Governance perspectives on achieving demand side flexibility for net zero

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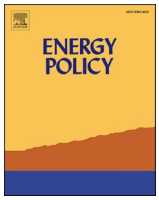

Governance perspectives on achieving demand side flexibility for net zero

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A B S T R A C T

Net-zero has rapidly become the accepted way of framing mitigation policy and sustainable development goals. A critical step to achieve net zero targets consists of demand side flexibility, i.e. the ability to flex consumption according to levels of low carbon electricity generation. There is much emphasis on the importance of reaching high levels of flexibility, as this will enable balancing of renewables supply with demand, hence lowering energy costs. However, little attention has been paid to governance aspects, i.e. how demand side flexibility can happen and which institutions are responsible for delivering it. This policy perspective paper makes use of net-zero "good governance" principles to review evidence on demand side flexibility governance in the UK. It discusses which areas are most relevant and how they could best be developed.

1. Introduction

Net-zero has rapidly become the accepted way of framing mitigation policy and sustainable development goals, in particular SDG 7 (Affordable and clean energy). In 2019 the UK government made a legal commitment to achieve net zero greenhouse gas emissions by 2050. With the publication of the Net Zero Strategy (Department for Business, Energy & Industrial Strategy, 2021a), the UK has a plan to achieve deep emission cuts for the first time. The focus is moving from net-zero targets to "net-zero governance", i.e. how policymaking can best be configured to deliver these targets.

An emerging area of energy demand consists of demand side flexibility. As part of the progress towards a net zero economy, electricity generation will become less controllable. The integration of intermittent renewables in the supply mix, as well as high penetration of electric vehicles and electric heat pumps, will challenge the balancing of demand and supply. Hence, it is increasingly important for electricity demand to respond flexibly. Demand side flexibility is viewed as a way to reduce dependence on fossil fuel generators, to improve security of supply, to avoid network constraints, and to reduce the cost to customers.

Despite the widespread consensus on importance of reaching high levels of flexibility, little attention has been paid to governance aspects. Governance of demand side flexibility is concerned with how demand side flexibility can happen and which institutions are responsible for delivering it. This policy perspective paper focuses on demand side flexibility governance and has two objectives: (i) to review evidence on demand side flexibility governance; and (ii) to discuss which areas are most relevant and how they could best be developed.

Section 2 introduces a "good governance" framework for net-zero. Section 3 presents starting points on the governance of demand side flexibility. Section 4 identifies needs in demand side flexibility governance based on existing applications of "good governance" principles. Section 5 provides further detail of the analytic areas and interventions associated with demand side flexibility governance. Section 6 concludes by discussing policy perspectives in the field of net zero governance.

2. A "good governance" framework for net zero

Over recent years, the European Commission has recognised the advantages of energy demand reduction through a range of directives and long-term strategy documents, including the Energy Performance of Buildings Directive 2010/31/EU, the Energy Efficiency Directive 2012/27/EU, and the Energy Roadmap 2050. These initiatives aim to enhance the current policy framework and advance energy efficiency across the EU (Trotta et al., 2018). Numerous energy efficiency policies and regulations target demand, along with extensive historical regulation of energy usage per square meter. The primary legislative instruments for addressing energy efficiency are the Energy Efficiency Directive and the Energy Performance of Buildings Directive. The Energy Performance of Buildings Directive employs two key regulatory mechanisms: Energy Performance Certificates and Building Standards.

The UK has implemented climate change legislation, including influential initiatives aimed at reducing energy demand Internationally recognised, the Climate Change Act stands as a pioneering legislation, while the GB energy efficiency obligation scheme has notably impacted EU policies. Additionally, schemes such as the London Congestion Charge have served as models for similar programmes globally (Eyre

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and Killip, 2019). Nevertheless, substantial reforms are imperative for the UK to attain its 2050 and intermediate goals, aiming for an 80% reduction in greenhouse gas emissions (Climate Change Committee, 2023). A net zero good governance framework is crucial in driving systematic and coordinated efforts essential to address the pressing challenges of climate change. To deliver the strategic aims, objectives and priorities of net zero, sound governance arrangements need to be in place. A tentative definition of "good governance" framework for net-zero is founded on laws, policies, processes, systems and behaviours and together they provide a system for the way in which multiple organisations are directed, administered and controlled towards net zero goals.

Although extensive literature exists on mitigation policies (Fawzy et al., 2020), the domain of governance, particularly at the national level, remains in a nascent stage of development. As a general point, the current governance mechanisms for achieving net zero are insufficient (Fankhauser et al., 2022). Due to the heavy reliance on fossil energy resources in existing systems, achieving net zero emissions will necessitate numerous transitions across various demand and supply systems (Rosenbloom and Meadowcroft, 2022). The integration of demand consideration seems critical for net zero policies as increased levels of energy demand reduction help to address technological hurdles, like expanding renewable energy capacities and levels of investment (Johnson et al., 2023).

The emphasis here is on governance -rather than just policies- because governance in its broadest sense is about shaping society in desired directions (Shove and Walker, 2010). Butler et al. (2018) outline four analytic areas related to the governance of energy demand. First, under direct forms of influence, the focus is on policies and departmental governance processes, aiming to understand their impact on energy matters. Second, wider agendas of governance partly shape energy issues and the relationality between these agendas and energy concerns. Third, moving to broader forms of influence, long-term trajectories are influenced by governance, both historically and in the future, and they affect energy challenges. Fourth, framing and agenda setting within diverse governance areas either limit or enhance possibilities for addressing energy issues.

Having established the importance of demand in energy systems governance, are there frameworks which enable the analysis of specific demand solutions (such as demand-side flexibility) for Net Zero? There are attempts by international organisation and Non-Governmental Organisations (NGOs) to provide some of the principles of net zero "good governance". A working paper by the World Bank (2009) explores the broader dimensions of climate governance in terms of: building strategic capacity, integrating climate change into development decision making, societal mobilisation, and learning how to do climate change governance. Useful in the context of energy demand, the UK Institute for Government (2020), identifies five core principles of good governance in the realm of net zero.

