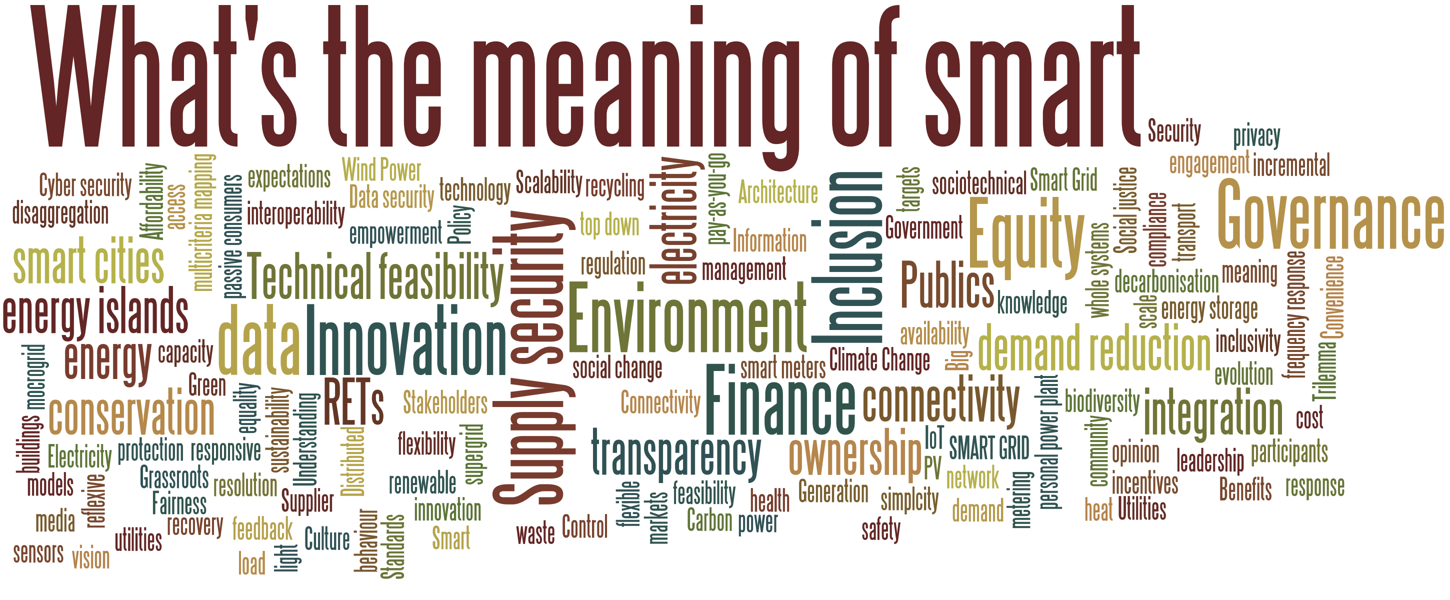
What’s the meaning of ‘smart’?

A study of smart grids

Sociotechnical Report

Nigel Hargreaves, Jason Chilvers, Tom Hargreaves

University of East Anglia, 2015



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Established in early 2011, and building on a tradition of leading environmental social science research at UEA, we are a group of faculty, researchers and postgraduate students taking forward critical social science approaches to researching the social and political dimensions of environment and sustainability issues.

The overall aim of the group is to conduct world-leading research that better understands, and can potentially transform, relations between science, policy and society in responding to the unprecedented sustainability challenges facing our world. In doing this our approach is:

INTERDISCIPLINARY, working at the interface between science and technology studies, human geography and political science, as well as linking with the natural sciences and humanities; ENGAGED, working collaboratively with publics, communities, civil society organisations, government and business; and REFLEXIVE, through being theoretically informed, self-aware and constructively critical. Our work is organised around five interrelated research strands:

KNOWLEDGES AND EXPERTISE
PARTICIPATION AND ENGAGEMENT
SCIENCE, POLICY AND GOVERNANCE
TRANSITIONS TO SUSTAINABILITY
SUSTAINABLE CONSUMPTION

3S researchers working across these strands focus on a range of topics and substantive issues including: climate change, energy, smart grids, emerging technologies (such as biotechnologies and geoengineering), natural hazards, responses to the economic and financial crisis, and grassroots actions and social movements on sustainability.

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Any errors remain the responsibility of the authors

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CONTENTS

NOMENCLATURE

AO	Additional Option
AMI	Advanced Metering Infrastructure
BAU	Business as Usual
CfD	Contract for Difference
CO	Core Option
CSO	Civil Society Organisation
DCC	Data Communications Company
DECC	Department of Energy and Climate Change
DG	Distributed Generation
DNO	Distribution Network Operator
DO	Discretionary Option
DSR	Demand Side Response
DSM	Demand Side Management
DSO	Distribution System Operator
E2E	End-to-End
EDR	Electricity Demand Reduction
EMR	Electricity Market Reform
ESCO	Energy Service Company
FAR	Field Anomaly Relaxation
FiT	Feed-in Tariff
GLS	Government Led Strategy
ICT	Information and Communications Technologies
IHD	In Home Display
IoT	Internet of Things
MCM	Multicriteria mapping
NGO	Non-governmental Organisation
ODI	Overseas Development Institute
OECD	Organisation for Economic Cooperation and Development
PV	Photovoltaic
SocSci	Social Science
SET	Smart Energy Technology
SG	Smart grid
SMETS	Smart Metering Equipment Technical Specifications
TOUT	Time Of Use Tariff
UKERC	UK Energy Research Centre
UKPN	UK Power Networks
VPP	Virtual Power Plant

EXECUTIVE SUMMARY

The research published in this report has been undertaken over the course of a one-year exploration into the meaning of 'smart' in the context of, but not necessarily limited to, the GB electricity system. A key aim was to expose and articulate for the first time, criteria, concerns and considerations from a diverse array of electricity system stakeholders to reveal where comparable and contrasting understandings of smart grids lay. It was our intention to address stakeholders that were not normally included in such a technologically dominated debate, such as electricity end-users, who form a 'critical node' in electricity systems. This enquiry was particularly timely with the imminent mass rollout of electricity smart meters in the UK.

The findings of our analysis demonstrate that smart grids are not only a technical matter but depend upon integration with *social smartness* as well. Important implications arise from this in terms of vision for possible smart grid development and success. They also revealed how a lack of attention paid to considerations of social smartness risk missing the potential for future grids to be fully integrative across social and technical interfaces. This work found eight critical issues as focal points from the perspectives of our study participants contributing to the meanings of smart - these included criteria around equity, inclusion and governance as well as the more familiar issues of data security, supply security, technical feasibility, finance and environment.

These critical issues are representative of an underlying weave of numerous nuanced concerns and considerations that form a complex spread of social and technical factors for smartness in electricity systems and their associated markets. What this told us was there is no singular meaning of smart as it is seen differently through the perspectives of different people from different sectors. The implication for smart grid making from this discovery is that processes of policy-making, decision-making, design and innovation that will lead to future smart grids will need to be distributed and multiple. Then strategies accounting for the social dimensions of these processes will themselves have to be diverse rather than prescriptive. Following this, problem framing will need to be opened-up to a wider set of considerations than are currently focused upon through the energy trilemma.

If future work on smart grid development should therefore place more emphasis on understanding what it is to be socially smart and how it intersects with established technical understandings, what are the means and processes by which this could take place? We need to bring tools, devices, procedures and ways of being that seek the meaning of socially smart - including concerns over equity, inclusion, directionality, privacy and trust - into smart grid design and innovation processes. In our conclusions we suggest in more detail how these can be created and how this work can be applied and furthered to maintain clearer direction in the forming and reforming of future smart grids.

1. INTRODUCTION

The UK Government has instituted by Acts of Parliament approaches to a low carbon future that heavily depend on the implementation and adoption of new energy technologies [1,2] that operate as part of a "bigger, smarter electricity grid" [3]. Responding to these directives, various institutions composed of Government and energy industry experts have elaborated upon the intention to implement a smart grid [4,5,6]. These intentions are backed by a number of strategic policy instruments that include Electricity Market Reform (EMR) [7] and a Carbon Floor Price [8]. They introduced tools to change the electricity market that would make it more compliant with the needs of low carbon energy generators to contribute to the robustness and security of the national electricity supply. EMR tools include the use of Contracts for Difference (CfDs), an Electricity Demand Reduction (EDR) pilot [9] and a Capacity Market [10] that pays generators to be available to supply electricity. Feed-in tariffs (FiTs) were also introduced in April 2010, to financially incentivise a diverse range of micro-generators to invest in low carbon technologies such as photovoltaic (PV) panels and wind turbines [11].

The impacts of these kinds of policies extend over a very large socio-technological domain, from generators, through transmission and distribution networks to the low voltage networks that supply energy end-users. They potentially also open up traditional electricity supply architecture to new decentralized social and technical interventions that could, with the right support and conditions, encourage active participation in the electricity market [12,13]. Emerging interventions, particularly from Community Energy and the rapid growth of private distributed renewable energy generators and acquisitions of energy-related companies by large data-oriented companies, are challenging established utility business models to change and reflect on new partnerships with their customer base [14]. Redesign of some electricity markets that have opened to these new participants, has challenged the profitability of our dependence on fossil fuel driven generation, and at times of high wind and solar radiation (coupled with moderate demand) demonstrated negative spot prices for electricity. The GB day-ahead market currently allows for this but not the intraday market as yet. Recent reports of negative electricity prices that undermine profits of established energy utilities, are indications of the mounting pressures forcing generator-supplier thinking to change [15,16].

The scope of an electricity smart grid is multi-dimensional, linking it to gas and other sources of thermal energy, such as heat from industrial processes and buildings, electrified and hybrid transport systems. As these linkages develop there is potential for it to become more dependent on a spectrum of considerations ranging from purely technical, to social and societal. For example, water infrastructure could also one day be included within the remit of multi-vectoral smart grids that further integrate and sustainably manage essential resources [17]. Recent research by the UK Energy Research Centre (UKERC) however, found that this more open and inclusive vision was yet to emerge in expert analyses. In a survey of the opinions of over 100 experts about what they considered were the essential functions expected of smart grids, UKERC found the top five responses were all purely technical, concerning grid stability management with increasing amounts of renewable energy technology (RET) deployment [18]. While cost, data privacy and protection were reported among benefits and pitfalls of smart grids, over a quarter (27%) of respondents cited "*Disengaged or uncooperative customers*" as a further top concern.

Such evidence reflects how smart grids are regarded with a dominant technological perspective as a strategic component of our efforts to address the 'energy trilemma' built upon the dimensions of security of supply, energy decarbonisation and affordability. Grid renewal is also timely from a network owner's perspective, as national grid infrastructure assets are continuously modernised. Motivation for technical enhancement of electricity networks into a smarter grid has been driven in part by cost of technical breakdown in the past [19]. European Governments also support the expansion of the area of the European synchronous AC network (from an energy security perspective) and more recently, to engage within a unified transnational wholesale electricity market, addressing the affordability criterion of the energy trilemma. It has been argued that the evolution of smart grids will manage electrical energy more efficiently while providing it reliably, efficiently and cost-effectively as demand changes in line with societal developments [20,21]. With the rollout of smart meters and development of Advanced Metering Infrastructure (AMI) opportunities could also potentially open for consumers to become engaged with the day-to-day operation of smart grids through microgeneration and Demand Side Response (DSR) activities.

Much of this, and other essential smart grid activities, could only be possible through advances in data and communications technologies alongside more traditional grid infrastructure. Layered, integrated, smart grid connectivity architecture is already proposed by the EU to establish end-to-end (E2E) interoperability of smart grid equipment and human interventions [22]. The data-driven nature of smart grid development at all levels and is becoming more generally accepted but with this comes the likelihood of previously un-encountered data related challenges, ranging from quality of data to cyber-security for example. The evolution of smart grids to incorporate domestic smart meters opens up a new dimension where concerns of data security, privacy, transparency, authenticity and quality are becoming instantiated, joining several other cyber security challenges where ICT dependence is critical to the running of national electricity infrastructure [23].

As the proportion of distributed intermittent renewable energy sources increases [24], smart grids will have to manage demand in accordance with variable supply technology that does not offer system inertia compared to the stabilising effect from large rotating machine generators. This requirement impacts upon electrical frequency stabilisation [25] across a national grid-scaled infrastructure. It represents a turning point in the history of grid design with centralised generation, and increasingly exposes the stability of the electricity system to environmental factors, from a less determinable supply-demand scenario. The rising distributed microgeneration capacity from small scale, renewable energy generators connected through end-user low voltage networks is contributing to this turning point. It also affects the traditional pattern of network energy flows, moving us away from a traditional radial pattern [26]. Smart grids need to be increasingly 'meshed' to manage energy flows in all directions. As part of the low carbon energy transition therefore, it is of increasing importance for demand to be modified in relation to availability of supply. We could also see the possibility of a radical reorganization of networks to reflect the move towards increasing distributed generating capacity as well [27]. In turn this will require far greater understanding of, and cooperation and engagement with energy end-users, especially to secure national-scale grid infrastructure.

The emergence of increasing numbers of energy end-users as energy suppliers could also drive changes effecting traditional utility market models [28]. New market segments could open-up to sell power and energy as 'services' that help to maintain the stability and security of grid infrastructure. These already include established models for commercial and industrial demand reduction but could now extend to include a range of energy and power storage capabilities within the community and domestic arenas. Technologies to reveal the demand from individual loads using 'demand disaggregation' techniques can now be deployed to the domestic appliance level for example [29]. Appliances whose operation can be deferred to selected times of the day and thermostats that ‘learn’ their owners’ heating behaviours are already available. If managed over a large number of participants, aggregated demand from domestic appliances potentially offers network utilities DSR services such as peak shifting and demand designed to absorb excess power [30]. This would support voltage and frequency (or power quality) at the periphery of the electrical network infrastructure, helping to defer costly network reinforcement.

However, the predominant understanding of smart grid end-users is still as a 'consumer' responding to price incentives and modifying energy use behaviour accordingly. This model of understanding could be used to extend control by utilities, perhaps over appliances in the home, for Demand Side Management (DSM). It is possible though such a perspective would reinforce the techno-centric tendency to generally see smart grids as a technical solution to a problem of society. It risks exclusion of issues like social equity, control, acceptance and energy democracy in smart grid design at all scales. Warning against such a lack of understanding and a failure to engage more with more diverse range of actors within distributed energy systems, Wolsink [31] argues that smart grid success in supporting the transition to low carbon energy through renewables deployment, could be at risk. The increased complexity of usefully exploiting renewable resources technically, and marketising them more openly, is also reflected in sociotechnical configurations of increased complexity around access as well. Walker and Cass identify a multiplicity of roles implicated for ‘the public’ that span meaning, access and new social identities [32]. Multiple roles and novel types of engagement are envisaged that could include individuals in organisations such as Community Energy groups and Energy Islands. Devine-Wright has proposed these new forms of engagement could contribute to an identity of ‘Energy Citizenship’ [33]. This study has chosen to use the term ‘energy end-user’ to deliberately blur the context in which the energy citizen is situated to confer demand or supply upon shared electricity networks. In doing so, we accept that there will be potential for a mix of both demand and supply in end-user energy activities that could be mediated for example by age, economic, geographic, cultural and informational factors personal to the individual.

If the notion of sources of renewable energy as collective commons is adopted, with increased access to capacity and marketisation than today’s ‘closed-shop’, generator-supplier-consumer business models, there would be the requirement for further Government intervention in energy market reformation. “*The setting of boundaries, responding to change and meeting the information needs of all interested parties*” are proposed as three aspects of an appropriate commons management regime [34]. The question of energy data availability, ownership and access is thus forced into the forefront of the debate driving smart grid evolution. In turn, it weighs upon the expectations of the proposed national rollout of smart meters to realise such potentials [35]. As smart meters represent a bridge to a significant new source of energy system data they are key assets that if designed appropriately to meet end-user expectations, would make a powerful contribution to smart grid evolution. For example, within the public domain, the ‘Internet of Things’ (IoT) phenomenon could interconnect many such devices and is currently growing in size at the rate of about 100 *things* per second with an estimated 50 billion things interconnected by 2020 [36]. This development, perhaps more than others concerning smart grid technology, could be where the greatest potential for engagement of end-users within smart grid lies and offers enormous potential to challenge established norms [37,38]. From this perspective it is possible to see how smart grid design and operation, in response to wider stakeholder engagement, could become like a ‘product’ that is centred on end-user experience.

Given the potential for smart grids to disrupt and their intimate connection to society and the environment, there are reasonable concerns around issues of ownership [39], trust [40], the direction of ‘technological leadership’ [41], equity [42], privacy and security [43] and expectations of personal integration into the energy system [44]. As a backdrop to these issues there are tensions emerging between the end-user and the developer/policy maker communities over how influential the publics are in publicly funded energy research and developments [45]. These concerns suggest we can no longer understand smart grids entirely from a ‘technical’ perspective, because their success as a ‘solution’ to the energy trilemma increasingly depends upon mass adoption. Yet smart grid research to date has predominantly focused upon technical issues and that there now appears to be, with the advent of AMI, greater urgency than before to open up to different social understandings of the meaning of 'smart'. In developing wider understanding of the meaning of smart in this context, it would be necessary to engage with views and attitudes from a variety of electricity stakeholder perspectives. Applying this thinking to electricity smart grid development, integration of social and technical considerations within their design could result in greater benefits and smarter grids.

In exploring this proposition in the context of the electricity system, we have hypothesised that the essence of smart grid co-creation is connected to the meaning of ‘smart’ and so pose the question: “What is meant by ‘*smart’*?” in the hope that we may contribute essential considerations to help guide smart grid evolution. An enhanced sociotechnical understanding of the multi-faceted electrical smart grid concept could also offer value in other technology contexts that are socially situated and depend upon mass adoption. Given that the electricity system does not exist in isolation of other systems, such as heat, water, transport etc., further understanding of the meaning of smart could therefore also assist in developing the interfaces between the electricity system and other essential systems engaged with sustainability.

In the next Section we discuss our motivations for this research by exploring the sociotechnical basis for technology development and reflect upon research indicating the lack of integration between technical and sociotechnical perspectives on low carbon energy technology. In Section 3 we express the aims, objectives and constraints of this research project and in Section 4 describe the methodology we undertook to approach better understanding of the meaning of 'smart' in the smart electricity grid context. In Sections 5 and 6 we report on the results from different stages of the adopted approach. These stages entail feedback both on elements of diverse visions for smart grids as well as important criteria for their success from an array of electricity system stakeholder perspectives. Conclusions arising from these Sections are revealed in Section 7 that include advice and practical recommendations to apply to smart grid development from the learning of this study.

2. FOUNDATIONS AND MOTIVATION FOR THIS RESEARCH

The approach taken in this research project benefits from foundational work on the smart home context carried out by Wilson et al [46]. In this paper three ‘Grand Narratives’ were derived from an analysis of a very comprehensive literature review of the smart home topic. These were defined as follows:

1. The **Instrumental** view of smart homes emphasises their potential to help achieve energy demand reduction goals, with associated benefits for households, utilities, and policymakers.

2. The **Functional** view points to a wide variety of tasks and activities that smart homes could help people achieve.

3. The **Sociotechnical** view sees smart homes as simply the latest (or perhaps the next) episode in the coevolving relationship between technology and society.

While these semantic definitions for ‘Instrumental’, ‘Functional’ and ‘Sociotechnical’ are derived from research into the smart home context; the question was asked whether they could also be used to apply generically to the wider smart grid? This proposal is coherent with the desire for a scalable framework to which research into smart grids at different levels or scales of thematic context could refer. Adaption of the principles of the Grand Narratives to smart grid context is presented in Fig. 1 with some exemplar themes and contexts.

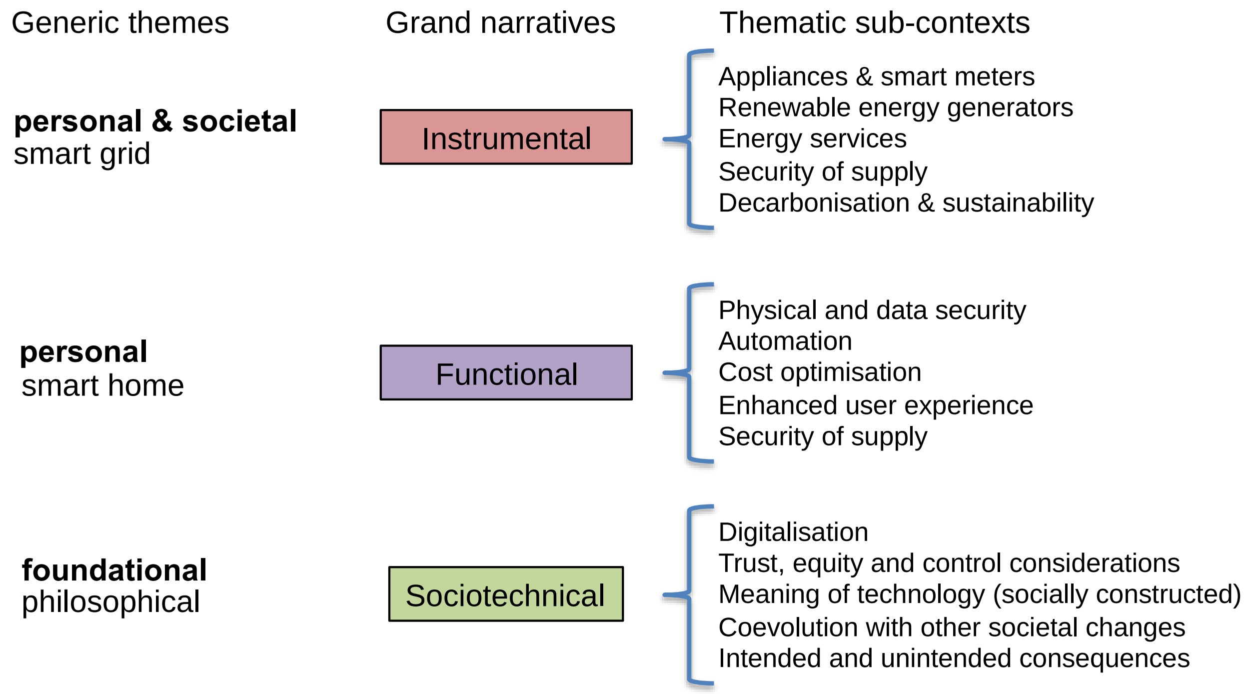


Fig. 1. Grand Narratives from [43] are presented in a re-formatted architecture following generic themes.

The Grand Narratives described in [46] were found to have certain connections and disconnections that marked the division between the technical and the sociotechnical narratives, revealing a very poor level of power from publics to affect change upon energy issues in the UK. This was clear from the polarisation of sub-texts or crosscutting issues between the broadly technical narratives (Instrumental and Functional) and the Sociotechnical narrative (Fig. 2). Bold lines reflect strong evidence of crosscutting from the literature analysis of research into smart homes, while dashed lines on the other hand reflect a weaker evidence of research effort. This analysis gives rise to a sense that engineers approach the development of technology from a more instrumental objectification of its purpose, which is narrower perhaps when compared to the end-user public who's concerns include affordability, social value, ethics, fairness and equity, amongst other considerations.

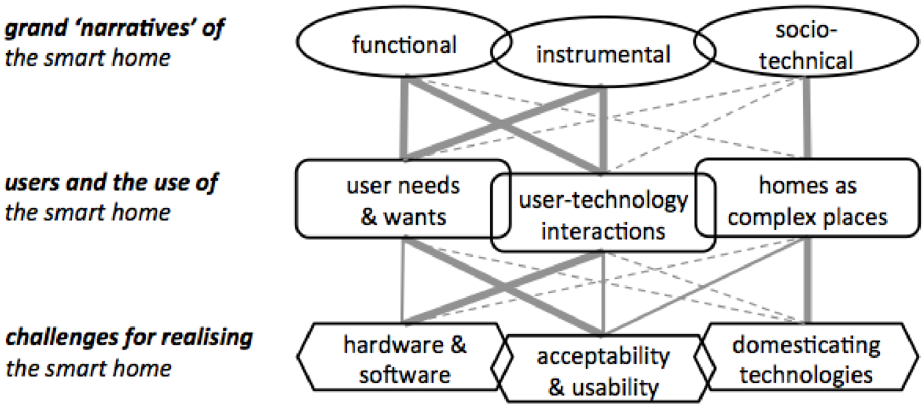


Fig. 2. Relationships between narratives and themes based on literature review analysis in [43]

The issue of dialogue between the end-user publics and the developing and implementing authorities of the GB energy system is also illuminated in [47]. This synthesis report from in-depth deliberations, expert interviews and a representative end-users survey offers four key messages:

- Publics are willing and fully capable of engaging critically with energy system transformation.
- Actors involved in energy system transitions need to treat public viewpoints with integrity, valuing the contribution they make to envisioning transitions.
- Policy-makers and other actors need to make clear how current and proposed changes to the energy system fit within a long-term trajectory.
- Actors involved in energy system change need to ensure that their actions are transparent and mirror rhetoric.

Coherent with these recommendations, Sørensen [48] proposes that the chance of technological 'success' can be enhanced by the degree to which technology policy concerns itself with socialisation, as well as interactions between issues of innovation and deployment. His argument that deployment requires technology domestication for '*sense-making*' and use, may offer useful reflection on the design of smart grid end-user technologies.

The notion that a technology is 'smart' suggests therefore, that contained within the strands of the 'DNA' it is composed of is achievement of some form of social adoption and engagement. And that this has arisen from sense-making and placing of the technology through its perception by end-users. Engagement with, and social adoption of the technology may also be composed of a myriad of other 'issue-strands' such as cost, innovation and efficacy for example. Indeed, if we consider smart things in sociotechnical space, they are often identified as belonging to networks, ecosystems and platforms. A recognizable identity (or brand) and an interoperable capability, (which may be more or less important in respect to scale) often reinforces these considerations.

Technological innovations on a system scale have been addressed by Hofman et al [49] who describe a multi-level theory of 'technology ascendance' to model technological innovations in The Netherlands electricity system. Geels highlights technology as being only one part of sociotechnical system transition under exogenous pressures (eg. climate change, energy security) that opens-up to create niches. Niches set-up the opportunity for technological acceptance and regime change that "*not only involve changes in technology but also changes in user practices, regulation, industrial networks, infrastructure, and symbolic meaning or culture*". [50] Changes may manifest themselves through technological substitution or transformation of user behavior. Smart grid technologies are attempting to make such changes – the smart meter is an example of technological substitution but enhanced user interaction with the energy market could help bring about system transformation if AMI enables behavioural change as well!

Applying the concepts referred to above to smart grid technology, an ascendant trajectory within a sociotechnical space, in response to exogenous pressures, could be represented by reformatting the Grand Narratives described in [46] (Fig. 3). It may be that there is a dependency on *smart* technologies to successfully pass through Sociotechnical, Functional and Instrumental filters. And in the absence of transparent long-term regulatory guidance and policy, there is a possibility that the market may drive technology development into sociotechnical niches in a less organised manner than under a coordinated strategy. If this were the case and inward investment was not attracted by a stable long-term policy regime, evolution of smart grids could be more powerfully influenced by those players who have the risk appetite and the competence but potentially limit "the transition to greater smartness" [18].

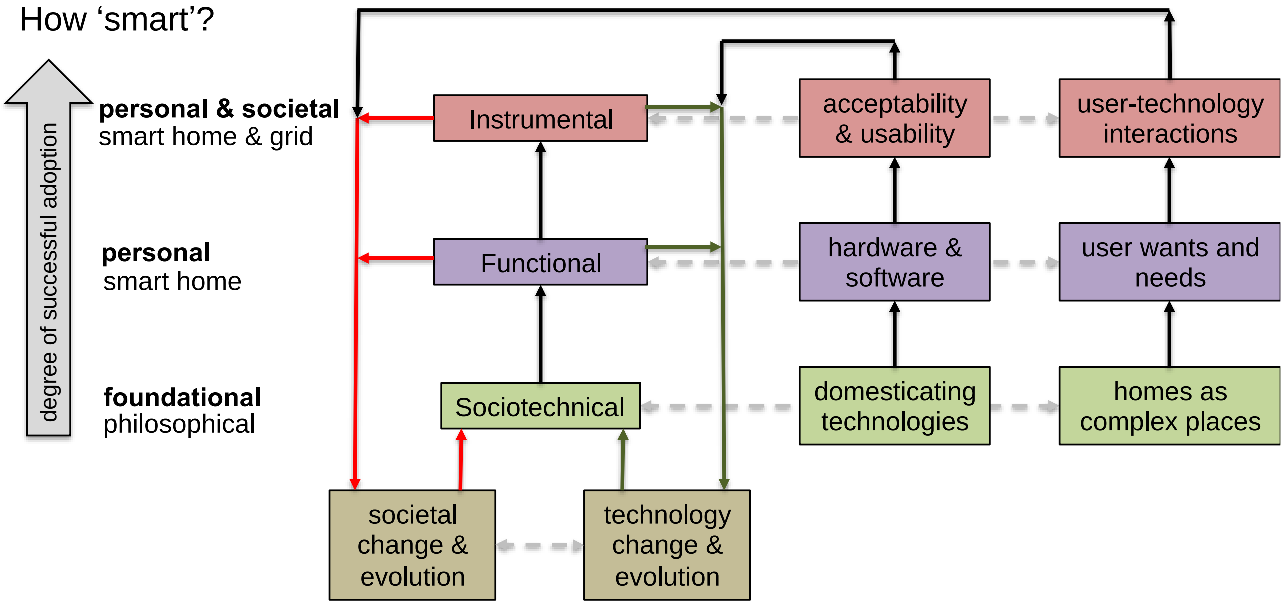


Fig. 3. Re-formatted model of Grand Narrative and thematic relationships from [3]

If understanding technological smartness can then be approached through narrative, context and point of view, it may be possible to construct a conceptual framework describing the way technological transitions occur. In Fig. 4 we attempt to schematically represent the generalised suggestion that the Instrumental Narrative drives the starting point for much smart grid technology development from an engineering technical *perspective*. For example, this perspective seeks to address the grand challenges posed by the Energy Trilemma concerning issues such as energy security or energy decarbonisation. The Functional perspective by contrast could be concerned more by issues of *platform* and *ecosystem* and apply more equally to a Technical or Sociotechnical perspective. On the other hand, the Social perspective could be driven from the prevailing Sociotechnical narrative with concerns of more personal control, safety, and immediate environmental needs. The trajectories that follow these starting points could be mutually complementary or competitive as co-creating recursive processes involving all three Grand Narratives engage to determine whether a particular technology will be successfully deployed and adopted in the shaping of smart grids. As Stephens et al, point out there are tensions within a shared smart grid vision that are molding electricity system innovation – it may be “difficult for non-experts to shape smart grid design, but their behaviour is crucial for system operation” [51].

