Models of governance for energy infrastructure

UKERC Working Paper

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Introduction to UKERC

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Our whole systems research informs UK policy development and research strategy.

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Contents

Acronyms

BEIS – Department for Business, Energy and Industrial Strategy

BIS – Department for Business, Innovation and Skills

CCC – Committee on Climate Change

CCGT – Combined Cycle Gas Turbine

DECC – Department for Energy and Climate Change

GHG – Greenhouse gas

MCHLG – Ministry of Housing, Communities and Local Government

NIC – National Infrastructure Commission

PPP – Public Private Partnership

RAB – Regulatory Asset Base

SPSS – Strategy and Policy Statement

1. Introduction

Theme 4, 'Energy infrastructure transitions', of the current phase of UKERC considers the challenges associated with the transition to a net zero energy system, and how the necessary infrastructure to support this transition will be delivered.

The term 'infrastructure' is not well defined and at its broadest can include institutional, personal and material elements and the network between them (Buhr, 2003). Like the UK's National Infrastructure Commission, our focus is primarily on material elements of infrastructure (National Infrastructure Comission, 2020) and our specific focus is those elements associated with the energy system. Unlike the NIC, we do take an active interest in housing because of its centrality to heat decarbonisation.

This paper considers the issue of infrastructure governance associated with the UK's transition towards an ultra-low carbon energy system in line with the net zero emissions goal. It is clear that significant changes to infrastructure are needed as fossil fuel combustion technologies are replaced with low carbon alternatives. Yet the required speed and scale of these changes imply radical reforms to how the energy (infrastructure) transformation is delivered.

In this paper we consider what 'governance' is and the role it currently plays in the energy system. We then go on to consider the various approaches to infrastructure governance before proposing our next research steps.

1.1 Why governance?

In their review of 'global energy governance' issues, Florini and Sovacool (2009) explain that '*Governance refers to any of the myriad processes through which a group of people set and enforce the rules needed to enable that group to achieve desired outcomes'* (p5240). Governance therefore goes well beyond a traditional narrow policy focus on the details and performance of specific instruments but broadens the focus to consider not just specific policies but the social, political and institutional context in which they sit and how they might develop over time.

Adapting North's famous definition of institutions (North, 1992), the recently completed IGov project which focussed on UK energy governance suggested '*governance is taken to mean policies, institutions, rules and incentives (i.e. the rules of the game)*' (Mitchell *et al.*, 2016, p3). An even broader definition suggested '*Governing can be considered as the totality of interactions, in which public as well as private actors participate, aimed at solving societal problems or creating societal opportunities*' (Kooiman, 2003, p3).

Clearly, governance is a wide subject covering a multitude of institutions, actors and processes fundamentally tied together by ideas of authority, power and decision-making. In an attempt to make sense of some of this complexity, Howlett (2009) argues that how governance is implemented is driven by broad ideological choices about what the process of governance is meant to deliver. So, for example, if a

Government believes that market forces are the most effective way to deliver policy outcomes, then policy design and implementation is likely to focus on economic measures design to deliver the desired outcomes in cost effective, often competitive ways. Different ideological starting points will favour different policy outcomes. We adopt this broad approach when considering different potential governance arrangements in Section 3.

Table 2 Modes of governance

Mode of governance	Overall governance aim	Implementation preference
Legal governance	Legitimacy and compliance through the promotion of law and order in social relationships	*Legal system*: legislation, law and rules and regulations
Corporatist governance	Controlled and balanced rates of socio-economic development through the management of major organized social actors	*State system*: plans and macro-level bargaining
Market governance	Resource/cost efficiency and control through the promotion of small and medium sized enterprises and competition	*Market system*: auctions, contracts, subsidies, and tax incentives and penalties
Network governance	Co-optation of dissent and self-organization of social actors through the promotion of inter-actor organizational activity	*Network system*: collaboration and voluntary associational activity and service delivery

Source: Modified from Considine (2001) and English and Skellern (2005)

Figure 1. Modes of governance (Howlett, 2009, p77)

Scholars suggested over a decade ago that energy governance in the UK, which had focused on privatisation, may not be suitable for the governance of a sustainable energy transition (Smith, 2009) in part because of an institutional focus on and expertise around liberalisation (Mitchell, 2007). Meanwhile, some areas of the UK energy system, such as elements of electricity generation, have taken a path towards geographical decentralisation as renewable electricity generation, much of which is connected to the distribution network, has expanded. Further change in this direction may mean that governance, or elements of it, may need to decentralise alongside energy systems (Goldthau, 2014).

Over the past decade, little appears to have changed to how energy in the UK is governed and also how energy governance works across political scales. This is despite a rapidly changing political and technological landscape.

In the following sections we focus on the Governmental elements of governance in the UK. We also recognise the potential for much wider societal involvement in governance. In particular we recognise calls for energy governance to be increasingly democratic and inclusive which could entail a greater focus on citizen outcomes, participatory decision making and more civic ownership of the energy system (Szulecki, 2018). We also note the rapid expansion in the use of national and sub-national citizen assemblies and juries. However, for the sake of maintaining a sensible research scope, we focus on Government elements of governance.

1.2 Current energy and climate governance in the UK

The Engineering and Physical Sciences Research Council funded two stage 'IGov' project described existing GB energy governance institutions, these governance arrangements are shown in Figure 2. In this framework, various Government departments, some with their own advisory bodies, sit below parliamentary authorities. Ofgem, regulator of gas and electricity markets and networks, forms the key governance link to the private sector which owns the vast majority of the physical assets associated with the GB energy system.