First, good governance requires policy co-ordination within central Government departments and between the different layers of national, local and devolved government. Management of carbon emissions is the responsibility of several government departments as well as other public bodies such as Ofgem. Local government also has a key role, especially in land use planning, transport and buildings.

Second, performance management relates to both target setting and the use of performance standards, data and benchmarks. Responsibility is widely shared, often devolved, and in some cases not in the public domain.

Third, fiscal management concerns both the provision of government support and the allocation of costs and benefits across the economy. Financial incentives are a mix of 'user pays' through regulated companies, public expenditure and taxes, with different governance systems and distributional outcomes.

Fourth, market transformation consists of the role and capacity of government in driving both behavioural and organisational change and technology innovation. Innovation theories point to the synergies of regulation, financial incentives and information/engagement which can cross divisions of responsibility.

Fifth, the engagement of people, businesses and communities is critical in owning, prioritising and legitimising net-zero actions, particularly behavioural and organisational change. Legacy policies tend to focus on 'information', such as labels, and personal advice, with less emphasis on collective action.

This policy paper embeds these five principles for examining evidence concerning the governance of demand-side flexibility in the UK. Fig. 1 illustrates how the five principles of "good governance" for net zero are addressed in various sections of this paper.

3. The governance of demand side flexibility: starting points

The governance of demand side flexibility can be defined as the policies, institutions, rules and incentives related to energy demand, and the underlying decision-making process which establishes those rules and incentives. In essence, demand side flexibility governance is about the complex of rules and market arrangements which foster consumers' ability to shift the consumption of energy in time or location.

Demand side flexibility is a cross-cutting issue, ranging from the use of appliances in the home to mobility. This makes the governance of demand side flexibility challenging. Ensuring that energy services are provided to households and businesses, securely, at reasonable cost has historically required central co-ordination to ensure that the system operates flawlessly and reliably. Transmission and distribution companies for electricity and gas are historically highly regulated around principles of security of supply which are not necessarily consistent with opportunities for flexibility. Demand side flexibility should also not undermine how vulnerable customers have access to energy services.

Whilst the governance of demand side flexibility is not straightforward, the opportunities are significant due to the estimated benefits associated with both generation and demand aspects.

The generation mix is shifting rapidly towards variable renewable energy sources and demand will increase through electrification of heat, transportation and industrial processes. Electricity generation in Great Britain has significantly transitioned to low-carbon sources, with gas contributing 38.5%, wind 26.8%, and nuclear 15.5% of the energy mix last year. This shift away from fossil fuels is notable, as renewable energy consumption has surged by more than 30 times compared to 25 years ago. Notably, the transformation is driven by increased generation from offshore wind and other renewables, positioning energy production closer to the edges of the energy system. The England/Scotland constraint contributes significantly to the Balancing Services Use of System. Network constraint costs are rapidly increasing, with a substantial portion of market outcomes being re-dispatched by the Electricity System Operator to address constraint challenges. Between 2015 and 2020, constraint costs tripled to £1.1 billion (Ofgem, 2022a).

With regards to demand, according to estimates frequently cited in UK Government documents, 30 million electric vehicles (EVs) will be on the road by 2050, representing 100TWh of additional demand and 19 GW of additional capacity (National Grid, 2021). 600,000 heat pumps are expected to be installed per year by 2028 (DESNZ, 2023). 11 million electric heating units in 2050 will add 48TWh of demand. High levels of electrification will fundamentally change consumption profiles and require a significant increase in peak capacity and wholesale energy supply.

Flexibility can significantly reduce the costs of adapting to these changes, by reducing investments in generation and network infrastructure, and reducing the cost of operating the system.

Table 1 presents a review of annual benefits of flexibility by source. At the lower end of benefits estimates, it has been estimated that in the UK increasing the level of flexibility could reduce system costs by £3 billion per year by 2030. The Climate Change Committee (2019) found that deployment of greater system flexibility such as demand response,

