

Governance Challenges Emerging from Energy Digitalisation

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Abstract: The UK energy sector is experiencing a particularly rapid shift towards increased use of digital and data-based technologies, referred to here as energy digitalisation. Energy digitalisation holds potential to significantly change the ways in which energy is generated, managed and consumed. In doing so, it opens a door for new actors, roles and responsibilities to evolve. This paper presents evidence that novel governance challenges are also emerging from energy digitalisation that both complicate and differ from known energy governance issues. These challenges are testing institutional, policy and regulatory regimes across energy and broader digital systems; neither of which appear to fully serve the specific needs of digital energy governance at present.

Keywords: digitalisation, data, technology, automation, governance, institutions

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Executive Summary

The UK energy sector is experiencing a particularly rapid shift towards increased use of digital and data-based technologies, referred to here as *energy digitalisation*. Energy digitalisation holds potential to significantly change the ways in which energy is generated, managed and consumed. In doing so, it opens a door for new actors, roles and responsibilities to evolve. This paper presents evidence that novel governance challenges are also emerging from energy digitalisation that both complicate and differ from known energy governance issues. These challenges are testing institutional, policy and regulatory regimes across energy and broader digital systems; neither of which appear to fully serve the specific needs of digital energy governance at present.

This paper provides an overview of findings from the first stage of PhD research, examining governance challenges emerging as a result of energy digitalisation. The paper begins with a discussion of key actors, technological changes and trends forming the context of energy digitalisation in the UK. Research findings are then presented, outlining six key governance challenge categories emerging from energy digitalisation. The paper concludes by introducing future research regarding institutional change in response to new governance challenges.

Contextual factors

Actors: The number of actors, and diversity of actor types, is increasing within the energy system. This is linked to a diversification of business models, new types of customer relationship, and decentralising trends that enable more

granular, active participation in the energy system. The potential for digital new entrant businesses to permanently ‘disrupt’ the actor landscape is currently unclear and they face competition from incumbents’ data access power.

Technological Changes: Energy digitalisation is framed by changes in software and data processing, physical energy technologies, and connectivity. Changes in software and data processing are particularly influential as they enable insights to be drawn from energy data, and actions to be taken based on those insights. The application of optimisation algorithms and machine learning are particularly anticipated to grow as energy digitalisation develops. Automated control technologies offer the potential to link advances in digital technologies with the needs of an energy system based on intermittent renewable generation.

Trends: Energy digitalisation is shaped by four key trends in the wider sector landscape: datafication, decarbonisation, increased cross-sector linkage and decentralisation. These trends, and their interactions with energy digitalisation, are rapidly changing the boundaries and operation of the energy system away from traditional system models.

Digital Energy Governance Challenges

Six key governance challenge categories were identified from preliminary interview data. These are: ***data, distributional effects, organisational culture, politics, regulation and automation***. An overview of the six challenge areas, including challenge sub-categories, is presented in Figure 1 on the following page (p.5). Research findings strongly indicate that emergent digital energy governance challenges both complicate and differ from known energy governance challenges; presenting unfamiliar issue areas, new actor dynamics, and different scalar consequences.

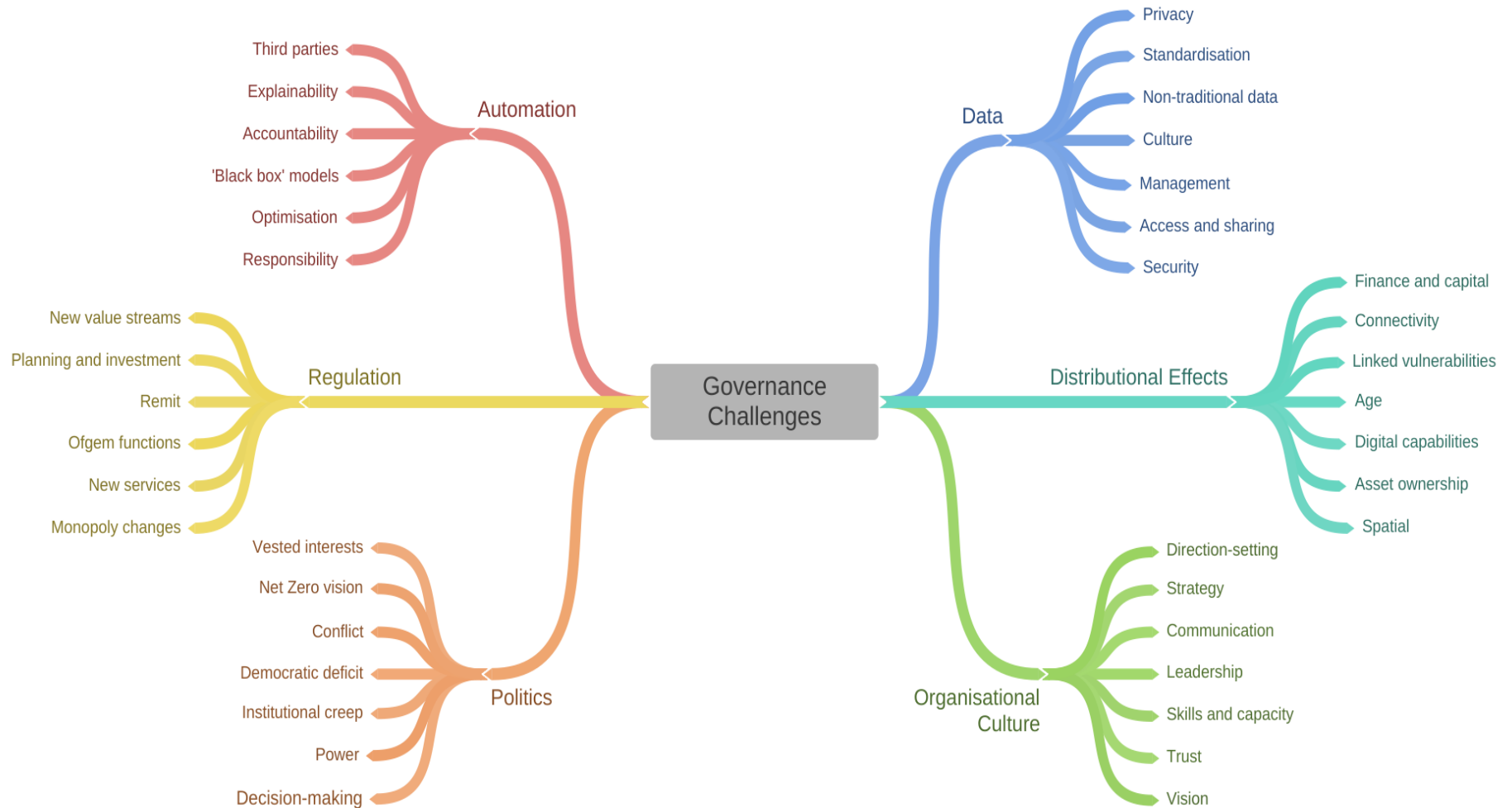
These challenges are testing institutional, policy and regulatory regimes across both energy and broader digital systems; neither of which appear to fully serve the specific needs of digital energy governance at present. Further research is required to explore how governance regimes can be best developed to support a just transition to Net Zero.

Further Research

Starting in June 2020, series of online research workshops will be held, focussing on the structure of the current institutional landscape, and governance models guiding these institutions. Workshops seek to answer the research question: Is the existing institutional landscape fit for purpose to address governance challenges emerging from energy sector digitalisation? Research will consider institutions as organisational bodies as well as factors informing their governance, capabilities and coordination (e.g. remit, relationships, powers and decision-making processes).

Readers interested in participating in a workshop should please contact e.judson@exeter.ac.uk for further information and/or complete the availability and consent form via [this link](#).

Figure 1: Overview of six key digital energy governance challenge categories



1 Introduction

Digitalisation and decarbonisation are two global mega-trends that affect the way we as individuals live, socialise and consume. On a societal level they influence the economy, finance and business practices, and shape the nature and scope of rules, institutions and law. There is also a need to understand how the two trends interact, for example how digital technologies are being developed or adapted to support whole-economy decarbonisation.

In the United Kingdom (UK) the energy sector is experiencing a particularly rapid shift towards increased use of digital and data-based technologies, referred to here as *energy digitalisation*. Digital technologies and techniques can provide tools to coordinate increased levels of decentralisation and flexibility within the UK energy system, that are required to achieve Net Zero ambitions (Shakoor, Davies and Strbac, 2017). The central capacities enhanced by digitalisation are data-collection, data processing, and automation. In the energy sector, digitalisation enables data to be collected in more granular units, in closer to real-time, and from previously unreachable spaces and subjects. Key processing functions for the sector include monitoring, prediction and control of energy assets, flows, consumption and other system variables (e.g. voltage or frequency). Digitalisation could also enable automation of many physical and cognitive functions across the system, from domestic energy management through to industrial demand-side response. These changes, and their monetisation through novel digitally-facilitated business models, are catalysing significant changes to the actor landscape and operation of the energy sector.

Digital technologies hold potential to make a profound impact on energy sector carbon emissions by optimising energy flows and enabling further integration of low carbon generation in energy networks. For example, digital technologies offer new ways to predict the output of intermittent renewable electricity generation, support efficient grid balancing and markets at more local scales, and enable new ways to optimise use and planning both of networks and distributed renewable generation. On the demand-side, digitalisation could also facilitate granular and automated flexibility and coordinate new moveable loads such as electric vehicle (EV) chargers or heat pumps. Some actors further advocate the potential of digitalisation to disrupt – or even ‘democratise’ – certain elements of the system by empowering new, decentralised actors to become active system participants with revenue-generation and decision-making opportunities. Across these different functions, digitalisation affects the spread and types of actors within the system and the distribution of new roles and

responsibilities. The significance and depth of these changes for actors across the energy system, including civil society, is profound.

