals. This question may require practical trials in order to be answered.

5.1.2. Cost uncertainty

The discourse coalition suggested that converting the gas grid to hydrogen would be cheaper than an electrification based approach. The lack of practical hydrogen conversion projects and the scale of the potential conversion programme means that all costs are estimated and uncertain. Two pieces of analysis by Government advisors have investigated potential costs of hydrogen as a heat decarbonisation option:

- Analysis by the National Infrastructure Commission into space and hot water heating suggested that there were very large uncertainties associated with the costs to decarbonise heat although converting the gas grid to hydrogen from fossil gas with CCS could be cheaper than the alternative of electrification (Element Energy and E4tech, 2018). However, following sensitivity analysis, the authors explain '*no pathway can definitively be ruled the lowest cost option*' (Element Energy and E4tech, 2018, p86). Specifically on the uncertainties of hydrogen, the report goes on: '*Cost-effective hydrogen heating is highly likely to be reliant on carbon capture and storage (CCS), which is also as yet unproven, and carries substantial cost uncertainty*' (p9). Within this analysis, hydrogen was only expected to reduce emissions from heat by around 75 % and so while hydrogen may appear potentially cheaper, carbon reduction potential is not seen to be as high. Because this analysis was carried out before the introduction of the UK net-zero goal (when the target was an 80 % reduction in GHG emissions by 2050 on 1990 levels) and because of the residual emissions from CCS, this analysis may now only have limited value because it doesn't model costs for a very low carbon hydrogen system.
- Analysis by researchers at Imperial College London on behalf of the Committee on Climate Change into space and hot water heating suggested that, electrification or hybridisation (incorporating electrification) approaches appeared cheaper than hydrogen conversion scenarios for deeper decarbonisation although costs were similar at lower levels of carbon reduction. For a zero emission scenario, full electrification was modelled to cost £92 billion per annum compared to £121.7 billion per year for a conversion which sees the current gas based heat demand converted to hydrogen[8] (Strbac et al., 2018).

Despite apparent cost uncertainties, gas network owner Northern Gas Networks explain in a promotional video: '*The H21 Leeds Citygate project has established that converting a city like Leeds is both technically possible and financially viable*' and that low carbon hydrogen can be produced at an '*extremely modest cost*' (Northern Gas Networks, 2018). This member of the green gas DC may be overlooking some of the apparent uncertainty around hydrogen.

The costs for any form of major transition are likely to be uncertain because of the scale of change and wider landscape level impacts such as technology cost reductions. Global falls in the cost of renewable energy and batteries mean that decarbonisation via electrification may now be cost less than was previously assumed (Committee on Climate Change, 2019a). The promotion of hydrogen as an obviously cost-effective option for low carbon heat is not reflected in current analysis and remains deeply uncertain.

5.1.3. Technical uncertainty

A lack of real world experience means that technical uncertainty around low carbon hydrogen production and use exists. A key uncertainty is the technical feasibility of large scale carbon capture and storage which is seen as deeply uncertain globally (Middleton and Yaw, 2018) and a key uncertainty for the UK's future energy system (Ketsopoulou et al., 2019).

There is also uncertainty around the safety of hydrogen, the suitability of pipework in people's homes and the development of appliances to burn hydrogen (Lowes and Woodman, 2020). There are also potential uncertainties around the sourcing of fossil gas feedstocks for hydrogen production with the requirement for fossil gas demand to increase due to hydrogen production losses/leakage. The industry led Leeds Citygate project suggest that 47 % more fossil gas would be needed to provide the same amount of energy from hydrogen as is currently supplied by fossil gas (Northern Gas Networks et al., 2016), a potential issue recognised in a review of UK gas security (Bradshaw, 2018).

As a novel approach, the idea of hydrogen conversion is fraught with technical uncertainty. While research is underway to reduce this uncertainty (including Hy4Heat, 2020 which is looking at the viability and safety of hydrogen boilers), if hydrogen conversion isn't technically possible, or comes up against unexpected hurdles, relying on it as a strategy represents a high risk approach. Further still, despite suggestions from the DC that low carbon gas may present only limited consumer disruption, the apparent requirement for geographically based conversions, new appliances and issues with internal pipework may mean that the potential disruption to householders is significant.