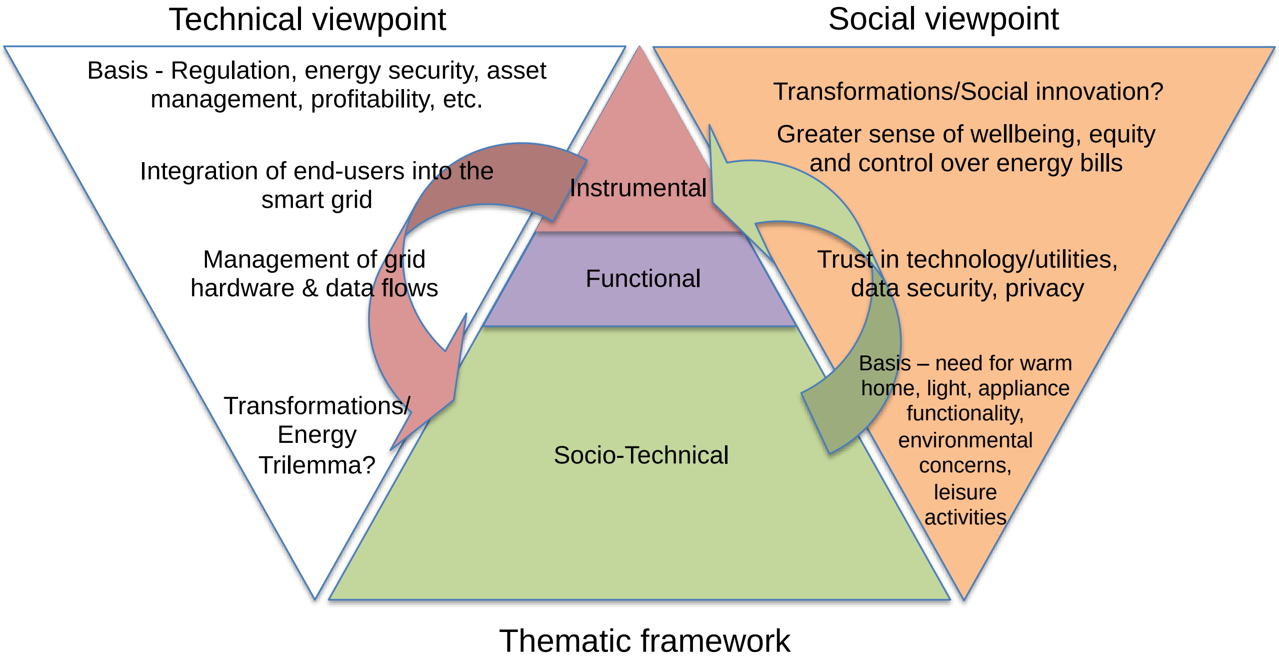


Fig. 4. The co-creating environment of Technical and Social viewpoints around a common thematic framework out of which technology can become smart.

This simplified interpretation of the complex processes involving technologies making up smart grids offers a starting point for the questions within this research project. We are motivated by the very narrow way questions of 'smartness' have so far been addressed as a technical issue. What if we were to ask more social questions of smartness? Such questions include; "*What is the meaning of ‘smart’?*" and how do we make energy systems smarter from a sociotechnical point of view? How could we involve the energy end-user in their energy system and include their understandings and perceptions in its design, operation and finance? The following exploration aims to address these questions from different stakeholder and sectoral perspectives.

3. STUDY DESIGN: AIMS, OBJECTIVES & CONSTRAINTS

3.1 Why we did this study

In Section 1, we discussed how significant aspects of smart grid development are a response in technical engineering terms to the energy trilemma, which is itself a relatively narrow problem framework. Smart grid research and decision making has tended to focus upon technical considerations and as a result has not appeared to sufficiently address social concerns, or how different forms of smart grid development can be understood and visualised and impact upon different groups of society. In Section 2 however, we have introduced an argument from a social science perspective that notions of socialisation and sociotechnical considerations profoundly influence technology development, including smart grids at different scales. It is the evident lack of connection and integration between these two broad based understandings that we attempted to address within this study in the context of GB electricity smart grid development. Although this is only one element of GB smart grid development, it also seemed particularly timely to be investigating this topic, as the mass rollout of electricity and gas smart meters is due to begin.

We hypothesised that enhanced understanding of 'smart' within the sociotechnical base of smart grids could offer insights into, but not exclusively, the design, policy and engagement strategies required in smart grid development. If this understanding were then to be integrated with technical perspectives it could be instrumental in more fully realising 'smart' grid functionality.

To develop understanding of the multiple meanings of ‘smart’ held by a diverse array of actors in the GB electricity system, using an approach that did not close down opportunities for learning or deliberation, then became the core research aim of this study

In order to achieve this aim, the study had the following objectives:

1. To develop a Focal Goal that was open to a range of interpretations of smart grids.
2. To generate several different Options for smart grid realization that characterize the multiple competing visions for smart grid development currently in circulation.
3. To elicit a number of Criteria against which all Options for smart grid realization could be assessed.

All three of these objectives were designed to open up discussion about smart grids in a manner that reflected both their social and their technical underpinnings.

The study was constrained to a one-year post-doctoral fellowship and availability of a manageable number of participants selected for their sectoral diversity.

4. METHODS

4.1 Multicriteria mapping and Focal Goal

The study aimed to elicit opinion from a diverse array of smart grid stakeholders on the meaning of ‘smart’. An in-depth structured interview technique that did not closeout participation or closedown deliberation across a broad and diverse study population was used in 26 recorded and transcribed interviews.

We chose an expert-analytic approach that was developed and refined by the Science Policy Research Unit at University of Sussex [52, 53]. The Multicriteria Mapping (MCM) procedure was used because of its success in other studies requiring deliberation over complex topics by participants. Key underlying values of the MCM process are outlined in the Multicriteria Mapping Manual [54] as follows:

1. *Inclusion: MCM aims to promote more inclusive, equitable and accessible appraisal. This means engaging in a respectful and balanced way, with a diversity of relevant perspectives – especially those most often marginalized.*
2. *Opening Up: MCM aims to help ‘open up’ appraisal. This means giving balanced attention to exploring and illuminating contending views. Using MCM just to aggregate a single final view has the effect instead of ‘closing down’.*
3. *Agency: MCM aims to ‘put participants in the driving seat’. An MCM project should be designed, implemented and analysed to maximise the agency of participants over the ways in which their own perspectives are represented.*
4. *Transparency: MCM only ‘opens up’, if results are conveyed fully and clearly to all parties with an interest in debates over the focal goal. Depending on context, this means publishing results and giving reasonable access to data.*

As the MCM tool can be used either as an offline or online variant, we chose to conduct our interviews using the offline tool to avoid complications arising with Internet access in certain locations. Data recorded from the interviews in the offline tool was later uploaded to the online tool for analysis. The MCM tool provides the means to enter qualitative and quantitative information in a standardised interview format. Together with the audio transcriptions from each interview, we used the information captured in the MCM tool to identify perspectives on ‘smart’ from a diversity of participant values and understandings bearing on different ways to achieve a broadly shared objective called the *Focal Goal*.

Guided by our hypothesis that concerned the sociotechnical dimension of the energy system, we compiled the Focal Goal for participants to appraise as follows, “*How should smart grids be organised to account for social and technical concerns within all dimensions of the energy trilemma?*” As this study was primarily investigating the electricity system, it was important that stakeholder deliberation was guided to focus upon the common topic of smart grids while at the same time being able to openly capture the diversity of the opinions offered. Therefore we established the context of our study was specific to electricity smart grids with participants prior to their engagement, but in doing so tried to avoid the sense that understanding of ‘smart’ must only be limited to electricity systems.

4.2 Participant selection

Participants were recruited to the study after a preliminary telephone call to establish their interest in terms of professional function. A diversity of electricity end-users, chosen from outside of the electricity related industries were also recruited. Participant diversity was a high priority to help us capture a representative set of perspectives. We settled on a sample of 26 interviewees as a representative cross-section of stakeholders across different sectors and domains of expertise and interest. There was greater emphasis however, on end-user recruitment, in order to elicit more responses from a generally under-represented sector in energy system development. Clustering of perspectives representing the sectoral groups was used to develop our analysis of the interview data (Table 1).

The (*) next to the participant code marks those who chose an alternative way to use their Criteria when scoring the Options. This is further explained in Section 4.5 (see p19).

Table 1. Study participant demography

Serial No.	Code	Sector	Actor domain	Cluster
1	G1*	Government	Future electricity networks	Government
2	G2*	Government	Sustainable development	Government
3	G3	Local government	Energy services	Government
4	C1	Commercial	Wireless systems	Commercial
5	C2	Commercial	Smart hardware/software	Commercial
6	C3*	Commercial	Smart grid applications & solutions	Commercial
7	N1*	NGO/CSO	Sustainable development	NGO
8	N2	NGO/CSO	Environmental campaigning	NGO
9	A1	Academic	Smart ICT engineering	Academic
10	A2	Academic	SocSci Energy issues	Academic
11	A3	Academic	Electrical engineering	Academic
12	A4	Academic	Natural capital/Environmental science	Academic
13	L1	Community energy	Rural community energy	Local
14	L2*	Community energy	Urban community energy	Local
15	U1*	Network utility	Future power demand	Utility
16	U2	Network utility	Network infrastructure development	Utility
17	U3	Energy supplier	Metering	Utility
18	E1*	Energy end-user	ICT Internet applications	End-users
19	E2*	Energy end-user	Architecture	End-users
20	E3	Energy end-user	Art & Education	End-users
21	E4*	Energy end-user	Unemployed	End-users
22	E5	Energy end-user	Health	End-users
23	E6	Energy end-user	Environmental activism	End-users
24	E7*	Energy end-user	Music	End-users
25	E8	Energy end-user	Financial & microgeneration	End-users
26	E9*	Energy end-user	ICT Training	End-users

4.3 Options

In line with the guidelines described in [54] for using the MCM technique, we constructed a diverse range of *Options* that were constituted from salient practices, policies, strategies and technologies relevant to the Focal Goal, from which appraisal by interviewees could be elicited. The Options were designed to reflect the potential diversity of smart grids under different meanings, contexts and scenarios from different stakeholder perspectives. To keep the process focused and manageable within our resource constraints, we created two sets of Options comprising four ‘Core Options’ (COs) and four ‘Discretionary Options’ (DOs).

We approached Option development by mapping a wide range of issues elicited from available technical, economic, political, environmental and social literature referring to smart grids and their social contexts (Fig. 5).

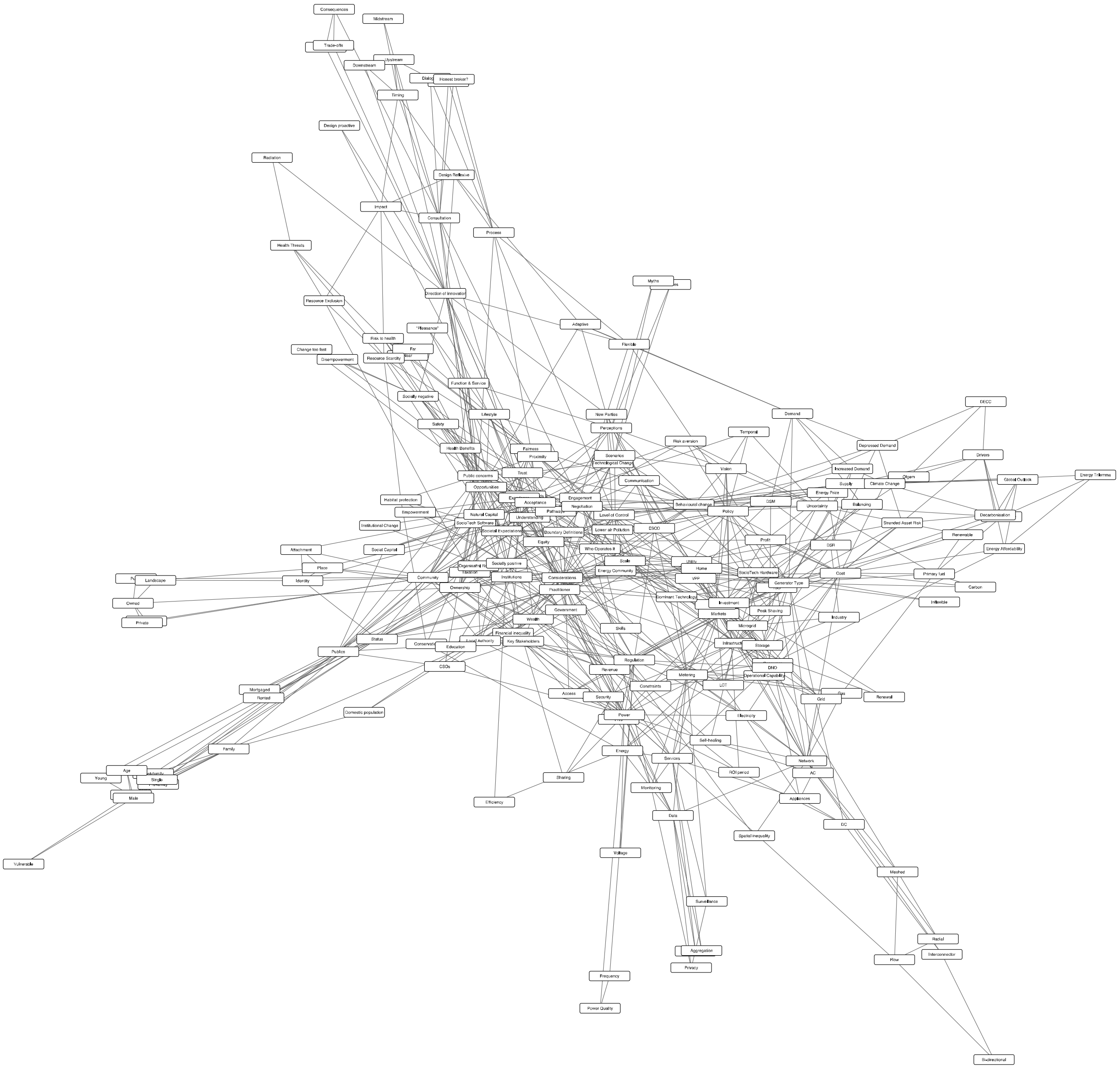


Fig. 5. Issue tree formed by mapping issues referring to smart grids in technical, economic and social literature.

In particular, attention was given to recent works on energy scenarios developed in [13,18,55]. This process gave rise to over 200 interconnected ‘issue nodes’ that were then reduced to a set relevant to the FG inspired by the technique known as Field Anomaly Relaxation (FAR) [56]. FAR was developed to create consistent futures projection in circumstance where diverse visions of the future were possible. It uses an array composed of 'sectors' and 'factors' to describe the projections, some of which will exist, be possible or be impossible. It was therefore useful in eliminating combinations not considered plausible to the design of our Options.

In (Table 2) of our Option building process shows how we applied sectors at different scales (Government, Commercial, Community, End-user) to form one side of the array to which we could attach key factors derived from analysis of the issue nodes in Fig. 5. The 'governance logic' applied to collecting factors was broadly driven by social and technical matters. Discretionary Options were created to supplement the diversity of the COs with the key sectors and factors from which they were built presented in Table 3. A process of twelve iterations (overseen by other team members) then followed to clarify and distinguish all the Options such that they could be presented as a consistent, yet diverse set of approaches addressing the Focal Goal. The Options were finalised after trialing in a pilot MCM session (Table 4 & 5).

Table 2. Core Option key sectors and factors

Government	**Commercial**	**Community**	**End-user**
Leadership	Energy technology markets	Local control	Centralised management
Smart meters	Innovation	Energy devolution	Engagement
Cyber crime	Data	Funding	Security of gas supply

Table 3. Discretionary Option key sectors and factors

End-user technology	**Energy democracy**	**Microgrids**	**SG alternative**
Choice	Transparency	Supply expectations	Conservation strategy
Digital tech evolution	Engagement	Energy independence	Fuel poverty
Ownership	Consultation	Operational skills	Economy

Table 4. Core Options

Core Option 1: Government led strategy This Option is characterised by new market and service opportunities becoming possible to encourage end-users to participate in the smart grid following the Government led rollout of 53 million domestic smart meters by 2020. The energy supplier owns the meter and data is harvested and disseminated to licensed parties by the Data Communications Company (DCC). Risks to the success of this Option range from user concerns about security of personal data and intrusion upon privacy to exposure to more microwave radiation and loss of customer rights. Utility systems could also become more vulnerable to cyber crime threats.
Core Option 2: Commercial engagement This Option is characterised by companies like Google, Apple and Samsung exploiting end-user data for commercial gains by extending their product range and influence into the energy technology market. By making new equipment that integrates domestic energy technology such as heating and lighting systems with users' daily activities, they open-up opportunities to improve understanding of the use and operation of the smart grid at all levels from analysis of end-user data. Risks to this option include loss of control over data by users as cyber security requirements widen with another layer of complexity added to smart grid management.
Core Option 3: Community energy This Option is characterised by end-users taking more control over their energy requirements, motivated by Government incentives and opposition to powerful utilities. It aligns with DECC's Community Energy Strategy as part of meeting 2050 energy targets. Community Energy projects proliferate, enabled by distributed energy resources such as PV and biogas, connected through microgrids and supported by smart metering and monitoring technologies. As end-user energy capacity develops to be a significant presence in the market, pressure mounts on the big utilities to change their business models, forcing them to enter into new forms of partnership. Risks to the success of this option would include lack of funding streams and inadequate engagement amongst community members.
Core Option 4: Passive consumers This Option is characterised by rendering end-users as passive consumers. The price of wholesale gas to large utilities continues to decline and interconnector capacity grows, making gas-fired generators and interconnectors sufficient to balance the variability of large-scale renewable energy installations. These then form the main thrust of national decarbonisation efforts. Despite rollout to all end-users, the need for smart meters to assist in domestic demand side response becomes unnecessary. Risks to the success of this option would include interruption to the supply of gas, which would be heavily reliant on imports and domestic shale gas production.

Table 5. Discretionary Options
Discretionary Option 1: Smart meter redesign This Option is characterised by giving users greater ownership and choice about what happens to their data. The DCC-connected smart meter is still capable of billing functions but due to disruptive effects from rapid advances in digital technology innovation, first generation smart meters are soon outmoded. Correspondingly, DECC call for another meter rollout that gives more choice to the end-user over the smart energy technology they install in their homes. This would move the focus of responsibility for personal data security away from the DCC and utilities, to the trusted brands chosen by end-users through the technology they buy. But risks to the success of this option would include the cost to the end-user adding to greater social energy division and fuel poverty.
Discretionary Option 2: Energy democracy This Option is characterised by the process of engaging end-users in the design of the smart grid. Emulating the way publics are engaged in infrastructure developments in other countries, like Denmark, DECC could institute a nationwide series of midstream workshops in which communities are introduced to the Government's vision for end-user interaction with the smart grid. Feedback from these workshops could indicate the need to further restructure energy markets and even the kind of technology used in metering infrastructure, to improve adoption and access by end-users. Risks to the success of this option would include the need to change institutionalised protocols for technology co-creation between government, industry and society. It may also be a case of too little too late.
Discretionary Option 3: Energy islands This Option is characterised by citizens taking full control over their electricity supply and data ownership, removing the need for connection to both the centralised grid and DCC. Smart metering technology and microgrids owned by end-users connect distributed generation capacity and virtual power plants into energy islands balanced by third party energy management services. In some cases a 'lifeline' connection could be maintained that enables access to the wider smart grid and energy market. Risks to the success of this Option are the potential for intermittency of supply as well as the cost and complexity of managing multiple islanded electricity systems.
Discretionary Option 4: Conservation alternative This Option is characterised by end-users choosing to support other ways to address the energy trilemma than an expensive smart metering infrastructure. They choose paying towards a national programme of energy conservation and efficiency instead of the smart meter rollout. Measures include insulating homes, refitting them with energy efficient lighting and wider benefits to those in fuel poverty. This option challenges the vision of big energy companies and risks include a lack of Government commitment and innovation to meet energy targets.

4.4 Interview process

On average each interview lasted around 2 hours and an audio recording was made to capture all of the interviewee statements. These recordings were later transcribed and analysed using Nvivo for qualitative data analysis. The MCM online tool provided features for quantitative analysis of data recorded in the MCM offline tool during each interview.

Each interview followed an advanced mail out of information relating to the interview process to inform participants of the stages of the process to expect. Details of the Option choices and the Focal Goal were included in this information to give the participant time to consider and prepare for their interview. As participants were drawn from both urban and rural locations, venues were selected to suit the participant and generally were held at premises of work, home or a neutral location such as a business center. The interview followed a standard format consisting of 4 stages:

- Understanding of the Focal Goal
- Understanding, deliberation and selection of the Options to carry forward
- Criteria building and scoring of the Options
- Weighting of the relative importance of the Criteria

During the interview, the maximum number of Options for deliberation by the interviewee was set at six. Core Options were presented to study participants as a prerequisite for deliberation. This meant that the interview needed to choose their preferred DOs, up to a maximum of two, or eliminate more than two DOs to give them the space to include self-built Additional Option(s). In either case, the ceiling of Options for deliberation remained at a total of six.

Acknowledging the multilevel complexity of smart grids we presented each of the Options as being viable strands of strategies relevant to the Focal Goal. This did not closedown interviewee deliberation over their validity, or closeout the possibility of the interviewee creating their own Additional Option (AO).

4.5 Criteria

The third stage of the interview process required interviewees to define Criteria to appraise the performance of the Options. Criteria are composed of factors that are important from the interviewees' point of view that can then be used to expose the pros and cons of the different Options they selected in the previous stage of the interview. Background questions to help interviewees in Criteria formulation included considerations about the Options such as:

- "Is it smart?"
- "Are your priorities/needs met by it in addressing the Focal Goal?"
- "Does it meet what is important to you in respect of a smart electricity system?"
- "What are your concerns/fears, hopes/aspirations for the electricity system?"
- "What do you think Options need to do or what needs to be done most of all by the Option?"

Generally a list of between 4 and 8 Criteria were composed in each interview and defined as distinctly as possible by the interviewee. These were recorded in the MCM offline tool before proceeding to score the performance of all Options against each Criterion.

The choice of scoring process by which interviewees approached Option appraisal was opened to the interviewee to decide, as it became clear that two possible approaches emerged from our experience of the interview process. This was possibly due to the different ways in which interviewees had constructed their Criteria. Posing the question of Option performance in respect of each Criterion we found some interviewees were more comfortable with an approach not approved within the MCM Manual (2) below, while others were comfortable with the approved approach (1). Each approach is paraphrased below:

1. "How well do you think this Option performs (in respect to smart grids and the Focal Goal) under this criterion?"
2. "How important to the success of this Option (in respect to smart grids and the Focal Goal) is this Criterion?"

In Table 1, those interviewees who chose to approach Option appraisal scoring using approach (2) are marked with (*) next to their code. This amounted to 11 participants or 42% of the sample. Once an approach to Option appraisal using the Criteria had been chosen by the interviewee, all Options were scored in accordance with the logic of the approach. As each approach placed a different emphasis on how the Options were then scored it is important to recognise that we had diverged from the approach of assessing

Option performance described in the MCM Manual. With those interviewees that followed approach (2), we divided our sample of study participants into those that fully conformed to the data recording protocol of the MCM process (approach 1) and those that did not.

4.6 Criteria weighting

In stage four of the interview process, interviewees were asked to give a Weight to establish the relative importance of their Criteria. Regardless of the number of Criteria the Weights were normalized to a total of 100. The MCM tool uses these Weights to adjust the aggregated Option scores from the previous stage and presents a final chart depicting the relative performance of the Options in conclusion. In the quantitative analysis (presented in Section 7) overall Option performance was measured for only those interviewees who chose to follow approach (1) for this assessment (n=15). Those that chose approach (2) were excluded from this analysis.

5. RESULTS

In this section we examine qualitative and quantitative data concerning (1) Discussion of FG, (2) Exploring the Options, (3) Criteria development, (4) Option scoring and performance.

5.1 Discussion about the Focal Goal

As we were seeking to explore the meaning of ‘smart’ in the context electricity smart grids, and be inclusive of social and technical perspectives in this study, the Focal Goal was preformatted before the interviews as follows, “How should smart grids be organised to account for social and technical concerns within all dimensions of the energy trilemma?”

Adding to our confidence that we had pitched the FG in an appropriate and accessible way, only one participant (4% of interviewees) directly commented on its construction: “*This looks more like a Focal ‘Question’ to me.*” (A2). We felt that this comment was technically true but the sentence construction of the FG did not detract from the enquiry concerning the meaning of ‘smart’ implicit within the question.

As the study was oriented around smart grids we accepted that it was not possible to close out comment on cross-system factors that electricity would engage with such as heat networks: A2:

“*One other general comment I'd make is that this is obviously electricity focused but in terms of the energy trilemma heating is massive for this country and most of our heating is not electric.*”

Other participants accepted the FG as a reasonable basis from which to assess the Options and beyond that, to develop their Criteria.

5.2 Exploring the Core Options

The design of the Options was aimed at reflecting key parameters within the smart grids debate and to serve as touch points for interviewees of different interests and expertise to gather ideas around the meaning of ‘smart’. Due to their concise nature, all Core and Discretionary Options inevitably contained a limited ‘vision bite’ of real world issues, and followed a similar pattern of ‘purpose, means and threat’ attributes.

In this section we will look at the comments study participants made about the Core Options. Fifteen participants (58%) made direct comments on the COs. This relatively low response could possibly be explained by the fact that the COs were obligatory and therefore not attracting as much deliberation as the DOs and AOs, which were open to interviewee discretion. One interviewee (E2) felt all Options, apart from the Conservation alternative DO, presented a technology-led vision of smart grids and would have liked the opportunity to “*chop out*” some of the Core Options.

On the diversity of our COs, some interviewees (L1, L2, G3) observed that in practice some of the Options will combine or need to be combined. Our process of separating them was then only necessary to distinguish the issues. For example, if there is going to be Community energy, there will also be Commercial engagement (CO2). We found the potential for conflation of issues was not possible to avoid, despite care in the design of the Options, possibly due to the highly integrated nature of smart grid concepts and their associated issues.

5.2.1 CO1/ Government led strategy

“*This Option is characterised by new market and service opportunities becoming possible to encourage end-users to participate in the smart grid following the Government led rollout of 53 million domestic smart meters by 2020. The energy supplier owns the meter and data is harvested and disseminated to licensed parties by the Data Communications Company (DCC). Risks to the success of this Option range from user concerns about security of personal data and intrusion upon privacy to exposure to more microwave radiation and loss of customer rights. Utility systems could also become more vulnerable to cyber crime threats.*”

(U1) reflected the discussion about smart meters is focused on electricity smart meters and that gas has issues that aren’t the same as electricity; so was concerned about a possible lack of active debate about the gas smart meter rollout. The need for gas smart meters, in contrast to electricity smart meters, was also questioned because gas generally has more modulation due to its type of load (C3). Gas loads are generally on or off, such as in heating or cooking. Therefore what use is it to the customer to have this information?

It was noted by (U1) that a huge customer engagement was required for the success of the smart metering programme (aligning with the risks outlined in CO1). For example most houses will have to be entered to install meters and this could be seen as having an impact on Government popularity. Would the Commercial Sector then be willing to pick up the risk of carry out deployment of a smart metering capability if there were places where the Government led strategy (CO1) had failed? (A3). This could potentially leave the rollout programme vulnerable to holes and open further opportunities for third party interventions.

The Options were open to some interpretation by participants, as anticipated, from the diversity of stakeholder perspectives. We were reminded that issues like ‘health hazards’ from metering equipment (E1, E2) and end-user ‘choice’ were not mentioned explicitly in any of the 8 Options (E2). This concern reflects a general mistrust of technologies that are installed in the home by directive of which ever party in Government through large energy companies.

Extending the discussion on metering, it was noted how odd it was to have meters in the home at all (C3). Everything else in home use is metered remotely, such as telecoms, or at the supermarket or petrol station (an exception is water). Could we consider metering appliance electricity usage remotely for example? In future (C1) noted it may also be possible that electricity is metered at the appliance and then this value is transmitted remotely. Or the use of an appliance could be leased which would include the power that it consumes.

Why there was a need for the proposed GLS smart meter (E2), when a radio transmitter could be switched on to transmit the meter reading to the supplier relatively infrequently for billing purposes, which was all that end-user required?

5.2.2 CO2/ Commercial engagement

“*This Option is characterised by companies like Google, Apple and Samsung exploiting end-user data for commercial gains by extending their product range and influence into the energy technology market. By making new equipment that integrates domestic energy technology such as heating and lighting systems with users’ daily activities, they open-up opportunities to improve understanding of the use and operation of the smart grid at all levels from analysis of end-user data. Risks to this option include loss of control over data by users as cyber security requirements widen with another layer of complexity added to smart grid management*.”

In terms of what is in their best interest, trust of Government and large commercial organisations was a common concern of end-users within this study. On the Commercial engagement Option, (E2) described the issue as, “*abrogation of responsibility and knowledge to a third party when it comes to saving and reducing electricity bills*”. Some end-users believed that their interests are not the priority for commercial organisations, and as large energy companies were seen as established by Government, trust in Government is also weakened. These concerns feed into the issue of who has access to personal end-user energy data and how, without satisfactory access end-users must rely upon third parties to lead them in reducing their bills and consumption (E9). There was a question of determining ‘lifestyle choice’ therefore that seemed to be missing within the scope of the Options (E2).

The question of learning about one’s ‘energy lifestyle’ was thought to be dependent upon having access to comprehensive energy usage data in order for end-users to be able to take their own decisions and make their own choices (E9). In shared occupancy situations a level of uncomplicated energy data may be enough to satisfy many people’s needs.

“*My daughter and her boyfriend rent a shared flat in London with 'coin' energy meters. I was shocked by this because I thought these were the biggest rip-off meters you can have. I asked her what it is like to have to pay this way with a pay as you go meter. She* *said it's great dad, because our bills are very low, we know exactly where we are with it and there's no misunderstanding with who is putting what into the meter.*" (E2)

In terms of engagement generally, (U3) suggested the Government should consider intervention in the education system to help the younger generations to understand the power demands of different domestic appliances and even building standards. It could also help if energy companies put the cost of using different appliances on their websites to provide customers with more transparent information (U3).

5.2.3 CO3/ Community energy

"*This Option is characterised by end-users taking more control over their energy requirements, motivated by Government incentives and opposition to powerful utilities. It aligns with DECC's Community Energy Strategy as part of meeting 2050 energy targets. Community Energy projects proliferate, enabled by distributed energy resources such as PV and biogas, connected through microgrids and supported by smart metering and monitoring technologies. As end-user energy capacity develops to be a significant presence in the market, pressure mounts on the big utilities to change their business models, forcing them to enter into new forms of partnership. Risks to the success of this option would include lack of funding streams and inadequate engagement amongst community members.*"

(L1) suggested Community energy developments in the UK lag behind those in Germany and that this could be as a consequence of a "hangover" from the times of a "huge centralised energy provider". But the way DG is marketed to local communities to encourage their acceptance was also raised as a contributing factor BY (E20). For example, are the financial incentives for communities, to accept new renewable energy developments within their locale, adequate and comparable to those in other countries? Should communities be paid royalties beyond the lifespan of the intervention to ease local opposition?

"*It's about acknowledgement of the interventions that occur within the space of your community. Which is pretty important really. I think people would be encouraged by change if they were approached in the right way. And it's so often not.*" (E2).

This issue was a variation on the intended theme of CO3, where owner-generators within the community were assumed. However this perspective is of interest because it proposes a way in which communities may be encouraged to accept third party development within the community context. It contributes a perspective from an end-user on how 'Community energy' is understood and how 'place attachment' might be positively influenced with the provision of a long-term financial remuneration from the third party developer. A similar conclusion was reported in [57].