Despite its tantalising potential, energy digitalisation does not necessarily present an uncomplicatedly positive picture for carbon reduction. Neither does it escape the production of potentially negative socio-economic effects. The environmental impacts of digital technology life-cycles – including extraction of raw materials, manufacturing processes, energy demand and ‘e-waste’ – can be harmful (Berkhout and Hertin, 2004; Widmer *et al.*, 2005; Morley, Widdicks and Hazas, 2018; Coroamă and Mattern, 2019; Hintemann and Hinterholzer, 2019; The Shift Project, 2019). Digitalisation also presents increased cyber and information-security risks across all levels of the energy system, raising questions about the reliability and resilience of a more interconnected system (Lin and Bergmann, 2016; Butler, 2018; Marsh and McLennan Companies, 2018). Finally, research from other sectors suggests that digitalisation can have pervasive socio-economic and political impacts (Ng, 2015; Kelly *et al.*, 2018; Goldfard and Tucker, 2019; J. Wood *et al.*, 2019; Mattsson, 2019). Although the eventual impacts of energy digitalisation are as yet unclear, a growing body of research suggests that it presents potential for unjust outcomes that may exacerbate existing system inequalities, or indeed create new drivers of energy injustice (Fairchild *et al.*, 2017; Lennon, 2017; Milchram *et al.*, 2018; Sareen and Haarstad, 2018; Fortier *et al.*, 2019; Powells and Fell, 2019).

1.1 Research aims and methodology

This PhD research aims to identify priority areas in which UK digital energy governance can be improved to facilitate energy system decarbonisation, while also supporting other ‘public impact’ goals as to mitigate negative socio-economic effects. Empirical data will be collected through a qualitative, mixed-methods approach using three main data sources: documents, interviews and online workshops. Data collection and analysis are iterative, structured over the stages detailed below.

- i. **Literature review:** This provides a deep dive into energy system change, energy digitalisation and the UK policy and regulatory landscapes in which these developments are located. The review will remain a ‘live’ document under continuous evaluation throughout the PhD research period to retain responsiveness to technological, policy and academic developments.

- ii. **Preliminary interviews:** 18 semi-structured interviews were conducted between November 2019 and March 2020 with energy and digital sector experts from all key constituencies in the UK digital energy landscape. Participant recruitment was guided by the literature and policy reviews, a review of the commercial landscape, and attendance to sector conferences and events. Findings - outlined in sections 2 and 3 of this report - have been used to test themes arising from the literature review and to steer the focus and design of upcoming online workshops.
- iii. **Online workshops:** Commencing in June 2020 a series of online facilitated workshops will be held, as outlined in section 4 of this report. Discussions will focus on the institutional landscape of digital energy governance and attendees will include representatives from all key constituencies in the UK digital energy landscape. Each workshop will be curated to maximise organisational variety in order to explore diverse perspectives, interests and interactions. Participant recruitment will be guided by the literature and policy reviews, a review of the commercial landscape, and 'snowball' participant recommendations from preliminary interview and workshop participants.
- iv. **Follow-up interviews:** commencing in October 2020, a small number of lightly structured follow-up interviews will be conducted to further explore key points of consensus or conflict emerging from workshop findings.

Findings from all stages of research will inform the PhD thesis and will provide the basis for further academic publications (e.g. journal papers). A shorter report will also be made available for a practice-based audience, outlining key findings and policy recommendations.

1.2 Discussion paper

The following sections of this paper present findings drawn from preliminary interview data. Section 2 explores key contextual factors shaping the development of energy digitalisation. Section 3 explores six governance challenges emerging from energy digitalisation.

It is acknowledged that the data sample size and the single interview time-point (November 2019 – March 2020) limit the conclusions which can be drawn from data presented; particularly in relation to assigning definitive priority weightings to the governance challenge categories discussed in section 3. As such, the aim of this paper is to present a snapshot of thought from a cross-sector sample of expert interviewees, designed to provoke discussion for future stages of PhD research.

2 Digitalisation and changing energy landscapes

This section presents an overview of the actors, technological changes and trends identified as key contextual factors surrounding energy digitalisation. Data informing this section is mainly drawn from responses to question 1 in Annex 2.

2.1 Actors and business models

Interview participants identified two broad changes in the actor landscape of the energy sector with relative consensus. Firstly, there has been growth in the number of actors and diversity of actor types. This is linked to a diversification of business models, new types of customer relationship, and decentralising trends that enable more granular active participation in the energy system. Secondly, the actor landscape is still developing, such that it may not yet be possible to identify all key actors that will populate the mature digitalised energy sector.

Participants identified developments within business as the most significant change to the energy sector actor landscape. By developing new value propositions and challenging established business models, energy digitalisation is effecting change within the ecosystem of commercial energy actors. However, interview participants disagreed whether key business actors will be dominated by new entrants or incumbent market players over time.

2.1.1 Incumbent businesses

Six participants cited incumbent energy businesses - namely regulated monopolies - as key actors that are likely to seek to retain their position moving forwards. Participants identified the market power of these businesses as presenting a significant advantage in terms of the sheer quantity of data they are able to collect and process. This may help to secure a high future market share, so long as business practices are updated. Relatedly, participants discussed three processes through which digitalisation is changing the structure of existing energy businesses:

- i. *Adoption of new software practices*: software is becoming increasingly central to almost all business functions. This includes 'back office' functions, such as human resources, through to more visible functions related directly to energy management or customer relations. The changes needed to fully digitalise incumbent businesses present particular challenges regarding the development of a digitally skilled workforce

and digitally-friendly ways of working, which may differ from entrenched organisational culture or practices.

- ii. *Use of legacy IT systems:* incumbent businesses generally do not have to digitalise completely from scratch as some computer systems are already in use. However, existing systems may be old or unable to adapt to change. As such, a patchwork of IT systems has reportedly developed which can present problems regarding system interoperability and agility. These problems are compounded if legacy IT infrastructure is mission-critical and updates are perceived as risky, leading to change-aversion or maintenance of unsuitable systems.
- iii. *Portfolio diversification:* incumbent businesses were identified to be responding to digitalisation through portfolio diversification. Related literature demonstrates that mergers and acquisitions (M&A) represent one strategy through which incumbent energy businesses can access new business models and digitally skilled workers (Sand, 2017). For example, Shell New Energies has acquired a sizeable portfolio of small businesses spanning aggregation, EV charging and renewable electricity supply functions, amongst others (Schaps, 2017; Shell UK, 2018; Limejump, 2019).

2.1.2 New entrants and business models

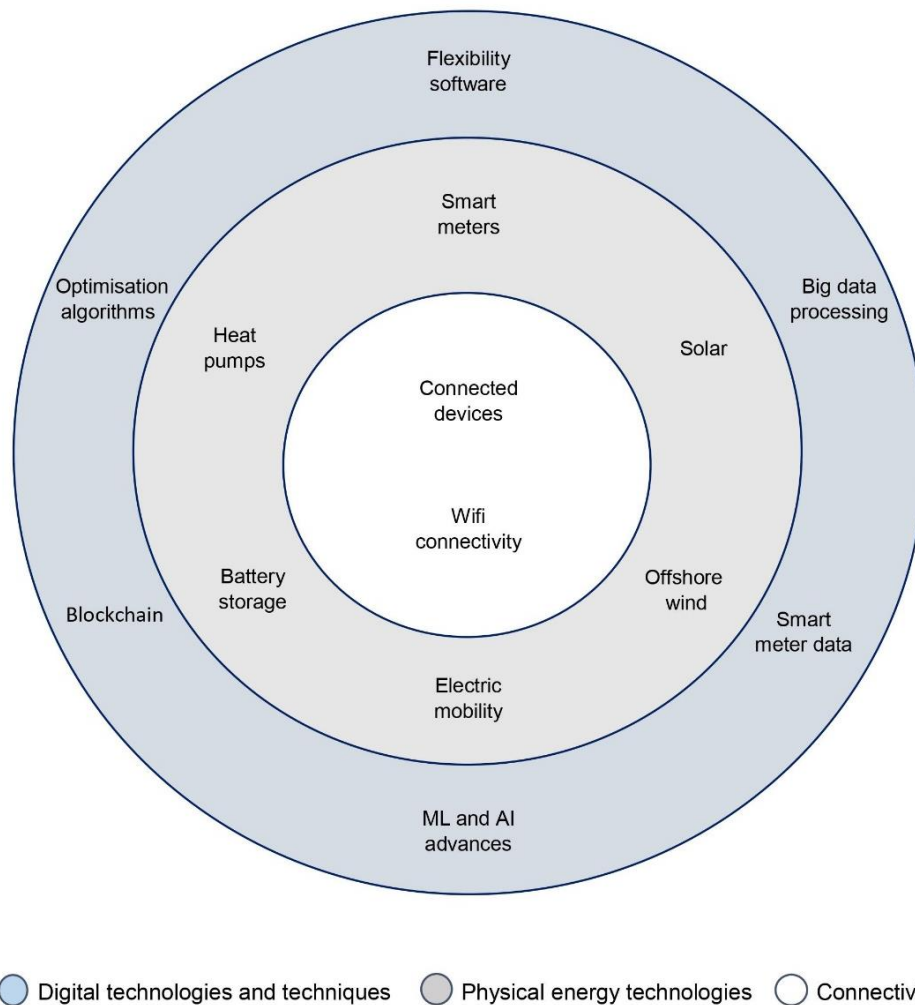
Participants identified business model diversification as a key trend amongst new entrants, emerging across the three areas below. Although business model diversification is not only demonstrated by new entrant businesses, participants identified a tendency for new entrants to exhibit a wider range of model innovations than incumbents.