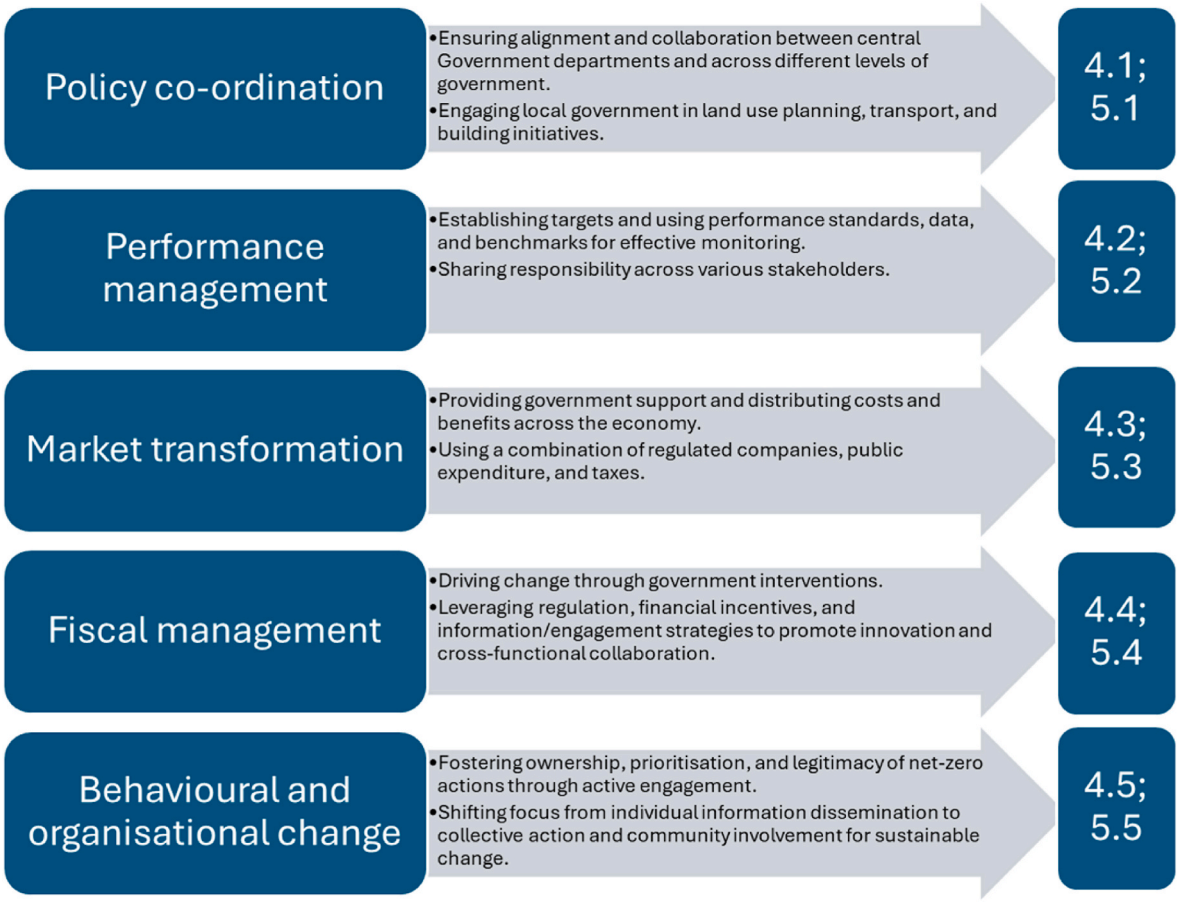

Fig. 1. Five principles of "good governance" for net zero and corresponding sections of this paper (author's elaboration based on Institute for Government, 2020).

Table 1
Review of annual benefits of flexibility by source.

Source	Annual benefits of flexibility
PicloElement Energy and Graham Oakes, 2020	£3 billion - £4.55 billion
Climate Change Committee (2019)	£3–4 billion
National Grid ESO (2022)	£3.2 billion - £4.7 billion
Cornwall Insight (2023)	£4.6 billion - £14.1 billion
Carbon Trust, Imperial College Consultants (2021)	£9.6 billion - £16.7 billion

alongside variable renewables, is a low-regrets and low cost means of decarbonising the UK energy system, leading to £3–4 billion savings per year. Similar analysis points to flexibility reducing the whole-system cost by £4.55bn per annum by 2050 (Piclo, Element Energy and Graham Oakes, 2020). According to National Grid ESO (2022) between £3.2 billion and £4.7 billion of benefit could be realised per year, through integrating high levels of flexibility such as interconnectors, demand-side response and storage across the whole energy system. Flexibility can reduce costs by contributing to shifting the system demand profile to follow variable generation, reducing curtailment of renewables and investment in generation capacity; responding to network conditions in a particular location enable efficient network investment and reinforcement decisions and contributing to services for maintaining a secure and stable system, as traditional sources retire. At the higher end of benefits estimates, a fully flexible energy system has the potential to deliver material net savings of between £4.6 billion and £14.1 billion (Cornwall Insight, 2023) and even between £9.6 billion and £16.7 billion per annum by 2050 (Carbon Trust and Imperial College Consultants, 2021).

Demand side flexibility is expected to originate from various grid-scale and demand-side sources across different applications. These sources vary in cost, with Demand Side Response expected to be the lowest-cost. Electric vehicles (EVs) and heat pumps are growing sources of demand side flexibility as well as drivers of system challenges (National Grid, 2021).

Governance efforts to increase flexibility are supposed to keep pace with their deployment, to mitigate cost increases. Large-scale, long-duration storage are also expected to provide flexibility services, including for inter-day variations in electricity demand and supply (Royal Society, 2023).

In a nutshell, the governance of demand side flexibility is expected to deliver opportunities on four critical issues. First, it is an urgent priority that is being driven by technology and net zero policy developments. Changing the energy system implies radical changes in governance. Decisions will be needed before there is evidence about how the flexibility outcomes will come forward. Second, demand side flexibility will be essential for maintaining an affordable electricity system. Unlocking significant flexibility from across the full value chain of energy system users could reduce system costs by billions of pounds per year in a net zero system. Third, flexibility will need to become a fundamental part of how markets and the system are designed and regulated. The total opportunity for flexibility to reduce costs is spread across a wide range of electricity system requirements and users, meaning measures to deliver flexibility will need to become embedded within all of our major policy and regulatory frameworks. Fourth, significant changes in terms of the role of demand and distributed energy resources in system operation will be required. Unlocking the critical role of Demand Side Response will require a complete transformation of how system operators engage with users. This will require step changes in how system and user data is collected and used, alongside a technology-enabled shifts in the

behaviours and devices that shape energy use.

Against this background of opportunities that demand side flexibility may bring about, its governance has been developing slowly in recent times. For the past two decades, primary Transmission Operator, The National Grid, has been providing two main forms of Demand Side Response (DSR) programmes within its balancing services portfolio: Short Term Operating Reserve (STOR) and Frequency Response (FR) (National Grid, 2021). STOR requires providers to deliver a minimum of 3 MW of generation or load reduction that needs to be achieved within 20 min of being notified (Grünewald and Torriti, 2013). While FR requires delivering a minimum of 10 MW of load reduction within seconds based on a change in system frequency (Curtis et al., 2018).

From a previously centralised entity (the Electricity System Operator) responsible for balancing demand and supply governance responsibilities are increasingly shared among multiple layers of governance. Distribution Network Operators have started issuing flexibility contracts; aggregators have developed a Demand Side Response code of conduct; and the British Standards Institute (2021) set a classification for energy smart appliances and created a framework for Demand Side Response.