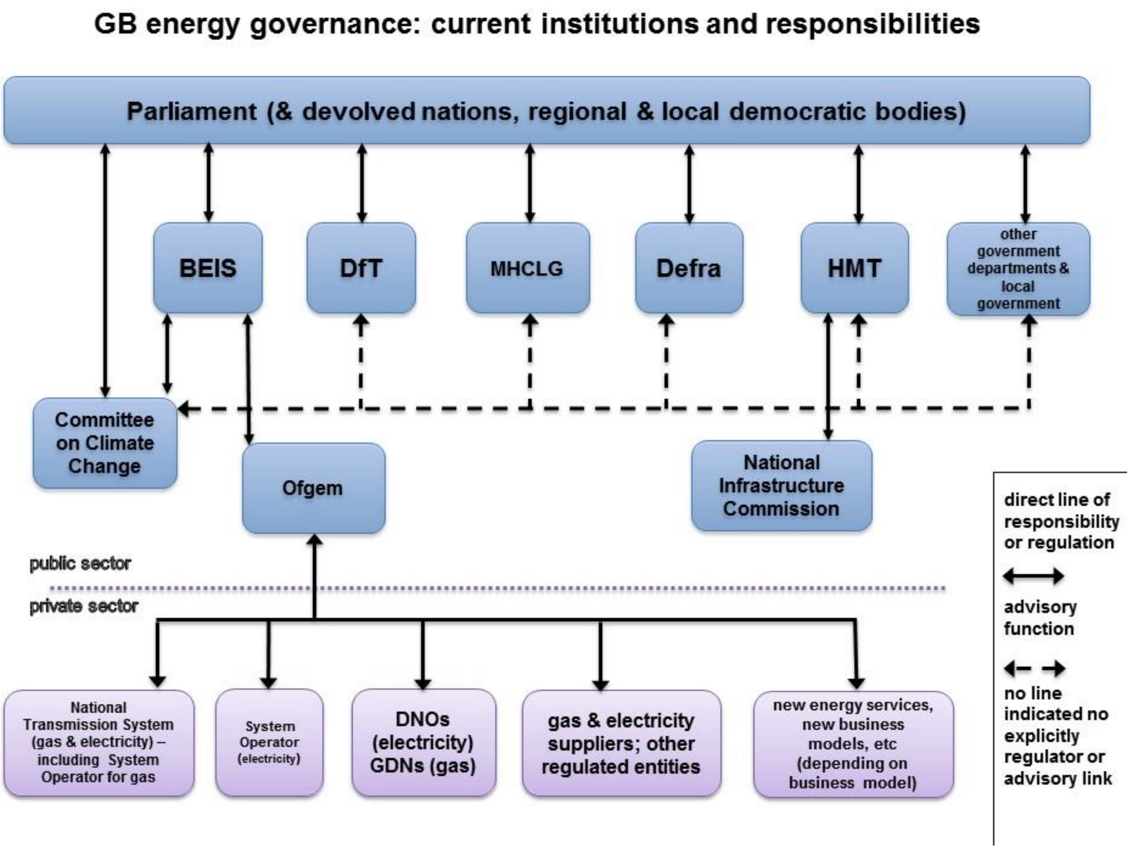

Figure 2. GB Energy governance: current institutions and responsibilities (Mitchell et al., 2019)

The IGov project proposed a number of significant changes to the current institutional structure of energy governance in the UK including a new 'Energy Transformation Commission' which could co-ordinate and develop consensus across the existing institutions as well as reducing the remit of Ofgem from policy delivery to economic regulation and moving gas and electricity system operators into public ownership. Full details of the proposals can be found in Mitchell *et al.*, (2019) which also take into account local governance reform and electricity governance reform.

Building on the IGov work, this paper focuses specifically on the potential changes that may be required to the governance of energy infrastructure in the UK in light of the target for net zero emissions by 2050. In order to support this analysis, and using the framework highlighted through IGov, the following sections consider the current power and authority to develop policy and make decision that are relevant to energy infrastructure in the UK.

1.2.1 UK Parliamentary sovereignty

The supreme power in the UK's political system to create and modify legislation sits within the UK parliament[1]; primary legislation can only be created or changed if agreed to by a majority in both the House of Commons and Lords (Parliament, 2020a). Secondary or 'subordinate' legislation, often referred to as 'statutory instruments' which often contains the detailed elements of laws and relate to primary legislation must also pass both Houses of Parliament although this process is more passive - not all secondary legislation requires active approval by politicians (Parliament, 2020b).

While parliament may have the deciding vote on legislation and can amend legislation as it sees fit, the majority of what become successful laws (initially referred to as draft laws, or 'bills') are introduced by the Government in power and these bills tend to be led by Government departments. Back bench (non-government) MPs can introduce so-called private members' bills but these are much less likely to become laws than Government sponsored bills in part because the Government can control timings of Parliament (Parliament, 2020c).

1.2.2 Central Government authority

Despite attempts at decentralisation, political power in the UK remains much more centralised than other similar economies (Institute for Government, 2014). The Prime Minister '*is responsible for the overall organisation of the executive and the allocation of functions between ministers*' (Cabinet Office, 2011, p26) and is therefore able to set the agenda and shape of Government and its various departments.

Below the Prime Minister, HM Treasury is responsible for overall control of Government spending and therefore has the de facto power of veto on all Government departmental spending decisions. As has been shown through the development of the 'Levy Control Framework', the Treasury's economic authority can also cover levies raised on energy bills as well as direct Government spending (House of Commons Library, 2017).