- i. *Data analysis, software and digital control:* business models focussing entirely on data and software are widely emerging. Data/software companies may either be energy-specific or tech companies that are working with energy data as part of a broader portfolio.
- ii. *New supply propositions:* energy supply is a rapidly diversifying business field, with new value propositions emerging around aggregation, service bundling (within energy but also across other utilities), energy as a service (e.g. warmth or miles), peer to peer (P2P) trading, and dynamic pricing through time of use (TOU) tariffs.
- iii. *Customer relationships:* this area of new value proposition development concerns businesses working both in and beyond the energy sector. Trends in energy customer relationship management may therefore reflect broader trends shaping this space. New value propositions include personalised services, 'set and forget' utility or asset management services, and interfacing services (e.g. voice technology, applications) designed to render background technologies 'invisible' to the consumer.

2.2 Technological changes

Participants discussed a range of technological changes shaping energy digitalisation, spanning three themes: digital technologies and techniques, physical energy technologies, and connectivity. Categories below are ordered by the number of participants referencing each, from highest.

Figure 2: Technological changes shaping energy digitalisation



2.2.1 Digital technologies and techniques

Ten participants referenced key digital technological changes focussed on software and data processing development, rather than physical equipment. Software and data processing developments are important components of the digitalisation process as they enable insights to be drawn from energy (and related) data, and actions to be taken based on those insights.

Developments cited include, but are not limited to: optimisation algorithms, 'big data' handling techniques, blockchain, flexibility-enabling software, forecasting, machine learning, AI advances, cloud computing, edge processing, cybersecurity improvements, and smart meter data flows. Amongst these changes, developments in optimisation algorithms - monetised through new business models such as home energy management systems - were referenced most frequently. It is possible that these tools have evolved particularly rapidly due to their relative adaptability; enabling the repurposing of existing algorithms to align with new energy sector needs. The importance of smart meter data was further referenced by three participants; connecting physical equipment rollout (outlined below), with digital advances building from newly available data. Across all areas of software and data processing development, there is evidence of increased buy-in from new business entrants to the energy sector. New entrants include energy-specific start-ups as well as established digital or telecommunications players that are expanding into the energy sector.

2.2.2 Physical energy technologies

Eight participants highlighted how energy digitalisation is affected by development of physical energy technologies including: electric mobility and vehicle charging, decarbonisation of heat, battery storage, smart meters, and the wider distributed energy resources (DER) ecosystem. Technological changes in this category were frequently discussed in light of 'virtual cycles' relating to economies of scale; cost reductions can upscale technological adoption, driving further cost reductions and the development of related technologies and services. For example, significant cost reductions in offshore wind and solar were cited as notable factors driving the upscaling of renewable generation in the UK. Higher renewable uptake has then driven demand for development of electricity storage, leading to significant cost reductions in battery technology. The falling costs of battery storage can be further linked with associated technology and service development such as smart EV chargers and domestic battery networks (e.g. SonnenCommunity). These combined effects push the expansion of a more holistic DER ecosystem over time.

2.2.3 Connectivity

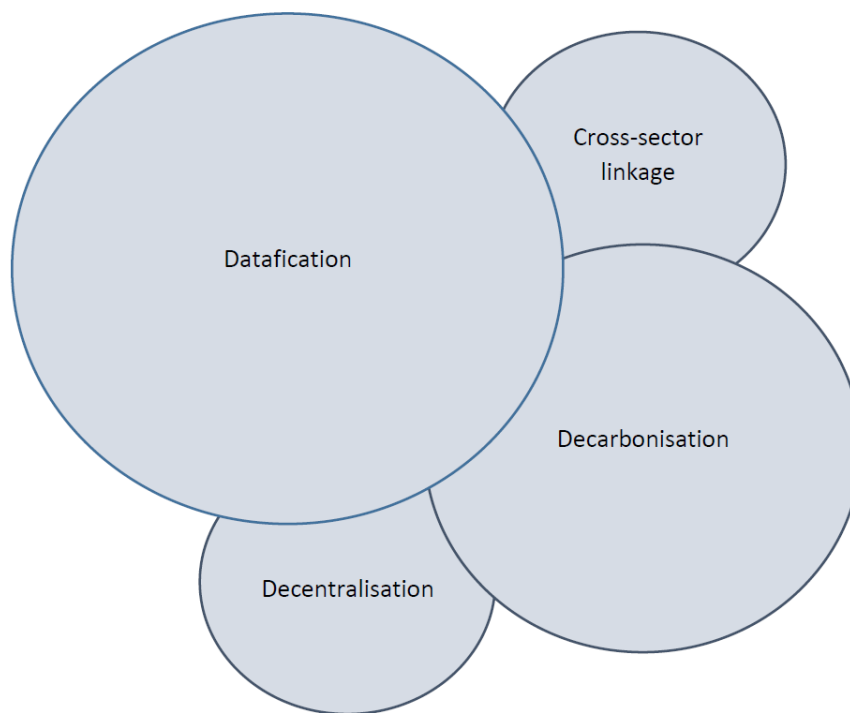
Changes in connectivity were referenced by three participants, with two separate elements. Firstly, the expansion of high-speed Wi-Fi was raised as a vital factor enabling digital energy technology adoption, albeit a currently patchy one in the UK. Secondly, the vast increase in device connectivity, and the related increase in machine to machine communications, was referenced as a notable technological change. This change is a key enabler of automation

and autonomous control of energy devices; from industrial equipment through to individual ‘smart’ household appliances. Governance challenges related to the increase in automation are discussed in more depth in section 3.6.

2.3 Trends

Stakeholders discussed a range of trends grouped into the following categories: datafication, decarbonisation, cross-sector linkage and decentralisation. Categories addressed below are again ordered by the number of participants referencing each category, from highest.

Figure 3: Trends shaping energy digitalisation¹



2.3.1 Datafication

Datafication of the energy industry, defined by four main elements described below, was identified as a key trend by 12 participants. Datafication is considered an enabler of the broader trend of digitalisation.

¹ Bubble size represents the number of participants referencing each trend

- i. *Information granularity and richness*: datafication enables gathering and processing of richer, granular information about the energy system. Advances in datafication were identified particularly at the network edge. The collection and processing of data at shorter time intervals, underpinning the development of the half-hourly settlement, was deemed to be an important factor in further development of DER and dynamic pricing.
- ii. *Measurement, monitoring and modelling*: new means of measurement, monitoring and modelling are being developed in the energy sector as more data becomes available. In some areas these changes are catalysing the development of new standards, in order to improve interoperability.
- iii. *Prediction and forecasting*: increased data availability provides new material on which to train predictive tools. These tools could enable the energy system to manage growth in dynamic loads such as electric vehicles (EVs), support the planning and balancing of intermittent renewable generation, and improve network or asset reliability through predictive maintenance. Use of predictive technologies was identified as a future growth area, particularly if combined with automation.
- iv. *Decision-making*: as above, increased data availability provides new material on which to train decision-making agents. Decisions, and consequential actions, can be taken by humans, automated agents, or a combination of both. The use of automated agents in the energy system is increasing, driven by: shorter decision-making timescales (e.g. responses to dynamic pricing), the complexity of responses needed to handle renewable generation intermittency, and the growth in devices and data sources that require integration to act as a coherent system.

2.3.2 Decarbonisation

Eight participants referenced decarbonisation as a key trend informing the context of energy digitalisation. This trend can be broken down into five areas.

- i. *Renewables integration*: the challenge of integrating intermittent renewable electricity generation is driving innovation around smart technologies, automation, distributed asset management and flexibility.
- ii. *DER developments*: high levels of renewable generation are enabled by a wider ecosystem of DER assets, for example storage and flexibility assets. The need to monitor and control a system made up of a large number of distributed 'moving parts' is driving digital innovation focussed on energy flow coordination.
- iii. *Demand side changes*: energy efficiency measures – both 'smart' (e.g. system optimisation) and 'non-smart' (e.g. building retrofit) – contribute to reducing overall

energy demand. The development of demand-side flexibility can also help to reduce and shift energy demand peaks, supporting grid balancing.

- iv. *Whole-system decarbonisation*: there is a pressing need to address energy decarbonisation beyond the electricity grid. Decarbonising heat and transport sectors may be harder to achieve and digital technologies can help address these challenges. For example, developments in EV smart charging and vehicle-to-grid (V2G) technologies could help reduce electricity network stresses.
- v. *Cultural changes*: heightened emphasis on decarbonisation is informed by socio-political changes including: a perceived cultural shift in awareness, social movements and protest action (e.g. Extinction Rebellion), institutional innovation informing climate policy (e.g. the Citizens Assembly), and growing recognition of energy decarbonisation co-benefits (e.g. public health). This broader cultural shift is starting to interest the digital sector, with companies looking for new opportunities in environmental fields (e.g. Microsoft's AI for Earth programme (Microsoft, no date)). The societal shift required to achieve Net Zero goals further raises new opportunities to address connected environmental and social justice concerns.

2.3.3 Cross-sector linkage

The trend of increased cross-sector interaction was referenced by five participants, with three features identified.