In essence, the 'business case' for flexibility is simple and straightforward, but the governance mechanisms for delivering demand side flexibility are increasingly multifaceted due to the multiple interests and organisations involved. This calls for a closer examination of how to apply the abovementioned "good governance" framework for net-zero to demand side flexibility.

4. Examples of good governance principles applied to demand flexibility

This section examines UK initiatives on demand side flexibility based on the principles of "good governance" for net-zero introduced earlier in the paper (i.e. policy co-ordination, performance management, fiscal investment, market transformation, and behavioural and organisational change).

4.1. Policy co-ordination

The 'Upgrading our Energy System, Smart Systems and Flexibility Plan' (Department for Business, Energy & Industrial Strategy, 2021b) emphasised the strategy for government and industry to make the transition to a flexible energy system. Opportunities for policy co-ordination are largely missed as part of the plan due to its focus on individual technologies (e.g. home battery storage, electric vehicles, boilers, etc.) in delivering demand flexibility in relation to their technical potential. The plan states that consumers are more directly involved in managing demand in the electricity system through smart appliances that react to the availability of electricity on the grid in determining their operational cycle. The lack of policy co-ordination has characterized the UK demand side flexibility landscape for some time as demonstrated by the multiple targets associated with demand response services.

The following stylised example of the issue associated with multiple targets and lack of policy co-ordination.

- A consumer x had applied to an EV export tariff pilot with their retailer. However, before committing to this, the Demand Flexibility Service (DFS) increases as uptake of DFS schemes has been below expectations. The consumer shifts their choice towards DFS.
- That is perfectly rational, and in fact is the signal the policy instrument is trying to give. But because the policy instruments are targeting the same EV charger, then EV pilot schemes need to find another provider.
- It is also extremely likely that the consumer will not be able to make such rational choice because the retailer will not allow to opt out of the EV export tariff pilot.
- In this case, as a response to low take-up, the DFS adjusts in order to ensure delivery of a single target. But this might lead to inefficient delivery of overall system outcomes.
- In essence the problem is of multiple policy instruments chasing the same EV charger therefore
- The problem can be addressed by having a landscape of policy instruments that is together achieving that set of targets, rather than individually trying to meet only their own (i.e. policy instrument design has spillovers on other policy instruments & objectives).

Policy co-ordination on demand side flexibility involves reforms which change the roles of institutions which are central to the design, management and delivery of flexibility services. The reform of the Great Britain system operator involves additional responsibilities in terms of net-zero roles and a move to a public, non-profit organisational model. The changes enable enhanced functions and facilitate an integrated, flexible energy system.

4.2. Performance management

Central to the reform of demand side flexibility is performance management, both in relation to target setting and the use of performance standards, data and benchmarks. Several flexibility scenarios set a number of flexibility targets (but no institutional responsibility for performance). The lack of a conceptual discussion around how flexibility is measured implies that performance is *de facto* measured in terms of DSR capacity (Lo Piano and Smith, 2022). For instance, currently flexibility services deliver around 2.7 GW of DSR capacity (Cardoso et al., 2020). A report by the Association of Decentralized Energy estimates that Demand Side Response capacity could be increased to 4.5 GW of DSR by 2030 (2.8 GW industrial and 1.7 GW commercial and public sector). Previously, a report by Element Energy estimated that the potential of turndown from the non-domestic sector in 2011 was in the range of 1.2GW–4.4 GW. The scenarios by Carbon Trust and Imperial College suggest optimal DSR deployment of between 4.1 GW and 11.4 GW by 2030.

4.3. Market transformation

Data, digitilisation and decentralisation are supposed to transform the market. Demand side flexibility governance will involve market transformation in the shape of energy as a service, exporting back to the grid, peer-to-peer services and local energy systems. Digitalisation has the potential to unlock inefficiencies across the entire energy system, providing innovative solutions to manage the electricity system. Ofgem's regulatory providing network companies with incentives to encourage innovation and facilitate investment -known as 'RIIO2'- requires all network companies to publish digitalisation strategies with updates every two years. Active engagement in demand response requires a robust digital infrastructure that manages data effectively and ensures consumer privacy. Enabling confident participation hinges on implementing Energy Digitalisation Taskforce's suggestions, particularly finalizing consumer data governance (Energy Systems Catapult, 2022). Enhancing consumer involvement in demand response also entails conducting research on consumer motivations and decision-making processes, further supporting engagement and interaction. A recent example consists of a research initiative aimed at introducing a demand flexibility certificate for buildings (Ramirez-Mendiola et al., 2023). The buildings sector is anticipated to be the most numerous potential source of demand flexibility. However, its untapped potential so far is mainly due to the absence of robust frameworks for estimating the flexibility potential of individual buildings reliably. To tackle this, a demand flexibility certification has been put forward to address gaps in net-zero policies by systematically assessing the demand flexibility potential of specific buildings. Similar to Energy Performance Certificates, these demand flexibility certificates aim to rate buildings, but instead of

assessing general energy performance, they focus specifically on summarizing a building's capacity to provide demand flexibility.

4.4. Fiscal investment

Demand side flexibility is an area which traditionally does not require significant commitments in terms of fiscal investment. Whilst the generation of energy often requires public financing, the temporal adaptation of demand is supposed to be investment-free. In other words, the balancing of demand and supply of energy is supposed to operate according to market-only logics. Demand Side Response programmes incur into operating costs in terms of reduced business and site-specific acquisition costs. In order to absorb these costs, aggregators work on a shared revenues model, whereby the aggregator takes a percentage of the DSR revenues earned by the participating end-users site. Extraordinary peak mitigation measures -such as the European Commission imposing 5% reductions of peak demand in member states as a response to the energy crisis-can be indirectly financed through fiscal investment. In such circumstances, the investment in interruptible programmes, which consist of bilateral agreements between large industrial usage manufacturers and either utilities or government to reduce power demand at scheduled times when generation and transmission costs are particularly high for the grid.