Beneath the authority of the Prime Minister and HM Treasury, but still within central Government, near total energy authority sits in three Government departments. 'Energy' is currently covered by the remit of the Department for Business, Energy and Industrial Strategy (BEIS). Authority for the policy associated with English

[1] Technically the Head of State, currently the Queen can block all legislation as all primary legislation needs to receive Royal Assent.

buildings' standards sits with the Ministry for Housing, Communities and Local Government (MCHLG)[2]. While not directly considered as an energy department, the Department for Transport (DfT) is responsible for all issues associated with transport at a UK level.

It is also worth noting that the Department for Environment, Food and Rural Affairs (DEFRA) is responsible for climate change adaptation and some energy related elements of waste management such as incineration, with elements of anaerobic digestion also covered by its remit in England. Many of these policy functions are devolved.

Other departments may also be involved in energy issues in less significant ways, one such example may be health and safety issues such as those associated with gas infrastructure; these issues sit under the Department for Work and Pensions (HM Government, 2020a).

1.2.3 Devolution

While still sitting under the overall legal authority of the UK parliament, the nations of the UK have seen some significant powers devolved to them. It should be noted that the authority for devolution and the ability to further or reverse it sits with the UK parliament.

Under current devolution agreements, the Northern Ireland Executive has near total authority of energy issues with only nuclear energy issues an 'excepted' matter (House of Commons Library, 2020a).

The Scottish Parliament has less authority over energy issues than the Northern Ireland Executive. In Scotland, while in general, electricity, oil and gas, coal and nuclear energy are 'reserved' issues, certain exceptions meaning some power has been devolved over energy issues (The Scottish Parliament, 2020). Further powers have also been devolved to Scotland under the 2016 Scotland Act with the Scottish Government now also able to legislate on issues of heat, energy efficiency and buildings policy but with market and consumer protection issues still reserved (Scottish Government, 2019). The government has set out its own strategy for energy system development up to 2050 (Scottish Government, 2017).

Wales is in a similar situation to how Scotland was before the further devolution of authority in 2016 with the headline energy issues of electricity, oil and gas, coal, nuclear energy and heat and cooling fundamentally reserved matters (National Assembly for Wales, 2020). Some specific exceptions exist which are detailed in the 2017 Wales Act (Parliament, 2017).

Authority over energy governance could of course be devolved further and local authorities have been recognised as potentially important actors in relation to change (e.g. Smith, 2007; Tingey *et al.*, 2017). Tingey *et al* (2017) highlighted local authority

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[2] Devolved nations each have their own policies and procedures for the development of buildings regulations which cover energy efficiency and heat sources.

engagement in energy but showed that capacity in local authorities for major and strategic involvement was limited. More recently, however, energy knowledge and capacity has been suggested to be increasing in English local authorities even at a time of economic austerity (Kuzemko and Britton, 2020).

There are of course variations across local authorities, in part in relation to national devolution described previously. Following trials, the Scottish Government is now considering mandating the production of local heat and energy efficiency strategies (LHEES) for local areas (Wade et al., 2019). City scale plans may also exist and one example is London which has some energy authority over rules for planning and new buildings (Greater London Authority, 2020).

Cleary, with varying levels of devolution to UK nations and the potential for further devolution to local authorities, existing multi-level energy governance in the UK is complex and as a result, complex governance interactions exist. Yet as Cowell *et al.* (2017) show, the strategies for, and the (varying) deployment of, renewable electricity at national levels has depended on UK wide financial support and policies.

1.2.4 Government energy bodies and advisors

Ofgem, the regulator of wholesale markets, networks, suppliers and system operators, remains a non-ministerial Government department with an independent board but subject to the rules and direction of BEIS. The 2010 Energy Act gave Ofgem a duty to take into account ‘future’ consumer issues and explicitly referred to greenhouse gas (GHG) emissions (HM Government, 2010), and the 2013 Energy Act provided a route for Government to prescribe a strategy and policy for Ofgem through a so-called ‘Strategy and Policy Statement’ (SPSS) (DECC, 2014). However, despite a Department of Energy and Climate Change (DECC) consultation in 2014, a final statement has never been issued leaving Ofgem with only limited ‘social and environmental guidance’ issued by DECC in 2011 as a basis for environmental and social decision making (Mitchell, 2018). While a recent ‘decarbonisation action plan’ has suggested some steps for Ofgem to support net zero goals, specific details have not been published (OFGEM, 2020).

The Committee on Climate Change (CCC), an executive non-departmental public body, is statutory climate advisor to the UK Government and is enabled through the 2008 Climate Change Act (Parliament, 2008). It has not had its functions modified since its inception although its advice and analysis is now aligned with the UK’s ‘net zero’ goal for 2050 (rather than the previous 80% on 1990 level GHG reduction target). The CCC advised on the net zero target which is now included in an amended version of the Climate Change Act. The Government is legally required to respond to the CCC’s advice, though it is not obliged to act on it.

While not solely energy or climate focused, the ‘National Infrastructure Commission’ (NIC) is an executive agency of HM Treasury that operates ‘*independently, at arm’s length from government*’ advising on infrastructure issues (HM Government, 2017a, p3). Unlike the CCC, the NIC is not a statutory body although some have suggested it should be (Institute for Government, 2017) but Government is expected to respond to the recommendations of the NIC (HM Government, 2017a).

1.3 Section summary

This section has outlined the shape of energy governance in the UK in particular considering how energy infrastructure is governed. Energy governance in the UK is complex and takes place across many levels of government but much authority remains centralised. While some decentralisation of power has taken place, further decentralisation may be required in order to support decarbonisation.