Despite this deep technical uncertainty, hydrogen is being presented by the discourse coalition as a workable option with suggestions that other technologies based around electrification shouldn't be deployed. With no practical trials of fully hydrogen areas, we suggest that relying on this technology and delaying the deployment of known technologies represents a high risk approach leading to the potential delay of the deployment of technologies with much more better known cost, performance and immediate decarbonisation potential (Rosenow and Lowes, 2020).

5.1.4. Blending hydrogen with fossil gas

Our DC analysis highlighted the promotion of the potential for blending hydrogen into the fossil gas grid. However, despite being promoted as a widely valuable approach, blending is naturally limited to only partial (relatively minimal) decarbonisation.

Firstly there are limits on how much hydrogen can be blended with fossil gas due to the behaviour of gases in appliances when combusted. Research in the United States has suggested an upper limit of around 25 % hydrogen by volume may be possible for blending situations (Melaina et al., 2013). This upper limit is due to the changing energy content and combustion properties of gas as hydrogen is added to methane; these include wobbe index and flame velocity (de Vries et al., 2017d). A current UK trial is attempting a blend of up to 20 % by volume in a discreet UK gas network (HyDeploy, 2019).

The potential upper bound on the level of hydrogen blending implies the fossil gas would be required in concentrations of at least 75 % limiting the potential for decarbonisation. Compounding this issue is the fact that hydrogen has an energy density around 3 times lower than methane (de Vries et al., 2017d). This therefore means that if 25 % zero carbon hydrogen was blended with fossil gas, this would only reduce emissions from gas by around 8%.

It is therefore very unlikely that hydrogen/methane blends could play any role in a net zero UK energy economy. Hydrogen could potentially be blended with low carbon methane but there are also uncertainties over the availability of biogases (see section 5.2).

There appears to be a suggestion by some incumbents, such as gas network owner Northern Gas Networks that blending could '*pave the way for a clean, low carbon gas grid*' (Northern Gas Networks, 2016) and blending could deploy some hydrogen production technologies and create wider market learning. While some learning may be possible, because blending utilises existing infrastructure and appliances, it seems unlikely to provide learning around the network and domestic requirements for full hydrogen conversion. Blending therefore has only limited carbon reduction potential and it is not clear that wider benefits will accrue around its deployment.

5.2. Biogas

The discourse coalition identified has also been promoting biogenically sourced gases as a means to decarbonise heating. Biomethane is one form of low carbon gas which has already seen growth across Europe and the UK. Biomethane is biogas, produced from certain types of biomass, most often via anaerobic digestion (AD), which is treated and injected into the gas grid where it functions exactly like fossil gas (Speirs et al., 2017). As of September 2019, there were 94 operating biomethane injection sites which inject treated biogas into the UK's gas network (BEIS, 2018c) and there are over 500 plants operating across Europe (European Biogas Association, 2018).

While biomethane is a technology which is currently operational, the type of bioenergy feedstocks used to produce biomethane can have a significant impact on the carbon intensity of the resulting biomethane; for the lowest carbon biomethane, waste feedstocks are required rather than purpose grown energy crops (Adams et al., 2015).

The national availability of suitable biomass resource for large-scale UK production of biomethane from AD is likely to be limited. Overall the CCC suggest that sustainable, UK produced biomass could meet between 5% and 10 % of UK energy demand by 2050, however within the buildings sector, bioenergy looks likely to only provide a niche role in a decarbonised system (Committee on Climate Change, 2018b).

Analysis of a net-zero UK energy system suggested that sustainable biomethane produced from AD, could meet a maximum of 5% of current building heat demand the optimal use of this resource was for peaking heat demand (for hybrids) or other niche roles such so in local heat networks (Committee on Climate Change, 2019d). It is also possible that biomethane could be of value in other sectors such as freight transport or industry where high temperatures are needed, further reducing the resource availability for domestic heat applications.

Another challenge for the carbon intensity of biomethane injection is propanation. In order to ensure the calorific value of injected biomethane is within the very fine tolerances set by gas network regulations, fossil propane may also be injected (Ofgem, 2018). Propanation increases the carbon intensity of biomethane operations although research is currently underway into potential approaches to remove this requirement (Ofgem, 2017).