- i. *Non-energy influences*: neither energy consumption practices nor energy policy can be viewed in isolation from the influences of business, practice and policy in other sectors (Royston and Selby, 2019). For example, one participant discussed a particular example of how non-energy sectors can influence EV charging. Furthermore, given the cross-sector fluidity of data flows and the potential for application of software to similar problems, digital businesses increasingly cross sector boundaries seeking expansion opportunities.

“[EV drivers] may actually not even charge at home - they may charge it entirely at work because they get free electricity from their employer - or they may charge it when they go to Tesco's or somewhere else, or they may have a Shell card which means that they can get cheap Waitrose shopping so they do it there”

Alistair McGirr, Head of Strategic Policy, SSE

- i. *Learning*: the energy sector has an opportunity learn from more mature digitised sectors, such as banking and telecoms, with regards to data management, digital strategy, and consumer expectations
- ii. *Standards*: as cross-sector and vector interactions grow, there is increased pressure for governments to set standards for technology. Businesses operating at the edge of, or across, traditional sector boundaries are also becoming advocates for the establishment of standards (e.g. smart appliances).

2.3.4 Decentralisation

Decentralisation of energy generation resources, and the ways in which this has encouraged decentralisation of other energy system features, was discussed by five participants. Four features were identified.

- i. *Decision-making*: there is evidence of a transfer of energy-political decision-making to local authorities, metro mayors and devolved governments. This includes some localisation of policy-making, which participants contrasted with the previous decade of largely 'top-down' policy reform.
- ii. *Whole-system planning*: a local lens can potentially better serve complex and granular planning requirements of multi-vector energy planning, enabling adaptation to the specific features of different localities. For example, electrification of heating may be able to progress more quickly in rural areas with a higher percentage of homes located off the gas network. This changes electricity demand patterns within that locality, potentially altering the planning of renewable generation or storage build-out.
- iii. *Local energy optimisation*: local area energy planning, in tandem with the increase in grid-edge activity, opens doors for more local processing and use of data for energy system optimisation. Although technical capacity for local energy optimisation exists, this is currently prevented by existing market structures.
- iv. *DNO transition*: the DNO-DSO transition is an important part of changes to local energy system operation. The establishment of DSOs as local energy market facilitators was discussed as an important enabler of new business models and means for broadening two-way market participation. However, differences of view were demonstrated with regards to the exact role and responsibilities of a market facilitator. Further differences arose regarding whether the transition would be sufficient to enable a highly decentralised energy system with large volumes of new market participants, including human actors as well as those trading through digital automated agents.

3 Energy digitalisation governance challenges

This section presents an overview of six key governance challenge areas identified from preliminary interview data. Interviews took a generative approach to the concept of governance; encouraging participants to speak from their own point of view rather than providing a prior definition. Interview data therefore incorporates multiple conceptualisations of governance, reflecting both formal (e.g. regulatory) and informal (e.g. cultural) elements of the landscape. Based on learning from the interview data, this research will henceforth use a working definition of digital energy system governance that is adapted from Willis *et al.* (2019, p. 4). The adaptation is designed to reflect two points of learning from interview data: the repeated importance placed on cultural or ‘informal’ aspects of digitalisation and its governance, and the way in which energy digitalisation brings together energy and wider digital systems.

Digital energy system governance:

The policies, institutions, rules, incentives and cultures related to the intersection of energy and digital systems, and the underlying decision-making processes which establish and maintain the above.

Although interview participants were requested to rank governance challenges in order of priority, responses outlined such a variety of perspectives that it was not possible to draw out a clear consensus. Several participants explicitly stated that it is not possible to pick out individual priority challenge areas due to their inherent links. For example:

“I sometimes feel that we break things down into individual challenges too much, and try to tackle them separately when actually they’re all completely interrelated. So it all comes back to thinking about the broader system, and understanding how the system is working, and thinking about it from that system perspective.”

Dr Rebecca Ford, Research Fellow, University of Strathclyde

Due to the lack of consensus, governance challenges prioritised in future stages of research will be guided by the same two criteria determining the challenge areas included in this paper: number of participants referencing the area (taken as a proxy indicator for the degree of cross-

sector awareness of the challenge) and the identification of new digital-specific challenge areas that have shown demonstrable importance in other sectors.

Participants identified challenges grouped into 15 categories in total. Presented alphabetically these are: automation, consumers, coordination, cross-sector linkage, data, distributional effects, markets, environmental impacts, international positioning, networks, organisational culture, planning, politics, regulation and spatial impacts. This report analyses **six** of these categories, prioritised by breadth of participant reference and relevance to current digital policy debate²: **data, distributional effects, organisational culture, politics, regulation, and automation**. Challenge categories are presented in order of the number of participants referencing each, from highest.

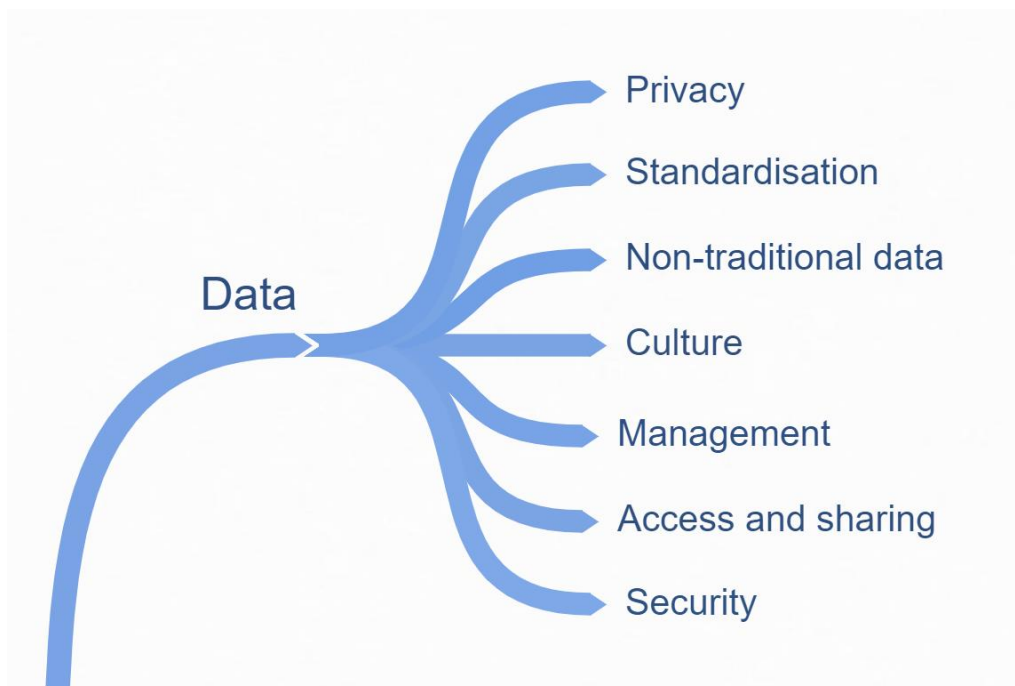
3.1 Data

Data governance challenges were referenced by all participants and were largely identified in connection to recognised themes within policy and research literature (for example see Bloomberg New Energy Finance, 2017; Frerk, 2019; Ofgem, 2019; Sandys *et al.*, 2019). The breadth of references to data governance challenges likely reflects increased stakeholder engagement with sector data governance initiatives, which have received significant investment in recent years. The Energy Data Task Force (EDTF) and joint Modernising Energy Data (MED) work stream received particular mention. Participants also showed awareness of a variety of work streams in commercial, research and third sector spaces.

Amongst data governance challenges, it is difficult to ascribe importance weightings due to notable variation in the level of detail provided by participants. For example, there was a tendency for participants to flag the importance of well-known issue areas - particularly privacy, security, and access and sharing - but to gloss over the detail due to the challenges being perceived as 'common knowledge' in the sector. By contrast, several participants spoke in depth about areas which have perhaps occupied less prominent positions in policy dialogues. For example, one participant discussed challenges emerging around 'lock-in' to using particular data models or operating systems; restricting system interoperability and choice.

² Governance issues concerning market design and function, referenced by 14 participants, are an exception to this rule. This category represents a distinct, separate field of research that falls outside the scope of PhD research, thus will not be explored in this paper.

Figure 4: Data governance challenges



The surge in activity around data governance was welcomed by participants, who also expressed broad agreement with best practice principles and guidelines developed via the EDTF and MED initiatives. Within the focus of these initiatives, participants identified three challenges requiring further attention:

- i. *Enforcement gaps*: energy data governance work remains early stage, with outputs focussing on the establishment of best-practice principles and guidelines. Support for these guidelines may be tested once data-sharing is ‘mainstreamed’ in practice; particularly where commercially sensitive. To ensure that data is opened fairly, a neutral arbiter and/or enforcement mechanism is likely to be necessary. This is partly addressed by the EDTF recommendation of a ‘data triage’ process (Sandys *et al.*, 2019, p. 26). However there remains a need to monitor the efficacy of the process, and openness to influence, once applied more widely in practice.
- ii. *‘Hard’ barriers to openness*: best practice guidelines currently do not have the power to override ‘hard’ barriers to data-sharing written into existing codes and licenses. This can lead to the prevention of data-sharing even where there is the will. A review of existing barriers, and/or the introduction of an over-riding function, may be necessary to combat blockages to following best practice in future. This is an area deserving of further research, likely requiring legal and code governance expertise.

- iii. *Asset registration granularity*: the most desirable and feasible level of granularity in the proposed asset registration strategy remains an open question. While maintenance of a more granular register may present challenges, in a more decentralised energy system there are benefits to registering smaller assets, including those under the 1MW clip size and behind the meter. This level of data granularity could prove particularly useful for operationalising more local grid balancing mechanisms.