2. The infrastructure challenge

Despite significant progress in UK electricity system decarbonisation associated with the deployment of renewables and the removal of coal generation, decarbonisation of buildings and transport remains limited (Committee on Climate Change, 2019a). In fact, overall, emissions from transport have increased slightly and emissions from buildings, while seeing some reduction since 1990 have recently stalled (see Figure 3).

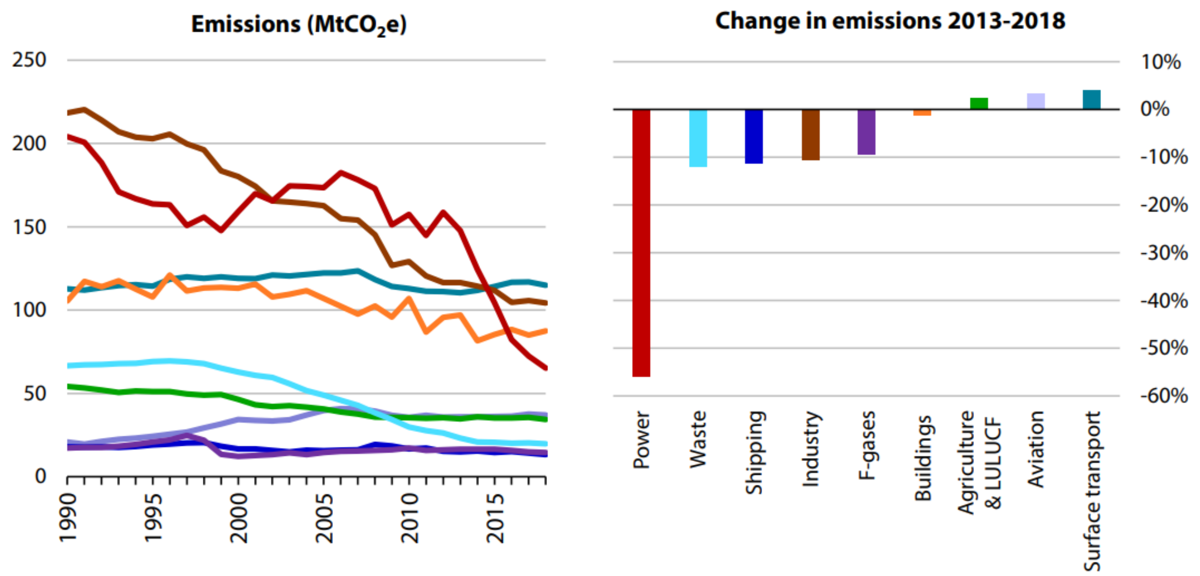

Figure 3. Trends in sectoral greenhouse gas emissions (Committee on Climate Change, 2019a)

Transport, industry and buildings are now the largest emission sectors in the UK and the UK's goal for net zero implies total decarbonisation of these sectors by 2050. Across these sectors, the need for a significant increase in the scale of certain infrastructures appears apparent.

Across all sectors, a significant proportion of electrification seems to be needed but we now drill down into some detail on each of the three largest emitting sectors.

2.1 Industry

The potential technologies to decarbonise industry depend on the particular industrial process. Some of the most detailed analysis on industrial heat decarbonisation pathways was released by the UK Government in 2015 and created pathways for the eight largest industrial sectors, which cover two thirds of industrial greenhouse gas emissions. An outline of different industries and potential decarbonisation options is shown below in Figure 4 (Parsons Brinckerhoff and DNV GL, 2015).

Sector	Pathway	Base year (2012) emissions (million tonnes CO_2)	Relative emissions reduction in 2050 (relative to 2012)	Absolute emissions reduction in 2050[3] (million tonnes CO_2)	Technology groups (in descending order of relative contribution)
Cement	BAU	7.5	12%	0.9	Others; Energy Efficiency
	Max Tech - with or without carbon capture		33-62%	2.5-4.7	(CCS); Biomass; Others; Energy Efficiency; Fuel Switching
Ceramics	BAU	1.3	27%	0.3	Energy Efficiency; Others; Material Efficiency; Fuel Switching; Biomass
	Max Tech		60%	0.8	Electrification of Heat; CCS; Energy Efficiency; Biomass; Others; Material Efficiency; Fuel Switching
Chemicals	BAU	18.4	31%	5.8	Biomass; Energy Efficiency; CCS; Fuel Switching; Clustering; Others
	Max Tech – with and without biomass		79-88%	14.6-16.1	CCS; (Biomass); Others; Energy Efficiency; Clustering; Fuel Switching
Food and Drink	BAU	9.5	40%	3.8	Energy Efficiency; Biomass; Electrification of Heat; Material Efficiency; CCS; Others; Fuel Switching
	Max Tech - with and without electrification of heat		66-75%	6.2-7.2	(Electrification of Heat); Energy Efficiency; Biomass; Others; Material Efficiency; CCS; Fuel Switching
Glass	BAU	2.2	36%	0.8	Energy Efficiency; Material Efficiency; Others; Fuel Switching
	Max Tech – with or without carbon capture		90-92%	2.0-2.0	(CCS); Electrification of Heat; Fuel Switching; Material Efficiency; Energy Efficiency; Others
Iron and Steel	BAU	23.1[4]	15%	3.4	Energy Efficiency; Material Efficiency; Fuel Switching
	Max Tech		60%	13.9	CCS; Energy Efficiency; Clustering; Material Efficiency; Fuel Switching
Oil Refining	BAU	16.3	44%	7.2	Energy Efficiency; Fuel Switching
	Max Tech		64%	10.4	Energy Efficiency; CCS; Fuel Switching
Pulp and Paper	BAU	3.3	32%	1.0	Energy Efficiency; Electrification of Heat
	Max Tech – clustering and electrification		98%	3.2	Energy Efficiency; Clustering; Electrification of Heat
	Max Tech - biomass		98%	3.2	Biomass; Energy Efficiency; Electrification of Heat

Figure 4. Potential reductions and technology options for the decarbonisation of key UK industrial sectors (Parsons Brinckerhoff and DNV GL, 2015, p6)

Reflecting the technologies shown in Figure 4, Cooper and Hammond (2018) recognise that four technological categorisations cover the key industrial decarbonisation technologies for the UK.