Investments from the UK government of £265 million over 5 years in research, development and deployment of smart systems to reduce the cost of electricity storage, advance innovative demand response technologies and develop new ways of balancing the grid. Innovative flexibility products and services are emerging but incentives, market rules and mechanisms to enable markets to deliver the right products and services are not in place.

4.5. Behavioural and organisational change

Behavioural and organisational change involves the engagement of people, businesses and communities in owning, prioritising and legitimising net-zero actions. Flexibility relies on changes from consumers, primarily through technology (e.g. electric vehicles, storage, smart heat pumps) and price (Time of Use tariffs, Demand Side Response). The change is multifaceted and involves different spatial and temporal scales. Change in behaviour refers to those instances where individual members of households or organisations modify their behaviour in response to the signals or incentives applicable at the time, in order to shift their typical demand loads or reduce their overall consumption. For example, the Demand Flexibility Service is a programme which was active during the winter of 2022–2023 and engaged 1.6 million households and businesses, resulting in a collective reduction of 3300 MW-hours (MWh) of electricity. The role of local flexibility will challenge current settings in terms of governance. As a minimum, Distribution Network Operators are increasing their ability to enable flexibility programmes. The first tenders for flexibility services by Distribution Network Operators (DNOs) were issued in 2018; volume procured quickly grew to 1.2 GW in 2020 (Cornwall Insight, 2023). Distributed generation will make up 42% of GB capacity by 2050 (National Grid ESO, 2023). Cornwall Local Energy Market trial saw 310MWh of power traded successfully and flexibility services procured via DNO and National Grid ESO. The latter launched a new flexibility offering which is supposed to increase people's engagement through the first a service which is part of their business-as-usual operations, in which domestic consumers at the national level can participate in DSR and compete directly with generation.

5. Intersection of principles and analytic areas of governance

Examining how "good governance" principles intersect with analytic areas of energy governance can shed light on their collective impact on shaping demand flexibility governance. Table 2 summarises definitions of "good governance" principles, examples of their applications in demand flexibility, as well as gaps and needs in demand flexibility governance.

The examples of how "good governance" principles have been applied to demand flexibility show a set of gaps and needs in relation to governance.

Fig. 2 illustrates the intersections between good governance principles, governance interventions, analytic areas of governance and analytic questions when it comes of demand side flexibility. These are further detailed in the following sub-sections.

Table 2
"Good governance" principles: definitions, examples of their applications in demand flexibility, gaps and needs in demand flexibility governance.

"Good governance" principle	Definition of the principle	Examples of principle applied to demand flexibility	Gaps and needs in demand flexibility governance
Policy co-ordination	Efficient governance necessitates coordinated policies among various government tiers, central departments, and bodies like Ofgem, especially crucial in local government	Initiatives by Ofgem and Department for Business, Energy & Industrial Strategy in the reform of the Great Britain system operator (significant institutional adjustments, expanding its roles and responsibilities to align with net-zero objectives, transitioning to a public, non-profit organisational model)	Opportunities for policy co-ordination are largely missed
Performance management	This principle involves setting targets, using performance standards and data, often decentralized and not always transparently available	Current estimations suggest a potential increase in DSR capacity from the present 2.7 GW to approximately 4.5 GW by 2030, encompassing industrial, commercial, and public sectors	No national flexibility target exists
Fiscal management	It revolves around providing government support and distributing costs and benefits across the economy through a mix of regulated charges, public spending, and taxes	European Commission imposing measures for peak demand reductions during energy crises might indirectly involve fiscal investment, where interruptible programmes are utilised through bilateral agreements between large industrial users and utilities or governmental bodies to curtail power demand during periods of elevated generation and transmission costs	No substantial public financing is in place for demand flexibility (in the same way as for demand)
Market transformation	Governments drive behavioral, organisational, and technological changes by employing synergies between regulation, financial incentives, and information strategies, transcending responsibilities	Recommendations of the Energy Digitalisation Taskforce (e.g. finalizing consumer data governance) and research initiative on a demand flexibility certificate for buildings.	Strong reliance on digital transformation
Behavioural and organisational change	Involving people, businesses, and communities is crucial for embracing and legitimising net-zero actions, emphasising collective rather than individual-focused legacy policies	Demand Flexibility Service engaged 1.6 million households and businesses, resulting in a collective reduction of 3300 MW-hours (MWh) of electricity.	Ad hoc initiatives on behavioural and organisational change