5.2.4 CO4/ Passive consumers

" *This Option is characterised by rendering end-users as passive consumers. The price of wholesale gas to large utilities continues to decline and interconnector capacity grows, making gas-fired generators and interconnectors sufficient to balance the variability of large-scale renewable energy installations. These then form the main thrust of national decarbonisation efforts. Despite rollout to all end-users, the need for smart meters to assist* *in domestic demand side response becomes unnecessary. Risks to the success of this option would include interruption to the supply of gas, which would be heavily reliant on imports and domestic shale gas production.*"

This was created as the Business as Usual (BAU) Option where the dominant element in the assumed smart grid vision was centralised control over networks, generation and balancing with minimal engagement, apart from consumption, by energy end-users. As (N1) observed, it favoured the big energy companies with investment in large-scale assets,

"*It feels a very polar scenario to community energy scaling-up. I could see it working - more interconnection, cheaper gas supply. Big players continuing to operate the big flows. If CE doesn't work, then we still have these big options available.*" (N1).

The key feature of this Option makes it largely dependent upon affordable and available gas to run large-scale, fast response generators. From this it was the avoidance of scenarios that could be more complex for large utilities to control and balance. However, while this may be appealing to some in the near term of 5-10 years say, it was also recognised as a high risk strategy (A3) and that the burgeoning opportunities for data and distributed generation driven interventions in smart grid evolution, would make such a model appear inappropriate in 20-40 years time.

"*The most successful strategy potentially, and possibly the simplest because it's least risk, is the Passive Consumers. Passive Consumers is the lowest risk but in many ways is one that will only work in the short to medium term and what I think I've done is take a long-term view, which does look at R&D, does look at change. And in the short term that'll be seen as disruptive. But if you take the 2030/2050 view, the grid we have today is going to be utterly inappropriate for purpose in 30 years time.*" (C1).

The term 'Passive Consumer' was also deliberated. It was recognised that consumer passivity could be a function of "*personal situation*" (E3, E9), the time available, education (U3) or interest of an energy end-user to engage with the electricity system (E7).

"*Could be passive because they can afford to be, single mothers or the utilities are doing it all for them very well. Need to raise the level of education to get their interest. People in debt with us are often on lower incomes and haven't understood what the costs of things are. A smart pre-paid meter will support this education within a week*." (U3).

Feedback on energy usage and ownership structure were seen as ways to change passivity in electricity system stakeholders from a Community energy perspective:

"*More frequent feedback about demand, benefits and generation. I think it's partly through ownership as well. If you've got an ownership structure that people feel part of, rather than at the end of a long chain, they do engage. It's the opposite of passive consumers!*" (L1).

(L2) also suggested that technology (like adaptive learning devices) could support learning about energy usage and start to turn passivity into engagement through helping the end-user to change by becoming more aware of their practices involving energy.

"*If you want to include as many people as possible, the front end interface needs to be understandable. A lot of people don't know how to read their own meter. If they have a prepayment meter they don't know what all the different buttons mean. Which one means*

how much debt they have and what it does to the debt? If you can understand them [the buttons] it changes the way our system works now." (G3).
On the other hand (E4) reflected on passivity as a service option,

"*By being passive I would expect high quality because this is what I am paying for.*"

5.3 Exploring the Discretionary Options

The MCM process provides Discretionary Options to further nuance and open up the issues derived from the Focal Goal by offering interviewees the opportunity to select or reject those DOs according to their discretion and interest. Unlike Core Options, at least two Discretionary Options had to be eliminated before proceeding to the next stage of the interview.

In this section we will explore the comments made by the 26 interviewees (n = 100%) who addressed direct comments to the DOs. One interviewee (n = 4%) decided to carry only one DO forward to the next stage of the interview process. One interviewee (n = 4%) elected to carry no DO forward. Both of the latter interviewees created an Additional Option of their own design, discussed in the next section.

5.3.1 DO1/ Smart meter redesign

"*This Option is characterised by giving users greater ownership and choice about what happens to their data. The DCC-connected smart meter is still capable of billing functions but due to disruptive effects from rapid advances in digital technology innovation, first generation smart meters are soon outmoded. Correspondingly, DECC call for another meter rollout that gives more choice to the end-user over the smart energy technology they install in their homes. This would move the focus of responsibility for personal data security away from the DCC and utilities, to the trusted brands chosen by end-users through the technology they buy. But risks to the success of this option would include the cost to the end-user adding to greater social energy division and fuel poverty*."

This Option reflects the comparatively short lifecycles of digital, connected consumer technology, as well as the potential for opportunities for new actors to enter the 'smart energy' space through digital connectivity. Some interviewees (U2, G3, E7, E2) put emphasis on future-proofing the initial design.

"*Who would want an 'iPad 1' or an 'iPhone 1' now? They are great when they come out but look obsolete now. It [DO1] feels like something that's going to have to happen every 5-10 years if computer obsolescence is anything to go by. Within 10 years your smart meter is useless - the cost and waste and carbon footprint, redundancy is inevitable.*" (E7).

Frustration with the degree of openness in the process the GB smart meter design had followed was clearly raising concerns in some expert interviewees from the Commercial perspective. The complexity of the proposed smart meter design was considered to be very expensive and over-engineered (C1, C2, C3). A strong message seemed to be that if the smart meter was acknowledged to be a ubiquitous connected device, then it should be radically simplified (C3).

"*Radical simplification is my thesis. A meter would just be a very basic IoT data gathering device, as simple as possible, in the way Internet of Things are supposed to be - you put the simple stuff at the edge and do all the complicated stuff at the back-end. The thing you have to rollout 40-50 million of, you want to make as cheap as possible. At the moment it's looking like £450 a pop, where as if you can make it £50 a pop, that's an awful lot of money you've just saved.* " (C3).

Premature obsolescence of the of the proposed smart meter design was another concern, "*We're about to spend £18 billion on something that doesn't work, is my considered view on that. The technology in it, particularly the comms is already obsolete*." (C1).

The Zigbee protocol was singled out for specific criticism for use within GB smart meters, as there are signs that other communications technologies (such as mobile phones) are starting occupy its waveband, which could potentially point to problems of radio interference in future. Often devices using wifi and Bluetooth encountering difficulty to communicate clearly over one frequency have some ability to seek a channel in another. Channel hopping helps to maintain connection to other devices, yet this facility is not available to devices running Zigbee according to (C1).

"*Zigbee looks as if it's going to die in the next year. Most of the companies involved in Zigbee are pulling out. Nest and Google are coming up with a new meshed network, which they are all jumping on board. LTE is moving up into the 2.3-2.4GHz band. Now, that causes problems for everything that runs in the 2.4GHz spectrum, which is wifi, Bluetooth and Zigbee. Wifi and Bluetooth have some ability to cope with interference because they can either frequency hop, or move around or are wide enough to avoid interference. Zigbee doesn't. Zigbee stays stuck on one frequency and at the point it starts to get interference it basically gives up and dies.*" (C1).

From Utility, Commercial, Government, Academic and Community energy perspectives smart meters were seen to offer a potentially positive contribution to smart grid development (U1, U2, C1, C3, G1, A3, A4, L1). However the type of data they generate (according to current meter specifications) and the use that can then be made of it was called into question by interviewees from the Commercial and Academic sectors in particular. The issue then became not smart meter redesign *per se*, but a better understanding of data science that could lead to a better smart meter design to meet the needs of different applications (C1, A1).

"*I think smart metering is important, but it is because it generates data. I actually think we don't need smart meter redesign. We actually need an understanding of data science. Smart meters are just the sensors that give you the data. If you don't know what to do with the data there's not a lot of point in having the smart meter.*" (C1).

Some interviewees eliminated DO1 due to worries about the Data Communications Company (DCC), which has been set up by the Government to provide communication services between smart meters and the business systems of energy suppliers, network operators and other authorised service users. With the Government track record of delivering large infrastructure projects (A2) considered the risk to the success of the DCC was high. And the process of AMI design had been conducted in a closed manner by the industries concerned (U3).

"*The actual mechanics of the meter are not necessarily the problem but it's the communication with them and what you can do with the data, who can access that data. Part of the reason the energy sector has been slow to improve it's technologies is because it's always asked itself - always got together with like-minded individuals with protection in mind and made things complicated for no good reason.*" (U3).

From a Government perspective (G1) it was felt that the cost of getting this far with the proposed smart metering project was a reason to reject DO1, advocating a smart meter redesign. Other participants also commented on the expense of the national rollout, which is estimated to be approximately £12 Billion for both gas and electricity smart meters.

“*I certainly believe that smart meter redesign is vitally important. If only because if you don't do it, you're going to saddle the consumer with £18-20 billion of wasted spend.*” (C1).

The electricity Supplier driven deployment of electricity smart meters was seen from a Commercial perspective by (C2) as potentially very costly to energy Suppliers due to the added complexity of infrastructure management derived from this. The GB rollout is unlike other countries where AMI is already established in this respect.

“*DNO led rollout has massive economies of scale and reduces the overall bill massively. It’s what they did in Italy, it’s what they did elsewhere in the world, I think we are the only country that decided to do it Supplier led, with the additional complexity that brings. The bill for the DCC is huge. The bill for the Supplier rollout is huge.*” (C2).

Could there be business models that “*rendered smart meters worthless?*” in reference to the kind of equipment proposed for installation in CO1 (G2). In comparison to some other connected devices that are driven by the potential from using their data, GB smart meters and their accompanying infrastructure, were criticized for underperforming (C1, C2). It was thought GB smart meters could also be circumnavigated by third party equipment (A1) to obtain the high-resolution data necessary for domestic applications not currently planned to be made available under the national smart meter rollout. For example, is the risk to the success of the smart meter rollout increased by technology such as the In Home Display (IHD) as this device can potentially be circumnavigated, by directing domestic smart meter data to other end-user technology such as tablets, TVs and mobile phones (A3).

DO1 was also eliminated from an Academic perspective by (A2) because of the risk and managerial challenges from adding higher complexity to the electricity system through the proposed Advanced Metering Infrastructure (AMI). Some interviewees rejected the Smart meter redesign Option because it would reduce inclusivity, as technology refreshments and extensions would be expensive and not affordable to all (E3, E5). The potential for greater intrusion and surveillance from smart metering was another reason for its rejection (E4).

5.3.2 DO2/ Energy democracy

“*This Option is characterised by the process of engaging end-users in the design of the smart grid. Emulating the way publics are engaged in infrastructure developments in other countries, like Denmark, DECC could institute a nationwide series of midstream workshops in which communities are introduced to the Government’s vision for end-user interaction with the smart grid. Feedback from these workshops could indicate the need to further restructure energy markets and even the kind of technology used in metering infrastructure, to improve adoption and access by end-users. Risks to the success of this option would include the need to change institutionalised protocols for technology co-creation between government, industry and society. It may also be a case of too little too late.*”

Some interviewees (A2, E5) selected DO2 because of the way the electricity system links people together and therefore could offer a platform for furthering democratic principles.

Further engagement with energy communities to better understand what they want was considered to be a positive step although it wasn't clear from DO2 how that looked (G1).

It was also selected because beyond the workshops mentioned in DO2, greater energy democracy could address how the grid is planned, paid for, managed and connected to. From an NGO perspective (N1) the rules for connection of DG to the grid can present barriers to small, decentralised generators:

"*I'd like to use energy democracy to change that a bit and see whether more democracy over what we now have is possible, with 'district networks' and how they're governed and controlled to be the central theme of that option.*" (N1).

Beyond this, there was an interest expressed in how energy democracy could be used to elect overseers of district grids that would connect more people into engaging with the energy system up to a regional level. However, others thought that it was possible to explore the issue of energy democracy within the remit of the Energy island Option (U1) or the Community energy Option (U2).

Other interviewees rejected DO2 because the outcomes and benefits were not clear (A1), it relied too much upon the leadership of too few people (E8, G3) or because it involved 'ordinary people', at risk of lethargy and apathy when it comes to the energy system (A3, C3, E2, E7). Members of the Community energy and End-user Sectors thought DO2 was "*unpractical*" (L1) and "*tokenistic*" (E1) because it involves society in a way that it is normally unaccustomed to and unprepared for, in terms of organisation.

"*It sounds to me that it [DO2] is too reliant on just ordinary people leading change. The most effective way to quickly bring about change needs to be led by government or by utility corporations given the right fiscal incentives. They are the ones who have most power to change, as long as they've got the right incentives*" (E6).

DO2 was also criticized for not being effective:

"*Energy democracy would be like tokenism - it's pandering to get the public involved, but it won't make a blind bit of difference to anything. It's like focus groups - they don't do anything, it's box ticking. Changing institutionalised protocols is enormous! The education need to do that is so vast.*" (E1).

5.3.4 DO3/ Energy islands

"*This Option is characterised by citizens taking full control over their electricity supply and data ownership, removing the need for connection to both the centralised grid and DCC. Smart metering technology and microgrids owned by end-users connect distributed generation capacity and virtual power plants into energy islands balanced by third party energy management services. In some cases a 'lifeline' connection could be maintained that enables access to the wider smart grid and energy market. Risks to the success of this Option are the potential for intermittency of supply as well as the cost and complexity of managing multiple islanded electricity systems.*"

With the increasing devolution of authority from centralised administrations, end-user interviewees found the energy islands concept was fairly easy to imagine and adopt, possibly in combination with energy conservation (E5). Another response was that, although challenging, it could help bring communities closer together (E7).

"*I like the concept of energy islands, I'd like to explore that one. It's different in terms of actually how the grid works and who controls it. I like that. I definitely like the scenario, it's got a lot of merits to it, intuitively."* (N1).

It appealed to the Commercial perspective because it meant change to current thinking and practices:

"*The two [DOs] that makes most sense to me are Energy Islands and Energy Democracy because those are the two that say 'let's change the thinking'.*" (C1)

Energy islands appealed to Utility interviewees because they could contribute in extreme cases to greater energy security (U2) and from a Commercial perspective be scaled if applied to a city or a region of the country with a concentration of DG. However, the scale of the urban energy island and the number of participants within it could be a limiting factor if the granularity of data was not small enough according to (G3).

"*As a macro thing, this whole community, stroke municipal energy and energy island thing, coupled with energy efficiency is very interesting, if you create an ESCO or whatever it is you want to do. These ideas in terms of devolution of responsibility are not a great leap of faith to give a city responsibility for its energy.*" (C2).

There was then discussion from the Commercial sector (C2, C3) about the relative merits of using the technologies of Virtual Power Plants (VPPs) to create the building blocks of some forms of (virtual) Energy Island. These could include distributed storage and generation capacity that would already be wired to the grid. On the other hand, there may be a requirement for implementing additional network infrastructure to link assets through a microgrid to create a localised energy island.

"*Federation of energy islands is the way to build the smart grid rather than a big-bang approach that we did with National Grid 30 years ago as that isn't going to happen in the modern world. So the only way it can really happen is through individual projects federated together."* (C3)

Other interviewees (A3, U3) rejected this Option for reasons like it was 'ahead of its time' and that 'ordinary people' could not voluntarily organise themselves to manage an energy island (E1) as it was too complicated (E3) and likely to be more vulnerable to outages (E4). It appeared to be too challenging from an end-user perspective to organise effective and sustainable management of energy islands:

"*I do not have faith in the mass public for bringing about change. If we had an energy literate, climate change literate nation, which we don't it would be a different story*" (E6).

Or was "*Based too much on a few people doing everything. I know from experience when you have local situations, is that it falls very much on one or two motivated people and you end up with people who are either not interested or anti.*" (E8).

The promotion of inequality was also raised as a potential concern about Energy islands with the potential for some well resourced communities benefiting more than others:

"*Mostly in Great Britain energy islands could be, rather a recipe for inequality. The most resourceful communities would have very nice well functioning energy islands. Those with fewer resources and those that weren't really communities at all but just random assemblies of people, a lot of whom haven't lived there for long would not do nearly so well.*" (A2)

5.3.5 DO4/ Conservation alternative

"*This Option is characterised by end-users choosing to support other ways to address the energy trilemma than an expensive smart metering infrastructure. They choose paying towards a national programme of energy conservation and efficiency instead of the smart meter rollout. Measures include insulating homes, refitting them with energy efficient lighting and wider benefits to those in fuel poverty. This option challenges the vision of big energy companies and risks include a lack of Government commitment and innovation to meet energy targets*."

This DO was chosen by the Utility and Academic sectors because conservation was "*an essential dimension of the smart grid*" (U2) and promotes downscaling of demand, affordability and understandability of the technologies deployed to address the Energy Trilemma (A2). 'Smartness' seen in this way, by developing energy conservation to downscale demand, was also felt to offer better general equity than those only aimed at supporting the supply side. But from a Government perspective (G3) saw it currently only as:

"*A simple bolt-on solution that will have a real effect. So it has the pro of predictable and measurable impact, whereas smart metering is still a little woolly in that sense. But the big disadvantage of being unintelligent.*" (G3)

And an interviewee (C1) within the Commercial sector concurred with this view:

"The conservation alternative is another way just trying to maintain the status quo. It's effectively saying there is nothing wrong with the grid as it is, it's your fault for wasting energy." (C1)

End-user interviewees felt that energy conservation should be implemented more actively, by switching loads (like street lighting) off when they are not required, even extending to periodic outages (E7, E6). From a Commercial perspective (C1) felt that the trend of national domestic energy demand reduction, from factors including conservation and increasing energy efficiency of appliances, was not fully understood as we are still paying more for energy overall. This raised the question how this could be unless the costs could be attributed to other subsidies and misaligned incentives for example? From an end-user perspective it was because profit is made from selling more energy, with the wrong incentives currently in place for energy companies to bring about decarbonisation through energy demand reduction and alleviate fuel poverty. This sentiment advocates the onus upon energy demand reduction to be upon energy suppliers, but that would require the incentives to be aligned in favour of demand reduction.

"*Currently, society offers us either fuel poverty or carbon emissions. Because energy is expensive and we aren't very good at controlling our energy needs. The only way to get people to stop using energy is make them really poor by making energy really expensive. We are not very good at changing our behaviour, changing our home.*" (E6).

Some interviewees from different perspectives eliminated the Conservation alternative Option because they thought energy conservation should be implicit within the practice of the other Options given the right political impetus (A1, A3, N1, G1, G2). Others thought the strategy would attract only a short-term commitment to conserve energy such as with closing windows or installing double-glazing (E8).

One End-user perspective (E2) made a general comment about the Options that highlighted the how the discussion had become heavily influenced by technology:

"An observation I have about this research is it's very technologically led. If each Option has 12% of the cake, of the 100% there is only one Option [Conservation alternative] that says you can walk away from the smart grid if you wanted to." (E2)

5.6 Exploring the Additional Options

By creating an Additional Option study participants can apply at their own discretion further nuancing and opening up of the problem framing posed by the Focal Goal. In this study, the number of AOs must not exceed the total compliment of Options, which was limited to six, to include the four Core Options and up to two Discretionary Options.

Only two (n= 8%) interviewees (L2, E2) decided to create their own AOs. This added to our confidence in the design of the preformatted Core and Discretionary Options to stimulate deliberation and compilation of Criteria in stage 3 of the MCM interview process.

AO1/ Public and Private Option

"*The Government goes ahead with its planned rollout of smart meters and these smart meters are designed such that third party private companies can build add-ons. The meters continue to provide real-time feedback to energy suppliers but consumers are able to purchase private add-ons or third party add-ons, which means that their data is also shared with the private companies. The real benefit of this is that people can purchase home appliances and apps that give them better control and better information about their energy use costs.*" (A4)

The design of this Option integrates the principles of two of the preformatted Options (CO1, DO1) and was driven by the desire to maximise the flexibility and opportunities potentially arising from both public and private technology interventions in the energy system. However some important risks were identified:

"*These would include personal data loss or personal data security, exploitation of consumer data, privacy and I suppose you'll end up with rich people having more control over their energy use and being able to minimize their energy bills while poor people can't afford these technologies.*" (A4)

AO2/ Reality Option

"*Allows for a more natural diversification of smart grid rollout. The only way to make it work is to implement lots of those small solutions to a centralised, capitalised market. All of these things (Options) are necessary tools to a decentralised, disruptive market where citizens are integrated.*" (L2).

This interviewee felt the detail, range and scope of the preformatted Options (COs and DOs) were not sufficient on their own to address the complexity of the Focal Goal and therefore it was necessary to combine all of them into an open framework for energy system evolution. They would then be seen as the tools to 'disrupt' established regulatory and market conditions in an open and competitive way as long as citizens (as energy stakeholders) could gain access to use them through open data.

5.7 Quantitative analysis of Discretionary and Additional Options

The degree of acceptance of the Discretionary Options suggests they were generally successful in stimulating debate and deliberation prior to Criteria building in the next stage of the interview process. This gave us a ‘sense check’ that our approach, providing a set of Options without prior deliberative mapping of issues relating to the Focal Goal, was reliable. Two interviewees (C1, U3) noted the absence of any accommodation within all Options of the energy storage issue. We considered the absence of some aspects of smart grids in Option composition was inevitable due to the complexity and number of issues potentially deriving from the Focal Goal.

As Core Options were not eligible for elimination, in this section we will report on the choices of Discretionary Options and Additional Options made by interviewees. The Discretionary and Additional Option choices made by interviewees are presented in Table 6.

Table 6. Discretionary Options selected and Additional Options								Sample segment
Code	Sector	DO 1	DO2	DO3	DO4	AO1	AO2	
G1*	Government		✓	✓				11.5%
G2*	Government		✓	✓				
G3	Government	✓		✓				
C1	Commercial		✓	✓				11.5%
C2	Commercial			✓	✓			
C3*	Commercial	✓		✓				
N1*	NGO		✓	✓				8%
N2	NGO			✓	✓			
A1	Academic			✓	✓			15%
A2	Academic		✓		✓			
A3	Academic	✓			✓			
A4	Academic				✓	✓		
L1	Local	✓		✓				8%
L2*	Local						✓	
U1*	Utility	✓		✓				11.5%
U2	Utility			✓	✓			
U3	Utility		✓		✓			
E1*	End-users	✓			✓			34.5%
E2*	End-users			✓	✓			
E3	End-users		✓		✓			
E4*	End-users		✓		✓			
E5	End-users		✓	✓				
E6	End-users	✓			✓			
E7*	End-users			✓	✓			
E8	End-users	✓			✓			
E9*	End-users	✓			✓			
TOTALS		9	9	15	16	1	1	100%

The Energy island and Conservation alternative DOs appear as favourite discretionary approaches to addressing the Focal Goal from the presentation of this data in Fig. 6. The clustering of Option choices also provides an initial insight into the contrasting Perspectives from interviewee sector. For example we can see 50% of the choices for the Conservation alternative are derived from the End-users sector. This may suggest that from the End-users sector Perspective, the most accessible way to engage in addressing the Focal Goal, is currently through the Conservation alternative pathway.

There was no selection of the Conservation alternative DO by the Government sector, which could be explained partly by their understanding that this is already embedded in energy policy although it was not presented as an explicit element within the other Options in this exercise. It was also notable the most favoured DO from Commercial and Government perspectives was Energy Islands.

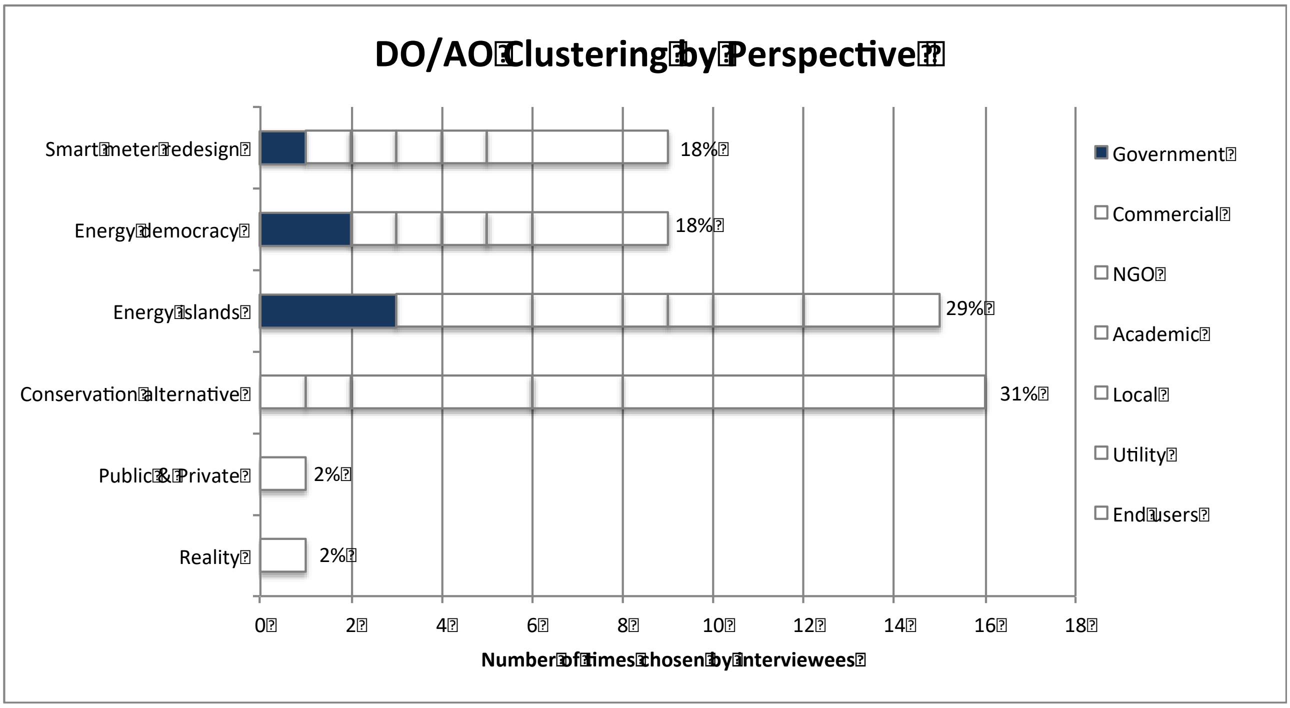


Fig. 6. Clustering of choice around particular DOs across all 26 interviewees.

From the comments about the DOs reported in preceding sections, we can now see evidence of the resulting selection of DOs and AOs. A short précis, drawn from interviewee comments has been made to summarise the themes.

Smart meter redesign:

- Too costly to contemplate and too late for design change before planned rollout implementation start in 2016 (Government perspective)
- Essential because we are heading for an expensive 'white elephant' (Commercial perspective)
- We can work around current specifications despite potential for premature technology displacement/obsolescence (Utility and Academic perspective)

Energy democracy:

- Too difficult to implement (Academic and End user perspective)
- Relies on a few champions to do most of the work (End user perspective)

- Not enough interest or motivation overall from End-users (End user perspective)

Energy islands:

- Ideologically forward looking although technically challenging (Government perspective)
- Could strengthen sense of community and community energy opportunities (Community energy and NGO perspective)
- Attractive because of promise of greater electricity system resilience (Utility perspective)

Conservation alternative:

- Should be implicit, not excluded from within other Options (Government perspective, End user perspective)
- Easy to understand and is not technology led, therefore potentially more accessible to public engagement (End user perspective)
- Immediate measurable benefits although maybe be ‘one off’ measure (Utility and Commercial Perspectives)

6. Exploring the Criteria Issues

In stage three of the interview process participants were asked to define Criteria they considered important to appraise the performance of all the Options they had chosen to address the Focal Goal. Each participant composed a short list of Criteria with a clear and distinguishing description to support it. The MCM tool allows for a Criterion to be defined by interviewees in the following format:

- Title
- Key Features
- Description

It was the considerations and issues that emerged from the different interviewee perspectives in deliberation over Criteria building, rather than Option performance scores *per se*, that this study was particularly keen to capture. We hypothesised these would reveal key features of 'smartness' in the electricity system context.

In this section we will explore the 141 Criteria designed by the 26 interviewees. An overall breakdown of the number of Criteria contributed from the different sectoral perspectives is presented in Fig. 7. The numerical dominance by the End-users sector is reflected in the larger number of interviewees within this sector compared to the other sectors (see Table 6.)

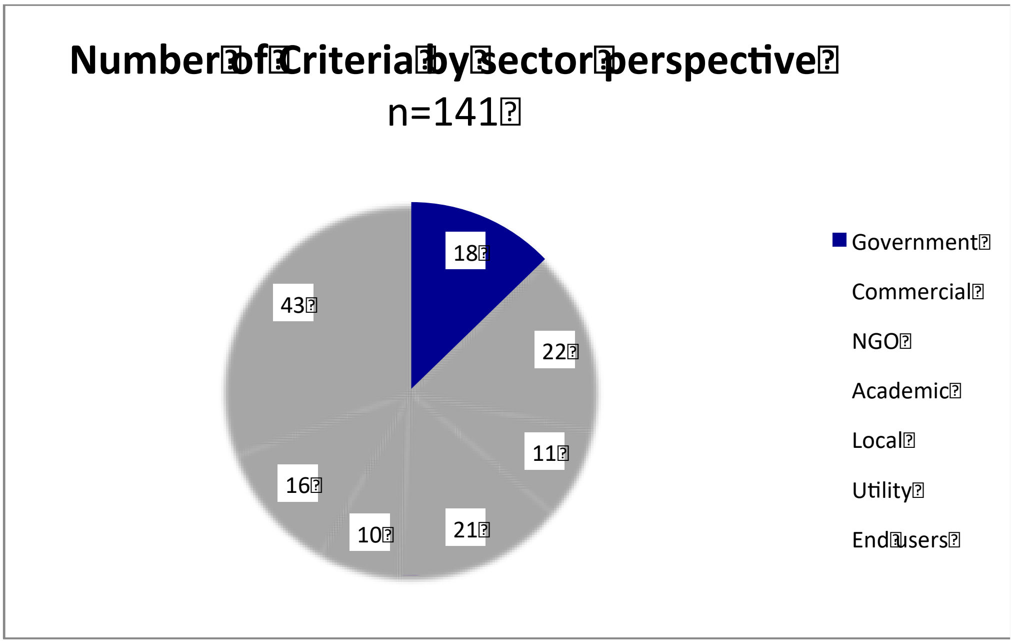


Fig. 7. Number of Criteria contributed by each sector of interviewees

In Fig. 8, we lay out how Criteria created by interviewees across all sectors cluster and map to key sociotechnical Issues relating to smart grid development.