- Energy efficiency;
- Bio-energy or hydrogen;
- Carbon capture and storage (possibly alongside bio-energy and hydrogen);
- Electrification based around low carbon electricity.

Cooper and Hammond (2018)

The authors do, however, recognise that novel policy and financial instruments will be required to support the deployment of these technologies (Cooper and Hammond, 2018).

The CCC also recognised these four technology options in its net zero report but also includes the need to reduce fugitive methane emissions (Committee on Climate Change, 2019b).

2.2 Transport

As shown below in Figure 5, 91% of the UK's transport emissions come from road transport making it the key segment where emission reductions are needed (Department for Transport, 2019). Electrification is widely seen as the key approach to the decarbonisation of much existing fossil fuelled transport with the CCC suggesting all cars and vans need to be electric by 2050 and HGVs should be powered by either hydrogen or electricity; increasing levels of walking and cycling are also needed (Committee on Climate Change, 2019b).

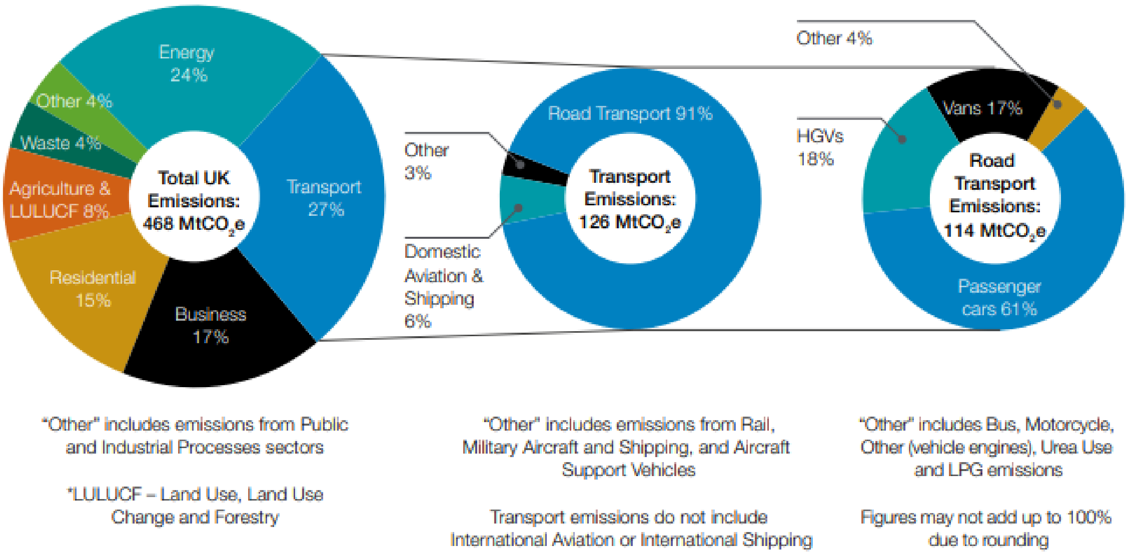

Figure 5. Road transport emissions as a share of UK greenhouse gas emissions from transport (Department for Transport, 2019)

Clearly a transformation to electrified transport will require major expansion in charging facilities. Currently, however, there is no regulation to mandate the deployment of charging infrastructure although public funds are available to support the installation of charge points at home and in public areas (House of Commons Library, 2020b).

2.3 Heat and buildings

Despite a widely perceived need for mass electrification of heating in buildings alongside reductions in demand, pathways for heat (space and hot water) decarbonisation have become more complex with options for decarbonised gas (hydrogen) alongside or potentially combined with electrification. The UK Government's Clean Growth Strategy contains pathways with high levels of hydrogen or electrification (HM Government, 2017b).

The CCC has suggested that a full hydrogen pathway which replaces all gas demand used for heat with hydrogen may not be sensible. Instead, a very large level of electrification will be needed alongside the possibility of hybrid heating systems where hydrogen is combusted at times of peak demand (Committee on Climate Change, 2018).

It should be noted that the Clean Growth Strategy pathways also contain a significant increase in the scale of district heating in the UK, increasing to 17% of domestic heating in all scenarios and between 17 and 24% in non-industrial business use and in the public sector (HM Government, 2017b). The CCC suggests that around 5 million homes (around 19% of the number of current homes[3]) should be connected to heat networks with low carbon sources of heat in 2050 (Committee on Climate Change, 2019c). This potential growth is a significant increase from current levels of around 2% of total heat consumption (BEIS, 2018).