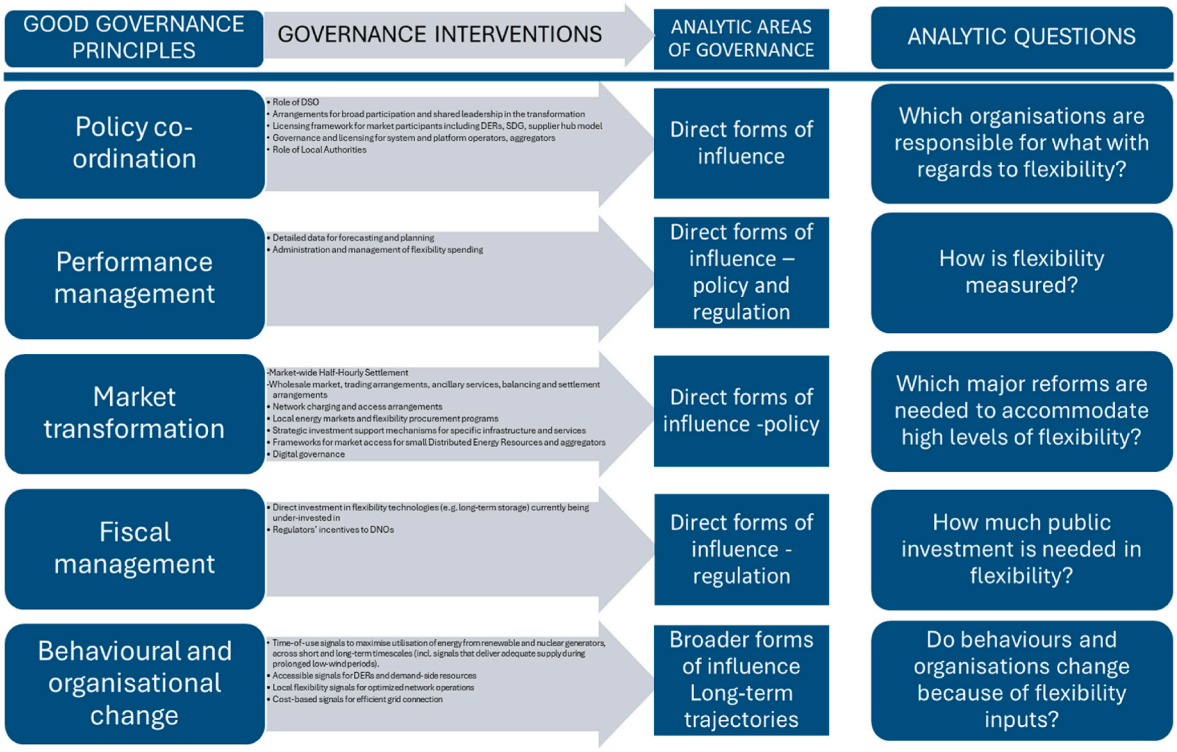

Fig. 2. Good governance principles, governance interventions, analytic areas of governance and analytic questions.

5.1. *Policy co-ordination*

Policy co-ordination entails expanding coordinated planning across network boundaries. For instance, the Distribution System Operator (DSO) Incentive Governance Document sets out the processes and requirements involved in the DSO incentive (Ofgem, 2022b). It delineates the procedures and standards employed to evaluate the performance of a DNO for the DSO incentive. It outlines the reporting obligations imposed on DNOs and defines the approach the regulator will employ to ascertain an incentive reward or penalty. The arrangements for broad participation and shared leadership in the transformation could foster inclusivity and collaboration among stakeholders from various sectors, ensuring that diverse voices and perspectives are considered in decision-making processes. The licensing framework for market participants, which encompasses Distributed Energy Resources (DERs) and the supplier hub model, may establish the regulatory requirements and criteria for entities seeking to participate in the market. Governance and licensing for system and platform operators, aggregators. For example, Ofgem (2023) took the decision to reform governance of key energy system functions critical to distribution system operation: energy system planning, market facilitation of flexible resources and real time operations. The role of Local Authorities may evolve as key enablers of demand side flexibility, whilst local aggregators may provide ad hoc services for local community energy schemes. Local Area Energy Plans represent a promising yet complex endeavor in navigating the evolving flexibility landscape within local communities. In this innovative journey, challenges and opportunities converge, requiring a strategic approach to harnessing resources and overcoming existing barriers.

5.2. *Performance management*

Market participants of all types and sizes should see signals reflecting available energy and network resources in real time, at the location where they are connected. This can happen upon two conditions of (i) detailed data for forecasting and planning; and (ii) administration and management of flexibility spending. If more sophisticated and detailed approaches to forecasting and planning are developed for long-term system needs, as data availability and visibility of the system improve. Granular, high-quality data and information for assets and devices at all voltage levels leads to improved understanding of the system, how it is being used and how it is developing. System planners adopt new approaches to delivering comprehensive, long-term forecasts and network development plans, considering flexibility opportunities, trade-offs and options to enable whole system optimise. Data and information is widely available to market actors, signalling the value of flexibility and how it is evolving, across specific applications and locations. The second condition consists of setting a central body administering and managing spending on the design, build, operation of flexibility. Such body would either approve or reject annual budgets and spending forecasts and its recommended options to fund the design, build and operation additional functionality for flexibility.

5.3. *Market transformation*

System operators and market actors should have detailed information about the system, transforming system operations and planning. The electricity settlement reform, through the Market-wide Half-Hourly Settlement means that generators and suppliers will be able to trade electricity in the wholesale market in half-hourly periods (Yunusov and Torriti, 2021). This is one of the most significant market transformations because it enables the diffusion of Time of Use Tariffs in the market. Wholesale market reform might lead to the introduction of a central body which attracts additional demand into the system during periods of over-supply/low prices via auctions. The introduction of Regional Energy Strategic Planners could ensure that there is appropriate accountability and effective coordination for strategic planning at a sub-national level. Network charging and access arrangements encompass the regulatory protocols and policies governing the fees, tariffs, and conditions associated with accessing energy networks. Strategic investment support mechanisms for specific infrastructure and services refer to targeted financial incentives, subsidies, grants, or other forms of support provided by policymakers or regulatory authorities to encourage

investment in critical energy infrastructure or essential services. Frameworks for market access for small Distributed Energy Resources and aggregators entail the regulatory frameworks and guidelines governing the participation of smaller-scale optimised energy resources and aggregation entities in energy markets. Digital governance needs to consider the roles and responsibilities associated with the design, development, and operation of a flexibility digital infrastructure (Energy Systems Catapult, 2022).

5.4. Fiscal management

Major investment decisions should take into account the flexibility behaviours which contribute to various system requirements. Two examples are put forward here. First, there is currently a missing market for low carbon flexibility. A problem with the current market design is that it values all MW as equal, regardless of location, capability and carbon intensity. Markets fail to provide a price signal and therefore do not value the duration of storage despite a need for it in future. Without fossil plant on the system, it could be cost efficient for long duration storage to provide significant value, but there is a risk that the markets do not value this service. Second, as another example on fiscal management, the regulator can optimise DNOs through public spending to invest in low-carbon technologies which advance flexibility provisions. DNOs do not control volumes of low-carbon technologies, but they influence the forecast they use to set investment plans. The profile of expenditure they subsequently incur and an understanding of how their investment might drive growth in flexible technologies.