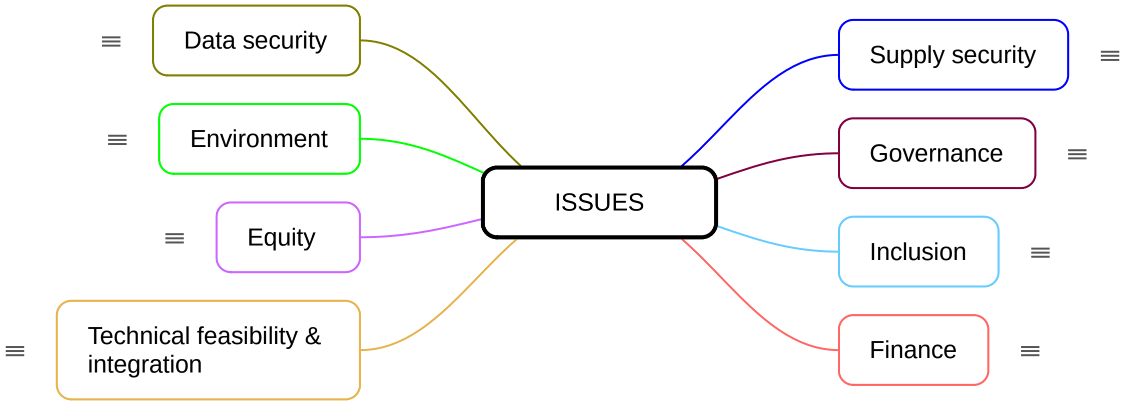


Fig. 8. Low-resolution map of Criteria clusters to form key smart grid sociotechnical Issues

The Criteria spanned a diverse range of considerations that were nuanced by the detail in their key features and descriptions. Eight key Issues were revealed from the clustering of Criteria details and are presented by sectoral perspective in Fig. 9. and by sectoral contribution of Criteria in the pie charts of Fig. 9.1. These Issues then became a guide to the qualitative analysis of the interview transcriptions and pointed towards key considerations for smart grid evolution. The Issues can be summarised as follows:

- Data security; as more data is generated by meters and other networked devices monitoring electricity usage, there is a span of concerns ranging from protection of end-user privacy to intervention in grid operation by cyber criminals.
- Environment; concerns about environmental impacts as electricity smart grids develop and whether they are addressing considerations ranging from personal safety to climate change.
- Equity; the extent smart grids bring about a fairer society and electricity system, compared with perceptions of one dominated by multinational companies.
- Technical feasibility; how smart grid technologies can be implemented to optimise low carbon generation, data integration and concerns relating to stakeholder engagement.
- Supply security; continuity of supply is taken for granted by most people but it is recognised that changes to the electricity system reflected in smart grid development could effect this.
- Governance; risks relating to long-term energy policy and the need to be open to innovation in a changing vision for the electricity system.
- Inclusion; ways in which smart grids interface with end-users to promote engagement, stakeholder equity and social acceptance.
- Finance; the organisation of benefits and incentives to align smart grid implementation with long-term goals.

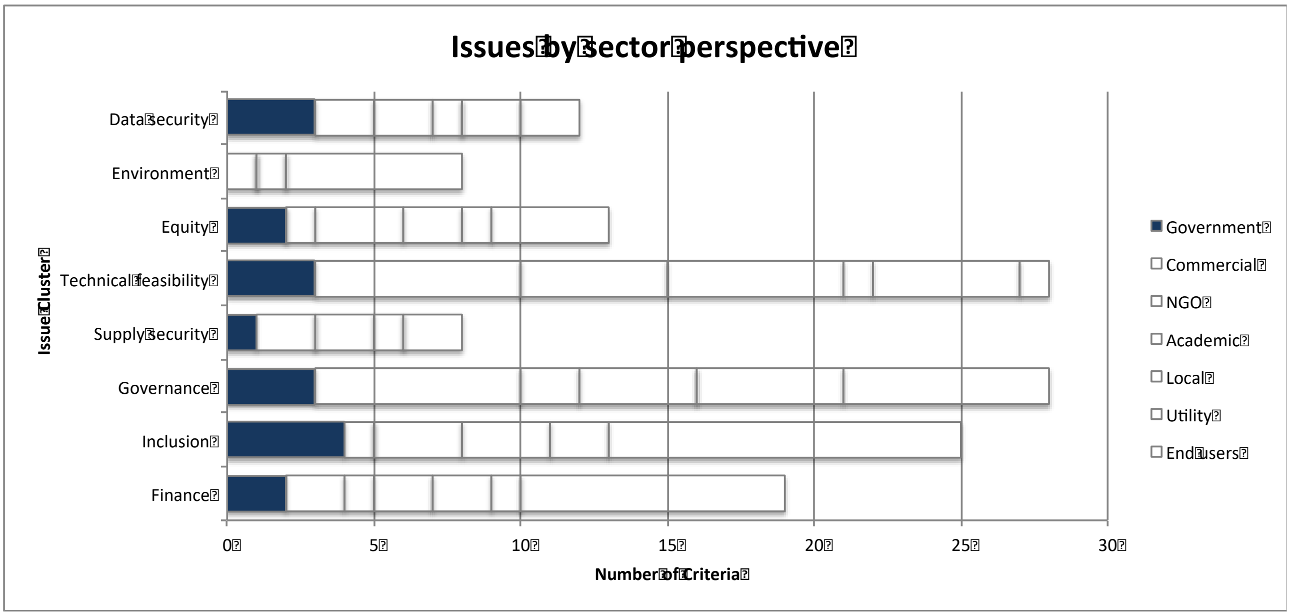


Fig. 9. Clustering of Criteria around Issues

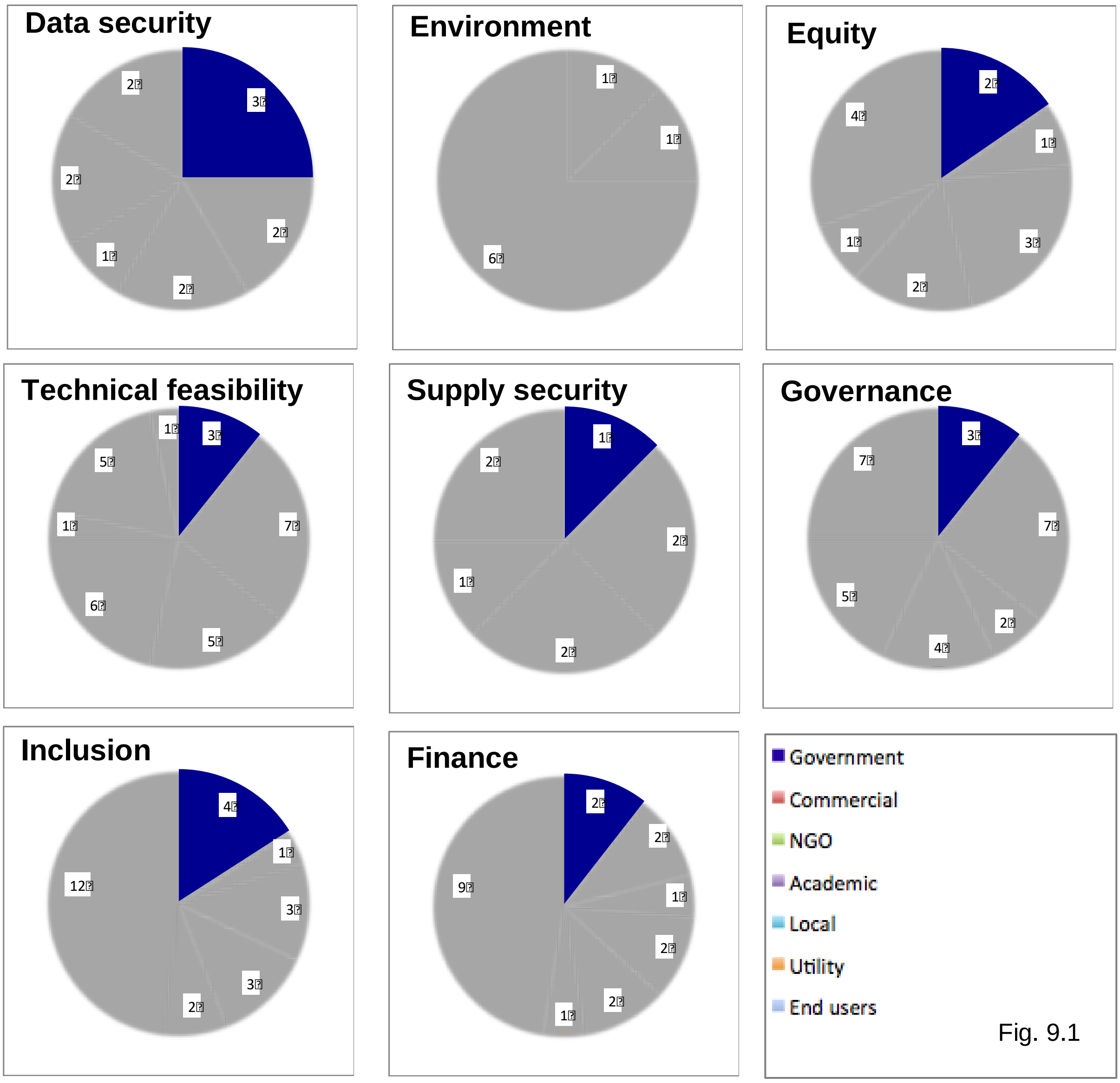


Fig. 9.1

6.1 Data security Issue

From deliberation over the Options, the importance of data in driving the development of smart grids was prominent with all interviewee sectors contributing directly related criteria, apart from 'Local' (Community energy sector). The absence of Criteria contributing to an Issue should not be interpreted as a sector having no perspective on that particular Issue, as comments made in interview proceedings could be about Issues without being formulated into Criteria. With the advent of the smart metering era in the End-users sector, and more ubiquitous sensing devices generally, it is not surprising that a lot of consideration was given to Criteria formulation around the issue of data security. In Fig. 10, we can see that there is an overlapping range of considerations comprising the Data security Issue, spanning the following sub-issues:

- Security; Concerns about personal data security ranging up to the possibility of cybercrime effecting electricity system operation.
- Privacy; Concerns about intrusion upon personal privacy by Government, commercial and other bodies trusted with the use of this data.
- Trust; Concerns about transparency and safety around data handling to protect both consumers and grid infrastructure as well as access to personal energy data collected through smart meters and other energy devices.

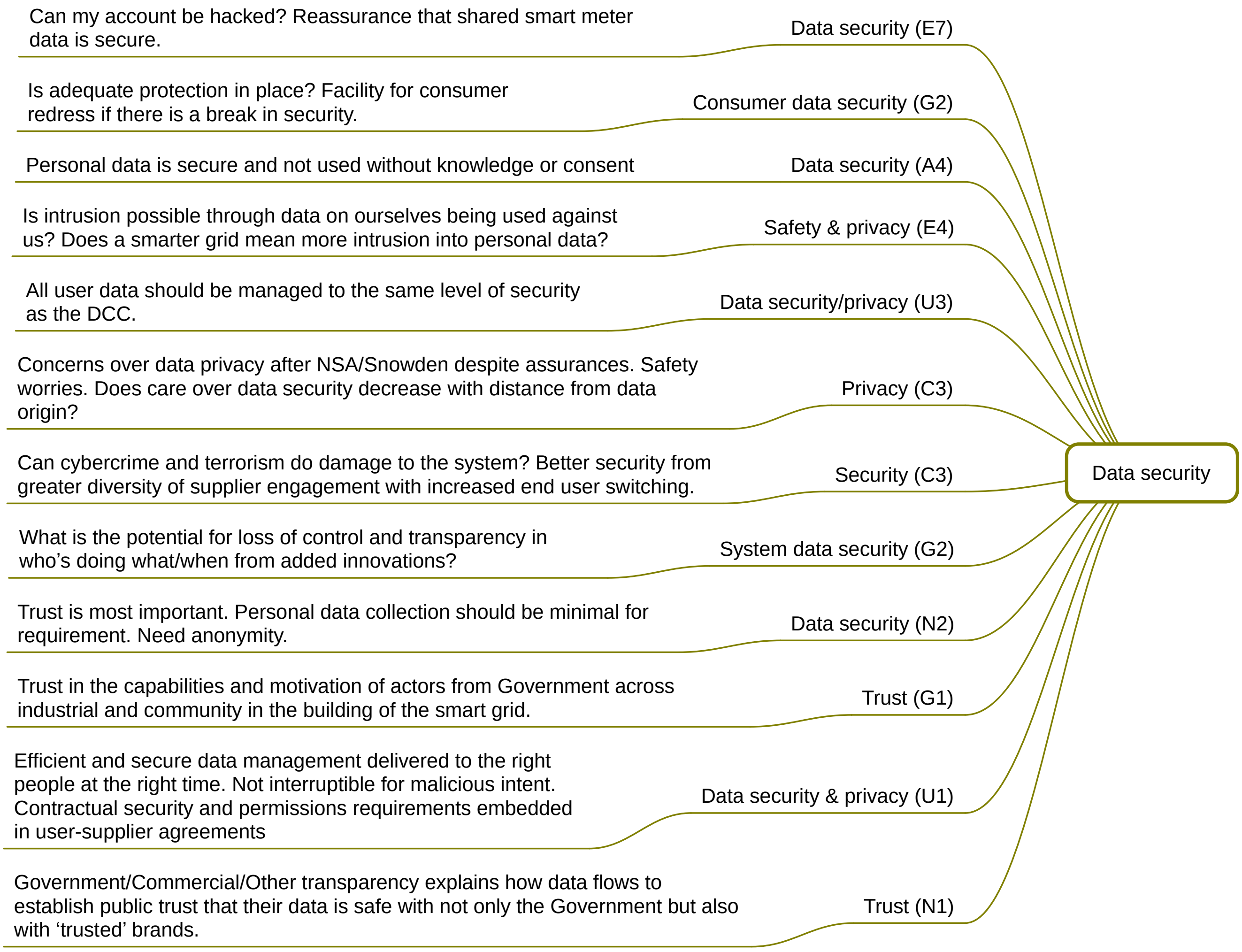


Fig. 10. Criteria cluster forming the Data security Issue

6.1.1 Data security

From a Utility Perspective access to smart meter data by relevant parties is moderated by security considerations within the electricity industry.

"*The data has to flow easily from the meter to the relevant end-user - whether that's your supplier or DCC. Security - this data must not be intercepted by third parties - malicious or curious. If I'm having a smart meter outputting data, I don't want anyone to take it, even if I am not doing anything particularly sensitive to security concerns.*" (U1).

However, from an end-user perspective (E7) there were doubts whether any data could be fully secured, raising questions from that perspective about the need for smart metering technology to pay for electricity when there could be other ways that are more secure.

"*I really don't think it [data security] exists once you put anything on line. Even the Pentagon gets hit by Aspergic teenagers in other parts of the world. I'd have to be really assured about the security. And nobody has yet invented the lock that can't be picked either, or the system that can't be hacked. It should be of concern not only to the end-users but also to the utilities.*" (E7)

From an Academic perspective (in deliberation over AO1), where customisation of the smart meter by extending its functionality with third party devices was presented as a scenario, there could be multiple risks associated with data security:

"*These would include personal data loss or personal data security, exploitation of consumer data, privacy.*" (A4)

So far, we have reported considerations about the Data security Issue with a focus on the end-user scale. One interviewee (A1) reflected on the impact of breaches in data security at a national scale but was able to accept that the DCC were capable of managing to protect data at this level.

"*...the web makes it easier to attack people at scale and at distance...if you could cut off two million people, switch off their electricity supply, then that's going to impact the grid and all sorts of things could happen. It's not one of my concerns. But that's the kind of thing they [the DCC] could probably protect against very well.*" (A1)

The way in which smart meter data infrastructure had been structured by the DCC also seemed secure from a Commercial perspective (C3).

"*I think the likelihood of it [data security breach] happening is very, very low because of the way the DCC has been structured. The one thing that's making meter rollout harder, because you can't just walk down one street and install them into each house because they could be on different Suppliers is, actually a good thing.*" (C3)

Despite 'best practices' being implemented in smart grid development, from a Government perspective (G2) there was concern that the 'smarter' the grid becomes and dependent upon data systems for its operation, there could be unforeseen high-level questions about risk yet to be answered due to perceptions of greater data transparency and a widened 'surface area of attack'.

"*Much more transparency of what is going on from the domestic level right up to the system level. That means more things are controllable remotely - that's where the benefit lies. So is there the possibly of different sorts of security of supply risks arising as an unintended consequence when you pressed the button?"* (G2)

6.1.2 Data privacy

From one Commercial perspective it was felt data privacy should be considered an implicit aspect of 'data competence' that is so important to effective implementation and understanding of smart grids. In this sense data competence can be taken to mean the understanding of how to protect data from theft and intrusion by a sufficient level of encryption, but it could also include the level of security of the infrastructure carrying the data to intrusion.

"*I see it [data security] as part of data competence. If you are going to start playing with data you need to take that into account. I don't think anybody knows the answer on that issue.*" (C1).

There were also arguments put forward from the Commercial sector to say questions of personal data security, privacy and trust have long been in the End-users domain and so to some extent responsibility for it should fall to the end-user, to be vigilant over how much of their personal data they release to a third party.

"*Let's face the fact we give our data to Tesco, don't we. The whole data privacy thing, and the related delays around data privacy are just absolutely inexplicable given the amount of data people put on Twitter, Facebook, etc."* (C2).

The anonymity afforded by data aggregation may be one way to alleviate concerns around personal data being put to unconsented uses but could also contradict the need for personal data required to build tailored energy and other services. Data disaggregation for example, is targeted at breaking down the amorphous energy demand profile, into distinct demands relating to when we carry out practices using different appliances or services such as lighting and heating. From an NGO perspective demand data disaggregation was one way commercial organisations could pursue the use of smart metering:

"*I think we can all safely say that if you have a commercial imperative, then presumably Apple or Vodaphone or Indesit or Hotpoint or whoever, are going to want to know what time you run your washing machine. They are going to know what devices you use and when you use them, when you have your fridge on because there is value in that for them, potentially.*" (N2).

Without detracting from the Data security Issue, the vision portrayed in the last quotation could be an example of the kind of business model innovation that constitutes smarter grids. For example, where instead of owning an appliance, it is leased as a 'washing service', or 'heating or refrigeration service' from a company that maintains, updates and knows when to replace it through remote monitoring. Some high-end appliances like heat pumps could for example, be constantly monitored and tuned to current operating conditions as part of a condition monitoring asset base owned and operated by a manufacturer. End-user concerns at this level however were raised and therefore must be addressed if such a business model were to stand a chance of success, maybe by realising it is not what everyone aspires to?

"*I don't know if we can go backwards but I'd certainly like to see not more intrusion, not more access to our personal every move and whereabouts. Not more access to personal information as I think it's saturated already. I feel like our privacy is invaded, not necessarily personally, but on a mass level.*" (E4).

Such visions do require higher resolution data than is currently planned for the GB smart meter to be realised. The increasing amount of portable and wearable, connected devices are part of the same market potential for some energy services, especially when networked through the IoT. Some large companies offering these devices are beginning to realise that consumer behaviour, with sufficiently high resolution data (in the sub-minute order) can be pinpointed to a high degree of certainty (C1). This, in itself has opened-up opportunities to exploit the data in originally unintended ways, such as in medical profiling and location services. These could in turn impact on the insurance and job prospects of the data originator for example. It is not unrealistic therefore to imagine similar events from within the home energy market with the intervention third party data collection devices adding another level of complexity to the communications infrastructure, or through redesigned, higher resolution smart meters.

Personal data has been consumed to select goods and services that match online search interests and whole profiles about consumer habits have been built around these. With the advent of smart meters, a massive increase in this data is anticipated. Closely monitoring behaviours and practices using energy in the home, it is not surprising why this issue has gained prominence from a Utility perspective.

"*We collect data all the time now and know lots about people. Data will not go around just energy companies when we go outside to other third parties for further services. Need to tick a box to indicate when permission is granted... Lot's of people will struggle to know why it's important.*" (U3).

6.1.3 Trust

From an NGO perspective (N2) the question of trust in the AMI was of most concern to its success despite the apparent willingness of some people to share data about themselves through other channels, such as Facebook and Twitter. The fact that to have a smart meter is not obligatory did not take away concerns about the need for trust or the impacts upon end users who did not comply with the mass rollout.

"*I think trust would be absolutely key to the success of this. People need to feel that they can trust that their information is not being used for anything else or anything else that they're not happy about.*" (N2).

Trust in who we give data away to may have an interesting relationship in terms of degrees of separation according to one Commercial perspective. Considerations of this kind could have implications for the smart grid information architecture inferring that the fewer 'handlers' of the data, the more secure it will be:

"*Despite the person you've given it [energy data] to's best assurances that they'll look after it, it only takes a memory stick left on a train or whatever, to accidentally lose it. The safest thing is obviously to keep it to yourself because if you give it to anybody, because they are* *less interested in looking after it than you are, the degree of care drops off, as it gets further away from you.* " (C3)

On the issue of who can access energy data, concerns were raised about the priorities for approval of who could handle personal data. From an Academic perspective (A1) data security priorities seemed to be inverted and therefore potentially open to abuse:

"*The DCC is locked down. It makes it impossible to do anything new. But with a small bit of hardware to plug into a wifi router you can get the data straight off the meter, then send the data to some web service. It seems a lightweight process compared to having to prove your trustworthiness as a data handler [to the DCC]. I think it is completely the wrong way around. People just seem more willing to sign up with small companies that are offering interesting services.*" (A1)

6.1.4 Summary of perspective patterning

In this Section we aim to summarise by drawing out the high-level 'patterns' reflected in the Criteria and comments presented above. From the number of Criteria representing this Issue (see Figs. 9 & 9.1) it is clear that the Government sector perspective holds more concern than others. The comments given by interviewees in the Data security Issue Section reflect a broad range of considerations upon smart grids some of which concur and others oppose. Reflecting upon these in relation to the broader meaning and understanding of 'smart', we are able to identify the following patterns around the Data security sub-Issues:

1. Utility, Commercial and Academic sector interviewees (U1, A1, C3) argued that data security is satisfactory at the large-scale infrastructure level because of DCC management protocols. End users and Government perspectives (E7, G2) expressed less satisfaction, however, and instead emphasized the risk of even highly secure organisations being hacked or unforeseen circumstances resulting from greater reliance on data infrastructure within smart grids.

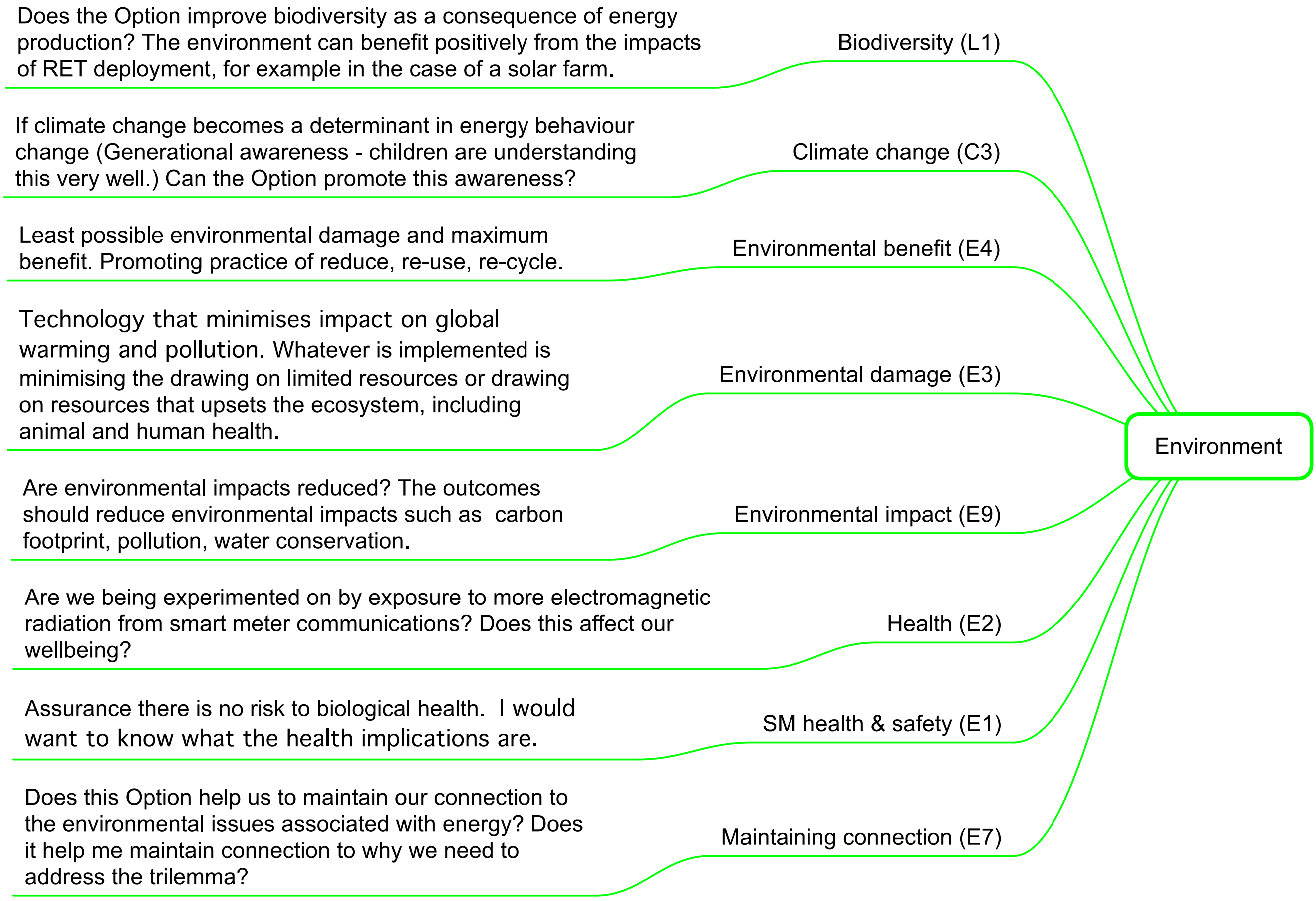
2. Data privacy was a concern from an End-user perspective under increased monitoring of energy usage behaviour (E4). The understanding of energy usage behaviour to appliance level was seen as a potential future from Commercial and NGO perspectives (C2, N2) although adequate understanding of data privacy issues should be implicit if this were to happen (C1). From a Utility perspective, the end-user will struggle to understand the importance and implications from the release of their data to third parties (U3).

3. Trust in electricity data handlers was imperative to the success of smart grids from an NGO perspective (N2) but it was felt from a Commercial perspective (C3) the further data travelled in terms of handling, from its origin that the risk for its loss could increase. And from an Academic perspective (A1) the level of controls applied to accessing data from the smart meter by third-party devices was disproportionately too low compared to the level of security applied to accessing data from the DCC.

6.2 Environment

Criteria directly addressing environmental concerns were chosen to compose the Environment Issue cluster. They comprised of only three sector perspectives, making Environment the least represented Issue in terms of perspective diversity out of the eight clusters of Criteria. End-user Criteria made up 75% of this Issue (see Figs. 9 & 9.1). One explanation for this could have been, as considerations of sustainable energy can be implicit within the purpose of smart grids, environmental considerations could be addressed within these, and so did not form a prominent concern of many interviewees. As one interview said, "*What I have focussed on is consumer protection and security rather than low carbon but as that is the purpose of the smart grid, I am not so concerned about it.*" (G2)

Nevertheless, this Issue was dominated by the number of Criteria expressed within the End-user sector, as presented in Fig.11.



Does the Option improve biodiversity as a consequence of energy production? The environment can benefit positively from the impacts of RET deployment, for example in the case of a solar farm.

If climate change becomes a determinant in energy behaviour change (Generational awareness - children are understanding this very well.) Can the Option promote this awareness?

Least possible environmental damage and maximum benefit. Promoting practice of reduce, re-use, re-cycle.

Technology that minimises impact on global warming and pollution. Whatever is implemented is minimising the drawing on limited resources or drawing on resources that upsets the ecosystem, including animal and human health.

Are environmental impacts reduced? The outcomes should reduce environmental impacts such as carbon footprint, pollution, water conservation.

Are we being experimented on by exposure to more electromagnetic radiation from smart meter communications? Does this affect our wellbeing?

Assurance there is no risk to biological health. I would want to know what the health implications are.

Does this Option help us to maintain our connection to the environmental issues associated with energy? Does it help me maintain connection to why we need to address the trilemma?

Fig. 11. Criteria cluster forming the Environment Issue.

The range of Criteria broadly fall into two categories of different scale:

- Global scale; impacts upon climate and environment from smart grids.
- Local scale; impacts upon personal environment from smart grid technologies.

6.2.1 Global scale environmental sub-issues

On the global scale, interviewees from the end-use sector (E3, E9) were concerned that smart grids minimised further damage to the already compromised environment, with many aspiring to the implementation of smart grids to have directly positive environmental benefits. Thus whether smart grids were reducing environmental impacts like carbon footprint and broader pollution concerns were implicit within their Criteria.

"*Whatever is implemented should minimise drawing on resources that are limited. Or drawing on them minimises upset to the ecosystem that could have negative consequences for other species and resource, animals, human health.*" (E3)

"*Fracking can affect the water supply, so does have a broader impact on the environment.*" (E9).

Making the connection between food water and energy, in a recent report, the World Wildlife Fund (WWF) recommends the acceleration of the shift to smarter energy production as one measure in mitigating the alarming rate of global biodiversity loss [58]. Another end-user perspective placed this emphasis upon the design of smart grids to positively affect and in some cases, improve or repair environmental depletion through support for biodiversity:

"*Maximum environmental benefit with least possible environmental damage and maximum benefit - the ideas of re-use (waste to energy and storage), reduce (conservation), recycle (storage). The grid should improve the environment I am living in.*" (E4).

Distributed generation technology such as PV arrays were seen from a Community energy perspective as potentially supporting biodiversity by being able to protect important habitats for insects and other animals. This then became a consideration of smartness within a smart electricity system (L1).

"*Improving biodiversity as a consequence of energy production. Most energy sources actually destroy biodiversity. So to put a solar farm on a bit of land means it lays fallow for 25 years. You can cut the grass but you can do it like a hay meadow. You can put sheep on it.*" (L1)

Climate change was a concern from End-user and Commercial sectors, raising considerations of how to connect impacts on the atmosphere and energy use to behavioural change. A criterion was created by (C3) to assess whether smart grids could be a determinant to encourage behavioural change in energy use and raise awareness of the environmental damage from burning fossil fuels.

"*Whether it [smart grid] will precipitate or become a determinant in behaviour change if something happens. Will climate change impinge on people's consciousness enough to make them reduce their use of fossil fuels, or the consequence of that fossil fuel use itself causing climate change?"* (C3).

With concern about such a large-scale challenge, it was clear that some interviewees (E2, E6, E7) from the End-user perspective were struggling with the options they had to engage different energy behaviours, even if they were aware of the need to connect them to climate change. This resulted in Criteria that called for smart grids to demonstrate stronger Government interventions and leadership on carbon reduction planning.
"*All we ever hear from Government is that we are going to pull every drop of oil out of the ground and every drop of gas out of the sea and we never hear anyone say we are going to maximise every potential for renewable energy in this country.*" (E6).

"*Global warming is too vast, vague, remote and long time scale from my personal circumstances. If you think Governments struggle with thinking long term, what hope do the rest of us have? We need to connect."* (E7).

End-user sector (E6, E7) reaction to these perceptions of lack of Government intervention in the energy-climate change dilemma, raised some insights into the willingness for heroic social action to regain a sense of connection and control to the Environmental Issue including the openness to a personal carbon budget and electricity scheduled outages.

"*Surely personal carbon budgets are the only way we are going to get the carbon reductions we need. Otherwise what is going to stop people jumping on planes? Unless they simply can't!* " (E6)

End users (E6, E7) stated how aware they were of the global issues as well as recognising the need for others to connect their energy usage to environmental impacts such as climate change. There was a lot of concern about the disconnect they perceived between people taking electricity for granted and the impacts on the global environment. They saw outages as being acceptable and manageable using information technologies embodied in smart grids.

"*This is why I don't mind outages because it would remind people of the value of electricity. And it's that level of disconnect we have with the connection between me boiling a kettle and my contribution to global warming. It is that remote. I am talking about maintaining connection to climate change and environmental issues. Outages could be symbolic of maintaining connection.*" (E7)

"*If it means we can prevent climate change then I would accept greater intermittency and risk blackouts. We live in an age of information technology so it's very easy to warn people that tomorrow their energy's going to be off between 4 and 8. You just get used to it.*" (E6).

6.2.2 Local scale environmental sub-issues

Moving to a more local scale, Community energy was seen by (L1) as potentially able to address other important considerations, such as keeping the experience of the natural environment alive. In addition to biodiversity, there were other considerations of how electricity production is only one part of integrated multi-vectoral systems of sustainability.