2.4 The size of the infrastructure and investment challenge

Major investment across all energy sectors will be required if the net zero goal is to be met with cost estimates ranging from £50 to £70 billion per annum although there is some disagreement over this between the CCC and HM Treasury (New Scientist, 2020). The Treasury is currently conducting a review into the funding of the transition to a net zero economy (HM Treasury, 2019). The three sectors considered in the previous section all show a need for significant change to how energy is provided in response to decarbonisation. Some key possibilities for technological change have emerged:

1. Increases in energy efficiency;

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[3] Based on ONS statistics on 2017 UK household numbers https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/families/adhocs/005374totalnumberofhouseholdsbyregionandcountryoftheuk1996to2015

2. Electrification of services currently provided by fossil fuels;
3. The use of hydrogen for some industrial processes and a potential role in goods transport and heating;
4. An increase in the use of district heating.

These changes all suggest significant implications for infrastructure in the UK with the potential for:

1. Mass upgrades/electrification transformation of buildings;
2. Increases in electricity generation capacity;
3. Increases in electricity network capacity;
4. The conversion of (parts of) the gas network to hydrogen alongside the potential for decommissioning of parts of the gas network;
5. An expansion in the scale of district heating.

The 2018 National Infrastructure Assessment recognised a number of these issues, and in particular highlighted the need for immediate energy efficiency and renewable electricity deployment (National Infrastructure Commission, 2018). The assessment, however, made no mention of district heating and suggested more research on heat was required before major decisions could be made but it explained '*In the 2020s, decisions will be required on whether the gas network should be maintained and converted, or phased out*' (p44).

The CCC's net zero review suggested net zero could be achieved by 2050 at a cost (compared to doing nothing) of between 1 and 2% of UK GDP; the two largest sectors for investment are the electricity sector which requires around a doubling of investment from current levels to £20 billion per year and around £10 billion a year for low-carbon heating (Committee on Climate Change, 2019b). Interestingly, electrification of transport is seen as a positive cost overall although increased investment in the electricity sector will be needed for charging and capacity. According to the CCC, overall an increase in capital investment up to around 1% of GDP in 2050 is needed; 1% of 2019 GDP is around £22 billion per year[4].

In its assessment of heat decarbonisation costs, the National Infrastructure Commission suggested that in a decarbonised world heating costs would be less that today in real terms, but between £120 billion and £300 billion (central case) of additional costs would be required between now and 2050 (Element Energy and E4tech, 2018). These figures for heat are similar but slightly lower than those costs suggested by the CCC, likely reflecting the fact that the NIC analysis resulted in some residual emissions from the heat sector as it was prior to the introduction of the net zero target.

As shown below, Government figures suggest annual investment in the UK's energy system is currently around £19 billion per year with the majority (60%) of this in the electricity sector. It is, however, apparent that not all energy investment is considered in this figure, for example transport and energy efficiency does not feature. It should be noted that trade body Energy UK uses a slightly lower number

[4] Based on GDP data from: https://www.statista.com/statistics/281744/gdp-of-the-united-kingdom-uk-since-2000/

with £13.1 billion invested in 2018 (Energy UK, 2020). Either way, the net zero target implies both an increased level of investment and increased investment in sectors which currently see only limited investment.

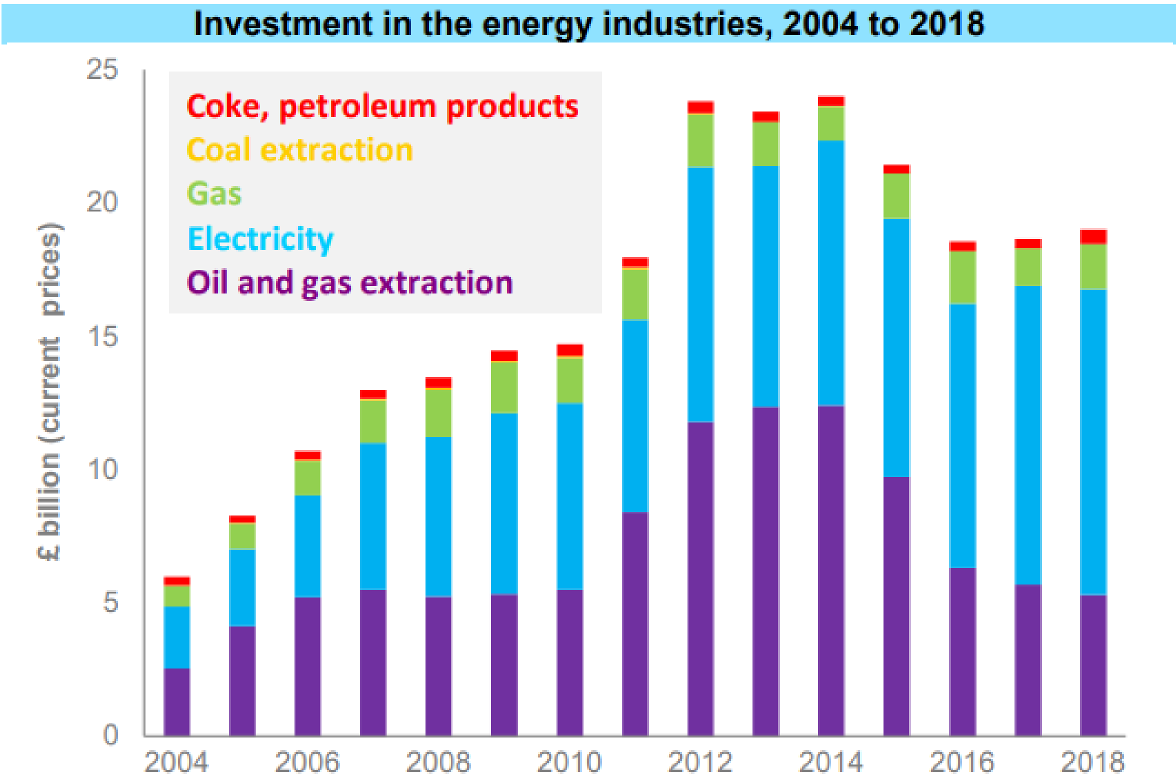

Figure 6. Annual investment in the UK energy industries (Department for Business Energy and Industrial Strategy, 2019a)

In light of questions over the appropriateness of energy governance in response to the requirement for energy system transition and the scale of infrastructure investment needed, this paper now goes on to review potential approaches for the governance of energy infrastructure.