5.5. Behavioral and organisational change

System users should respond efficiently and consistently to flexibility signals. Three examples are highlighted here. First, signals that are accessible to DERs and demand-side resources (including EVs, heat pumps, industrial demand), either directly, or via third parties can include real-time electricity prices, demand response signals, grid congestion alerts, or other market-based mechanisms communicated directly to DERs or through intermediaries like aggregators or energy service providers. Second, signals for efficient local flexibility, to optimise distribution network operations and investments can allow local flexibility resources to respond to whole system needs. They are designed to enable efficient use of local flexibility resources within distribution networks, such as rooftop solar panels, battery storage systems, or DSR programmes. Third, signals can also reflect the cost of connecting at different locations, to drive efficient investment between projects, where relevant. By reflecting factors such as grid capacity, congestion, voltage levels, and infrastructure costs, these signals inform developers and investors about the relative costs and benefits of connecting their projects at different locations within the grid.

6. Conclusion and policy implications

Recent price shocks emphasise the crucial importance of energy security. Demand side changes, both to reduce demand and increase flexibility, can play a key role (Barrett et al., 2022). Net-zero targets cannot be viably achieved without energy demand side flexibility. There is widespread agreement that demand side flexibility is needed.

The transition to variable renewable energy sources will increase the value of flexibility in electricity use. To decarbonise the electricity system at an acceptable cost and an acceptable level of demand for new infrastructure, energy efficiency, flexibility services and technologies and demand response, are not optional, but mandatory. This does not mean that demand side flexibility will happen by itself.

In the UK, several key energy policy issues centre around the Electricity Market Reform (REMA), which targets aspects beyond retail in electricity markets. REMA focuses on ensuring a balanced supply and demand of electricity and incentivising investments in electricity-generating or consuming assets. This includes areas such as the balancing mechanism, ancillary services, Contracts for Difference scheme, and the Capacity Market, which are designed to regulate, incentivise, or ensure the reliability, stability, and economic viability of the power generation sector.

The governance of demand in the drive to decarbonise the electricity system and the linked benefits is an overlooked area in energy policy. Although much attention on demand flexibility and energy efficiency focuses on interaction between the energy sector and consumers, scaling this will require government backing and arrangements. The common perception that consumers are uninterested in actively managing their energy use and costs needs to be challenged. Policies are necessary to support flexibility services, technologies, energy efficiency, and demand response, while fostering trust, confidence, and consumer protection for their active participation in the electricity system.

It is imperative that policymakers acknowledge the critical role of energy demand and demand side flexibility in the energy transition and future energy affordability. Demand-side flexibility is already central to several energy discussions, particularly in the context of P2X and the hydrogen economy, highlighting its pivotal role across various scales and involving diverse actors (Wan et al., 2023). In other places, the absence of flexibility governance is responsible for issues like inadequate incentives and fragmented coordination among various initiatives. An indication of the missed opportunities in the governance of flexibility consists of the exponential growth in balancing costs to manage the stable operation of the network and congestion. Arguably, a governance model should acknowledge both price patterns and demand patterns concurrently. One could argue that in a highly flexible system, demand aligns with supply without significant price fluctuations. Should such an ideal be integrated into the governance model? However, this may not necessarily represent the economic optimum if load shifting entails additional investments. For instance, the policy question of what the balance should be between reforming the system to enable more dynamic prices (e.g. wholesale market and network charging) vis-à-vis addressing residual imbalances through the balancing mechanism or other flexibility markets can only be understood by knowing the success and failures of implicit flexibility and explicit flexibility.

Further, there is a need to establish suitable consumer safeguards and incentives for engaging in energy demand. Balancing the level of consumer protection is crucial—excessive regulation could stifle innovation, while inadequate measures may leave vulnerable consumers unprotected. According to the National Infrastructure Commission's (2023) Second Infrastructure Assessment, the government needs to facilitate demand side measures (including energy efficiency) without adversely impacting low-income groups. These safeguards and regulations would foster trust between consumers and the industry, stimulate investment in low-carbon technologies, and ensure positive user experiences. Moreover, adopting measures like half-hour settlement, smart tariffs, expanded use of heat pumps and electric vehicles, and implementing policies for enhanced affordability are necessary to facilitate demand side flexibility.

Given the range of objectives on demand side flexibility, the chronology of governance development -flexibility services development and implementation is happening simultaneously, or on similar timescales- and the accompanying delivery mechanisms required, it is not surprising that demand-side flexibility measures are not necessarily aligned.

In addition there is also uncertainty as to the effect of governance mechanisms, in terms of how much change is incentivised, of what types, and where. Uncertainty in outcome may affect the optimum governance mix required to achieve objectives.

The paper makes the case for governance encompassing the roles and responsibilities necessary to deliver and support the functioning of flexibility. In essence, a comprehensive governance strategy for achieving net zero must encompass both energy generation and demand-related facets.

CRediT authorship contribution statement

Jacopo Torriti: Writing – review & editing, Writing – original draft, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Jacopo Torriti reports financial support was provided by UK Research and Innovation. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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References

Barrett, J., Pye, S., Betts-Davies, S., Broad, O., Price, J., Eyre, N., et al., 2022. Energy demand reduction options for meeting national zero-emission targets in the United Kingdom. Nat. Energy 7 (8), 726–735.

British Standards Institute, 2021. Energy Smart Appliances – Demand Side Response Operation – Code of Practice.

Butler, C., Parkhill, K.A., Luzecka, P., 2018. Rethinking energy demand governance: Exploring impact beyond 'energy'policy. Energy Res. Social Sci. 36, 70–78.

Carbon Trust and Imperial College Consultants, 2021. Flexibility in Great Britain. Available at. https://publications.carbontrust.com/flex-gb/report.

Cardoso, C.A., Torriti, J., Lorincz, M., 2020. Making demand side response happen: a review of barriers in commercial and public organisations. Energy Res. Social Sci. 64, 101443.

Climate Change Committee, 2019. Net Zero Technical report. Available at. https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-Technical-report-CCC.pdf.