"*It's like the consumer engagement process [of RETs] needs to be drawn out in combatting that 'extinction of experience' by helping biodiversity. The creation of energy is one system but there are other systems like how we make food. There are other systems that we need to integrate our energy production into synergistically.*" (L1)

This view concurred with an interviewee from the Government perspective (G1) that referred to a need to motivate energy behavioural change in ways that engage environmental values as well as financial ones.

"*Valued benefits. Whether the benefit being financial or helping decarbonisation - that motivates a willingness to engage... if so doing something like demand side response etc. helped with that, I may be more motivated to do something for a green reason rather than a financial.*" (G1)

In terms of behavioural change that has taken root without financial incentives but instead for environmental reasons (and possibly some financial penalties) that now has become 'common sense', a comparison was made from an Academic perspective (A3) with the precedent of recycling practice. From this perspective actors were seen to desire clean, non-polluting energy but would need further support and time to transition in their behaviour. Such support could come from colour coding appliance usage some how, to indicate environmental impacts:

"Green is very good, amber is a warning, red is very costly and wasteful of your energy use at the moment." (A3)

On a personal scale, Criteria were formulated by (E1, E2) that presented concerns about the environmental health impacts from electromagnetic radiation emissions of smart meters adding to the home environment. The sense of concern was related to where reliable evidence could be found to make an informed personal decision about smart meter health and safety, as it will be an additional piece of wireless technology communicating by regular pulses of electromagnetic energy. This sense of intrusion by radiation upon the home environment was exacerbated by feelings that reliable information upon which to draw a conclusion could not be obtained from Government (due to prior 'cover-ups' affecting public health), revealing 'trust' in the smart meter implementation authorities to be a further sub-issue.

"*As an end-user, I am told by the Government I am to have a new smart meter but I want to know in detail what the radiation risks are off that. I am worried about it from a health point of view. I immediately think they are not going to tell me that are they? They're going to tell me there are no health implications. Of course I don't trust the Government.*" (E1).

And taking this concern to another level, an end-user (E2) felt that technological deployment in the public sphere involving wireless radio communication was akin to forced experimentation on members of the population by the industries concerned with smart metering.

"*I feel we are being more and more 'experimented 'on by the world of mobile telephones and communication of every sort and this will be significantly added to by the smart meters. We are exposed to certain dangers by implementing of the smart grid. That's scary stuff to me.*" (E2).

6.2.3 Summary of perspective patterning

The comments given by interviewees in the Environment Issue Section reflect a broad division of considerations around the impacts from smart grids at the levels of global and local scale. These are composed however, of Criteria from only three sectoral perspectives (although a wider range of sectors submitted comments as environmental considerations), indicating that this was not an Issue of greatest concern relative to the other seven Issues (see Figs. 9 & 9.1). The patterning of perspectives is summarised below, by reflecting upon these in relation to the broader meaning and understanding of 'smart':

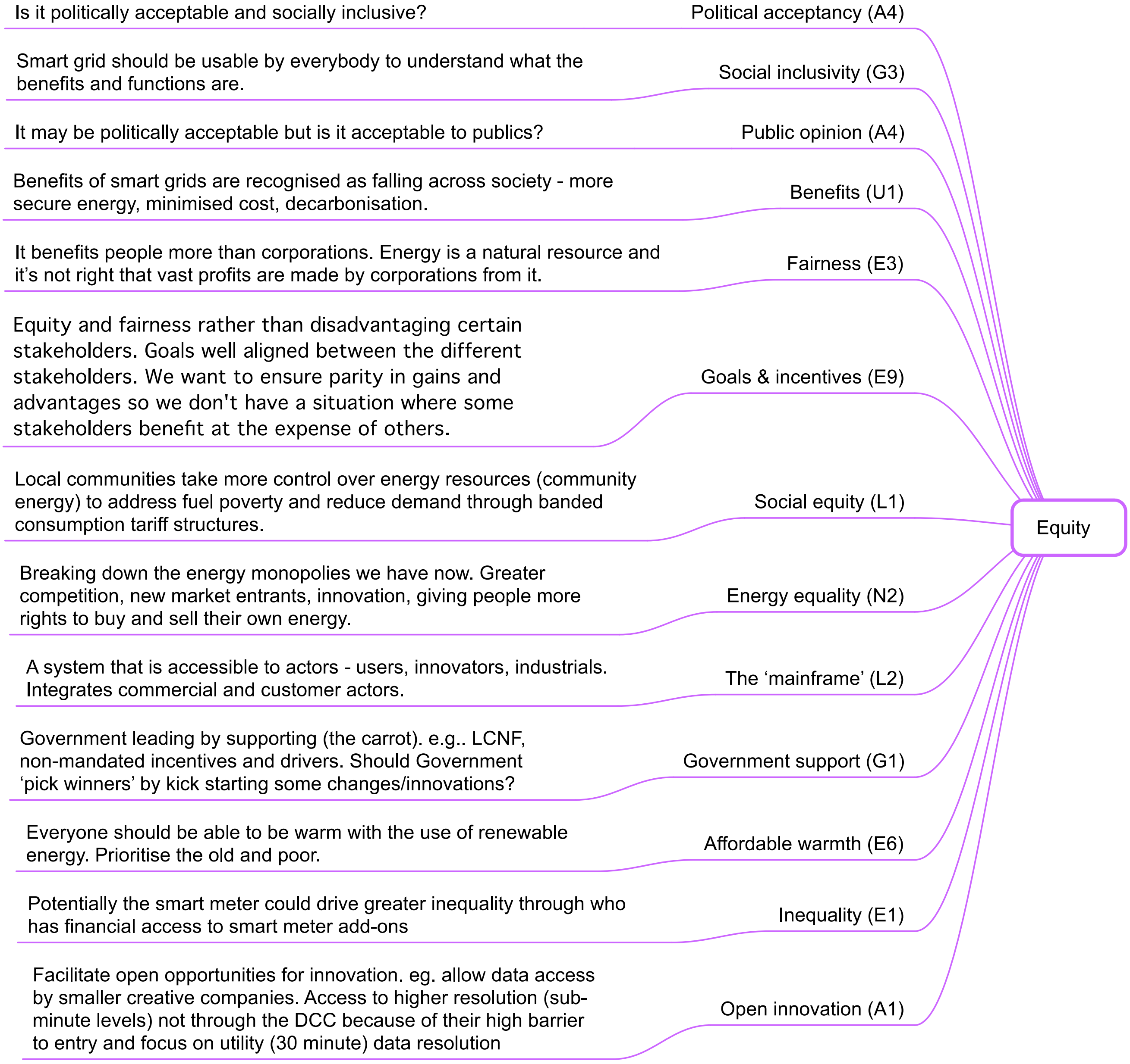
1. Environment global scale sub-issues were characterised by considerations of how Government leadership and intervention in smart grid development could lead to reducing the impacts of energy use and in particular climate change (E3, E4, E9). These were strongly represented in comments from the End-user perspective that expressed a willingness to consider staged power outages (and other means) that could be orchestrated through smart grids in order to urgently address environmental degradation (E6, E7). From a Commercial perspective, the effectiveness of smart grids in being a determinant in energy behavioural change to impact the issue of climate change was considered by (C3). Biodiversity was a concern from a Community energy perspective where distributed generation was seen to potentially make a positive contribution (L1).

2. Environment local scale sub-issues from a Government sector perspective included how behaviour change may be motivated (by engaging in DSR for example) through valuing the environment (G1) without the necessity for financial incentivisation. From an Academic perspective (A3) the introduction of waste recycling, that has become common practice in the public domain, was cited as an exemplar of how behavioural change could follow in the energy system. From a Community energy perspective (L1), the importance of distributed RET installations in preserving biodiversity as an 'experiential resource' was considered to be a function of smart grids. The impact of electromagnetic radiation from the deployment of smart meters was a concern from two End-user perspectives (E1, E2). (E1) felt that they could not trust Government to give advice on this sub-issue and (E2) saw the smart meter rollout as a continuation of the 'experimentation' on the end-user by industries involved with wireless technologies.

6.3 Equity

Criteria contributing to a multi-sectoral understanding of this Issue are drawn from six out of seven interviewee sectors of which 31% were contributed by the end-user sector (see Figs. 9 & 9.1). They are presented in (Fig. 12). Equity in smart grids covers a wide range of considerations that link to wider Issues including:

- Control and access to electricity markets through technology at various scales.
- Distribution of benefits across energy stakeholders from smart grid implementation.
- Who is able to implement energy production demand reduction and by what processes.



Is it politically acceptable and socially inclusive?	Political acceptancy (A4)
Smart grid should be usable by everybody to understand what the benefits and functions are.	Social inclusivity (G3)
It may be politically acceptable but is it acceptable to publics?	Public opinion (A4)
Benefits of smart grids are recognised as falling across society - more secure energy, minimised cost, decarbonisation.	Benefits (U1)
It benefits people more than corporations. Energy is a natural resource and it's not right that vast profits are made by corporations from it.	Fairness (E3)
Equity and fairness rather than disadvantaging certain stakeholders. Goals well aligned between the different stakeholders. We want to ensure parity in gains and advantages so we don't have a situation where some stakeholders benefit at the expense of others.	Goals & incentives (E9)
Local communities take more control over energy resources (community energy) to address fuel poverty and reduce demand through banded consumption tariff structures.	Social equity (L1)
Breaking down the energy monopolies we have now. Greater competition, new market entrants, innovation, giving people more rights to buy and sell their own energy.	Energy equality (N2)
A system that is accessible to actors - users, innovators, industrials. Integrates commercial and customer actors.	The 'mainframe' (L2)
Government leading by supporting (the carrot). e.g.. LCNF, non-mandated incentives and drivers. Should Government 'pick winners' by kick starting some changes/innovations?	Government support (G1)
Everyone should be able to be warm with the use of renewable energy. Prioritise the old and poor.	Affordable warmth (E6)
Potentially the smart meter could drive greater inequality through who has financial access to smart meter add-ons	Inequality (E1)
Facilitate open opportunities for innovation. eg. allow data access by smaller creative companies. Access to higher resolution (sub-minute levels) not through the DCC because of their high barrier to entry and focus on utility (30 minute) data resolution	Open innovation (A1)

Fig. 13. Criteria cluster forming the Equity Issue.

6.3.1 Control and access

Equity is a possible key to unlocking several aspects of the energy trilemma according to some perspectives from the End-user sector (E2, E4), NGO sector (N1) and Commercial sector (C2). A very strong message from the End-user Perspective about Equity in smart grids set the tone for reporting Equity Issue Criteria. It relates to whose interests control over the entities of smart grids and energy usage are being satisfied. This consideration was closely connected to concerns over transparency and democracy in the electricity system and whether that could be made clearer by smart grids (E4):

"*Who's got control? How is it controlled? And what does that mean to the consumer according to who's in control. Whether it's small community controlled or big corporate control. The aspect of control, I'd like to see more democracy.*" (E4)

This sentiment was also expressed in terms of how life was seen to be increasingly technologically-led from an End-user perspective, with smart grids reinforcing this. As a result the sub-issue of trust and the greater need for transparency around energy policy became highly apparent. Sentiments that the privatized electricity industry now acted against consumer interests were expressed and with that a mistrust of all party Government support for it from an End-user perspective (E2).

"*You become in a way led by people with other interests than your own... More and more decisions are made centrally in our lives and this takes the desire to know about and control things away from us.*" (E2)

There were however, differing interpretations of the meaning of 'equity' and how it could possibly impact upon the GB electricity system. Some felt smart grids were a vehicle for greater equity (E5) and others felt that equity through energy democracy would not happen in this country (A3), be too chaotic or occur in an insufficient manner (E1, G3). The sub-issue of 'energy democracy' is returned to in a different context below but the differences of understanding reflected here suggest the need for further deliberation over its meaning and implications for equity in GB smart grids.

"*In a society that is rapidly degenerating, I don't know how you could do it. Very much of too little too late as we are very far down the line now I think personally.*" (E1)

Leading from these responses, scale is proposed as a practical framework to approach the Issue of Equity, including various sub-issues such as benefits, equality, fairness and opportunity, and policy imperatives. From an NGO perspective (N1) there was consideration over how plans and decisions were taken to develop distributed generation strategies and smart grids at the district level of scale and whether governance and control could be changed to affect greater equity. The district level may align well with current DNO jurisdiction but could also be open to interpretation through other range factors, such as county boundaries, local enterprise partnership zones, city limits and municipalities.

"*So the barrier into that [energy market] isn't necessarily smart meters at all, it's the deployment of decentralised generation, which is currently hampered significantly by the rules of grid connection. I'd like to change it a bit and see whether more democracy over what we now have could be gained through district networks.* " (N1).

A strong emphasis from all perspectives was upon the need for Government intervention at a policy and regulatory level, or suitably incentivised large companies, to pave the way for changes to equity of ownership and access to market opportunities within the energy system.

"*I think if you build in engagement, community ownership, conservation and data security you've got something pretty special...What I'm getting at is breaking the energy monopolies, greater competition, new market entrants, new ways of doing things, giving people the right to buy and sell their own power etc.*" (N2)

To be successful in challenging the dominance of the 'big six' energy suppliers in the GB system however, further changes to the regulation of the electricity market was seen as necessary to encourage competition from a wider range of participants (such as ESCOs), before benefits through smart grid engagement could be equitably distributed. The rules around grid connection of distributed generation were identified as a specific factor requiring attention, to lower the 'barriers to entry' of new energy market actors (C2, U2):

"*The current regulations present barriers to entry. If I'm a new energy supplier, if I want it to be a municipal energy company based in whatever city there are significant barriers to entry based with the current regulation. Ofgem would have to fundamentally change the way they regulated the market.*" (C2).

6.3.2 Distribution of benefits

From an End-user perspective (E5) consideration of whether smart grids could resolve the profit motivation of large energy was raised with the suggestion that they should be renationalised:

"*Profit of the energy companies is a big and general problem behind why we are in such a state. Including water supply. I would like to see them nationalised again.*" (E5).

How smart grids are capable of delivering benefits in ways other than through the supply side was a consideration from an Academic perspective (A2). It was suggested that general policy review, not just at energy policy level, would be required to address considerations like affordability and would not be affected by smartness in the electricity grid.

"*On affordability, we're looking at tariffing and general equity in policy generally, not just energy policy, and we're also looking at investment in demand side rather than the supply side for people to get their energy services. So the extent to which a smartness in the grid can help I think is fairly limited here.*" (A2)

Extending this discussion on affordability, other interviewees (E3, L1, U1) suggested different ways in which electricity bills could be paid, including a change to taxation policy or the payment of 'social subsidies' to compensate the poorest energy users.

"*The argument is that everyone ultimately benefits, some more than others, but that not everyone contributes the same either, due to their ability to pay. If we assume costs are recovered through the energy bill, you could exclude some people on social tariffs - whether these are warm home discounts or others. An alternative would be to move cost recovery out under general taxation. Whether you consider general taxation fair is another issue.*" (U1)

From a Utility perspective, (U1) smart grids could be seen as providing benefits to society that referred directly to the energy trilemma but it was also recognised that some may benefit more from this than others:

"*From a societal point of view, we have a more robust energy system serving society. There is a security benefit, and a decarbonisation benefit. Secure energy and a decarbonised energy system is a benefit to both individuals and society.*" (U1)

From an End-user perspective (E9) smart grids could improve equity of benefit distribution and support the democratisation of energy through greater openness to market access, fairer competition and increased breadth of stakeholder engagement. Distributed generation intervention within a community's sense of space identity is an aspect of the Equity Issue that was the focus of a study previously carried out in Scotland [59]. The sentiment for decentralised renewable energy generation from the End-user perspective was generally positive for environmental reasons. But the concern of benefit distribution, in cases of asset ownership outside of the community while generator installations took place within its sense of space identity (such as in on-shore wind farms) was addressed by (E2). Considerations of how communities are compensated and remunerated for RET installations within their spaces are key from this perspective.

"*This thing [smart grid] might succeed better if the Industry, helped along by Government actually says, we are building a windfarm here and within an area say of 15-20 miles, you are going to benefit by your bills dropping down 15-20% for the lifetime of this windfarm. So that community hasn't got to do anything other than accept, or not. They don't have to put their hands in their pockets, they are going to be given money and they are therefore supporting a greener technology providing energy into the grid. And actually they are going to make the connection into their community. That windfarm is providing energy that their community is using because they are getting it cheaper, which is a very nice connection to be made really.*" (E2)

But if such interventions could be integrated carefully and with due respect to Community sensibilities around equity, there could be positive support and a greater willingness to engage with the challenges of the energy trilemma.

One interviewee from the End-user sector (E9) questioned whether equitable benefits distribution, where the gains are not made at the expense of other stakeholders, would be more likely to occur if there was a particular kind of smart grid policy design. This would aim to ensure greater cooperation through a realisation that no gains could be made without also the cooperation and benefit of others. It was proposed that gaming rules like the 'Nash equilibrium' could be used in benefit distribution design. Nash equilibrium is a solution concept of a non-cooperative game involving two or more players, in which each player has anything to gain by changing only their own strategy [60].

"*We want every one to benefit in lock step - like in a 'Nash equilibrium'. So who is gaining most, or are the incentives and goals aligned and coordinated? We want to ensure parity in gains and advantages so we don't have a situation where some stakeholders benefit at the expense of others.* " (E9)

Other considerations about 'optional' low carbon energy technologies affecting equity through affordability were also mentioned (A1, A4, C2, C3). For example, devices that could interface with the domestic smart meter or operate autonomously in the home through a connected environment. Such devices and service applications made by companies owned by Google, Apple and others, have already started to appear in shops. The concern from an Academic perspective (A4) was about whether they would advantage only those who could afford them and understand how to use them through their capability to bring about cheaper energy bills. One End-user sectoral perspective (E1) questioned how the smart meter proposed for GB rollout could avoid disproportionate benefits going to only those that could afford to buy this kind of additional equipment.

"*What I want to see is a smart meter, as a 'smart' meter, that does not disadvantage sections of society, such that those who have the education and wealth are not immediately hooking into cheaper electricity because they can afford to do it. Add-ons are only going to exist because they extend the 'product range' to save you money.* " (E1)

This sentiment was echoed from another End-user (E3), who wanted to see equity in the distribution of benefits from smart grids to be part of their function. There was concern that some disadvantaged end-users may feel frightened to use electricity as a result of the information they receive through the IHD.

"*It should be a system that doesn't privilege certain sectors of society. Benefits should be equally distributed. Someone living on benefits should have equal access to benefits from their energy usage as someone in a high paid job.*" (E3).

These proposals address the 'basic needs' of modern society that include affordable warmth and light and are specifically concerned with trying to avoid greater disadvantage and inequality through smart grid implementation. They pose fundamental questions about the orientation of energy supplier incentives in how we attempt to decarbonise through demand reduction.

From a Community energy sectoral perspective, one interviewee (L2) proposed a closer integration of the commercial sector with end-user consumers. Government should prepare for this by implementing a policy 'infrastructure' that the Community energy and Commercial sector could innovate onto. However more direct benefits were expected to be returned to the community in this way through the Community energy engagement than Commercial.

"*You allow communities and community energy groups to get involved. And I wouldn't treat community energy and commercial engagement as different in this context... [Smart grids] provides them a loose open data framework. Which creates a virtuous circle that empowers consumers to become active in solving the energy trilemma and change their behaviour.*" (L2)

Embedded in this statement is the notion that the community can be a 'commercial actor' and do so in ways that bring home more benefits to the community that are required by that particular community. From another Community energy perspective (L1), if community energy were to be organised under a 'community benefit society' structure this could enhance the return of benefits to the community:

"*A more equitable society. That's about tackling fuel poverty as well. It's through helping the fuel poor reducing their demand, but also through tariff structures so the smaller consumers don't get charged as much. Effectively a cross-subsidy from larger users. Banding of consumption amounts. Surplus profits can be ploughed back into energy measures in the housing stock. Better equipment. Through local communities taking control of their energy resources and their energy supply. There's all sorts of things that* *could be done, like heat as well for example. So you would have a house metered not just with a single point electricity consumption, you'd meter your washing machine, dryer, immersion heater, micro CHP.*" (L1)

6.3.3 Energy production and demand reduction

Different visions were presented from different sectoral Perspectives on the impacts of community energy. Community energy was seen from a Commercial perspective as:

"*Essentially decentralized energy, whether it is in a community, a city, a region."* (C2).

This understanding of a scalable community energy framework was reflected in a perspective from the NGO sector (N2) that imagined changes to smart grid service models in future that would radically alter the way the electricity industry is organised that could potentially have repercussions on equity:

"*I think the entire utility grid model is about to collapse. I think potentially you won't have energy companies in the way we understanding them now. You'll have energy service companies or energy management companies who will manage grids and manage all that kind of stuff.*" (N2)

From an Academic perspective (A2) this vision of smart grid arrangement (that could involve the creation of energy islands for example) should not be assumed to enhance equality, as it could benefit the most resourced communities. Another End-user perspective (E5) suggested that it is desirable for individuals to get involved in their own energy system in the longer term however.

Some interviewees considered the imperative for mandated policy was necessary to if there was inadequate energy demand reduction to meet targets. If decarbonisation did not happen according to the level required this would reinforce the dependence upon end-users' behavioural change. This dependency presents a policy dilemma between mandatory action and voluntary change.

"*There is a dilemma between whether people care or whether they don't care. And whether they do or don't care, how do you nudge them in the right direction? Is that a technology or psychology thing? What are the sticks and carrots? Is it straightforward as money or 'nectar points', or intangible benefits such as the glory or peer recognition in a high score table?*" (C3)

A related perspective from the Utility sector maintained the notion of 'polluter pays':

"From a decarbonisation and security of supply PoV, those people that use more should contribute more, similar to the polluter pays principal." (U1)

From a Government perspective (G1) it was acknowledged that there were policy instruments for reflective costing (of power plant type and network running expenses for example) within new dynamic Time of Use Tariffs electricity tariffs (TOUTs) to curb demand. This could result in higher tariffs when supply and demand conditions forced the use of higher carbon emitting generators for example, or to reduce congestion on networks due to an over-supply from generation. In a recent study carried out by the UK Power Networks (UKPN) DNO, a surprisingly positive response by energy end-users to the use of dynamic TOUTs was reported, with most participants wishing to remain opted-in after the study trial period had ended [61]. However, without nationwide experience of social attitudes to buying electricity and gas in this way, it could be too early to draw conclusions on the social equity of dynamic TOUTs.

How to bring down energy demand in a fair and equitable way that did not disadvantage the poorest were considerations from an End-user perspective (E6) suggesting the responsibility for doing this should fall more upon energy suppliers to orchestrate. Financial incentives could be changed to leverage the ingenuity within large energy organisations to develop the pathways to energy demand reduction. Instead of profiting from the sale of more energy, the incentives could be arranged to reward higher efficiency and lowering energy production. End-user sector perspectives from (E3, E6, E7) viewed individual end-users as not as capable to influence overall energy demand reduction compared to larger energy organisations. And that smart grids should facilitate a more equitable society with profit from energy demand reduction rather than through the sale of more kilowatt hours, while at the same time be reducing carbon emissions.

"*I was suggesting that the consumer pays a relatively level amount. That's how you deal with fuel poverty because the industry is then responsible for bringing your energy use down - because they wouldn't make profit unless they did.*" (E6)

"*It should be about equalising society rather than creating more division. Implementing the energy system in this new way should provide basic living and be an instrument to equalise society by reducing the social divide. It would be amazing if something like that could happen.*" (E3)

6.3.4 Summary of perspective patterning

The patterning of perspectives on the Equity Issue were approached by dividing the Issue into three sub-groups concerning who has control of smart grids and access to electricity markets, how the benefits of smart grids are distributed across energy stakeholders and who is empowered to implement energy production and demand reduction and by what processes. A review of Figs. 9 & 9.1 indicate from the number of Criteria composing this Issue that equity is a high priority for the End-user sector relative to other sectors but is marked by a low priority for the Commercial sector. A high level summary of the perspectives from different stakeholder sectors now follows:

1. There was a strong sense of 'stakeholdership' portrayed from the End-user perspective (E1, E2, E4, E5) but also a clear sense that the control of smart grids is vested with the large players in the energy industry. What was meant by 'equity' in the context of the electricity system and whether greater 'energy democracy' could bring it about was also discussed within the End-user sector. Greater ownership and powers of decision making by community energy groups at the scale of regionally organised networks currently owned by the DNOs, was seen by the NGO sector (N1, N2) as potentially a way of creating more equitable access to electricity system markets and decision making. Commercial and Utility sector perspectives on this included the need for Government to lower the barriers to entry for new ESCOs to be able to compete more fairly with established energy companies that currently dominate electricity markets.

2. How smart grids should improve the fairer distribution of benefits was addressed in perspectives from End-user, Academic, Community energy and Utility sectors. These benefits included the availability of a robust electricity system helping to address decarbonisation (U1) but also addressed sub-issues of electricity affordability and the need to share costs more fairly (E3, E5, A2, L1, U1). Taxation policy and the cross-subsidy of community energy from larger players in the energy system were referred to in how smart grids could help to level disparities in affordability for example. From another End-user perspective (E9) the design of policy could introduce gaming theories to ensure that no party involved in smart grids can benefit at the expense of others. (E2) said that companies implementing renewable energy installations with a community's 'space identity' should pay royalties and make low cost energy available to the community but from the Community energy sector it was felt that encouragement of community ownership of energy assets was going to return more rewards to the community (L1, L2). On the sub-issue of equity through smart meters, End-user and Academic perspectives (E1, E3, A4) raised concerns that these did not encourage unfair benefit distribution through access to third party equipment that extends their functionality

3. Referring to equity of energy production and demand, there was some consensus from Commercial (C2), NGO (N2), Academic (A2) and End-user (E5) perspectives that some form of grid reorganisation would happen in future towards the 'energy-island' scale. The perception was that at this scale it would be easier for benefits and costs (such as the payment for pollution (U1)) to be transparent and equitable. From a Government perspective (G1) there was acknowledgement of the need to introduce obligatory methods to steer decarbonisation that could include dynamic time of use tariffs that had been successfully trialed in a recent study by a DNO (U2). However from the End-user sector there were several perspectives (E3, E6, E7) that suggested the end-user was not the best target emphasis upon demand reduction. Instead it should be incumbent upon Government to align financial incentives to motivate energy companies to drive down energy production in return for financial reward, rather than profits from selling more energy.

6.4 Technical feasibility and integration

This research is aimed at investigating sociotechnical aspects of smart grids and so the Criteria cluster forming the Issue of 'Technical feasibility and integration' in Fig. 14, is presented to reflect the interwoven fabric connecting technical and social considerations. There are concerns addressing a diverse array of factors at scales ranging from overarching architecture down to smart meters and from institutional scale to end-users. They were contributed from all sectoral perspectives. Key sub-issues to emerge from analysis of this Issue can be summarised as:

- Smart grid architecture.
- Network reorganisation.
- Critical characteristics such as scope, scalability, flexibility, reliability, resilience and RETs.
- Factors enabling of smart grids such as technology adoption, data infrastructure and connectivity.

6.4.1 Smart grid architecture

Smart grid architecture was discussed from four sectoral Perspectives (C2, C3, N1, U2, A3). It is topical as it has also recently been raised as a concern of the Institute of Engineering and Technology (IET) [62]. From a Utility perspective (U2) the technical capabilities and the sort of market to provide necessary services to help system (and sub-system) operators to balance and provide system security would all be considered part of smart grid architecture. There was agreement on the reality of how low carbon developments are starting to impact rapidly upon many aspects of the GB power system posing challenges to management of system stability and balancing. From Academic and Utility perspectives (A3, U2) connections across the physical assets, market and regulatory dimensions of the smart grid vision, extending decades into the future, require an overall architecture to be implemented at optimal cost and efficiency.

"*Architecture is something that creates the necessary glue between all of the various dimensions of a smart energy system. The issue is about how you balance the national grid in real time, which is becoming extremely problematic, or will do once we have lots of solar PV and wind generation - irrespective of where it feeds into the transmission system, it will cause some serious stability issues."* (U2).

This concern was spelt out from an Academic perspective (A3) that reflected on the use of architecture in other complex and expensive infrastructure projects (such as the building of rail or towns) all of which had a system architecture role within their implementation. This would be expected of other large projects and perhaps especially so in the case of critical national infrastructure

"*To get a truly smart grid we need a vision of the system architecture and an expert panel who can deliver that system architecture. You could have linkage and look for extensions to other systems but people have accepted that most of the emissions reductions will come from the decarbonisation of electrical power, so let's focus on that initially. We need system architecture in place for that to happen to include offshore wind, and renewables, new nuclear, network reinforcement, interconnectors. If we are going to invest £Billions to do it and reduce our carbon emissions by 85%-90% by 2050, let's do it in a smart way.*" (A3)

The need for an overarching smart grid architecture is urgent as challenges to maintaining system balance with increasing grid complexity from added RETs increases.	Architecture U2)
It's not just about electricity it's about optimising heat, gas, electricity, and potentially transport- it's about optimising those vectors and not just treating them as silos. That's the concept of a smart city - optimising all of those.	Cross dimensionality (U2)
Technically inclusive - covers all technical requirements and flexibility going forward. And enables the technically separated utility streams to be integrated - extending across water and electricity and heat for example. Integrative and interoperable.	Technically inclusive (G3)
How the grid is organised at different levels of granularity. The social dimension brings about affinity to organise as a energy island. Essential element PPP as the ultimate particle - tending to off grid. How the optimisation between individuals and the community work out - autonomic system run by a third party service.	Grid reorganisation (C3)
There's a whole range of solutions. If you are going to operate a local microgrid, you need to have the skill set to do this. There needs to be sufficient appetite by risk takers and investors to invest.	Technical feasibility (U2)
Community or local scale control over grid flows, including the design of the grid. Oversight of system design at the local level. Access to data flows would enable management of the grid and its development.	Scaling up CE (N1)
Seamless integration. Smartness should apply everywhere including off-grid and can be interconnected. It has to reflect in some way the local and regional requirements but be extensible.	Coverage (G3)
Enhance visibility and control over end user energy use. Increased balancing and data tools - through better quality information and the possibility to instruct the SM to do some kind of operation with the end user consent - such as change the operation of an appliance (DSR	Network operability (U1)
A smarter system is a far more flexible system. We can flex our assets in a way responsive to user demand. This is a real potential that smart meters could help with. Not only about engaging with the user but also with appliances.	Flexibility (A3)
Is it scalable or could we waste time and money to produce a small amount of energy just to fulfil this option?	Scalability (A4)
Needs to be scalable and flexible to change. Avoiding the sense of the ultimate design. Ideally self-learning, responsive and reflexive. It is going to change and will have to improve. Avoid stranded assets and white elephants and 'closed conclusions'.	Flexibility (G3)
Encouraging flexible demand, local consumption and market arrangements. Enables renewable supply through flexible demand. as well as the technical arrangements to connect renewables effectively.	Enables renewables (A2)
The technology should work at the town/neighbourhood level to form microgrids. Is it available and cost effective to enable towns to have microgrids?	Microgrid technology (N1)
The key purposes of the smart grid are to enable us to minimise the amount of energy we use and maximise RETs. More efficient balancing - DSR - reduce the amount of generation needed.	Minimise energy use (N2)
Maximise RETs on the grid then energy generation no longer a major concern.	Maximise RETs (N2)
Reduce CO2, preferably through locally generated renewable energy and energy efficiency.	Reduce CO2 (L1)
Matching scale to efficiency measures is important. There is a tradeoff between scale and flexibility. In general it is easier to manage load shifting if demand is lower.	Resilience (A2)
Demand side load shifting to orientate demand according to supply. Having smart meters that give real time feedback is a key thing. Scope for services to reward for shifting loads and peak shaving.	Facilitates load shifting (A1)
User experience is about how technology integrates into the fabric of our lives. Pervasive computing, not just gadgets sitting on tables. The tech should be clever enough to do the right thing with out us intervening. Operation out of the box. The user experience is paramount to adoption - engineer the grid around user experience.	Technology adoption (C3)
Low cost, mass scale technology enablement. Local generation, in-home technology. A meter is a sensor. Current energy storage technology is too expensive for mass rollout. Wireless radio mesh and fibre communications would provide necessary near real time communications.	Technology availability (C2)
Hi reliability low failure rate. Smart meters do what they are supposed to with a very low rate of technical malfunction - accurate, transmit data in a timely fashion. Fail safe.	Technical reliability (N1)
Across smart meters and their add-on applications technology conformity to a standard.	Standardisation (E1)
Greater connectivity provides more data as well as better computing power to process the data. Smart metering data availability should be more granular and more available.	Big data (C2)
Appropriate communication technology to support new business models. Smart grid is essentially a set of connected controllable assets. In order to support demand response in a market for example - we need reliable comms technology as the corner stone for new business models.	Connectivity (C2)
Data is key to smart grid. Understanding and utilising data to change business models. Most grid optimisation needs to be data driven and the industry has virtually no understanding of data. Without this we are just tweaking something already highly optimised.	Data competence (C1)
Access to relevant data and how it is made available to the end user. In addition to the IHD, on the internet or mobile phone. This enables the convenient trigger to turn things off as well as save energy. Third parties will do this better than energy companies.	Data access (U3)
Are the Options technically feasible?	Feasibility (A4)
All about storage becoming cost effective to support new business models.	Energy storage (C2)

Technical feasibility & integration

Fig. 14. Criteria cluster forming the Technical feasibility and integration Issue.