3. Approaches to infrastructure governance

There is no one-size-fits-all best approach to how infrastructure and in particular energy infrastructure should be governed. In fact, as highlighted previously, the complex nature of the idea of governance and the fact it encompasses wide political structures and ideas and societal elements means that the style of governance and choices made about the means of delivering energy infrastructure outcomes will vary according to different political and ideological starting points.

The literature focusing specifically on the governance of energy infrastructure is relatively sparse and there does not appear to be a unified or co-ordinated research theme in this area. This allows our analysis to attempt to bring a broad and disparate literature together. Based on a wide ranging literature review, this section considers the key themes associated with the governance of infrastructure.

3.1 State versus private ownership

Debates around whether energy infrastructure should be owned by the public sector or the private sector have been taking place for decades. While Governments can (generally) get hold of lower cost finance than private companies, the value of private ownership is primarily associated with the potential for efficiency savings and cheaper alternatives by the private sector, encouraged by the profit motive and a better ability to innovate (Boyfield, 1992). Certain risks may also be managed better by public or private sector actors depending on existing skills and expertise (Ng and Loosemore, 2007). Concerns over reduced competition associated with public ownership could potentially be managed through the use of tendering for products and services.

Rightly or wrongly, the sale of British Coal, British Energy, British Gas, British Nuclear Fuels Limited, British Petroleum, Britoil and the various electricity boards (House of Commons Library, 2014) moved the ownership of much of the UK's energy infrastructure from state into private hands. The UK became the first country to privatise a complete electricity system (House of Commons Library, 2014), an approach which has been described in part as 'experimental' (Vickers et al., 2020).

While the vast majority of UK energy infrastructure is now privately owned, proposals were made by the official (unsuccessful) opposition during the last election period to re-nationalise gas and electricity networks (Labour Party, 2019). While large scale re-nationalisations are rare, commentators have pointed out that Labour's proposals could have allowed a level of state involvement in energy infrastructure currently seen in many countries (Institute for Fiscal Studies, 2019).

Although often controversial and highly politicised, the required scale and speed of UK decarbonisation suggests that greater state (UK-wide and devolved administration) involvement may be required; whether that could involve any renationalisation remains an unanswered question. Scholars have specifically considered how the UK's liberal market based approaches may be less suited to the development of heat networks compared to the more coordinated political-economies of Norway and the Netherlands (Hawkey and Webb, 2014).

Models exist where infrastructure sits between fully private and fully state ownership and control. Indeed, while the UK energy infrastructure may be owned privately, energy remains a heavily regulated sector. Non-ministerial government department Ofgem currently issues licenses which allow certain energy infrastructure owners and businesses to operate, regulates the performance and income of monopoly network companies and works to enhance competition. Overall, it may be the case that changes to regulation could provide similar outcomes to what nationalisation is expected by some, to be able to achieve.

3.2 Public/private partnership models

Approaches exist whereby infrastructure can be managed and/or delivered by the private sector but under the close control of Governments. So-called public private partnerships (PPPs) can remove the need for Government finance from projects as projects are financed by the private sector but allow Government control through contracting for services or outputs (Brown, 2007). This approach can of course shift elements of risk between actors with for example demand risk being taken on by Governments. However, it's argued that the Government balance sheet benefits of PPPs (freeing up cash) may not be material and so the value of PPPs is primarily on the grounds of potential efficiency (Engel et al., 2010).

The historic use of PPP approaches in the UK has often been referred to as Private Finance Initiative (PFI) and data on projects shows that this approach has mainly been used for schools and hospitals; it should be noted some 'energy to waste' projects have used a PPP model (HM Government, 2020b). Following concerns over value and service, the Government announced in the 2018 budget that the PFI (or more recent PF2) approach would no longer be used (HM Treasury, 2018).

3.3 Regulatory Asset Base (RAB) approaches

While PPP approaches are not currently seen by the UK Government as a useful option to deliver infrastructure, some have suggested that the inflexibility of PPP approaches could be overcome using RAB based approaches.

Energy network infrastructure in the UK is regulated based on a regulatory asset base model (RAB) whereby returns are linked to asset values, and investment and income are tightly controlled by regulator Ofgem. Statutory consumer watchdog Citizens Advice (2017) has, however, highlighted issues with network regulation and concerns over excessive profits.

There are also other potential issues with RAB models:

- Difficulties in assessing actual asset value;
- Actual funding of projects;

- Initial procurement of projects;
- A lean towards capital expenditure rather than operational expenditure.

(Meaney and Hope, 2012)

The use of the RAB model in the UK is primarily associated with governing existing infrastructure. While RAB approaches can be used to deliver new infrastructure, it's not clear that this approach offers any efficiency advantages to PPP models (Dejan Makovšek and Veryard, 2016). Combinations of PPP approaches and RAB approaches may have value although the use of this model in practice is limited.