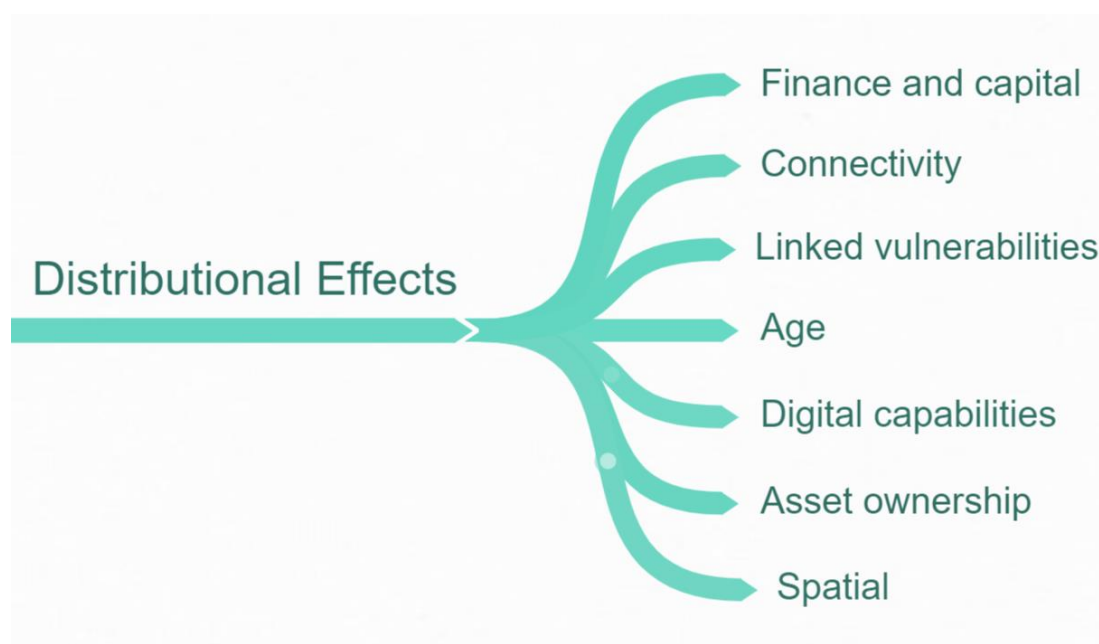
Beyond those addressed within the EDTF and MED initiatives, participants raised two broader challenges regarding the focus of data policy development:

- i. *Holistic data policy*: privacy and data access/sharing have been significant focal points of recent policy work, both across the energy sector and the broader economy. While participants did not dispute the importance of these issue areas, questions were raised about whether the depth of this focus could blinker development of a more holistic response to data governance challenges. For example, standards development was identified as a challenge that could benefit from increased policy attention.
- ii. *Digital beyond data*: participants broadly agreed that data collection, processing and use is a core part of digitalisation. However, there are distinctions between data governance and the broader concept of digital governance. For example, governance challenges concerning software and algorithm development, digital skills distribution, and computational decision-making are all digital governance challenges that extend beyond data governance. Conflation of terms, or an exclusive focus on data governance, risks a potentially reductive approach to important digital governance challenges.

3.2 Distributional effects

Distributional effects of energy digitalisation form the second most widely referenced governance challenge. Distributional effects were identified by participant reference to vectors of inequality. Extant distributional challenges in energy are addressed by a significant body of policy and academic literature. However, digitalisation holds the potential to change the nature, spread and scale of existing challenges, as well as introducing new ones. This area is likely to require further research as digital technologies expand across all energy vectors and intersectional distributional issues emerge.

Figure 5: Distributional governance challenges



Participant discussion focussed on four main distributional vectors: financial and capital inequalities, digital skills and capabilities, uneven innovation outcomes, and linked and cross-sector effects.

- i. *Finance and capital inequalities*: half of all interview participants referenced financial or capital inequality as a challenge. Although fuel poverty was raised, particularly in the context of heat decarbonisation, this was not a focus within interview data. Two main topics were raised: asset ownership and finance options.
 - *Asset ownership*: ownership of assets - including energy assets (e.g. domestic solar PV), digital assets (e.g. HEMS or voice assistants), and property (e.g. home ownership) - generally confers advantages. For example, ownership enables increased levels of choice and control over the asset (also discussed in Powells and Fell, 2019). Although non-individual and/or rental asset ownership models are being developed through energy digitalisation, the potential benefits and drawbacks of these models is as yet unclear.
 - *Finance options*: third party finance options for purchasing emerging energy and digital technologies were cited to be most readily available to wealthy actors. There is a need for development of more inclusive digital energy finance products in order to prevent finance systems from entrenching existing wealth (and related social) divides.

- ii. *Digital capabilities*: there is an uneven distribution of digital capabilities necessary to understand, use and build digital energy technologies. Age and spatial inequalities were particularly discussed.
 - *Age-related inequalities*: older demographics are particularly likely to lack the digital skills necessary to understand, customise and control technology in order to best serve their needs. Individuals lacking digital skills may also be unable to monitor their technology's performance - such as successfully reducing bills - or to seek appropriate help if the technology malfunctions. Low-skilled demographics therefore have a higher risk of receiving technological 'disbenefits' and becoming trapped in the role of passive technology 'hosts' rather than active system participants.
 - *Spatial inequalities*: there is a higher risk that rural areas lack the Wi-Fi and mobile data connectivity needed to facilitate the reliable function of digital technologies. There is also a growing concentration of digital skills within urban working-age populations, due to the development of technology business hubs attracting skilled people to move there (Department for Digital Culture Media and Sport, 2019). This concentration of skills can restrict the ability of businesses and community energy organisations operating in other parts of the UK to recruit employees. The underrepresentation of rural areas in digital business development may also risk entrenching the rural-urban divide through the overlooking of rural needs in the process of creating new, personalised products and services. Although data is not yet available on this topic, there is a danger that this may particularly affect processes of heat and transport decarbonisation, which must account for substantially different requirements of urban and rural populations.
- iii. *Uneven innovation outcomes*: there is a danger that the imperative to segment customers and personalise products and services may lead companies to focus primarily on the most lucrative market segments. As such, customers with higher disposable incomes or higher energy demand may end up with more energy service choice, and/or more favourable offers, than other demographics. Personalised services also hold the potential to enhance economic disadvantage, or other vulnerabilities. For example, individuals with medical needs requiring maintenance of a higher average household temperature, or who use energy in a set pattern due to work schedules, may risk being offered restrictive or very high-cost tariffs if their behaviour is deemed unfavourable to the company or energy system. The potential for

energy service personalisation to become punitive represents an area for future research.

- iv. *Linked and cross-sector factors*: Distributional issues present a particularly complex governance challenge area that will continually evolve as digitalisation affects patterns of vulnerability and unfairness. For example, a link between poor health and fuel poverty is well-established (Thomson, Snell and Bouzarovski, 2017; Oliveras *et al.*, 2020), however there is not yet a full understanding of how digitalisation will affect this relationship. Partnerships between energy sector and external researchers may be beneficial in understanding how linked vulnerabilities evolve in the context of digitalisation. Local authorities' holistic viewpoint over a particular geographic area, and explicit 'social value' mandate, could also prove an advantage in addressing linked distributional effects.

3.3 Organisational culture and management

Governance challenges related to organisational culture were explored by 14 participants with reference to business, regulation, policy and governmental organisations. Challenges were identified by reference to features of organisational culture that present barriers either to advancing technical aspects of energy digitalisation, or aligning energy digitalisation with environmental and socio-economic goals. A common thread to discussions within this category was the centrality of people to processes of technological and environmental change. Participants discussed how cultural and managerial factors - such as effective leadership or direction-setting - can sometimes be viewed as 'soft' or less pressing challenges than material and technical aspects of energy digitalisation. However, these factors have lasting power to shape, or even undermine, the intended use(s) and efficacy of new technologies. As such, there was broad agreement amongst participants that organisational culture and management presents a governance challenge that requires addressing in tandem with a technological focus.

Figure 6: Organisational culture governance challenges



Organisation culture governance challenges discussed include:

- i. *Software development*: a stark difference in software development practices was identified between energy and digital sector organisations. Here, energy sector organisations were described as less agile and more risk-averse in their approach towards innovation. Participants also flagged a knowledge gap in the energy sector regarding software development good practices considered 'common sense' in the digital sector.
- ii. *Subcontracting*: a lack of digital technical skills and capacity 'in-house' can lead organisations to sub-contract technical tasks to consultancies. While sub-contracting for specific technical expertise is not a negative practice in isolation, it becomes problematic if it is the only way in which an organisation engages with digital development. This can potentially lead to a lack of consistency and accountability in data processing and software development practices across different functions of the contracting organisation. If in-house employees are not trained to understand how new software is built - not just how to use it on a surface level - problems can also arise when the sub-contractor finishes a job. This practice can lead to lock-in, requiring additional sub-contracting if software requires adaptation. It may also reduce organisational digital agility if software is not easily adaptable. For example:

They [utilities] get consultants in for six months to write one bit of code, and the consultants leave and no one knows how to modify that code, and 20 years later it's even worse, because no one knows that [programming] language anymore.'

Anonymous

- iii. *Direction-setting*: building on discussions in section 3.1, participants emphasised that data openness alone is not guaranteed to produce innovation that builds towards environmental and socio-economic policy goals. For example:

"I think it's also probably important to communicate - especially to researchers, computer science researchers - what are the most important problems to try and solve? So just having the data isn't enough. You also need to say what the energy industry would like us to do with that data."