From a number of other perspectives, concerns about the lack of a system-wide architecture for the electricity system were raised that included institutional arrangement and function (A3, N1), competency (C1) and Government ability to successfully deliver large infrastructure projects (A3, E9, G3). From an Academic perspective (A3) it was time to review the use of 'market forces' driving the development of smart grids in the absence overall architectural coordination.

"*Ofgem is recognising this and is not fit for purpose to do something other than regulate. Their mantra is that the market will deliver if we want to do something. But it won't. The market won't take us to where we want to be. We can take the market to where we want to be. You'll only get from a market driven approach what's most appropriate for that market at that time.*" (A3)

The problem of the need for architecture in the case of the GB system is promoted by narrowing capacity margins (due partly to the closure of fossil fuel generators) that without intervention and coordination could leave the country exposed to problems with supply security. This complex challenge is being addressed in a way that does not match its urgency from an Academic perspective (A3) and is heavily reliant upon market forces, such as in the case of interconnectors being run under merchant arrangements and capacity markets for generators. The main concern arising from this scenario is the possibility of blackouts.

"We need somewhere in the region of 10-12 GW of interconnection with mainland Europe by 2020-22 and at the moment we only have 3GW. We are about to enter into a period where we have a very low margin of generation capacity compared with our peak demand. Less than 5% margin." (A3)

Architecture helps to identify where the scope of smart grids impact upon other technological and sociotechnological systems - for example in visions for smart cities. This feature was described as 'cross-dimensionality' by (U2) and linked the concept of the energy trilemma to other systems such as water and transport. Could new dimensions beyond the three making up the energy trilemma therefore be included in a more holistic conceptual framework to encompass 'smartness'? These dimensions might include heat and conservation systems (A2, G2), the social acceptability and potential for adoption of new technologies, market innovations and engagement strategies based around user experience (E2, E3, E6) and data (C1, C2, C3) for example. Does 'architecture' therefore become a framework by which smart grid technical and sociotechnical interdependencies can be visualised, directly reflecting the core of the Issue of 'Technical feasibility and integration'?

6.4.2 Network reorganisation

The exploration of microgrids and energy islands as important concepts for network organisation were discussed from Commercial, Academic and NGO perspectives (C3, A2, N1) that were derived from placing emphasis upon network development at DNO or Distribution System Operator (DSO) level.

"*Federation of energy islands is the way to build the smart grid rather than a big-bang approach that we did with National Grid 30 years ago as that isn't going to happen in the modern world, so the only way it can really happen is through individual projects federated together and islands tessellate and hopefully they will join up at the end.*" (C3)

This raises the question of the role of the DSO. Would it implicitly require a higher degree of proactive network coordination through local consultation, on topics such as trends in microgeneration, EV procurement, heat pumps and air-conditioning and other social needs and aspirations to successfully implement energy islands? The impacts of rapidly increasing numbers of these technologies upon local network capacity are already being felt and pointing to the importance of closer coordination between network operators and local trends.

"*We're already seeing in particular neighbourhoods there are stresses on the local network because quite a lot of people now have solar PV. You can see that if a bunch of people start getting electric vehicles in the same area and start charging them up at the same time that will cause stresses.*" (A2)

"*If you've got generators who want to connect an area in Kent, lots of capacity for wind for example, you co-ordinate them together and get them to invest as a consortium and say we're going to put this much new distribution capacity in to get your power onto the grid.*" (N1)

6.4.3 Critical characteristics of smart grid technical feasibility

Interviewees (A3, G3) contributed a wide scope of perspectives from different sectors on critical characteristics of smart grids. These included scalability of 'smartness' within the sub-systems of smart grid networks (A3), flexibility and extensibility (G3) that provided connection to other systems such as heat and water. Standardisation was also seen as an important consideration from a Government perspective (G3) to support future proofing and avoid technological lock-in. And attention to the requirement to measure and control at time scales that enable smarter operation of the grid.

"*A smart grid can help us transition to meeting the challenges of the trilemma. That's where the smarter grid as a whole comes in. It's not just about smart metering, or the smarter consumer and smarter appliances, it's also about smarter distribution, smarter transmission of electrical power as well.* " (A3)

To assess smart grids, scale and scalability have been identified as important measures. The consideration of scalability applies to the 'extensibility' of the physical smart grid network as well to its availability to connect with utility or end-user technology. This was a recommended design principle of smart grids from a Government perspective (G3) that accorded well with the concepts of a cellular grid structure.

"*I like the cellular notion as it has to reflect the local needs but the principles need to apply across all instances. It has to be technically possible to scale everywhere. If there is a smart grid, whether or not it the same degree of smartness the principles of the system have to be integrated, the parts need to be able to be integrated and seamless at some level, whether off-gas, inner city locations, or international.*" (G3)

Different measures of smartness such as resilience and flexibility should be expected from specific scales. Interviewees from Community energy, Academic and NGO sectoral perspectives (A2, L1, N1) said resilience was an important consideration. It should be optimised at different levels of planning through consultation with the local populations. (A2) commented on the trade-off between scale and flexibility.

"*Proactive co-ordination, perhaps working with communities, and obviously wanting to put generation onto the grid, working out how to get the most on for the least cost over 5-10 years in a fair way. Prioritising generation that has the most social value and the most community value is important.*" (N1).

"*I think resilience has quite a lot to do with the scale of demand probably. There's an interesting trade off there between scale and flexibility.*"(A2)

From a Utility perspective (U2) the ability to leverage benefits from having distributed energy resources, whether it's lots of offshore wind or lots of micro generation or anything between, to provide demand side response, storage and a generation capability were critical characteristics of smart grids. According to (U2) this would require system architecture for coordination of assets whether they were in microgrids or otherwise.

6.4.4 Factors enabling of smart grids

As smart grids develop at all scales, the amount of technology innovation taking place in the electricity system will present scenarios and repercussions that have not been encountered before. In this section perspectives are drawn together that can be considered as enabling factors that distinguish smart grids from previous designs underpinning electricity systems. Several of the perspectives contributed, were affected by the increased degree of component connectedness and the unprecedented levels of data that could be drawn from this kind of innovation. This data was seen from a Government (G3) perspective as not only supporting characteristics such as flexibility in measurement and control of the grid but also enabling it to interoperate and possibly integrate with other key systems:

"*[Smart grids] need to have a flexibility going forward. And enable the different, currently separate, utility streams to be managed together... interoperability would be needed to make the system achieve this.* " (G3)

From a Commercial Perspective (C2) smart grids represented technology enablement that is dependent upon mass connectivity of low cost technologies that could be situated at all scales.

"*Availability of technology, in home devices, meters, local generation. Low cost. Mass scale. Technology enablement. Current technology is too expensive for mass rollout. If you think about smart cities you can go and buy a sensor now from Maplin for £3. A meter is a sensor essentially.*" (C2)

This perspective challenged the relatively high cost of the smart meter proposed for mass rollout by the Government.

"And we are being asked to as a country to accept SMETs 2 meters that cost £150. SMETs 2 meters that were designed by the meter manufacturers with their current functionality is absolute madness." (C2)

From Government and Utility perspectives (G2, U2) smart grids could present us with the possibilities for previously un-encountered automated events that might present risk to system stability under certain circumstances. For example, if smart meter facilities were to reach maturity in communicating with domestic appliances, nation-wide agent based responses to dynamic TOUTs could be a reality and present the opportunities for unforeseen frequency events in a grid having a relatively low amount of system inertia.

"*Currently it's all done by human intervention but the sustainable way forward is by my appliance or an agent taking control. But do we want dynamic frequency response as opposed to fast frequency response? The danger is perhaps 'hunting' where lots of devices see that the frequency's dropped by 0.1Hz, therefore I will disconnect, then all of a sudden the frequency goes up by two thirds.*" (U2)

Such risks according to a Utility perspective (U2) would however, be ameliorated by the understanding of smart grid dynamics implicit within a system architecture.

There was concern from interviewees particularly within the Commercial sector (C1, C2, C3), that the proposed smart metering implementation plans do not capitalise on the potential for AMI, or even 'smartness' *per se*, but remain tethered to conventional thinking about technology, metering and bill settlement practice (C2). At worst, the Government are criticised for not having a sufficiently advanced and innovative understanding of the use meter data and what uses therefore it could be put to (C1). Although smart metering alone does not account for 'smart grids', these issues are serious enough to have a direct impact on the technical feasibility and integration of smart grids and potentially directly conflict with the meaning of 'smart' (C1).

"*Smart meter redesign - a message we need to get to DECC through every possible channel.*" (C3)

"*I don’t think it’s a re-design of the meter but a fundamental design of the [AMI] architecture that needs to happen and it needs to be distribution lead.*" (C2)

"*I actually think we don't need smart meter redesign. We need an understanding of data science. There's a pretty good reason for not rolling out smart meters in that they don't know what to do with the data once they've rolled them out. If we are talking about smart grid, data competency ought to be most important*." (C1)

"*In ten years time you can look to the model where any major appliance that's using electricity, you can actually meter directly at the appliance. So you can lease your washing machine or whatever. We are just looking at really old archaic models here when we are using smart meters.*" (C1)

The statement above resembles how telecoms are metered and how the options to meter electric loads in the contemporary sense may change our understanding of metering once appliance telemetric systems and load signal disaggregation become common practice. It again directs our attention to the importance of data (over an interconnected infrastructure) to smart grid technical feasibility and integration. Accumulating data about end-user energy use and lifestyle choices is part of the attraction to commercial enterprises, as it will also drive innovation in new products around electrical networks.

"*Big Data; Data is the killer app. Why do you think Google paid $3.2 Billion for Nest - because they want people's data.*" (C2)

All sectoral Perspectives contributed considerations outlining the importance of data to making grids smarter, but also to the opportunities to innovate around them. From a Government perspective (G2) there was concern about data protection and user privacy but from a Utility perspective (U1) meter data was seen as important to helping gain better visibility over grid generation assets and other factors concerned with balancing. From an Academic perspective (A1) there was frustration about access to smart metering data and an acknowledgement that security lockdown by the DCC would require SMEs to plug-in third party equipment to the smart meter extension port in order to gather data to open up innovative commercial opportunities. From a Commercial perspective, as we have seen above there were several consideration about the availability and use smart meter data is put to. But the resolution of data recordings was criticised as being directed mainly towards daily bill settlement purposes (C2). Besides end-user concerns about data privacy already addressed, the End-user sector (E2, E9) offered perspectives on access to personal meter data records as desirable to better understand domestic energy behaviour than the IHD was capable of showing. This sentiment was also reflected in a Community energy perspective by (L1) and necessary to open market opportunities to community energy schemes from the perspective of (L2). An NGO perspective (N1) smart meter data would facilitate coordination of DSR but a concern was raised about how heavily smart meter technology could be relied upon to perform as expected. Other considerations on data included quality, accuracy, reliability and resolution.

"*Managing the grid by 30 minute intervals is important. But for offering individual services to consumers there's probably a lot less value in the 30-minute data than in the much more fine-grained data. 10 second data or sub 1 minute data is much more useful in the house over the home area network. There seems to be very little scope for innovation from small companies, apart from the fact that they could offer a little bit of hardware that gets that internal data.*" (A1)

Other perspectives were raised on smart meters and the IHD. The delivery of information to mobile devices was considered from a Utility perspective (U3) and the increased value of the IHD in encouraging DSR was a perspective from the Academic sector (A2).

"*We need additional services to pull back half-hourly data to the end-user. It should be directed to your mobile phone or Internet. The service would be available to see your energy usage.*" (U3)

"*If you want people to take part in demand response too, certainly the demand response initiatives in the States show very clearly that the people who have some form of display show a lot more demand response. A good deal more than the people who don't. You get better results. So visibility to the end-user is the key thing."* (A2)

Simplicity of information and intelligibility of the meaning of this feedback, and the operation of equipment, are crucially important considerations according to several Perspectives (A2, U3, E1, E3). At this scale, these considerations help define the user experience of smart grids as well as their perceptions of smart grid usefulness and appropriateness to their lives. These considerations questioned how much could be expected from technologically led interventions in the energy domain, without running the risk of disengaging smart grid end users.

"*The sort of way we understand our energy services will have to do with how reliably consistent they can be so the extent to which people are able to power down will assist in reliability. You do have this dynamic between how much are we there for the system and how much is the system there for us? So, the extent to which people feel this is their system*" (A2)

"*I don't need to understand what the smart meter's doing as an end-user. I only need to understand the bit that's going to affect my daily life. Simplification to people of this complex information is crucial to people engaging with the smart meter.*" (E1)

"*People need to feel confident when they are using the system that they are able to have it work for them and that they can make decisions that will benefit them, so any information about it needs to be clear and help people feel in control and empowered.*" (E3)

Other related concerns were raised from a Government perspective (G2) that placed emphasis upon the transparency of information feedback to the end user to give them empowerment to act in their own interests and those of the wider grid:

"*The more transparency of information they have the more consumers will feel empowered. To what extent do the consumers feel empowered to act in their own interest? And secondly in the interest of the wider grid.*" (G2)

Concerns about open data security and privacy are also present, but need to be weighed against practices that are already commonplace in the public domain where granting of permissions for personal data access and use are the responsibility of the end-user. This reasoning was embedded in similar End-user sector perspectives (E2, E9) on the desire for meter data to be open to end-users but diverged where the means by which it was obtained was considered. One perspective (E9) accepted open data and that it will be used by others, while the second perspective (E2) wanted data about their energy behaviour to be made available only to them:

"*Open data access can enable better monitoring and insights into personal energy behaviour. I don't care about the display, I want access to the data.*" (E9)

"*Who collects that data? You don't really want it being collected by EoN and passed back to you. You want it collected by yourself and be able to analyse it. Who has control? Data is power. Edward Snowden is an example of that. The active consumer is what I seek and depends on the information being made available to the end-user.*" (E2)

Another enabling factor for smart grids from a Commercial perspective (C3) was to persuade end-users to adopt pervasive 'smart' technology within the home that could operate by providing services in accordance with grid conditions.

"*Technology adoption... we need to find a way of getting technology that will help energy usage in the home without it being a gadget in its own right. It's the whole thesis of pervasive computing, when it's successful, it disappears into the fabric of your life and you don't know that it is there any more. Rather than being a gadget that sits on the table, with flashing LEDs on it, it is just part of the system. So your tumble-dryer automatically delays until after midnight unless you explicitly override it. It doesn't ask you, it doesn't text you, it doesn't flash a light at you, it just gets on and does it."* (C3).

But from other Perspectives (A2, E2, E4), there were concerns about the degree to which technology increasingly intrudes upon their lives and can take away their sense of control, without many alternatives to choose from. There are concerns of entering into a continuous process of appliance upgrades, novel applications to save money and shift demand profiles, smart metering redesign or extension that could impact upon the Issue of smart grid technical feasibility. These perspectives questioned 'smartness' from a sense of intelligibility, priority and loss of trust in something that wasn't understood.

"*Does more technology make your life simpler because it manages things that you have to otherwise think about or does it make it more complex because you have to think about all the things managing information for you? It sounds too restless too confusing, too complex and there would seem to be quite a lot of risk of a lot people getting left behind as all this goes on* " (A2)

"*I am interested in people living lives where low technology is an option and high technology does not have the sort of priority that it has at the moment.*" (E2)

"*People might not want to pay for a smart fridge, not trust it, can't afford it."* (A4)

Energy storage (thermal and electrical) technology was pointed to from five sectoral perspectives (Commercial, End-user, Government, Utility and Academic) as being an enabling technology for smart grid development at a full range of scales from grid system to end-user domestic environments. This topic is familiar in the technical context and so will not be discussed in detail here. It is less common in a sociotechnical sense and therefore worthy of further consideration as to how energy storage meets the end-user needs and practices. The most obvious technological interventions in this context being the battery, hot water tank and vehicle fuel. Energy storage could also play a very disruptive role in energy markets from a Commercial perspective (C2) once the technology was cheap enough and business models were developed to exploit it.

"*Domestic storage, I feel ought to be more of a solution going forward. Just look at all of the subsidies that have gone into renewables and think, it might have been better to put them into storage.*" (C1)

Storage was seen as a repository for 'waste' energy from end-user (E2, E6) and Government (G3) perspectives as well as a means of capturing excess energy from RETs.

"*A grid that is designed for building in integrated renewables is friendly to storage.*" (A2)

Resilience of the electricity system was given as a reason to encourage energy storage (A2). It was also proposed as a technology that could assist in greater energy autonomy for end-users (especially if they operated microgeneration) (N2) and also at community level, scaling to municipalities and energy islands (C2, C3).

"*Energy storage is a big issue to overcome, to make the argument for energy islands more acceptable. It's the best one but the one that needs some major technical advancement before it can happen.*" (U3)

"*One of the benefits of having these distributed energy resources whether they are in microgrids or otherwise is to leverage that capability to provide demand side response but also storage and a generation capability.*" (U2)

6.4.5 Summary of perspective patterning

Four sub-groups were used to present the patterning of perspectives within the Technical feasibility and integration Issue. These addressed smart grid architecture, network organisation, critical characteristics and factors enabling of smart grids. From the Criteria composing this Issue, there was a marked engagement from the Commercial, Academic, Utility and NGO sectors (see Figs. 9 & 9.1). A high level summary of the perspectives from different stakeholder sectors now follows.

1. Four sectoral perspectives (C2, C3, N1, U2, A3) were largely in agreement in calling for the need to implement a GB smart grid architecture in order to leverage the capabilities of its major resources, ranging from new market and business model designs to RETs, AMI and network asset management. It was seen as a pertinent requirement from Utility (U2) and Academic perspectives (A3) to address the risks arising from a narrowing capacity margin and in terms of long-term 'big ticket' infrastructure development to reach given targets. There were concerns from Commercial and Academic perspectives around leadership at institutional level to meet the need for architecture while there appeared to be reliance upon 'market forces' to drive smart grid development.

2. Perspectives addressing different aspects of how network reorganisation would influence development of smart grids were contributed by three sectors (C3, A2, N1). There was emphasis placed at distribution network level where federated energy islands (C3) were envisioned to be more relevant that traditional centralised network arrangements. From Academic (A2) and NGO perspectives (N1) attention was drawn to the increasing stresses on local systems from the connection of DG, heat pumps and EVs.

3. Regarding critical factors enabling smart grids, there were a range of non-conflicting perspectives offered from Academic, Government, Utility and NGO sectors. These reflected on different aspects of 'smartness' but were largely technical considerations. They included scalability (A3, G3), flexibility, extensibility and standardisation (G3). Leveraging the capabilities of low carbon assets to help in delivering targets addressing the energy trilemma was give by (U2) as an essential characteristic of smart grids.

4. Factors enabling smart grids from some Commercial, Academic and End-user perspectives (C1, C2, A1, E9) reflected upon how technologies connected with AMI would need better understanding by Government of what can be done with data (C1) and greater access to information through open data (A1, E9) to enable smartness in homes. Technologies like smart meters for mass connectivity should also be available at prices far less than the cost of the proposed smart meter (C2). this would also influence technology adoption and pervasiveness from a Commercial perspective (C3). The increased dependency upon data from smart meters for smart grid operation drew concern from a Government perspective (G2) in terms of the risk of unintended consequences from such a highly connected system and the system dynamics that may arise as a result of DSR to TOUTs from a Utility perspective (U2). From an Academic perspective (A2) a smart meter with an IHD can bring more clarity to end users than without but information delivery is desirable to mobile devices as well from a Utility perspective (U3).
   There were different perspectives on the benefits to end users of smart metering data from the End-user sector (E2, E9) saying that personal data (in its raw form)

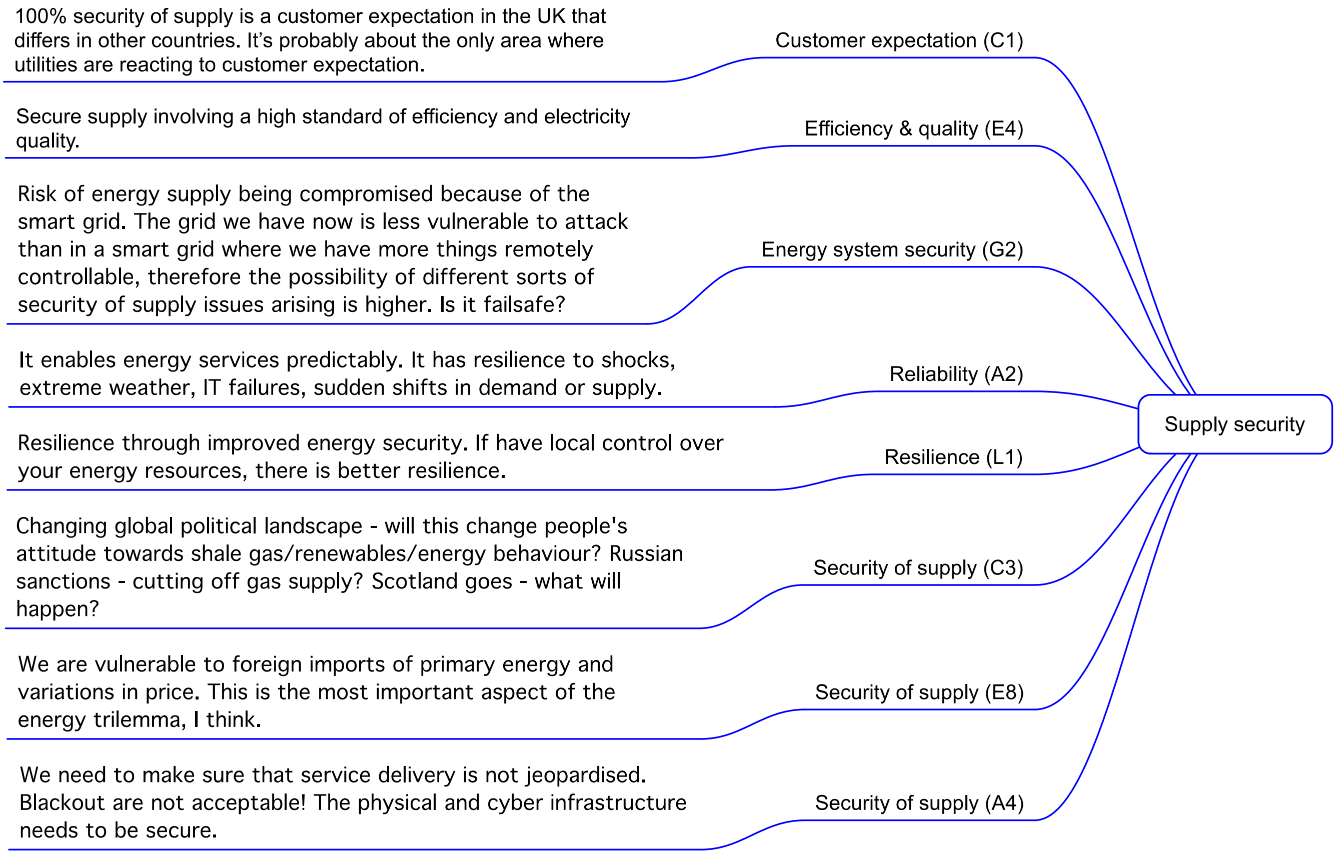
should be made immediately available to end-users desiring open access and not routed via the energy Supplier beforehand. From the Community energy sector (L1, L2) there were perspectives supporting the idea that smart metering data is important to communities to enable them to engage with electricity markets in a beneficial way. Simplicity and intelligibility of electricity information was seen as an enabling factor in terms of user engagement and service provision within perspectives from Academic, Utility and End-user sectors (A2, U3, E1, E3), with (A2) extending that perspective to include intelligibility of the smart grid operation from a resilience standpoint. There were concerns around technology intrusion and data security from several perspectives (E1, E2, E4) and whether the benefits from technology were real and clear (A2). From a Government perspective (G2) transparency in terms of data and service provision was a key enabling factor. Smart meter data was seen as necessary to grid balancing from a Utility perspective (U1) because of the added visibility it gave over DERs.

Energy storage including heat energy (G3), was addressed within perspectives from Commercial (C1, C2, C3), Academic (A2, A3) and Utility (U3). It was to be encouraged from both commercial opportunity perspectives and a grid resilience standpoint. These factors would support end-user and community energy autonomy from the perspectives within the End-user sector (E2, E6) as well as the NGO sector (N2). Smart grid resilience would also be benefitted by storage (A2) given that it is connecting increasing fractions of intermittent RETs, the benefits from which could be leveraged further by storage from a Utility perspective (U2).

6.5 Supply security

'Security of supply' is one dimension of the energy trilemma and can represent a wide range of concerns from access to sources of primary at the geopolitical level to continuation of and access to, high quality power at the end-user level. We will analyse the Criteria and comments made by interviewees in the 'Supply security Issue' in terms of impacts upon the meaning of 'smart' and smart grids. In other words by looking at how 'smartness' or smart grids more generally, influence supply security from different sectoral perspectives. The Supply security Issue cluster was composed of the Criteria shown in Figure 15. It covers two important overlapping sociotechnical concerns:

- Continuity of high quality electricity supply to end-users.
- How smart grids improve supply security.



100% security of supply is a customer expectation in the UK that differs in other countries. It’s probably about the only area where utilities are reacting to customer expectation.

Secure supply involving a high standard of efficiency and electricity quality.

Risk of energy supply being compromised because of the smart grid. The grid we have now is less vulnerable to attack than in a smart grid where we have more things remotely controllable, therefore the possibility of different sorts of security of supply issues arising is higher. Is it failsafe?

It enables energy services predictably. It has resilience to shocks, extreme weather, IT failures, sudden shifts in demand or supply.

Resilience through improved energy security. If have local control over your energy resources, there is better resilience.

Changing global political landscape - will this change people's attitude towards shale gas/renewables/energy behaviour? Russian sanctions - cutting off gas supply? Scotland goes - what will happen?

We are vulnerable to foreign imports of primary energy and variations in price. This is the most important aspect of the energy trilemma, I think.

We need to make sure that service delivery is not jeopardised. Blackout are not acceptable! The physical and cyber infrastructure needs to be secure.

Fig. 15. Criteria cluster forming the Supply security Issue.

6.5.1 Smart grids and supply security

Within the geopolitical level of the energy trilemma, there are questions within the energy security dimension of how to maintain electricity supply security. The focus in this study is upon 'keeping the lights on' instead of how sources of primary fossil or fissile energy are obtained to make power to transmission and distribution. This leads to a System Operator perspective (U1), where future network concerns automatically become a 'dilemma' (over decarbonisation and cost issues) because maintaining supply continuity is considered their primary duty. That perspective suggests deliberation over other forms of network architecture incorporating RETs and operating under islanded or local energy supply conditions may not be entertained.

"*Some people say you should have secure energy automatically and then it becomes a dilemma. We are not going to create scenarios 20-25 years out and not include a secure system. That seems odd and we would struggle to describe those. If you have no system then the cost and decarbonisation of the system is irrelevant.* " (U1)

From a Commercial perspective (C3) there was consideration of how electricity users could respond to geopolitical concerns for primary energy supply:

"*If Russia turns the gas off, it will actually have an effect on us by getting cold this winter. In which case will that change people's attitude to shale gas, will it make people more frugal with their energy use, will it lead to more accessibility of renewables? Will it lead to people going off grid? There is a whole spectrum of ways people could respond to that.*" (C3)

Comments previously reported from all perspectives (such as...A2, E6, G3, U2, N2, C3) could address these concerns. They have suggested that a primary function of smart grids is to accommodate increasing proportions of renewable energy generation capacity. Different sectoral perspectives have indicated that the challenges then arising to secure and balance a nation-wide grid system stem from which smart grid architecture (U2, C3, N1) is implemented and that it may eventually comprise of smaller, interconnected energy islands or microgrids at the personal, community, municipal or district scale. Demand reduction has also been raised from Academic (A2) and NGO (N2) perspectives as another side to the supply security argument.

"*I think the key purposes of the smart grid really are to enable us to reduce the amount of energy we use and also to maximise the amount of renewables we could put on the grid.*" (N2)

Another interpretation of the impact of smart meters, this time upon smart grid security was given from an Academic perspective (A4).

"*I think that smart meters aren't necessary for security of supply. I think they are needed for addressing the elements of the trilemma that are making energy more affordable, decreasing carbon.* " (A4)

6.5.2 Smart grids and supply continuity

Three sectoral perspectives (U1, C1, A4) agreed that the expectation of continuation of electricity supply as a *sine qua non* in the GB electricity system. From a SO perspective (U1) it would resolve to exploration of only the other two dimensions of the energy trilemma by addressing questions such as how carbon emissions be reduced or fuel poverty avoided to head off public disapproval.

"Which would cause more outrage? There would be a lot more vocal people if we were to say we are going to lock cost down and do everything really cheaply than if we lock down security of supply and maintain costs." (U1)

But as we can see from some end-user perspectives (E6, E7, E8) there is a willingness from some in the End-user sector at least to consider exploration of a different vision in the interest of mitigating unsustainable consumption and global warming, as long as it was managed equitably and incentivised accordingly.

"*Our starting point is all about meeting current energy needs and I feel we use too much so anything that reduces that is good. There was a campaign a few years ago about switching off lights - I like that. I don't see a problem with outages either. I know it's probably political dynamite.*" (E7)

Despite the importance put upon political issues and supply security, some End-users interviewees would be willing to consider managed intermittent blackouts. There was openness to considering a range of options that critically, were dependent upon sufficient advanced warning, protection of essential services and financial incentives. Insulation and other energy conservation measures were mentioned by (E8) as needing priority before the possibility of restricting electricity supply would be acceptable.