It's notable that the UK Government consulted last year on the idea of using a RAB model to deliver new nuclear power stations, suggesting this would be a similar approach to the Thames Tideway Tunnel. Through reducing risk for those constructing nuclear plants, this model was suggested to be able to reduce the cost of financial capital behind new nuclear power stations therefore potentially reducing the final cost for consumers (Department for Business Energy and Industrial Strategy, 2019b). However, the reduction of risk for constructors of new nuclear plant simply moves this risk to consumers/tax payers and so unless the economic regulation of plant built under the RAB model was extremely accurate, it's not clear consumers would see any benefit from this model (NERA, 2020). The Government has not yet responded to the consultation.

3.4 Market delivery

Large capital requirements and long asset lives mean that infrastructure has often been seen to require some sort of government intervention. It's worth noting that historically this hasn't been the case with gas systems developed by private sector actors (Arapostathis et al., 2013) and much of the UK's railway originally built by businesses (Shaw-taylor and Xuesheng, 2018).

In the UK electricity sector, following privatisation, non-renewable and non-nuclear electricity generation was delivered based on the electricity market with generation being built to match supply. In the 1990s, around 20GW of new combined cycle gas turbines (CCGTs) were built in response to the expected closure of coal and nuclear stations and the expectation of tightening capacity margins (DECC, 2012) alongside the removal of European Community rules which blocked the use of gas for power generation (EUCERS, 2017).

Gas generation can be delivered relatively quickly and global technological developments supported the deployment of CCGTs in the UK (Kern, 2012). Therefore, for UK electricity generation, this expansion of gas generation capacity may have been a unique occurrence. The recent growth in UK renewable electricity capacity has been supported by specific policies including the renewables obligation and the feed in tariff and more recently contracts for difference. The capacity market mechanism was also specifically expected by government to support new gas generation plant suggesting the market was no longer seen as able to support it (Lockwood, 2017).

3.5 Section overview

There is no one approach to the governance of energy infrastructure in the UK; however, multiple models exist and can be used. Indeed there are a broad spectrum of approaches which vary from 'state build and ownership' to 'unregulated and free market'. Building on Howlett's (2009) modes of governance approach outlined in Section 1, **Error! Reference source not found.** overleaf shows the various models which exist in the UK and where they might fit on a spectrum of political philosophy; it also provides some examples and suggests how these examples are built, managed and run.

The variation highlighted in the table suggests that the development of governance is a messy, complex and in part random process which is in part defined by overarching political approaches to state involvement.

In considering approaches to governance of infrastructure, institutional methods may have some value. In particular, historical institutional approaches may assist us in understanding how governance systems have developed over time and how historic decisions, approaches and ways of thinking shape and continue to impact policy and governance change (see Kuzemko *et al*, 2016). More recently developed ideational, institutional approaches may also shine some light on how ideas, particularly around thought paradigms and ideology have been incorporated in the development of policies and institutions (e.g Schmidt, 2010).

The following and final section of this paper considers how we will apply some of the foundational issues in this paper in the next steps of our research.

Table 1: Modes of energy infrastructure governance and ownership in the UK

	Statism (public)			Co-ordinated marketism (mixed)			Liberal marketism (private)			
Model	**Public build and public own**	**Public commission, private build, public ownership**	**Public commission, private build, joint ownership**	**Public commission, private build and private ownership**	**PPP/PFI**	**Regulated asset base**	**Direct financial incentives**	**Competitive incentive systems**	**Market creation through regulation**	**Active de-regulation/free markets**
Who decides?	State	State	State	State	State	State	Private sector	Private sector	Private sector	Private sector
Who builds?	State	Private sector	Private sector	Private sector	Private sector	Private sector	Private sector	Private sector	Private sector	Private sector
Who owns asset?	State	State	State/private	Private	Private? Special purpose vehicle?	Private	Private	Private	Private	Private
Who manages?	State	State	Joint	Private	Private/state	Private	Private	Private	Private	Private
UK examples	Roads	Publicly owned energy centres?	Heat networks	Fibre broadband?	Hospitals	Energy networks	Solar PV	Offshore wind	Condensing boilers	Buildings?

4. Conclusions and next steps

With such major energy system changes required and clear infrastructure impacts, the next stages of our research will investigate current UK energy infrastructure governance, consider any infrastructure governance issues that could put decarbonisation at risk and then investigate potential solutions.

We will focus on three infrastructure sectors which appear to be important areas for decarbonisation. These case studies are:

Networks: this will focus on the governance of gas and electricity networks and the potential development of heat networks.

Buildings: this will consider the idea of buildings as infrastructure noting the importance and lack of progress around heat decarbonisation.

Offshore wind: this will focus on the potential for rapid growth in offshore wind as a result of cost reduction, the current government target and the importance of cross-sector electrification and potential hydrogen production.

While these case studies may not cover all areas of the UK energy system they are related to key areas including heat, transport and industry. We expect synthesis across case studies will allow general energy infrastructure governance issues to be highlighted and we also expect significant case study detail to emerge.

For the ongoing research we plan the following steps:

1. We plan to use governance mapping to map the policy/regulatory institutional structure associated with each of our case study areas. This mapping will highlight the role of various bodies in the governance of each case.
2. For each case study, a number of semi-structured interviews will be used to:
    a. Test our governance mapping;
    b. Investigate concerns over existing governance associated with net zero;
    c. Consider proposals for infrastructure governance change;
    d. Consider historical and ideational institutional issues associated with UK infrastructure governance and what we may be able to learn from previous infrastructure successes and failures.

Results from these case studies will be reported in an upcoming synthesis report, UKERC blogs and academic journal articles. We are also planning a project close-out webinar.

We would be extremely pleased to hear any feedback on the ideas in this paper and our proposed research approach.

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