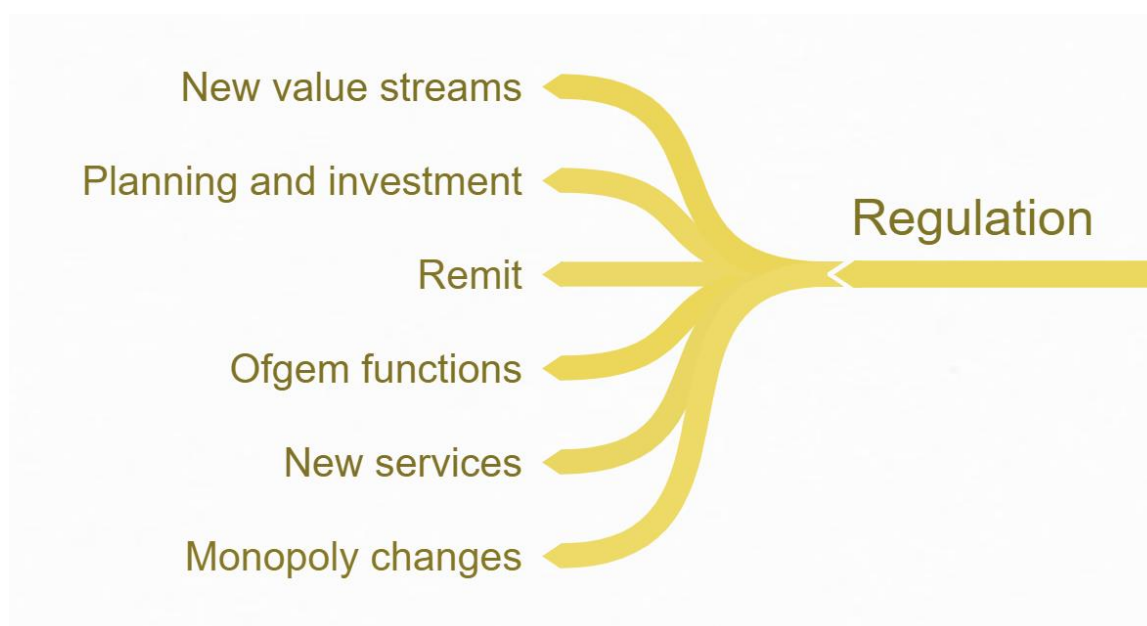
Jack Kelly, Founder, Open Climate Fix

Without clear direction-setting, both at national policy and organisational levels, digital innovators are left to be steered de-facto by the metric of maximising economic returns of new products. This has the potential to create perverse incentives and direct innovation away from areas that hold significant environmental and social value, but may be less immediately lucrative. Fundamentally, the balance between policy-led and market-led innovation is a highly political question that may play out differently across different levels within energy system. However, the current dominance of a market-led approach was raised as a factor that could restrict the ability of policy actors to provide clear steering where necessary. The best method of managing direction-setting challenges currently remains contested. This may be exacerbated as the energy system further decentralises and new actors develop a voice.

3.4 Regulation

Regulatory governance challenges were raised by 12 participants and were identified either by: reference to a relevant regulator (Ofgem, CMA, ICO and Ofcom were all mentioned but discussions focussed on Ofgem); reference to functions performed by a relevant regulator (e.g. charging); reference to regulations created by law; or reference to concepts that are relevant to regulatory approach (e.g. monopolies).

Figure 8: Regulatory governance challenges



Within this category, four themes were most commonly discussed:

- i. *Ofgem functions*: traditional functions of Ofgem, such as testing protocols, are being challenged by new technological developments. Participants identified a tension between system reliability versus freedom to innovate, and the adaptation of Ofgem functions to suit a more decentralised energy market with smaller participants.
- ii. *Planning and investment*: the ability of current planning and investment timescales to support the agility and new risk profiles required to run a digitalised business was criticised. By contrast, the five-year planning cycle also criticism for being short-termist; potentially blocking strategic infrastructural investment for Net Zero 2050 due to emphasis on short-term consumer savings. The interaction of demands for shorter and longer regulatory cycles requires further research.
- iii. *Regulatory remit*: digitalisation and decarbonisation both challenge existing regulatory remits. Questions were raised regarding two main areas of responsibility: decarbonisation and data governance. In both areas, tensions were expressed between Ofgem's defined role as an economic regulator, versus the practical demand to improvise and develop responses to a changing world responsive to factors beyond economics alone. For example, one participant expressed concern around the tension between different regulatory foci:

“You’ve got an economic regulator trying to make these judgements about privacy and fairness”

Anonymous

- iv. *New services and value streams*: four participants suggested the need for more direct guidance/clarity from Ofgem with regards to the development of new markets and value streams. There is a tension with regards to the role of the regulator versus the role of policy in this space; with some participants suggesting the regulator do more and other warning that this forces the regulator into an inappropriately ‘political’ role. One participant described this tension as:

“Ofgem are being asked to both regulate and in some ways design the system”

Anonymous

3.4.1 Monopolies

The changing nature of energy sector monopolies due to digitalisation was discussed as a specific regulatory sub-challenge by seven participants. These changes present new challenges to energy regulatory institutions, as well as to the economic regulatory philosophy guiding the sector. Two main issues were identified:

- i. *Energy monopoly changes*: digitalisation is changing the function(s) of existing physical energy monopolies. This is particularly apparent in the increased importance of data collection and processing within energy networks, as well as in the DNO-DSO transition. Ofgem’s response to new data governance challenges in this space was noted, however participant views were split with regards to whether this new stream of activity is sufficient. The potential for new M&A activity to compound sector monopolies may be worth monitoring.
- ii. *New digital monopolies*: digitalisation is creating new types of monopoly within the energy system. These can include, but are not limited to: data ‘walled gardens’, data collection/processing/modelling protocols, metering infrastructure, and market-enabling ‘platforms’. One participant discussed the emergence of digital monopolies as follows:

“I put the challenge to people - you're all familiar with the energy market. I bet you could tell me where what I describe as the physical energy monopolies are, because they're well-understood and they've been around for a while. And then I follow up and say, but as we increasingly digitalise how many of you are confident about understanding where the natural digital monopolies exist in the energy market?”

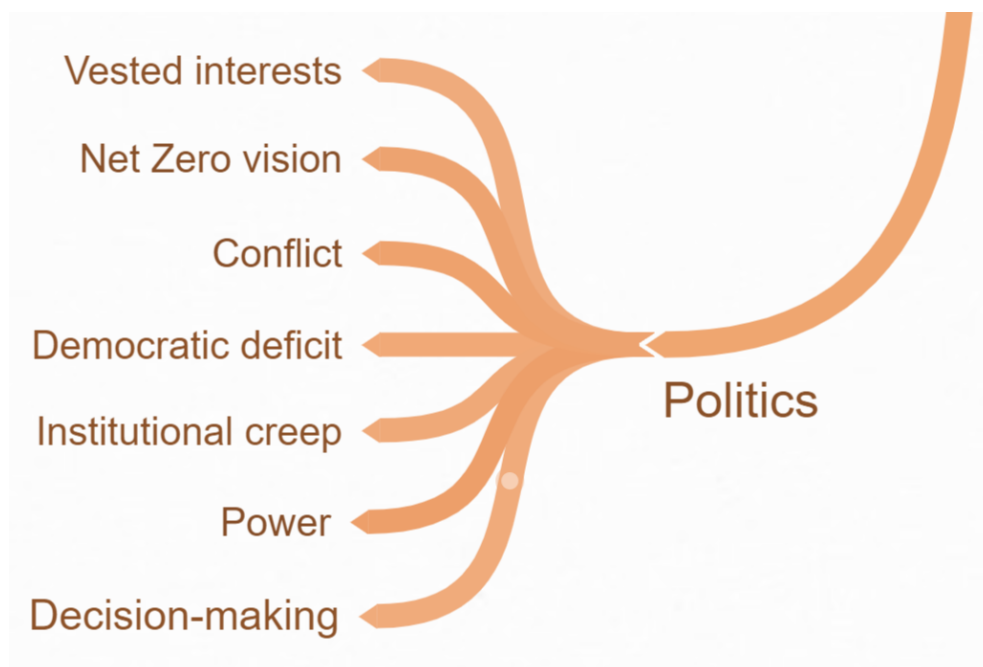
Steven Steer, Head of Data, Ofgem

The development of digital platforms in other sectors has been particularly identified to produce strong monopoly tendencies and “winner takes all” markets driven by five features: strong network effects; strong economies of scale and scope; marginal costs close to zero; high and increasing returns to the use of data; and low distribution costs that allow for a global reach (Zingales *et al.*, 2019, pp. 7–8). Learning from other sectors also indicates that economic regulation alone may not provide the best approach to regulating digital monopolies, which display very different features from physical monopolies such as energy networks. Given the centrality of monopoly regulation to the energy sector, in parallel with challenges related to digital monopoly regulation encountered elsewhere, this sub-challenge represents an area for further research. The newly established cross-economy Digital Markets Taskforce (CMA, BEIS and DCMS, 2020) may be a useful point of reference for any future research.

3.5 Politics

12 participants identified political governance challenges related to energy digitalisation. Although there is some overlap, this analysis separates political challenges from organisational culture and regulatory challenges (detailed in sections 3.3 and 3.4) in a manner that reflects how topics were separated in interview data. Identification of political challenges was guided the following: an explicit participant reference to politics, discussion of political concepts (e.g. power, conflict, interests, democracy), or reference to political bodies (e.g. elected figures, government). Due to the potentially contentious nature of discussions, all participants are anonymised in this section.