"*As long as essential services were protected and I knew it was coming. It makes life more interesting, doesn't it? I can read more. Ah but you need financial incentives to drive it. I am willing to sign up, if I am going to save 10% off my bill, it should be voluntary. I will sign up to intermittent power cuts.*" (E6)

"*I would say between 3 and 5 in the morning wouldn't effect me. If people knew about it and were able to plan for it like making sure their fridges were properly closed.*" (E8)

From a different perspective within the End-user sector (E4) the Issue was dependent on what had been agreed as a policy and also how a secure electricity supply has become an expectation, a sentiment more aligned with the SO perspective (U1):

"*If we are in agreement that we have a 24hr energy system and we are not running risks of blackouts. I'd like a secure electricity supply. It's what we are used to and live with. I'd like it to be maintained.*" (E4)

From a Commercial perspective (C1), the question of whether it is necessarily a condition of 'smartness' to expect a continuous electricity supply, or whether perceptions of smart grids can be designed to accept managed intermittency. This perspective redirected the focus of supply security politics to the challenge of the need to manage customer expectation. A high-quality, continuous electricity supply was considered by (C1) a national expectation because previous grid designs had done a very good job in addressing the problems of supply and demand.

"*In the UK in particular, probably more so than almost any other country, we're used to continuity of supply. In the USA, most people expect to have a number of outages per year, some of which will be several days. And just going around the world, we've got the highest belief that we should always have energy, probably of any country.*" (C1)

This perspective on customer expectation was echoed from an Academic perspective (A3) and refocused the argument of supply continuity upon why we need smart grids.

"*That's where the smarter grid as a whole comes in. It's not just about smart metering, or the smarter consumer and smarter appliances, it's also about smarter distribution, smarter transmission of electrical power as well. And then that can hopefully allow us to provide that same level of security.*" (A3)

From another Academic perspective (A4) blackouts were not considered acceptable and there was concern that smart grid development itself could result in unforeseen possibilities for disruption of electricity supply, such as because of the bigger role data will play in its operation and running. This was echoed from a Government perspective (G2) where the degree of automation that is expected to deliver benefits could also raise the risk of failure at some levels.

"*Need to make sure that service delivery is not. Blackouts are not acceptable*. *It needs to be secure against terrorist attacks, hacking. We wouldn't want someone shutting off power plants.*" (A4)

"*I think the fact there is much more information, data automation, in theory. Much more transparency of what is going on from the domestic level right up to the system level. That means more things are controllable remotely - that's where the benefit lies. The possibly of different sorts of security of supply risks arising because someone designed the technical specs wrong."* (G2)

The access to smart grid market operation through data openness exercised further concern about the possibility for illegal activities from a Government perspective (G2). In this the opportunity for data driven innovations through more open data were weighed against the restrictions on innovation from a more closed market model.

"It feels like a very centrally organised and top down and closed kind of market is more secure but not as innovative, whereas a more innovative open market, almost bottom up in some respects, maybe less secure because of the many different points of weakness. Both of them could have the same level of protection measures, but one of them has got more points of attack." (G2)

These kinds of concerns recognise the risks to a national electricity system from increasing complexity by making innovative changes in networks, generation and demand control equipment linked to markets at a number of levels. They acknowledge the open questions around innovation and third party technology interventions as part of smart grid development. In respect of these considerations from a Community energy perspective (L1) the question of how resilience in overall smart grid system security can be built was addressed.

"*Improve local resilience through improved energy security. If you've got local control over your energy resources - you've better resilience for energy security - it would involve energy efficiency on the demand side and through improved load profiling.*" (L1)

It was suggested from an Academic perspective (A2) that resilience in smart grids could be supported by considering demand reduction to be as important to supply reducing demand (including greater emphasis on conservation, energy recycling and efficiency measures). It was also concerned with the diversity of supply and demand options and the spread of intelligible opportunities for end-user engagement to create a combination of bottom-up and top-down solutions.

"*Intuitively it seems to me that a really resilient system is one in which we've got demand down a good deal. It's about adaptation. You'd start bringing in considerations like restructuring energy markets, the kind of technology choices that are made. Improving adoption access by end-users. It suggest to me that they're quite a nice combination of top down and bottom up of engagement at all levels.* (A2)

6.5.3 Summary of perspective patterning

Two sub-groups were used to present the patterning of perspectives within the Supply security Issue. These addressed smart grids and supply security, smart grids and supply continuity. Criteria composing this Issue were spread quite evenly amongst interviewee sectors, indicating it was a concern of similar priority across the sectors, although there was no NGO component (Figs. 9 & 9.1). A high level summary of the perspectives from different stakeholder sectors follows:

1. A striking assertion from the Utility sector (U1) was to reduce consideration of the supply security Issue to a dilemma between decarbonisation and cost. The assumption that there would be supply security was implicit. However, from other sectoral perspectives (A2, E6, G3, U2, N2, C3) there was openness to the possibility that grid architectures could approach the challenge of supply security that incorporated alternative or additional configurations to a national transmission system.

2. Supply continuity related to how a high quality electricity is delivered to end-users and perspectives varied on whether this was a defining quality of smart grids or whether it was due to an expectation that the GB should have this (C1). Planned blackouts for the sake of demand and carbon emission reduction were considered in some End-user sector perspectives (E6, E7, E8) although the perspective from another End user (E4) and from the Academic sector (A3, A4) was that it should be upheld. From a Government perspective (G2) there were concerns whether the additional complexity and data sharing in smart grids might contribute to supply continuity issues if some subsystems were to be incorrectly designed. This played to the strength of community energy in providing local resilience, which would contribute to wider grid resilience from the perspective of (L1). Demand reduction, improving end-user engagement opportunities from the top-down and bottom-up as well as energy market restructuring were all part of smart grid resilience-building considerations from an Academic sector perspective (A2).

6.6 Governance

Criteria contributions to the Governance cluster represented nearly 20% of the total number (141) of Criteria submitted (Fig.16). Only the number of Criteria within the Technical feasibility and Integration cluster equaled this, reflecting the relative importance of Governance as an Issue across the interviewee sectors.

Sub-Issues emerging from this cluster covered the following range of considerations:

- Leadership - the need for open and transparent long-term policy objectives out to 2050.
- Innovation - setting the conditions for acceptance of, and preparation for, the need to embrace technological changes that come with the development of smart grids
- Energy culture - attention to bringing the end-users on-board within the changes required to build smart grids

6.6.1 Leadership

An overall impression from the Governance Issue was the need for Government to publicly step-up efforts in leading (A3) and restructuring of the electricity system rather than placing emphasis on pricing issues to the end-user. From an NGO perspective (N1) this could be supported by more positive news of communities benefitting from smart grid developments (including distributed renewable energy generation) over the usually reported concerns about escalating costs. There was also a strong signal from a utility perspective (U2) for commitment to flexible long-term energy policy extending out to at least 2040, with strategy built to meet key milestones at 2030 and 2050.

"*The Government has to take more of a lead in infrastructure development on the transmission and distribution systems where at the moment there is far less targeting and subjection to pricing reviews and short termism. The main objective of Ofgem is to make sure the customer is getting a 'good deal' but we need a more conciliatory arrangement with the electrical power industry to build the infrastructure.*" (A3)

"*I wouldn't set the horizon any sooner than 2030 and there are arguments for setting it at 2050. And 2050 should be a key milestone that we have in mind when we can sensibly get to the level of carbon emission reductions that we believe we need to.*" (U2)

The starting point from a Commercial sector perspective (C1) was to ask, in reference to the energy trilemma and GB energy policy, what and who are our energy policies trying to satisfy? There was some concern that there had been a political imperative leading to over-emphasis on the dimension of carbon reductions on a global stage but not enough emphasis on the dimensions of supply security and cost at home (C1).

"*So the question I would raise then on Government Policy is "who are you trying to satisfy?" Because it does appear to be all about making political statements on a world stage rather than looking at UK Plc. The key objective should be about energy security or energy supply. And it should also be long term. 25 years for a starting point.*" (C1)

Government energy policy needs to be clear about it's objectives - key objectives should be about energy supply and long term - 25 years.	Energy policy (C1)
The smart grid helps us gets to meet the 2050 targets. Meets the expectations and targets.	Meets the targets (A3)
Need to understand what the investment and policy stranding risks are so if we commit to a certain direction and it becomes obvious that is a culdesac and we need to U-turn. Avoidance of lock-in. I wouldn't set the horizon any sooner than 2030 and there are arguments for setting it at 2050.	Flexibility/Agility (U2)
Government leadership for the right reasons. They need to tell people more what they need to do for the right reasons - not for profit. They need to make it easier to for people to do what is necessary.	Government leadership (E5)
Government commitment to a broad direction of policy. Policy redirection because it's informed is essential.	Energy policy commitment (U2)
The Gov. has to take more of a lead in infrastructure development on the transmission and distribution where at the moment there is far less targeting and is subject to a pricing review and short-termism. We need a system architecture that can then deliver the SG in a greater sense.	Long term planning (A3)
Concerns level of government understanding of the issues about smart grid. Access to decision making committees should be open to expert opinion from a competency basis.	Competency (C1)
Greater proactive coordination of connecting generation to the grid such that we can connect more generating capacity at least cost and engage more with community priorities within this. More partnership with infrastructure finance companies.	Proactive coordination (N1)
The energy system should not be profit driven because it is a basic human need and instead should therefore be need driven. Although some profit is required to upgrade the system, and re-invest in the system, this should be sensible.	Profit (E5)
Management of risk as technologies are displaced and new forms of large scale generation get implemented. We need to get cleverer in how we use new assets.	Risk & asset management (A3)
We need a culture of embracing technology to see what might be suitable. The grid is changing. There is little understanding of new technologies.There isn't the technical expertise at board level.	Technical competence (C1)
Gov. (includes Ofgem and DECC) intervention through setting certain policies to lead development of SG in the absence of voluntary developments, but also to exercise their role in managing for the greater good. eg, standards setting.	Mandated policy (G1)
Innovate and change quickly and fail quickly and get rid of failures quickly. We need an injection of new management, almost certainly from outside the industry.	To embrace change (C1)
Carbon reduction planning and implementation with setting up the right financial environment. It feels like local investment is more desirable than foreign investment.	Carbon reduction planning E6)
People will have to change their energy behaviour whatever happens. How do we make people not paying the bill motivated to change their energy behaviour - eg. children/ teenagers. Education of children to make energy consciousness a societal norm.	Behaviour change (C3)
The Government has to take a lead in levelling the playing field as well as setting up the conditions for change. The Gov. have to take a lead. Politicians need to take an active role and set examples in Gov. policy implementation. We are all in it together rather than pay lip service to it.	Top-down approach (E7)
It's about unblocking the barriers to fully leveraging the rich opportunities. We put a smart meter in and still settle on a dumb basis. So they are creating barriers to the optimum smart energy system.	Regulatory & market (U2)
The energy system should create a cultural shift in which people reflect on their energy usage and what is essential. The cost of energy would vary depending on what it is being used for.	Cultural change (E3)
Participants (consumers mostly) place sufficient value on a benefit (financial, decarbonisation) that it motivates or become willing to engage. These values and benefits may not just be to the consumer.	Valued benefits (G1)
Consumer protection adequate and comparable to current levels of protection.	Consumer protection (G2)
Makes sure that the latest technology has been included in the regulatory specifications. Challenging the use of conventional more wasteful technology.	Building regulations (U3)
The emphasis should be on reducing energy rather costs directly. Otherwise we will not necessarily reduce our emissions or costs if we bet on the wrong type of energy. There is a contradiction in having energy companies leading in energy conservation.	Energy before cost (A1)
Invest in people that can take the business to a new level. A culture that can embrace innovation and change. We need to get more interesting people involved in the industry and utilities.	Invest in people (C1)
Positive attitude to decentralised renewables and changes in investment in power grids. How?Community owned and controlled - this is positive.	Media attitude (N1)
There is a very blinkered focus on more of the same. Need to embrace change and this stems from the institutional level. Understanding of the need for innovation.	R&D (C1)
There has to be multiple options. Diversity of options reflecting diversity of potential outcomes. The Government will succeed because they offer a range of options.	Success & failure (E2)
Good policies but significant risks in the technical R, D &D in terms of capability to deliver at all levels. It's essential to have sufficient technical capabilities to deliver, ability to breakdown and manage project appropriately.	Technical practicalities (E9)
It's about understanding the risks and opportunities of those key pathways - what the risks and dependencies are. Also fundamentally about understanding what our energy policy is. What are the minimum levels of achievement against each of those wings. There isn't any option around the trilemma that doesn't involve consumer engagement.	Trilemma optimisation (U2)

Fig. 16. Criteria cluster forming the Governance Issue

However, there was evidence from Academic (A3) and Utility (U2) perspectives that the carbon reduction targets, in addition to cost and energy security, were accepted without question in driving objectives for smart grid development in the UK. Smart grid development was compared to a journey from an Academic perspective (A3) rather than an end in itself.

"*It's more like a journey that helps us to get there; one of the places to get is obviously to meet the 2050 targets. Agreed at a EU level, based on reducing CO2 emissions compared to 1990 levels and then hopefully effecting climate change. So that's the key thing. A smart grid can help us transition to meeting the challenges of the trilemma.*" (A3)

Objectives within policy directives should be transparent according to a Utility sector perspective (U2) while at the same time be flexible to admit changes from informed consideration of emerging challenges. Potential U-turns could occur over decisions to develop offshore or onshore wind resources for example but should avoid "*ad hoc short-termism*" and informed policy changes are essential (U2). Smart grid development is a process that involves a high degree of risk management and coordination as technologies are displaced to avoid stranded assets.

"*A recognition of whatever we do will need to evolve in ways we probably can't envision at this time. So depending on how successful we are with consumer engagement to think we can set in stone a policy direction now and not have to revisit it at some time would be naive. We also need to understand what the investment and policy stranding risks are so if we commit to a certain direction and it becomes obvious that is a culdesac we need to U-turn.*" (U2)

Risk management elaborated upon from an Academic perspective (A3) as it is important to give clear signals to encourage inward investment in smart grid development.

"*Risk management and asset management are related. We don't want stranded assets. Risks are involved in developing and investing in networks within a variable legislative environment. We must ensure investor confidence in the UK by sending out the right signals. Once assets are built we don't want to be constraining it off if we don't have the transmission capacity.*" (A3)

6.6.2 Innovation

In connection to risk management a change in management culture was called for from different perspectives (A1, C1, E9) to really embrace the challenges of smart grid development through technical innovation. There was a sense from a Commercial perspective (C1) that factors such as risk aversion and competence were holding back smart grid development in the GB system and new thinking from outside the industry would change this.

"*Risk aversion - a criteria for failure. Innovate and change quickly and fail quickly. See what works and see what doesn't work. That's absolute anathema to most utilities... We need an injection of new management. Almost certainly from outside the industry.*" (C1)

It was suggested from Commercial (C1), Academic (A1) and End user (E9) perspectives that the 'risk culture' of the electricity industry needs to change in order to open it to new approaches and technologies driving change in other 'smart' sectors. These perspectives reflected upon data-driven technologies of increasing complexity, and called for different competencies in the power industry such as already exist in the fields of IT and wireless connectivity for example (E9, C1, A1). One conclusion from this perhaps was the need to invest in people with skills not normally prioritised in electricity system development (C1).

"*Invest in people so that you can take the business to a new level. It's a real issue. You do need to get a lot more interesting people working for them [utilities] so you get a culture that is more exciting to embrace innovation and change.*" (C1)

Project management of large-scale and complex infrastructure projects (such as smart grid development and AMI as part of it) was also considered within an End-user perspective (E9), reflecting on recent Government led projects such as the NHS spine and child and working tax credit systems.

"*Good policies but underestimate or don't understand significant risks over the whole life cycle in the technical R, D &D in terms of capability to deliver at all levels. The risks escalate exponentially on big projects.*" (E9)

6.6.3 Energy culture

Moving the focus of governance to the implications for communities and individuals, a strong signal concerning the approach to engaging with energy end-users was received from a number of Perspectives. From a Utility perspective (U3) it was recognised that the latest low carbon technologies such as PV and LED should be mandated in standards to accelerate the energy transition through innovation. These technologies should also be made more widely available through subsidy where necessary to end-users to promote their engagement in the benefits of smart grids.

"*To make sure that the latest technology is standard. Challenging the use of more wasteful technology that should also bring the price down from economies of scale. For example LED lighting as standard. From the Government's point of view some subsidies should be there to help low income families.*" (U3)

Consumer protection was a primary consideration from a Government perspective (G2) reflecting on the likely proliferation of third party services and devices available to address some aspect of the low carbon transition. Concerns over customer redress in cases of mistreatment were at the heart of this perspective.

"*Under most energy arrangements there is clear consumer protection at its heart and options for consumer redress. Given a number of these smart features could lead to innovative business models coming forward in order to achieve the focal goal, the question is are consumers interests adequately protected in achieving this focal goal.* " (G2)

Beyond seeing energy end-users as the 'consumer', there is a 'partner-stakeholder' paradigm for end-users that needs acknowledgement in Governance of smart grid developments according to the perspectives from the NGO (N1) and Community energy (L1) sectors.

"*Yes, much more co-ordination function but a proactive co-ordination perhaps working with communities, and obviously wanting to put generation onto the grid, working out how to* *get the most on for the least cost over 5-10 years in a fair way. Prioritising generation which has the most social value and the most community value is important.* " (N1)

Contributing to the cultivation of 'energy culture', there is a sense from End-user interviewee comments and Criteria that they are willing to engage in smart grids and are motivated by the importance of low carbon energy transition, but critically, are seeking fairer and intelligible ways in which to do so. In exchange for their greater participation, they want smart grids to meet their needs but recognise that some options for this may fail according to an End-user perspective (E2).

"*There has to be multiple options - a broad range of options has to be offered. The politics and funding around the options should not favour one or the other. It's got to be flexible. We should accept that some options would fail and not be worth pursuing - have to set it up such that some will fail and not be too clever about it. Cannot know what is going to happen.*" (E2)

Trust is also of critical importance according to an End-user perspective (E5). End-user interviewees, whether individually or identifying as communities want to be on fairer and more equal terms to other energy system stakeholders than has hitherto been acknowledged.

"*Profit of the energy companies is a big and general problem behind why we are in such a state. Including water supply. I would like to see them nationalised again with a humanitarian rather than a profit oriented approach to energy supply. It's [energy] a basic human need. Should be need driven. Sensible profit to upgrade and re-invest in the systems will be required however.*" (E5)

End-user and community principles and motivation need to be acknowledged and rewarded as well as protected by governance legislation according to interviewees (E2, E5, N1, G2). Government should be setting the right examples and leading from the front in terms of bearing the risks and pain of making low carbon energy transitions according to End-user perspectives (E6, E7). The example of the how the financial crisis was managed was raised by one interview (E7) as not the way to go.

"*The Government really has to take a lead. The Government has to set an example and create conditions for saving electricity. I don't want to feel like I am wearing a hair shirt unless everyone else is also. "We're all in this together" has to be practiced rather than tipping it all on the population while they still drink champagne and caviar and have all three bars on the electric fire going! I would want for us to be all in it together in the way we haven't been over the financial crisis.*" (E7)

From a Government perspective (G1) it was recognised that their role included standards setting and 'acting for the greater good' if these were not met voluntarily:

"*Government places requirements on participants in the energy industry. Standards setting. Government can play a useful role in taking something forward, or in the absence of people doing something voluntarily.*" (G1)

The implementation of smart meters, or more specifically the IHD, has already been noted within Academic perspectives (A2, A4) as having an impact on demand reduction. But from a Commercial perspective (C3) interest was shown in how changes in behaviour with respect to energy could be cultured within end-users in addition to engagement with 'smart' energy saving devices.

"No matter how smart houses get, people will have to change their behaviour in order to survive in the future from an energy perspective. Whether it's avoiding peak power or spiraling energy costs, or whatever. We can't just sit back and wait for it to happen." (C3)

This view was supported by a perspective from the End-user sector (E3) who saw a more 'energy-cooperative society' is called for, that modifies demand to meet available supply. (E3) felt cultural change around energy has to penetrate deeper than financial considerations alone and requires more thought about how incentivisation and engagement in smart grids can be promoted through consultation with end-users.

"*The system, whatever's implemented should encourage people to reflect on what they value in terms of how energy is used. Even to create a cultural shift possibly. But we want to avoid a situation where the state decides what's right for you. So maybe that would be a consultancy exercise within this tiered system, what we as a country, or community, are agreeing upon is important.* " (E3)

From a Government perspective (G1) leadership in such aspects of energy culture or behavioural change are exemplified by smart meter rollout. Could this possibly reflect an emphasis upon a technology led approach than a sociotechnical one?

"*We spend a lot of time on informing consumers of the benefits of smart meters, demand side response etc. which I think is right. To an extent we are there but fall short of it with smart meters in that we have a nationwide rollout and we want every home to have a smart meter. But will we be breaking the doors down to say you must have a smart meter?*" (G1)

To tie-in Government intervention with clear and transparent long-term objectives accords with previously mentioned Academic and Utility perspectives (A3, U1, U2). Although in this case we are talking about changing attitudes and behaviour. From an Academic perspective (A1) observed, it is necessary to have realistic expectations about the pace with which cultural change in respect of everyday practices occur.

"*Very few examples of something that has been a commodity that no one has ever had to worry about becoming something that people actively care about. There are examples but they take a very long time. Look at recycling where it is now perfectly common and normal but it has taken 20-30 years of policy to get it to that stage but we need to be realistic about how much people will engage and I suspect most people don't have the time or interest to worry about it.*" (A1)

Further considerations about the need to align governance with long-term goals were contributed. From a Utility perspective (U2) the concern whether there is the right regulatory and market structure to enable and empower new stakeholders in the energy market, say from the introduction of TOUTs.

"*It's about unblocking the barriers to fully leveraging the rich opportunities. We put a smart meter in and still settle on a dumb basis! So they are creating barriers to the optimum smart energy system. Smart meters are giving us a tremendous opportunity assuming we are getting the necessary consumer engagement but in terms of making use of the AMI it needs some incentives.*" (U2)

From an End-user (E6) and Academic perspective (A1) there were concerns whether the incentives are aligned with energy policy objectives and whether the mechanisms for service delivery are misaligned? In the case of Suppliers being responsible for demand reduction, for example, can the intended outcome be expected if they are in business to sell energy?

"*Any system which starts off with all the incentives misaligned is never going to succeed. If energy companies are the primary mechanism for pushing energy conservation advice then there's some natural misalignment of incentives there. Lots of industries offer a service. Electricity was a service. Key stories around companies that have transformed themselves center around a manufacturer that has become a service provider."* (A1)

Following this observation, are there questions to be asked about how current governance of smart grids will change the electricity industry? Not only are incentives to affect the desired energy transition possibly misaligned, risking 'mass engagement failure', but also is understanding of the key messages that are used to formulate policy and governance in guidance towards achieving objectives? An example of such market policy inadequacy or incentive misalignment could be found in the area of peak-shifting according to a perspective from the Academic Sector (A1):

"*Addressing peak is expensive. If you fail to address it people notice. And it seems a relatively easy thing to do because we all run appliances at peak times and there is no feedback and no consequence. You can imagine demand response really working in that setting because all the incentives are clearly aligned. If they can avoid building another power station by paying for air conditioners not to be used at peak times then it works. You could fully automate it. Not a lot of control necessary - per house level of control with messaging over the Internet - don't need new infrastructure to do that. But at the moment it's not clear that the market is such that anyone could do that and make a profit."* (A1)

6.6.4 Summary of perspective patterning

The Governance Issue was the largest Criteria cluster together with the Technical feasibility Issue. In this Issue there was a much higher representation of perspectives from the End-user sector (25%) than within the Technical feasibility Issue (4%), indicating the relative importance of Governance to the End-user sector (see Figs. 9 & 9.1). Significantly, the Commercial sector was also responsible for 25% of perspectives within the Governance sector, indicating it is also of high importance to that sector. Three sub-groups were used to capture the patterning of perspectives within the Governance Issue. These concerned governance considerations within leadership, innovation and energy culture. A high level summary of the perspectives from different stakeholder sectors is presented below.

1. Perspectives from the Academic (A3), Utility (U2), NGO (N1) and Commercial sectors (C1) contributed Criteria to the leadership sub-issue. There were calls for Government to take a stronger lead in long-term infrastructure development (A3) with clear and transparent policy objectives and milestones (U2). Positive media management would help in this from an NGO (N1) perspective. A Commercial perspective (C1) was concerned about the clarity of Government energy objectives but from the Academic (A3) and Utility (U2) sectors there was agreement that these were to address the energy trilemma for which clear decarbonisation targets had

been set within the EU. Flexible policy (U2) and the appreciation of risk management (C1) to optimise asset usage (A3) were perspectives on the importance of clear policy from Utility, Commercial and Academic sectors.

2. Academic (A1), Commercial (C1) and End-user (E9) sector members had perspectives on the risk of developing smart grids and the need for competent project management to deliver (E). There was particular criticism from Commercial and Academic sectors of the apparent degree of risk aversion in the electricity industry, which was felt to be suppressing the pace of innovation.

3. A wide range of factors, considerations and Criteria made up the perspectives grouped under the sub-issue of energy culture. From a Utility perspective (U3) there was concern for the degree to which the latest technologies are entering the smart grid domain as 'standard'. While a Government (G2) perspective focused on 'consumer protection', perspectives from Community energy (L1) and NGO (N1) sectors wanted to see a greater realisation of a 'partner-stakeholder' paradigm that involved End-users and Communities in more partnership with the established energy industry actors. Several End-user (E2, E3, E6, E7) perspectives were directed at opportunities, or lack of them, for end-users to play a greater part in electricity system markets and decision-making. The profit motivation of large energy companies was seen as a barrier to this by (E5). A perspective on how to make an energy culture from (E7) considered Government's role in setting the right examples and leadership. From a Government perspective (G1) reflected on the need for enforcing standards, information dissemination to end-users and mandating policy in the absence of voluntary adoption. From a Commercial (C3) perspective, no matter how smart houses became it was felt behavioural change would still be important to realise targets. This view was supported in a perspective on how smart grids could help to deliver change from an End-user perspective e (E3).
   Smart meters were discussed in perspectives from Academic (A1) and Utility (U2) sectors with concerns raised by (U2) over the facilities, due to the absence of TOUTs, they make available under the planned rollout for end-users to engage and modify their energy culture. Using recycling practice as an example of behavioural change, an Academic (A1) perspective observed the need for a long-term vision over decades of years for it to enter a cultural level. To achieve the desired changes (A1) considered the crucial importance of aligning incentives and preparing appropriate governance mechanisms (such as markets) to encourage them to happen. From a Utility perspective (U2) saw the use of smart meters and AMI as a means of unblocking barriers to change.

6.7 Inclusion

Clustering of Criteria around the topic of Inclusion formed the second largest Issue. This was a highly important Issue to the End-user sector with 48% of End-user Criteria composing it (see Fig. 9 & 9.1). By contrast there were no Criteria from the Commercial sector. The Criteria are presented in Fig. 17. Sub-issues emerging from this cluster can be summarised as follows:

- Ways that make it possible for all stakeholders in smart grids to feel included and participate in the electricity system.
- The need to raise understanding of the issues surrounding smart grids at an 'energy cultural' level.
- The importance of convenience, intelligibility, clarity and understanding in assisting end-users to engage through smart grid technologies.

6.7.1 Ways to inclusion

From a Government sector (G1) perspective how end-users interpret the meaning of smart grids and the benefits to their lives will affect their participation.

"*I am not talking about the early adopters of the world - If you want wide scale participation it's got to have a clear benefit and it's easy to participate, with a broad interpretation of the smart grid. Better for the greater good. Valued benefits.*" (G1)

From another Government sector Perspective (G2) it was seen that shaping of smart grids is affected by the degree of end-user engagement in them.

"*This is about the level to which the end consumer is engaged in a particular scenario or future. I am saying if consumers were actively engaged you might have a different smart grid than if they weren't.*" (G2)

There were different perspectives from Community energy (L1), Commercial (C2), End-user (E6) and Academic (A1) sectors on approaches to addressing end-user inclusion at an energy culture level within the Criteria proposed by interviewees. These ranged across how to make it easier for end-users to use smart grid technology and facilitating business models and markets that they could participate in with a sense of equity and control. From a Commercial perspective (C2) clarity over the value to end-users from engagement would contribute to a sense of inclusion.

"*It is customer engagement but this is about creating a value proposition that the customer wants to buy.*" (C2)

From a Community energy perspective (L1), inclusion was promoted through ownership and active engagement.

"*Improved engagement with consumers over energy issues. I think it's partly through ownership as well. If you've got an ownership structure that people feel part of it rather than at the end of a long chain, they do engage. It's the opposite of passive consumers!*" (L1)

About creating a value proposition that the customer will want to buy People's relationship to energy needs to change to one based on a consumerist model like phones, wifi/internet rather than be in pre-payment.	Customer engagement (C2)	Inclusion
Improved engagement with consumers on energy issues. Partly through an ownership structure so that people 'feel part of it' encourages them to engage.	Consumer engagement (L1)	
Not relying on end user engagement but building it into the smart grid, facilitating it. Smart meters are a part of this.	End user engagement (E6)	
To what extent are consumers taking active decisions in the energy market? If the consumers were actively engaged we may see a different end result.	Consumer engagement (G2)	
Using technology to not only deliver efficiencies but also to change behaviour.	Consumer empowerment (L2)	
We need to find a cool and credible way of getting the educational message about the SG and SM over to the public. Need is to raise their value in the public perception.	Education & awareness (E7)	
Understanding of the issues associated with the energy trilemma and role that a smart grid (technically and socially) can play in addressing this.	Knowledge & understanding (G1)	
Whatever information is made available should help people to understand how it works and give them more confidence so that they feel it is working for them. Leading to a sense of being in control and empowerment as well as having more choice.	Understandability (E3)	
Important that we have a system that does not rely too heavily on very highly specialised knowledge held by a few people. Consumer engagement is promoted as a policy goal by politicians, therefore it is necessary to get across basic concepts about energy use. Visibility of energy use from the IHD.	Intelligibility (A2)	
The idea that people should just change in the interest of security of supply is wrong - there needs to be much more understanding beforehand. We don't realise what energy efficiency can do until we are shown or educated.	Education (E8)	
Education around energy efficiency. End user pay back periods for energy efficient tech. Education about the bigger picture, environmental impacts. It is a lever for a certain pocket of the population - everyone needs to benefit to hold onto, whether it be environment or cost.	Education (U3)	
We have 15 different suppliers giving us different tariff information all the time but how do we choose the best tariff. Concerns how economies could be realised through switching.	Making choices easier (E1)	
More and more decisions are made centrally in our lives and this takes the desire to know about and control things away from us. Who has control? Data is power.	Decision & control (E2)	
Who's got control? How is it controlled? I'd like more democracy less corporate control. Fair for the every day user. More transparency in control.	Control (E4)	
The options have to be very user friendly and almost automatic, because a lot of people will not understand or have the time to interact.	Simplicity (E7)	
Clarity of information dissemination to enable easier choices.	Simplicity (E1)	
It really has to be idiot proof and these things are not. It has to be really simple or upgradeable to have other levels of complexity. A lot simpler than the basic smart phone.	Ease of use (E8)	
Potentially a lot of signals being sent to ask the end user to do something from different stakeholders. Where is the transparency in all this and to what extent does the consumer feel empowered to act in their own interest.	Transparency (G2)	
Adoption is supported by ease and convenience of participating in the smart grid. Particularly effects the non-early adopters.	Convenience (G1)	
For the individual there is a convenience issue. With accurate information the consumer is more informed on how they purchase energy. Compare to how food is purchased, clearly visible and makes it easier to move supplier.	Convenience (U1)	
People didn't use to think about recycling but not do it automatically. Energy use could adopt a similar approach with a colour coding system and perhaps the choice of AC and DC to use the most efficient means of supplying energy.	Social & environment (A3)	
Better insights into personal energy behaviour. Don't care about the display, want access to the data. Would like access to open data. Would like to be authorised to access own end-user data.	Open data (E9)	
Advocate open access to data leading to consumer empowerment.	Open data (L2)	
Information/education to support more individuals to apply to local authorities for their insulation and energy conservation rights to be met.	Rights & responsibilities (E5)	
Any scheme which requires full time end user engagement will not work.	Realistic expectations (A1)	

Fig. 17. Criteria cluster forming the Inclusion Issue

Ownership of the local municipal utility was another important consideration raised in support of end-user inclusion in smart grids from an Community energy sector perspective (L2) and may point the way to how smart city energy islands could evolve on a community energy basis.