The limited potential of biogas as a means to decarbonise heat has meant that as a technology, it hasn't featured in energy system cost analysis in the same way that hydrogen has. Fundamentally it doesn't appear to be able to be delivered at a scale of value to the

UK heat transformation. Speirs et al. (2017) also show that mean biomethane production costs currently appear to be significantly above hydrogen production costs (by around 50 %, based on steam methane reformation with CCS).

Despite the promotion of biogenic forms of gas, the potential for them to replace fossil gas appears at best limited and worst niche. This situation is exacerbated by the fact that only certain feedstocks for biogas, in particular waste, provide significant carbon savings. While costs are uncertain, biogas appears to also be a relatively expensive option.

5.3. Synthetic natural gas (SNG)

Analysis of the DC highlighted some promotion of this technology approach. There is only a very limited evidence base associated with the production and use of low carbon SNG for heating. This technique normally involves the gasification of solids followed by a chemical synthesis process.

One UK gas network owner Cadent, has proposed the production of synthetic gas from black bag waste suggesting that '*this technology would secure low carbon heat to millions of homes and businesses in a cost effective way*' (Cadent, 2017, p1). Cadent is currently involved in a trial to produce SNG from 'refuse derived fuel' and inject in into the UK gas grid in Swindon although at the time of writing it is unclear that any gas has been injected.

The carbon intensity of synthetic natural gas depends on the feedstock use, plastics for example (made from oil) or the use of coal could result in a high carbon gas whereas some bio-energy sources could result in lower carbon intensities. According to Speirs et al. (2017), the first stage of the process, the production of syngas, can result in a gas with a variable carbon intensity depending on feedstock; however, the second stage to methanate the syngas into methane may undermine the benefits of the low carbon syngas by adding carbon into the process which will be released when the resulting methane is combusted.

The potential reliance on bio-energy feedstocks and unknown technical and cost performance means that like biogas, the role of synthetic natural gas as a low carbon heat option is limited. While a combination of biomass gasification and CCS could in theory result in a carbon sequestering fuel (i.e. negative emissions) (Speirs et al., 2017), the combination of technologies needed, the requirement for biomass and unknown costs make this approach deeply uncertain certainly not something that can be relied on either in the short term or at scale.

6. Discussion

Focusing on the issue of incumbency in the GB heat sector, and the emergence of a 'green gas' discourse in light of a perceived need for heat electrification, this article has set out to consider:

1 Can a DC can be identified and what practices are being used to promote the storyline?
2 How does the proposed storyline compare to relevant and recent analysis on UK heat decarbonisation pathways and the potential role for gas?
3 What are the transition and policy implications of the efforts of incumbents?

The existence of a DC is clear, and one element of the coalition self-identifies as an 'alliance'. A focus on the practices of the coalition, as suggested by Hajer (2006) has been valuable. The coalition appears to be formed of various actors ranging from some of the largest incumbents in the UK's heat sector currently involved in the gas regime to smaller actors such as consultants and universities.

The most active actors in the coalition appear to be those with business interests in producing gas, manufacturing gas appliances and owning and operating gas networks. However, as suggested by Lovell et al. (2009), it is apparent that actors have coalesced around a storyline which has value for them. This suggests that incumbent discourse coalitions can draw in actors, such as research organisations, who may reproduce storylines potentially enhancing the strength of the discourse further.

Our example clearly shows regime actors resisting change towards electrification highlighting ideas of regime resistance (Geels, 2014) and our study provides further analysis drawing together approaches to transitions and discourse coalitions as others have attempted (Späth and Rohracher, 2010).

This 'green gas' story is well aligned with the business interests of gas interests who are threatened by electrification, the competing heat decarbonisation pathway. The storyline appears to be promoted primarily through engagement with policy makers and through the related publication of analysis and reports.

The coalition's storyline is based around the idea of decarbonising heating by decarbonising the gas supply and maintaining gas infrastructure and the use of boilers in people's homes. The seductive element of this storyline is that it is framed as less costly and less disruptive to citizens compared to electrification. The promotion of a 'non-transformative' solution when required interventions may need to be much more transformative can be recognised as one of the 'discourses of delay' proposed by Lamb et al. (2020) where the discourse is based are the idea that 'disruptive change is not necessary'(p2).