Figure 7: Political governance challenges



Within this category, four themes were raised most frequently:

- i. *Vested interests*: if organisations with strong vested interests ‘capture’ decision-making processes, this can present barriers to change where interests are threatened. In the energy sector, this problem can lead to actors blocking or delaying changes necessary to digitalise the sector in a manner that supports a just transition to Net Zero. Participants also discussed how the absence of a neutral sector facilitator can increase the difficulty of system coordination, collective agenda-setting, and conflict-resolution. The EDTF were named as a respected neutral facilitator in the energy data best practice space. However, digital governance challenges extend beyond the EDTF’s specific remit, suggesting that further neutral facilitators may need to be identified, or created, to tackle challenge areas requiring different expertise.
- ii. *Institutional creep*: policy and/or leadership vacuums were cited to have led to the ‘politicisation’ of Ofgem and National Grid in relation to energy system digitalisation and Net Zero goals. In both cases, the practical need to respond to rapid energy system change was cited to have forced these organisations to act beyond their

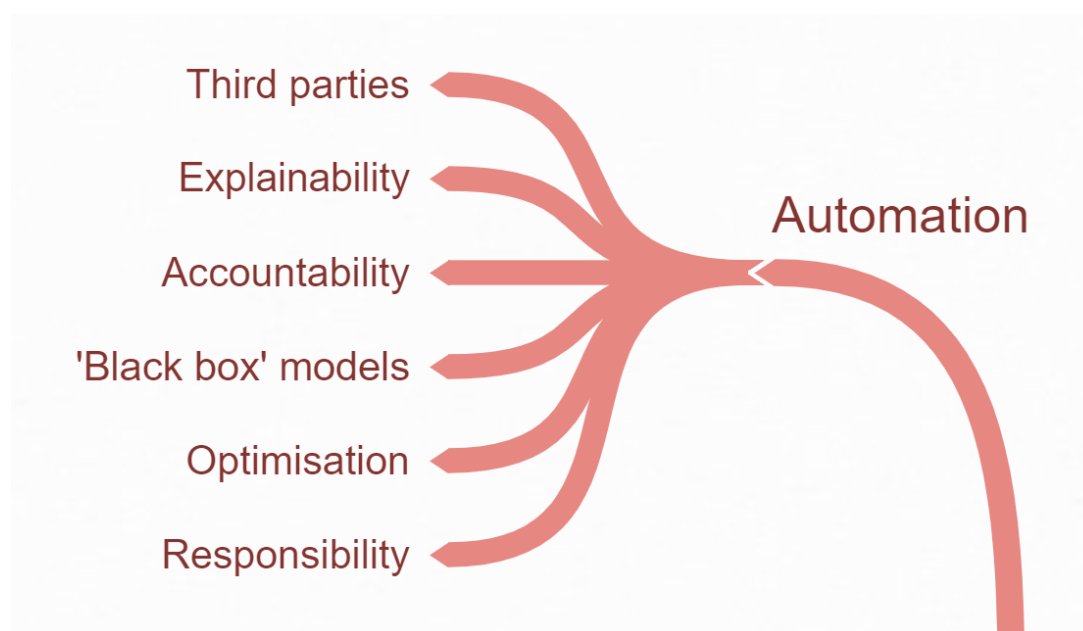
expected remits. Clarification of organisational roles and responsibilities may be required to ensure coherence as digital and climate policy develops.

- iii. *Spatial changes and decentralisation*: energy system change is empowering new voices and redistributing (some) power more in favour of the DNO and sub-DNO levels. Incumbency of large actors was discussed as a particular challenge to meaningful changes in sector power dynamics and decision-making processes (e.g. Code governance processes). However, some participants suggested that changes may happen despite resistance; driven by the sheer momentum of trends creating a more digital, decentralised sector.
- iv. *Creation of a Net Zero Vision*: participants raised several broad questions regarding: how to create a national vision for a digitalised Net Zero energy system, who should be involved in this process, which institution(s) are best positioned to lead, and how leaders should be held accountable. There was relative consensus that the creation of this vision is a highly political process, holding the potential to alter the social, political and economic values guiding how the UK is governed. The imperative for social and institutional innovation in addressing this challenge was particularly noted, with the Citizens Assembly on Climate Change cited as an example.

3.6 Automation

Governance challenges regarding automation were referenced by nine participants. This is striking as automation is increasingly recognised to be amongst the “biggest ‘prizes’ of digitalisation”, with potential to effect profound, systemic changes to the energy system (Rhodes, 2020, p. 38). Automation of physical tasks may already be familiar to the energy sector, particularly in manufacturing processes. However, automation of cognitive or decision-making tasks represents a notable growth area with applications across the system. For example, on a domestic scale it may be possible to automate battery storage charge/discharge cycles in order to minimise household electricity bills or reduce reliance on power import when the carbon intensity of the grid is high. To take another example at the network level, distribution automation offers the potential to increase remote control of assets, enabling more rapid isolation of faults and restoration of power after a blackout.

Figure 9: Automation governance challenges



Key governance challenges raised by participants in relation to automation include:

- i. *Optimisation*: algorithms are increasingly being used to support more efficient energy system functions from micro through to national scales. However, there are open questions regarding what is being optimised, by whom, and who benefits. Different configurations of system optimisation can affect the distribution of political power in the energy system and alter outcomes for different socio-economic groups. They can also have spatial effects; participants particularly raised the potential for automation to cause clashes between individual, regional, and whole-system optimisation.
- ii. *Responsibility and accountability*: increased use of automated and self-learning software raises questions regarding responsibility and accountability for the outputs or outcomes of these systems. For example:

“Where you're having increasing forms of autonomous control, and using techniques like AI or ML, then who is responsible or accountable if something goes wrong? Because if that system has been self-learning, and has moved away from its initial programmed operating conditions, then what about if stuff goes wrong?”

Rebecca Ford, Research Fellow, University of Strathclyde

- iii. *Black boxes*: machine learning represents a growth area in the energy sector. This raises new challenges regarding the interpretability or ‘explainability’ of machine learning systems, particularly those consisting of ‘black box’ (opaque) models. If systems and decisions are not clearly explainable, this presents an accountability problem related both to technical energy system faults and customer protection.
- iv. *Third parties*: new digital technologies and services are often provided by third parties, rather than developed ‘in house’ by large energy players. Third parties can include device-manufacturers, data storage and/or processing providers, digital service providers, and contractors. The ability of energy governance mechanisms to handle the proliferation of third-party technology and digital service providers was heavily questioned by participants³. In this area, governance responses must balance the need for third party intermediaries to act in the trusted interests of their customers, with the need to balance the distribution of benefits between individual and systemic goals. If misjudged, this challenge could damage consumer trust in automation, creating barriers to the adoption of technologies that could support grid decarbonisation.

³ Inadequate protections for energy customers using third party intermediaries more broadly also represents a current subject of research (Citizens Advice, 2020).

4 Conclusion and next steps

As digitalisation continues to accelerate across the economy, existing governance models are being challenged in novel and unexpected ways (BEIS, 2019). Within energy this manifests in terms of unfamiliar issue areas, new actor dynamics, and changing problem scales; demonstrated in various forms across the six issue areas outlined in section 3.

The confluence of energy and digital systems means that emerging governance challenges will be relevant, albeit in varying degrees, to governance landscapes overseeing *both* energy and broader digital matters. This is significant as it implicates a change in how institutions, regulatory and policy systems interact. It also opens doors for innovation; potentially creating, adapting, or combining tools in new ways to tackle emerging challenges.

The next phase of this project will focus on the institutional landscape; a topic raised broadly across preliminary interviews as requiring further research. Upcoming research comprises a series of online workshops focussing on the structure of the current institutional landscape, and governance models guiding these institutions. Workshops will run from June 2020 and seek to answer the research question:

Is the existing institutional landscape fit for purpose to address governance challenges emerging from energy sector digitalisation?

To address the research question, workshops will explore the following themes:

1. Is there demonstrable need to incorporate or develop new institutions in the energy governance space? Where new institutions are needed:
 - a. Are these sector-specific, sector-neutral, or other types of institutions?
 - b. What would be the relationship(s) between new and existing institutions?
2. Is it possible to adapt existing institutions to meet current governance gaps?
3. Is further governance required and if so, what?

Participants are encouraged to consider institutional types including, but not limited to: parliament and devolved governments; government departments (e.g. BEIS, DfT, DCMS, MHCLG, HM Treasury); local government (e.g. local authorities, metro-mayors); regulators (e.g. Ofgem, ICO, CMA); and independent advisory bodies (e.g. CCC, NIC, and the Citizens Assembly on Climate Change). Exploration of institutions will not be limited to the institutions as organisational bodies alone but will also consider factors informing their governance,

capabilities and coordination; for example terms of reference, remit, relationships, powers and decision-making processes.

Findings from the workshops are designed to address current policy debate regarding the constitution of an appropriate institutional landscape for a digitalised energy sector that can balance broad cross-sector requirements with the specific needs of the energy system and its centrality to meeting Net Zero 2050 goals. Following the workshops, data will be analysed and a final stage of interview-based research will be conducted to explore particular areas of conflict and consensus. Cumulative findings will then be distributed through a policy and practitioner-focussed report and PhD thesis.

Readers interested in participating in a workshop should please contact e.judson@exeter.ac.uk for further information and/or complete the availability and consent form via [this link](#).

5 Bibliography

Berkhout, F. and Hertin, J. (2004) 'De-materialising and re-materialising: digital technologies and the environment', *Futures*, 36(8), pp. 903–920. doi: 10.1016/j.futures.2004.01.003.