Climate Change Committee, 2023. Reducing UK emissions – 2023 Progress report to parliament. Available at: https://www.theccc.org.uk/publication/2023-progress-report-to-parliament/.

Cornwall Insight, 2023. The power of flex: rewarding smarter energy usage. Available at. https://www.cornwall-insight.com/wp-content/uploads/2023/08/The-power-of-flex-Rewarding-smarter-energy-usage-1.pdf.

Curtis, M., Torriti, J., Smith, S.T., 2018. A comparative analysis of building energy estimation methods in the context of demand response. Energy Build. 174, 13–25.

Department for Business, Energy & Industrial Strategy (BEIS), 2021a. Available at. Net Zero Strategy: Build Back Greener. https://www.gov.uk/government/publications/net-zero-strategy.

Department for Business, Energy & Industrial Strategy (BEIS), 2021b. Transitioning to a net zero energy system smart systems and flexibility plan 20–1 – appendix I: electricity system flexibility modelling. Available at. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1003787/smart-systems-appendix-i-electricity-system-flexibility-modelling.pdf.

Department for Energy Security & Net Zero (2023). Energy security bill factsheet: low-carbon heat scheme. Available at https://www.gov.uk/government/publications/energy-security-bill-factsheets/energy-security-bill-factsheet-low-carbon-heat-scheme#:~:text=The%20Prime%20Minis'er's%20Ten%2Dpoint,installations%20per%20year%20by%202028.

Energy Systems Catapult, 2022. Delivering a digitalised energy system: energy digitalisation Taskforce report. Available at. https://esc-production-2021.s3.eu-west-2.amazonaws.com/2022/01/ESC-Energy-Digitalisation-Taskforce-Report-2021-web.pdf.

Eyre, N., Killip, G., 2019. Shifting the Focus: Energy Demand in a Net-Zero Carbon UK. Centre for Research into Energy Demand Solutions (CREDS).

Fankhauser, S., Smith, S.M., Allen, M., Axelsson, K., Hale, T., Hepburn, C., et al., 2022. The meaning of net zero and how to get it right. Nat. Clim. Change 12 (1), 15–21.

Fawzy, S., Osman, A.I., Doran, J., Rooney, D.W., 2020. Strategies for mitigation of climate change: a review. Environ. Chem. Lett. 18, 2069–2094.

Grünewald, P., Torriti, J., 2013. Demand response from the non-domestic sector: early UK experiences and future opportunities. Energy Pol. 61, 423–429.

Institute for Government, 2020. Net zero: how government can deliver its climate change target. Available at. https://www.instituteforgovernment.org.uk/sites/default/files/publications/net-zero-government-climate-change-target.pdf.

Johnson, E., Betts-Davies, S., Barrett, J., 2023. Comparative analysis of UK net-zero scenarios: the role of energy demand reduction. Energy Pol. 179, 113620.

National Grid, 2021. Future energy scenarios. Available at. https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2021.

National Grid ESO, 2022. Towards 2030. Available at chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.nationalgrideso.com/document/161996/download. .

National Grid ESO, 2023. Future energy scenarios 2023: flexibility. Available at. https://www.nationalgrideso.com/future-energy/future-energy-scenarios-fes/fes-sections/flexibility.

National Infrastructure Commission, 2023. The Second National Infrastructure Assessment. Available at. https://nic.org.uk/app/uploads/Final-NIA-2-Full-Document.pdf.

Ofgem, 2022a. Net Zero Britain: developing an energy system fit for the future. Available at. https://www.ofgem.gov.uk/publications/net-zero-britain-developing-energy-system-fit-future.

Ofgem, 2022b. Distribution system operation incentive governance document. Available at. https://www.ofgem.gov.uk/sites/default/files/2022-10/DSO%20Incentive%20Governance%20Document%20Consultation.pdf.

Ofgem, 2023. Future of local energy institutions and governance. Available at. https://www.ofgem.gov.uk/publications/decision-future-local-energy-institutions-and-governance.

Piano, S.L., Smith, S.T., 2022. Energy demand and its temporal flexibility: approaches, criticalities and ways forward. Renew. Sustain. Energy Rev. 160, 112249.

Piclo, Element Energy and Graham Oakes, 2020. Modelling the GB flexibility market — Part 1 the value of flexibility. Available at: https://project-leo.co.uk/wp-content/uploads/2020/10/LEO-Modelling-the-GB-Flexibility-Market-Part-1-Value-of-Flexibility-new-cover.pdf.

Ramirez-Mendiola, J., Yunusov, T., Torriti, J., 2023. Demand flexibility certificates – increasing the visibility of demand flexibility through certification. Available at: https://www.edrc.ac.uk/publications/demand-flexibility-certificates/. .

Rosenbloom, D., Meadowcroft, J., 2022. Accelerating pathways to net zero: governance strategies from transition studies and the transition accelerator. Curr. Clim. Change Rep. 8 (4), 104–114.

Royal Society, 2023. Large-scale electricity storage. Available at. https://royalsociety.org/topics-policy/projects/low-carbon-energy-programme/large-scale-electricity-storage/.

Shove, E., Walker, G., 2010. Governing transitions in the sustainability of everyday life. Res. Pol. 39 (4), 471–476.

Trotta, G., Spangenberg, J., Lorek, S., 2018. Energy efficiency in the residential sector: identification of promising policy instruments and private initiatives among selected European countries. Energy Efficiency 11 (8), 2111–2135.

Wan, Y., Kober, T., Schildhauer, T., Schmidt, T.J., McKenna, R., Densing, M., 2023. Conditions for profitable operation of P2X energy hubs to meet local demand with energy market access. Advances in Applied Energy 10, 100127.

World Bank, 2009. Climate change governance. World Bank Policy Research Working. Paper No. 4941.

Yunusov, T., Torriti, J., 2021. Distributional effects of Time of Use tariffs based on electricity demand and time use. Energy Pol. 156, 112412.