However, our critical analysis has shown that there is significant uncertainty associated with the 'green' or low carbon gas pathway and disruptive and transformative change may be necessary. Of the technologies being promoted (biogenically sourced gas, hydrogen blending, synthetic natural gas, and full hydrogen conversion) only full hydrogen conversion appears to have the potential for significant decarbonisation potential. This is because both synthetic natural gas and biogas rely on bioenergy feedstocks which are limited in supply and expected to be needed elsewhere. Hydrogen blending is naturally limited to a small proportion of total energy throughput for technical reasons.

Yet even though the conversion of gas infrastructure to 100 % hydrogen could possibly have the potential to deliver major GHG emission reductions, it will require large scale carbon capture and storage, new hydrogen production facilities and new appliances. The entire approach also has extremely uncertain costs and it has not been trialled at scale. An incumbent heavy coalition is over-selling the green gas storyline and a fundamental question remains over whether the pathway is actually technically credible.

Our analysis has shown no evidence of incumbents attempting to actively block decarbonisation, but instead, approaches to resistance are based on reshaping the transition vision around the interests of the regime. Regime actors may be looking to capture the transition (Pel, 2015). It is possible that this apparent attempt to control change may be part of strategy to minimise overall change and maintain existing markets through the creation of uncertainty over options. This issue should be a key consideration for policy makers.

While a discourse coalition is clearly present and active, and the idea of hydrogen as a means to decarbonise heat has recently entered the GB heat decarbonisation policy discourse, it is not apparent that the green gas storyline dominates over other storylines. We previously suggested that despite being seen as important, electrification of heat doesn't appear to have shown hegemonic status. It is not possible at this stage to say that hydrogen is seen in policy discourse as the only means to decarbonise heating and indeed even UK Government documents recognise the two competing technological pathways (HM Government, 2017) and recent analysis highlights perceptions of uncertainty for policy makers around this issue (Lowes and Woodman, 2020).

This leads us on to some methodological reflections. We have found value in combining approaches and employing the lens of discourse coalitions, borrowed from ADA approaches with an overtly critical discourse analysis. Alone, the DC approach says little about the impact of the coalition and its potential impact on socio-technical system dynamics. However, when the discourse coalition and its storyline is critiqued using interdisciplinary analysis, useful insights on energy system transformations can be made. We therefore suggest that for those scholars interested in the acceleration of sustainable change, inter-disciplinary and explicitly critical discursive approaches may provide a useful method to unpick attempts by incumbents to (re)shape visions and policy discourses and consider policy impacts.

However, further micro-scale analysis of the policy changes associated with heat decarbonisation may be able to provide evidence of specific impacts of (incumbent) actors on policy change. A methodology based on triangulation of data sources may be of value (see Lowes et al., 2019 and Arts and Verschuren, 1999 for a potential methodology). Discursive approaches to investigate the influence of ideas in the policy process (such as discursive institutionalism, see Schmidt (2010)) may also have value in determining the embeddedness or hegemony of policy discourses within political institutions. Combinations of these methods and longitudinal analyses may be able to provide evidence of whether incumbent actors have successfully shaped policy discourses although of course resources available to researchers may limit the possibility of such complex and long term studies.

7. Conclusions and policy implications

The power of actors, and in particular incumbent actors on the dynamics of energy transitions, has featured frequently in considerations of socio-technical change. In particular, the power of actors to affect policy change has been suggested to be important. Yet specific analysis into how incumbents affect policy change is limited.

This article has described the existence and behaviour of a discourse coalition in GB formed primarily of gas industry incumbents, under threat from the decarbonisation of heating. This discourse coalition has presented a storyline to policy makers that an option which continues the use of the gas infrastructure and gas boilers but replaces fossil gas with some form of low carbon gas is the strategy which should be taken. This option is suggested by the DC to be technologically, economically and socially favourable compared to electrification.

While this analysis has shown the response of incumbents involved in gas heating to the threat of heat electrification, we note that some elements of the industry under study faces an existential threat and this may in part explain the forcefulness of their low carbon gas vision promotion. Not all incumbents will face such an existential threat and adaptation may be possible in other sectors leading to possibly more balanced responses.