Bloomberg New Energy Finance (2017) 'Digitalization of Energy Systems', p. 61.

Butler, N. (2018) 'Why cyber attack is the biggest risk for energy companies'. Available at: <https://www.ft.com/content/109350ea-c6f2-11e8-ba8f-ee390057b8c9> (Accessed: 8 October 2018).

Citizens Advice (2020) *Stuck in the middle*. London.

CMA, BEIS and DCMS (2020) *Digital markets taskforce: terms of reference*, Gov.uk. Available at: <https://www.gov.uk/government/publications/digital-markets-taskforce-terms-of-reference/digital-markets-taskforce-terms-of-reference--3> (Accessed: 6 May 2020).

Coroamă, V. and Mattern, F. (2019) 'Digital Rebound – Why Digitalization Will Not Redeem Us Our Environmental Sins', in Wolff, A. (ed.) *6th International Conference on ICT for Sustainability*. Lappeenranta, Finland: CEUR Workshop Proceedings. Available at: http://ceur-ws.org/Vol-2382/ICT4S2019_paper_31.pdf (Accessed: 12 September 2019).

Department for Digital Culture Media and Sport (2019) *Current and future demand for digital skills - a call to action*, UK Government. Available at: <https://www.gov.uk/government/publications/current-and-future-demand-for-digital-skills-in-the-workplace> (Accessed: 2 December 2019).

Fairchild, D. *et al.* (2017) *Energy democracy: advancing equity in clean energy solutions*. First. Washington: Island Press.

Fortier, M.-O. P. *et al.* (2019) 'Introduction to evaluating energy justice across the life cycle: A social life cycle assessment approach', *Applied Energy*, 236, pp. 211–219. doi: 10.1016/j.apenergy.2018.11.022.

Frerk, M. (2019) *Smart Meter Energy Data: Public Interest Advisory Group Final Report - Phase 1*. Available at: https://docs.wixstatic.com/ugd/ea9deb_244fa0e7997b43ceb453762d930bab93.pdf (Accessed: 25 June 2019).

Goldfarb, A. and Tucker, C. (2019) 'Digital Economics', *Journal of Economic Literature*, 57(1), pp. 3–43. Available at: <https://pubs.aeaweb.org/doi/pdfplus/10.1257/jel.20171452>

(Accessed: 15 September 2019).

Hintemann, R. and Hinterholzer, S. (2019) 'Energy consumption of data centers worldwide: How will the Internet become green?', in Wolff, A. (ed.) *Proceedings of the 6th International Conference on ICT for Sustainability*. Lappeenranta, Finland: Proceedings of the 6th International Conference on ICT for Sustainability. Available at: http://ceur-ws.org/Vol-2382/ICT4S2019_paper_16.pdf (Accessed: 12 September 2019).

Kelly, Y. *et al.* (2018) 'Social Media Use and Adolescent Mental Health: Findings From the UK Millennium Cohort Study', *EClinicalMedicine*, 6, pp. 59–68. doi: 10.1016/j.eclinm.2018.12.005.

Lennon, M. (2017) 'Decolonizing energy: Black Lives Matter and technoscientific expertise amid solar transitions', *Energy Research & Social Science*, 30, pp. 18–27. doi: 10.1016/j.erss.2017.06.002.

Limejump (2019) *Super-charged – Limejump completes acquisition agreement with Shell New Energies*, *Limejump.com*. Available at: <https://limejump.com/about-the-acquisition-of-limejump-by-shell/> (Accessed: 31 May 2019).

Lin, H. and Bergmann, N. (2016) 'IoT Privacy and Security Challenges for Smart Home Environments', *Information*. Multidisciplinary Digital Publishing Institute, 7(3), p. 44. doi: 10.3390/info7030044.

Marsh and McLennan Companies (2018) *Could Energy Industry Dynamics Be Creating an Impending Cyber Storm?* Available at: <https://www.marsh.com/uk/insights/research/the-road-to-resilience-2016-managing-> (Accessed: 8 October 2018).

Mattsson, T. (2019) 'Editorial: Digitalisation and Artificial Intelligence in European Healthcare', *European Journal of Health Law*, pp. 1–4. Available at: <https://brill.com/view/journals/ejhl/aop/article-10.1163-15718093-12264001.xml> (Accessed: 15 September 2019).

Microsoft (no date) *Microsoft AI for Earth*, *Microsoft.com*. Available at: <https://www.microsoft.com/en-us/ai/ai-for-earth> (Accessed: 6 May 2020).

Milchram, C. *et al.* (2018) 'Energy Justice and Smart Grid Systems: Evidence from the Netherlands and the United Kingdom', *Applied Energy*, 229, pp. 1244–1259. doi: 10.1016/j.apenergy.2018.08.053.

Morley, J., Widdicks, K. and Hazas, M. (2018) 'Digitalisation, energy and data demand: The impact of Internet traffic on overall and peak electricity consumption', *Energy Research &*

Social Science, 38, pp. 128–137. doi: 10.1016/j.erss.2018.01.018.

Ng, W. (2015) *New Digital Technology in Education*. Cham: Springer International Publishing. doi: 10.1007/978-3-319-05822-1.

Ofgem (2019) *Modernising Energy Data Update*. Available at: <https://www.ofgem.gov.uk/publications-and-updates/modernising-energy-data-update> (Accessed: 18 December 2019).

Oliveras, L. *et al.* (2020) 'Energy poverty and health: Trends in the European Union before and during the economic crisis, 2007–2016', *Health and Place*. Elsevier Ltd, p. 102294. doi: 10.1016/j.healthplace.2020.102294.

Powells, G. and Fell, M. J. (2019) 'Flexibility capital and flexibility justice in smart energy systems', *Energy Research & Social Science*, 54, pp. 56–59. doi: 10.1016/j.erss.2019.03.015.

Rhodes, A. (2020) *Digitalisation of Energy An Energy Futures Lab Briefing Paper*. Available at: <http://imperial.ac.uk/energy-futures-lab> (Accessed: 15 May 2020).

Royston, S. and Selby, J. (2019) 'Non-energy policy', in Rinkinen, J., Shove, E., and Torriti, J. (eds) *Energy Fables: Challenging Ideas in the Energy Sector*. 1st edn. Abingdon, Oxfordshire: Routledge, pp. 112–119.

Sand, J. (2017) *Why big data, AI and renewables are the perfect M&A storm*. Available at: <https://www.bdo.co.za/getmedia/9b39ded6-e999-434d-af9a-5e073db1285c/BDO-Renewables-and-artificial-intelligence.pdf.aspx> (Accessed: 24 October 2018).

Sandys, L. *et al.* (2019) *A strategy for a Modern Digitalised Energy System Energy Data Taskforce report chaired by Laura Sandys*. Available at: <https://es.catapult.org.uk/wp-content/uploads/2019/06/EDTF-A-Strategy-for-a-Modern-Digitalised-Energy-System-FINAL-REPORT-1.pdf> (Accessed: 25 June 2019).

Sareen, S. and Haarstad, H. (2018) 'Bridging socio-technical and justice aspects of sustainable energy transitions', *Applied Energy*, 228, pp. 624–632. doi: 10.1016/j.apenergy.2018.06.104.

Schaps, K. (2017) *Shell buys NewMotion charging network in first electric vehicle deal*, *Reuters*. Available at: <https://uk.reuters.com/article/uk-newmotion-m-a-shell/shell-buys-newmotion-charging-network-in-first-electric-vehicle-deal-idUKKBN1CH1R5> (Accessed: 31 May 2019).

Shakoor, A., Davies, G. and Strbac, G. (2017) *Roadmap for Flexibility Services to 2030: A Report to the Committee on Climate Change*. London. Available at: <https://www.theccc.org.uk/wp-content/uploads/2017/06/Roadmap-for-flexibility-services-to-2030-Poyry-and-Imperial-College-London.pdf> (Accessed: 11 September 2019).

Shell UK (2018) *Shell completes acquisition of First Utility, Shell.co.uk*. Available at: <https://www.shell.co.uk/media/2018-media-releases/shell-completes-acquisition-of-first-utility.html> (Accessed: 31 May 2019).

The Shift Project (2019) *Lean ICT: Towards Digital Sobriety*. Available at: <https://drive.google.com/file/d/1CFFQh0fmtOvGoll1bw6URoW9rSLyZiB9/view> (Accessed: 23 August 2019).

Thomson, H., Snell, C. and Bouzarovski, S. (2017) 'Health, Well-Being and Energy Poverty in Europe: A Comparative Study of 32 European Countries', *International Journal of Environmental Research and Public Health*. MDPI AG, 14(6), p. 584. doi: 10.3390/ijerph14060584.

Widmer, R. *et al.* (2005) 'Global perspectives on e-waste', *Environmental Impact Assessment Review*, 25(5), pp. 436–458. doi: 10.1016/j.eiar.2005.04.001.

Willis, R. *et al.* (2019) *Getting energy governance right: Lessons from IGov*.

Wood, A. *et al.* (2019) 'Good Gig, Bad Gig: Autonomy and Algorithmic Control in the Global Gig Economy', *Work, Employment and Society*, 33(1), pp. 56–75. Available at: <https://journals.sagepub.com/doi/pdf/10.1177/0950017018785616> (Accessed: 15 September 2019).

Zingales, L. *et al.* (2019) *Stigler Committee on Digital Platforms Organization: Subcommittee on Market Structure and Antitrust Subcommittee on the News Media Industry*. Available at: <https://research.chicagobooth.edu/stigler/media/news/committee-on-digital-> (Accessed: 5 May 2020).

Other:

Mind maps: created via coggle.it