Despite the promotion of the low carbon gas story line by incumbents, our critique shows that as well as being deeply technologically uncertain, the green gas storyline will not necessarily be cheaper or favourable. Indeed only one option for low carbon gas, hydrogen conversion, appears to be a serious contender compared to electrification and this technological approach is deeply uncertain. The green gas storyline is being oversold by incumbents. We make no prediction about optimal future energy systems in this paper but we note that electrification has be repeatedly been seen as an important low carbon heat option and can reduce greenhouse gas emissions immediately.

A key policy issue associated with the strong promotion of hydrogen is that it could have the effect of increasing uncertainty for policy makers therefore making any decisions difficult. The natural result of this could be a delay in policy development at a time when significant policy interventions are needed to drive rapid technological change in line with targets for net zero. Policy makers should be aware that attempts to increase uncertainty may be a strategy used by incumbents to delay the introduction of required decarbonisation policies.

While it comes as no huge surprise that low carbon gas is being strongly promoted by a gas industry under threat and that this industry engages with policy makers, a key concern for the transition to low carbon heating is the capacity that incumbents have to promote their storyline. It is not apparent from wider research around the issue of incumbency in the UK heat sector that niche actors have the capacity to compete with incumbents on policy and discursive issues (Lowes et al., 2018b).

This is a key structural issue associated with incumbency and while our analysis does not allow us to make specific recommendations on this issue we support the conclusion of (Lockwood et al., 2020) that greater awareness within Government of industry lobbying would be of value and the independent expertise should be valued. We also repeat calls for greater levels of transparency in UK policy making (Lowes et al., 2019).

In light of the UK's 2050 net zero target, heat needs to be decarbonised rapidly and any delay, caused by technological uncertainty, puts the UK target for GHG reduction at even further risk. While we recognise there is uncertainty, we suggest there is significantly less uncertainty over elements of electrification compared to hydrogen conversion. Low carbon heating appliances have been deployed at scale around the world and low carbon electricity is being generated. The same cannot be said for hydrogen boilers and low carbon hydrogen for heating.

To reduce uncertainty, independently verified, technical trials must rapidly attempt to reduce the uncertainties around hydrogen to see what, if any role, it can play in a sustainable heat system. Meanwhile, UK policy should focus on the deployment of known technologies which can decarbonise heating including heat networks, heat pumps and energy efficiency. Due to the uncertainties associated with hydrogen, in the short term, deployment of known low carbon heating technologies should be at a rate commensurate with the 2050 net-zero target with the expectation that low carbon gas including hydrogen may not prove viable at scale.

Declaration of Competing Interest

The authors report no declarations of interest.

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Annex 1 List of interviewees by sector and date of interview

- Energy consultant with interest in heat 07/03/2017
- Director of heat interested trade body 05/04/2017
- External affairs manager of energy supplier 05/04/2017
- Technology manager from heating appliance manufacturer 06/04/2017
- Director at fossil and low carbon heat appliance manufacturer 07/04/2017
- Representative from gas network owner 10/04/2017
- CEO of heat and energy efficiency interested trade body 11/04/2017
- Energy consultant with an interest in heat 11/04/2017
- Policy analyst at energy regulator 12/04/2017
- Analyst with an interest in heat from consumer protection body 12/04/2017
- Analyst at non-governmental organisation interested in energy 13/04/2017
- Analyst at UK infrastructure advisor 13/04/2017
- Ex civil servant who worked on heat 19/04/2017
- Representative from gas network owner 24/04/2017
- CEO of heat interested trade body 05/05/2017
- Civil servant working on heat decarbonisation 05/05/2017
- Policy and communications manager for heating trade body – 05/05/2017
- External affairs manager of heating appliance manufacturer 11/05/2017
- External affairs manager of boiler manufacturer 17/05/17
- Employees of government advisory body 18/05/2017
- Energy consultant with an interest in heat 30/05/2017
- Policy analyst at heat interested think tank 04/07/2017
- Policy and communications manager for heating trade body 05/07/2017
- Academic with research interest in heat 11/07/17
- Academic with research interest in heat 12/07/2017
- Director of low carbon appliance manufacturer 19/07/2017
- Policy analyst at heat interested think tank 25/07/2017
- Researcher at independent research organisation 27/07/2017
- Analyst at energy consultancy 29/10/2017
- External affairs manager and researcher from energy supplier 21/11/2017

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