"*The whole idea with Berlin was that the end-use consumer buys the grid. They run 'UKPower Networks'! London would buy the grid so the people own it and the Government say, runs it. Even though it's very separate, it's still owned by the people.*" (L2)

On inclusion through engagement with smart metering, there was caution within one End-user perspective (E6) about relying too heavily upon end-user capacity to drive the development of smart grids towards particular goals and targets.

"*The average family throws away the equivalent of £50 food per month, which for me is a sign of how bad we are at being empowered around our own homes and waste. This backs up what I am saying about how we can't rely upon the end-users if we want change. It's got to be much bigger.*" (E6)

From an Academic perspective (A1) it was suggested that inclusion could be built incrementally through coordinated elements of participation and not asking for too much in each step.

"*Any scheme which requires full time end-user engagement will not work but elements of low level coordinated participation would engender individuals with market power.*" (A1)

Implicit within this perspective (A1) is the question; can we consider evidence of behavioural change as a marker for inclusion? And if so, how do we address the Inclusion Issue by encouraging behavioural change through different forms of end-user behaviour? From an Academic perspective (A1) peak shifting could be a good example of a low cost method of end-user engagement that realises important benefits to the smart grid.

"*The seduction of changing people's energy behaviour is that it seems so easy and the gains are so big - if you can just persuade people to not use everything at the same time - there is enormous reduction in peak capacity requirement but it is really hard to encourage people not to all use everything at peak time. The potential gains are enormous but it's surprisingly hard to realise them.*" (A1)

6.7.2 Raising understanding

The use of smart metering from a Community energy sector (perspective L1) could help end-users understand how their energy behaviour connected to the source of their electricity. It could offer frequent feedback on consumption, cost and financial rewards through common mobile interface devices for example.

"*Principally I am thinking about getting people to understand the link between switching the light on and having a wind turbine they have to look at. It's not about education as much as engagement through smart metering. Feeding back information to educate them - you have your app on your iPhone which sends you a warning when your electricity's going through the roof. Or positive things like sending you £20 today because the sun's been shining on your solar roof.*" (L1)

From an End-user sector perspective (E9) there was a need for access by the user to the data recorded about their energy use in the home and not the need for the IHD. They also wanted to be able to maintain control over commercial third party access to their data through the use of 'permissions'. This perspective also recognised the need to benchmark the impact of smart metering against national energy statistics.

"*I don't really care about the display, I would like access to my own raw data. This would stimulate analysis and innovation of things not thought about to begin with, but once the data is out there, it could happen. I would like authorisation to access that data. I want to have that control. I think the Government should be publishing overarching energy statistics, because you need that information to evaluate the success of the system as a whole anyway.* " (E9)

Communicating the need for engaging with smart grids and the wider issues connected to it, were the concern of perspectives from Government (G1) and End-user sectors (E7). Contrasting visions were presented that illuminated their differences in approach to engagement. The Government approach appeared prescriptive on how end-users should understand and what they could understand.

"*Understanding the issues associated with the energy trilemma and role that a smart grid can play in addressing this. Understanding tools and ways of operating things. Understanding that a smart meter enables you to do XYZ and therefore has a useful role to play. Understanding the adoption of smart grids with distributed generation etcetera can be helpful. You got to have some knowledge of all this. I wouldn't expect them to understand how a piece of technology worked but something more at a very high level - understanding the roles and outcomes that the smart grid and people can play.*" (G1)

This contrasts with an End-user sector perspective that was more concerned with the complexities of the message and how it was conveyed.

"*Whatever you implement you have to have a massive public education and awareness campaign. I would say a television advertising campaign. Remember 'Creature Comforts'? I was so inspired. Something this big you need to do it well. Give it to somebody that knows how to spend money to make it cool and credible, not look like 'Protect and Survive'! People have to find it amusing so they want to engage with it. They don't want to be talked down to. Are we set on these two dreadful characters [Gaz and Leccy]?*" (E7)

The advertising campaign launched recently by Smart Energy GB [63] to introduce smart meters was referred to by an End-user sector interviewee (E7) because of how they appeared from that perspective to be un-engaging. The principal characters, '*Gaz*' and '*Leccy*', have also been parodied by at least one blogger within the Commercial sector already [64].

It is clearly challenging to engage the interest of generations of energy end-users who have been accustomed to passive consumption of electricity and may not have made the connections between their practices and the changing electricity system around them. Even highly experienced motivational speakers like Sir Bob Geldof, hired to speak at the Smart Energy GB launch of the Gaz & Leccy campaign in 2014, struggled to find anything enticing to say about the smart meter, despite its potential to become an extremely influential and invasive technology in our lives. If winning the hearts and minds of millions of people to accept smart meters into their homes and engage with smart grids through the IHD is the Government objective, then it presents a formidable public relations challenge from one End-user perspective (E7) where particular characteristics of national cultural identity were brought into consideration.

"*It needs to be in radio interviews on all the channels. They need to talk about it on Radio 4. We need lots of discussions at all kinds of levels. And hopefully they'll [smart meters] get lampooned. It needs to enter the public consciousness. It's got to culturally engaging and assumes that you feel up against it. We are conditioned to defeat, suspicious of our leaders, we expect the worst – and laugh at it. It's not like it was a 100 years ago.. You can't lay it on from above. What I think with Gaz and Leccy, they are a bit blokey, or made up by someone who has gone to Harrow.*" (E7)

Insights shared in the last comment may be instructive in how the smart meter, to successfully integrate into our lives and be an effective means to energy behavioural change, needs to penetrate into a cultural level of acceptance. This perspective aligned with another End-user perspective (E3) on relationships between home, identity, energy technology and cultural norms.

"*We should be able to feel our home gives us what we need and makes us part of society as well. Someone who has to currently turn off their heating a lot will suffer physically say, but they may also feel separated and more isolated. We need to look at how we prioritise our energy use. It's a matter of inclusion. People need to feel confident when they are using the system that they are able to have it work for them and that they can make decisions that will benefit them, so any information about it needs to be clear and help people feel in control and empowered.*" (E3)

Expectations of the time needed to culturally adjust to such technological interventions in the home, were placed at the order of a generation from Academic perspectives (A2, A3) similar to waste recycling practices. Such considerations could reflect on the complexity involved in adjusting to new services as well as the need for support in some cases.

6.7.3 Factors assisting end-user to engage

Moving to the factors assisting end-users in smart grid engagement, there were several perspectives from across the Government, End-user, Utility and Community energy sectors. Intelligibility of smart meter interfaces from an Academic perspective (A2) and services to assist end-users feeling in control from End-user perspectives (E2, E3, E4) were considered. Some interviewees (E1, E7, E8) stressed the importance of simplicity in operation and feedback from smart energy systems.

"*It really has to be idiot proof and these things are not. I'll probably have a heart attack with the IHD! I mean I will get seriously anxious. You can have data overload. You would have to have something that is really simple, or upgradable, or can have additional levels of data but starting off at the most basic level, so a little old lady can understand it. And then if you wanted to introduce levels of sophistication later on you could do so, but it needs to be extremely simple. It needs to be a lot simpler than the basic smart phone. Hopefully the system will be designed in such a way that you can phone up someone as you can if you have a problem with your Apple.* " (E8)

To assist in making choices, clarity of use and simplicity of information and convenience were seen as critical considerations from another End-user perspective (E7).

"*It has to be so simple to the end-user, it has to be almost automatic. And really communicate well. It's no good having little symbols and so on. Because I know a lot of people who, because they are too busy, too distracted or lack the language skills, the novelty will wear off like with my mobile phone here, even if they do learn to interact.*" (E7)

"*Simplicity with ease of operation, execution - we shouldn't need to be doing anything as we are only turning our lights on and off. So it's like dumbing down of clarity of information to make easier choices, I don't need to know how it operates. So the simplification to people of this complex information is crucial to people engaging with the smart meter.*" (E1)

Achieving these key considerations was conditional upon transparency according to a Government perspective (G2). Transparency was interpreted in two broad ways - one where it supported the understanding and decision making of the energy end-user to feel empowered and in control of their energy-related practices. The second - where end-users were making decisions in the knowledge of possible impacts upon the wider grid. Whether such a level of understanding and control as this would be possible may not be knowable until there is more experience of smart energy technologies connected. Could it also become a benchmark to assess levels of end-user competence and therefore directly addresses the Issue of Inclusion?

"*Transparency and simplicity. To what extent do the consumers feel empowered to act in their own interest and secondly in the interest of the wider grid? It's that user interface with the smart grid that I am concerned about. The transparency of what the smart grid is and how I interact and derive value from it. The more transparency of information they have the more consumers will feel empowered.*" (G2)

New, commercially available intelligent and assistive technologies (such as are found in smart phone apps and increasingly in home automation products) were considered from a Community energy perspective (L2) to be another way to promote inclusion. Providing end-users with reminders to support their behavioural change or assisting in the background by altering lighting and heating settings when they are present.

"*Smart is an integrated look at not only the mistakes you are making but also integrating all of the opportunities that you don't know about. So if energy is more prevalent and cheaper at this point coming from your renewables on the roof, if you use your provider now, you are 75% more likely to be using renewables.*" (L2)

This example reflects greater dependence on a technologically led lifestyle however and may not appeal to those seeking less technology and more direct experiential learning from energy usage, as in the case of some perspectives from the End-user sector (E2, E4, E7).

The benefits of engagement were also necessary to make clear from a Utility perspective (U1).

"*The elimination of estimated bills for individuals makes life easier. I don't have to argue with suppliers, it all happens in the background in a seamless way. Can change supplier instantaneously, easier than the current system. Consumer empowerment is a key feature by allowing taking more control similar to taking control over mobile phone.*" (U1)

Understand end-user '*Rights and Responsibilities*' was an End-user perspective on facilitating inclusion (E5) in respect of engaging with schemes like Ofgem's 'Carbon Emissions Reduction Target' (CERT) and 'Green Deal'. This interviewee's perspective was concerned with whether more effort is required to raise awareness of such measures especially to assist poorer households and alleviate fuel poverty. Similar views have been reported in [65].

6.7.4 Summary of perspective patterning

Approximately half of the Criteria composing the Inclusion Issue were from the End-user perspective, which reflects the high degree of their concerns around inclusion within the meaning of 'smart'. The Inclusion Issue addressed considerations of understandings and meanings of smart grids as well as their value and benefits through different means of stakeholder participation and engagement. Analysis of this Issue was then approached by dividing Criteria into three sub-issue clusters that are summarised below:

1. From a Government sector perspective (G2) the ways in which end-users interpret the meaning of smart grids would shape their participation in them. From a Commercial sector perspective (C2) engagement would require clear value end-user propositions and ownership was another form of inclusion from the Community energy sector perspective (L1, L2). There was concern from an End-user perspective (E6) about the degree of expectation placed on end-users to drive energy behavioural change, which aligned with an Academic perspective (A1) over how expectations should not expect fulltime engagement from end-users and be pitched at a low level with long time horizons to culture behavioural changes. The gains to be made from behaviour change, if end users can be persuaded, are very large for relatively low cost from an Academic perspective (A1).

2. Smart metering was seen as a means to raise end-user understanding of the energy system from a Community energy perspective (L1) but from and End-user perspective (E9) access to their raw energy data not the IHD was most important. Communicating the meanings of smart grids and the importance of engaging with them through smart metering then became the focus of differing perspectives on how to approach this from a Government sector perspective (G1) and an End-user sector perspective (E7). The nuances of penetrating to a cultural depth of understanding were inherent in perspectives from the End-user sector (E7, E3) and comparison was made with the transition to acceptance of recycling within cultural consciousness from Academic sector perspectives (A2, A3).

3. Factors assisting end-users to engage with smart metering technology were considered within several End-user perspectives (E1, E2, E3, E4, E7, E8) where the importance of intelligibility and simplicity in operating interfaces (such as the IHD) were stressed by (E1, E7, E8). From a Government sector perspective (G2) transparency was seen as critical to understand both how to engage and what the consequences of that engagement would be. From a Community energy perspective (L2) some of these functions, in support of energy behaviour change, could be provided by commercially available forms of 'intelligent assistive technology', but this proposal was not appealing to those in the End-user sector (U2) and Academic sector (A2) who had already question the value of increasing dependence upon technology.

4. A Utility perspective (U1) was to emphasise the benefits of clear billing from smart metering in assisting end-users but from an End-user sector perspective (E5) better knowledge of rights and responsibilities with respect to benefits that could be found in energy conservation and RET schemes would be important.

6.8 Finance

The Issue of Finance cuts across all of the aforementioned Issues at different scales and contexts and was formed of the Criteria cluster presented in Fig. 18. This Issue is composed of Criteria contributed by all sectors but 47% were from the End-user sector (see Figs. 9 & 9.1). The complexity of interviewee concerns and considerations within the Financial Issues warranted in some case fuller quotations. Key considerations emerging from this cluster include:

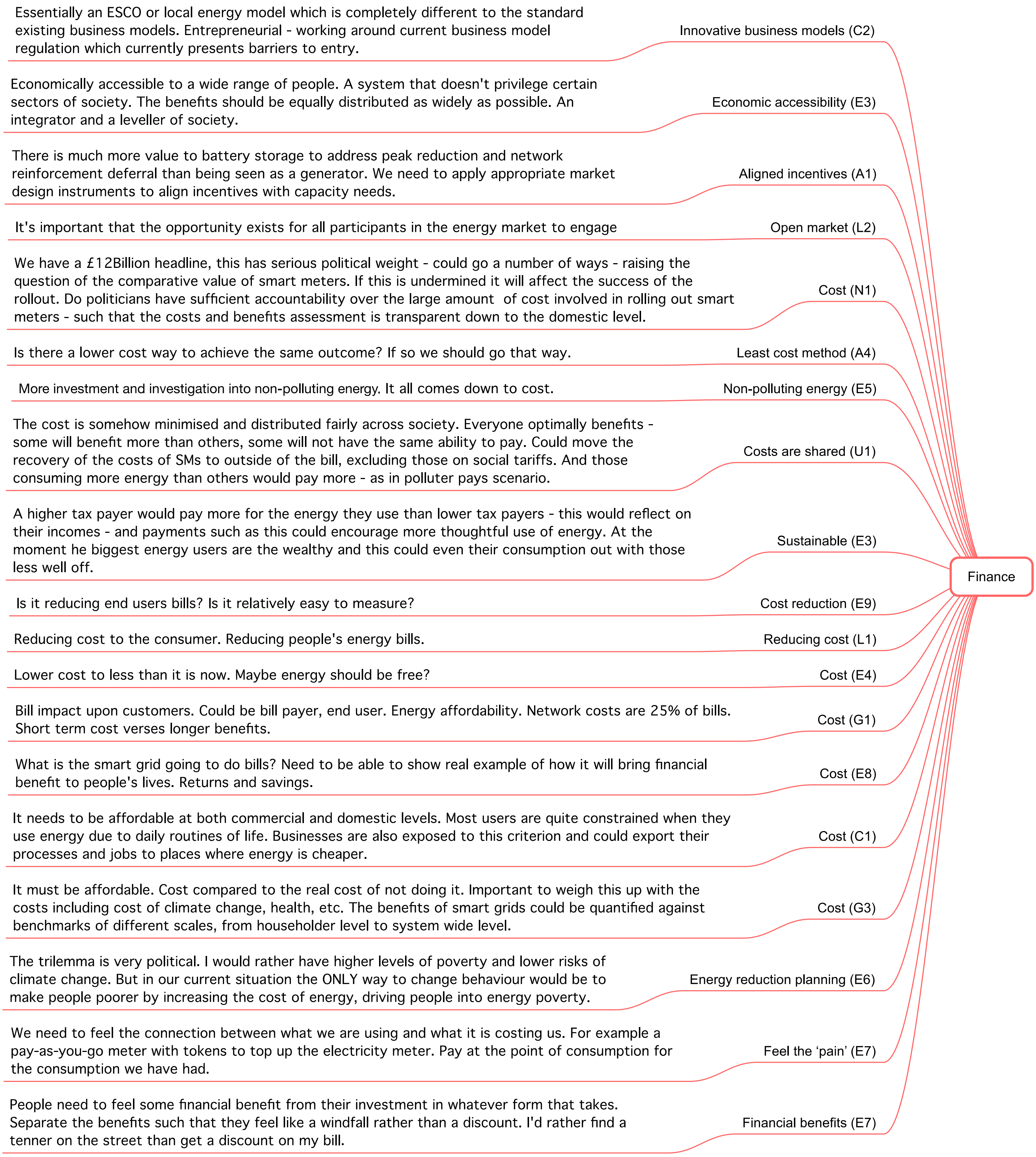
- How costs of smart grid development impact upon end-user energy bills.
- Smart grid development should be a least cost process compared to the cost of not doing it to address the energy trilemma.
- How smart grids can be marketised and financial benefits accessible to all stakeholders.

6.8.1 Cost to end-users

Smart grid technical development is very expensive and usually seen as an ongoing, incremental and iterative upgrade and extension process of energy assets including networks, generators and other elements of large-scale infrastructure according to a Government sector perspective (G3). The advent of smart metering extends the scale of smart grids into the home with the distinction that, potentially, for the first time there is integration of distributed 'smartness' into the wider grid infrastructure. From an Academic perspective (A3) this marks a step change in grid capabilities that has not been seen before. Smart metering is a 'big ticket' project (estimated at £12 Billion to £18 Billion by some interviewees) but not consolidated into a single asset, rather an integrated network of assets that play a proportional role according to (A3). From this, they could 'open-up' untapped commercial opportunities that extend from the home to distributed generation assets according to a Commercial sector interviewee perspective (C2).

"*The bulk of money that is going to be invested is in generation and transmission - upwards of £100 Billion in the UK alone, maybe £120 Billion over the next 10-15 years. You can argue smart metering is one project but it is a distributed asset - it's not reliant upon one major asset, one power station, it involves meters in everyone's home - so it's different in that sense.* " (A3)

The extremely large amount of money required to drive a low carbon energy transition and Government financial commitment to subsidising RETs is reflected in the recent £300 million green energy subsidy, Contracts for Difference (CfD) auction [66, 67]. Concerns about the relatively level of national investment in low carbon generation assets were raised within End-user sectoral Perspectives (E5, E6) in comparison with annual subsides paid to the fossil fuel industry. Financial figures vary for the amount of annual subsidies to the fossil fuel industry due to their disbursement in various forms. However, they have been conservatively estimated at £4 Billion per annum by the Organisation for Economic Cooperation and Development (OECD) [68], which includes the Overseas Development Institute (ODI) estimated average of $1.2 Billion per annum for just oil and gas exploration [69]. A clear concern about this in terms of carbon reduction planning was contained within one end-user perspective (E6):



Essentially an ESCO or local energy model which is completely different to the standard existing business models. Entrepreneurial - working around current business model regulation which currently presents barriers to entry.	Innovative business models (C2)
Economically accessible to a wide range of people. A system that doesn't privilege certain sectors of society. The benefits should be equally distributed as widely as possible. An integrator and a leveller of society.	Economic accessibility (E3)
There is much more value to battery storage to address peak reduction and network reinforcement deferral than being seen as a generator. We need to apply appropriate market design instruments to align incentives with capacity needs.	Aligned incentives (A1)
It's important that the opportunity exists for all participants in the energy market to engage	Open market (L2)
We have a £12Billion headline, this has serious political weight - could go a number of ways - raising the question of the comparative value of smart meters. If this is undermined it will affect the success of the rollout. Do politicians have sufficient accountability over the large amount of cost involved in rolling out smart meters - such that the costs and benefits assessment is transparent down to the domestic level.	Cost (N1)
Is there a lower cost way to achieve the same outcome? If so we should go that way.	Least cost method (A4)
More investment and investigation into non-polluting energy. It all comes down to cost.	Non-polluting energy (E5)
The cost is somehow minimised and distributed fairly across society. Everyone optimally benefits - some will benefit more than others, some will not have the same ability to pay. Could move the recovery of the costs of SMs to outside of the bill, excluding those on social tariffs. And those consuming more energy than others would pay more - as in polluter pays scenario.	Costs are shared (U1)
A higher tax payer would pay more for the energy they use than lower tax payers - this would reflect on their incomes - and payments such as this could encourage more thoughtful use of energy. At the moment he biggest energy users are the wealthy and this could even their consumption out with those less well off.	Sustainable (E3)
Is it reducing end users bills? Is it relatively easy to measure?	Cost reduction (E9)
Reducing cost to the consumer. Reducing people's energy bills.	Reducing cost (L1)
Lower cost to less than it is now. Maybe energy should be free?	Cost (E4)
Bill impact upon customers. Could be bill payer, end user. Energy affordability. Network costs are 25% of bills. Short term cost verses longer benefits.	Cost (G1)
What is the smart grid going to do bills? Need to be able to show real example of how it will bring financial benefit to people's lives. Returns and savings.	Cost (E8)
It needs to be affordable at both commercial and domestic levels. Most users are quite constrained when they use energy due to daily routines of life. Businesses are also exposed to this criterion and could export their processes and jobs to places where energy is cheaper.	Cost (C1)
It must be affordable. Cost compared to the real cost of not doing it. Important to weigh this up with the costs including cost of climate change, health, etc. The benefits of smart grids could be quantified against benchmarks of different scales, from householder level to system wide level.	Cost (G3)
The trilemma is very political. I would rather have higher levels of poverty and lower risks of climate change. But in our current situation the ONLY way to change behaviour would be to make people poorer by increasing the cost of energy, driving people into energy poverty.	Energy reduction planning (E6)
We need to feel the connection between what we are using and what it is costing us. For example a pay-as-you-go meter with tokens to top up the electricity meter. Pay at the point of consumption for the consumption we have had.	Feel the 'pain' (E7)
People need to feel some financial benefit from their investment in whatever form that takes. Separate the benefits such that they feel like a windfall rather than a discount. I'd rather find a tenner on the street than get a discount on my bill.	Financial benefits (E7)

Fig. 18. Criteria cluster forming the Finance Issue

"*I am not that bothered who invests [in renewable energy infrastructure]. Local investment is desirable but secondary to making things renewable. So you want to stop subsidising fossil fuel extraction and subsidise renewable energy infrastructure building. If you set that up right, everyone will be competing for it. It is the essence of carbon reduction planning. As a nation we have always subsidised the things we want to make happen. Food production.* " (E6)

A perspective on the high cost to the end-user of the current approach to electricity system development from the NGO sector (N1) addressed accountability for cost of the smart meter rollout. In view of the potential for a number of challenges to the success of this programme, including design issues, meter cost, acceptability and adoption by end-users and return on investment to the bill payer for example, (N1) reflected:

"*If you've got a £12bn headline, that carries some serious political weight. There are lots of scenarios where that could go. You've got some consumer associations that are somewhat skeptical about the comparative value against cost of smart meters. That's turning into headlines and people are less likely to support the roll out because it costs more than it should. Why is it costing us this much? And what are we getting out of it? Is probably a reaction people will have.*" (N1)

Other Criteria concerning the cost of smart grid developments and whether they could reduce the cost of electricity to end users were the subjects of perspectives from different sectors (C1, E4, E8, E9, G3, L1). Although most interviewees wanted bills to be less, others saw that they would rise, at least in the short term, to pay for the energy transition. From a Utility perspective (U3) costs to end-users were going to rise:

"*I don't think the average person realises that energy costs are just going to continue increasing.*" (U3)

But from a Government perspective (G1) the question of direction in costs to end-users was still unclear but there were inherent concerns about energy affordability to be determined here.

"*Starting point is cost and how that filters down to various customers. If it starts pushing that up and it gets more expensive - then we don't want that. What's the impact of the cost to the energy end-users? And might there be some longer term benefit?*" (G1)

From one Academic sector perspective (A4) the cost of smart meters (and IHDs according to (A2)) could be justified if their presence could stimulate an amount of demand reduction if the experience of water metering were to be repeated.

"*The water companies found that once people had these meters in their homes and could actually see their usage, even without any change in the rates, there was a 30% reduction in their water use. Just the installation of a smart meter could encourage people to bring their consumption down – which affects the decarbonisation corner of the energy trilemma.*" (A4)

6.8.2 Least cost development considerations

Reducing the cost of the low carbon energy transition is the subject of one dimension of the energy trilemma. From an Academic perspective (A4) a key feature of assessing costs and benefits is by the least cost method of achieving that goal, or in the deferred cost from not doing it from a different Government sector perspective (G3). According to (G3), it is possible to make large savings by introducing innovative smart grid processes at a system level and creating appropriate markets to monetise them, before involving the individual household level.

"*We tried to investigate on a very small scale the idea of a thermal storage in a hot water tank that we use for our heat network as a buffering vessel that could be used as a store of surplus electricity from night time wind generation. That would benefit our local wires people, who have a lot of power at night and nothing to do with it, and we would use the hot water in the morning before our gas engine had to kick-in. So we could both benefit from this. You have a carbon benefit and a cost thing and that in some tiny way says that you can maximise your renewable resource and use it sensibly. But agreeing on that as an economic benefit was very difficult in negotiations with the utility even though Ofgem supports it."* (G3)

The sensitivity and appropriateness of new market mechanisms was a consideration from an Academic sector perspective (A1), which concerned whether incentives are correctly aligned at capacity market level to encourage positive innovation and cost savings.

"*Capacity markets are one thing. They introduce incentives for people that do not exist in the current market. I'd advocate rewards to consumers for peak load shifting by using domestic appliances at off peak times, and battery storage for deferred reinforcement of the network, than using it for arbitrage, are examples where market design is not sufficiently sensitive or flexible enough to provide the right incentives. We must ensure new systems aren't deployed because of misaligned incentives, as they are never going to work from the start. The key danger is that a new scheme is introduced with misaligned incentives from the beginning and these then get embedded.*" (A1)

Another Government sector perspective (G3) considered whether the costs of not making smart energy innovations had been understood so an assessment of the value and direction of novel interventions through cost-benefit analyses could be made:

"*You can segment the costs - at generation , distribution, transmission, end-user - but what are the benefits of addressing these place? Does the Government know what are the costs of not doing that and therefore what is the goal? It's very difficult to achieve something if you don't know why you are doing it. The key feature is what is the benefit of doing this against not doing it.*" (G3)

6.8.3 Marketisation of smart grids

From the Commercial and Community energy perspectives (C2, L1, L2), Criteria were proposed, illuminating the potential for smart grids to support a diverse range of Energy Service Companies (ESCOs) and innovative business models. However, from a Commercial sector perspective (C2), barriers to market entry (such as minimum scale of the customer base) would need to be addressed by Ofgem and the Technology Strategy Board before they could be successful.

"*If I’m a new energy supplier and want it to be a municipal energy company based in whatever city there are significant barriers to entry with the current regulation. Credit cover is huge, entry processes are huge. Anything over 250000 customers and then you are hit by a raft of other obligations. Ofgem would have to fundamentally change the way they regulated the market.* " (C2)

Contained within the smart grid vision is a paradigm shift for energy markets according to perspectives from the Community sector (L1, L2). From one perspective (L1) the potential of smart grids is to turn over the control of energy markets to the bottom upwards, away from the top downwards. An example was given by (L1) where 'energy islanders' are selling their power and make viable profits. According to this perspective (L1), this model would work even if the generation assets were not locally owned.

"*The great thing that smart grids do is change the paradigm for the energy network. Say we get 5p a unit for electricity we produce from our solar farm. Consumers pay 15p. And you pay 2p for distribution. So you have 8p margin - that's about balancing and servicing. If you can keep that servicing cost down with modern IT equipment to me it seems there is enough margin in there to have a viable business using energy islands. It's impossible to do it without smart metering. Secondly it needs legislation to unplug the licensing. If you've got this cumbersome licensing system, that's unnecessary and too expensive.*" (L1)

This perspective on the potential for viable business model innovation if markets were opened was echoed from another Community energy sector perspective (L2) that reinforced the opportunities active engagement in the energy system gave them if markets were opened to their scale of operation.

"*We need a Governmental strategy with an open market inside it. Open market is very important. It is very important - the whole uptake of the consumers - is dependent on the behaviour change of the passive consumer.*" (L2)

A business model entailing the scaling-up of distributed community resources, to overcome minimum size entry barriers was outlined in another perspective from the Community energy sector (L1). It concerned the importance and opportunities for increasing market presence by pooling generation capacity from consortia of federated community energy schemes comprising of a few MW each.

"*Form a coop between Community Benefit Societies, workers and investors, so you have got three stakeholders: people who invest, people who work in it and people who trade with it. The traders get dividends based on the trade. The workers get dividends based on their work and investors get a return on their investment. You can't do each of these with an individual team because they are too small. But if you make them too big, you've lost the community engagement. It's not just about community energy its about accountability. Most people you talk to are really positive about it. They trust it more because they don't think they will get ripped off.*" (L1)

The sentiment of 'being ripped-off' by current market rules favouring large-scale players in the energy system was echoed in a perspective from the End-user sector (E3) that was concerned about benefits distribution.

"*It should be a system that doesn't privilege certain sectors of society. Benefits should be equally distributed.*" (E3)

And from the Academic sector (A1) an interesting parallel with the road network was drawn that contrasted business practice there with the electricity network.

"*If the grid is a common good then you let people around the edges make profit. No one's trying to stop UPS from running their business on public roads but they need good roads to make their business work.*" (A1).

From an operational standpoint, a Utility Perspective (U2) recognising the volatility in electricity spot price arising from intermittent sources of generation, contributed opinions including how a lack of tools are available to energy suppliers to deploy incentives to modify demand, such as with TOUTs.

"The question is what incentivises the energy suppliers at the end of the day? They should be incentivised because of the intermittency of renewable generation, but also to try and encourage them to defer energy usage when we have to despatch low merit order gas to meet peak demand. These are times when you would want tariffs to incentivise customers to make use of zero marginal cost generation (once it is built it costs the generator virtually nothing to run it - apart from a bit of maintenance and fuel in the case of nuclear). The TOUT has not been deployed in anywhere near the level of sophistication to follow the spot price." (U2)

Perspectives from Academic (A1) and End-user (E6) sectors prioritised the need for energy demand reduction as a means to bring down costs. From these perspectives (A1, E6) there was inherent uncertainty in the cost of energy due to the mix of generation available but a focus on cost as a priority could inadvertently incentivise the use of fossil fuels like coal as the cheapest way of producing electricity. It was therefore important, according to this perspective, to align incentives with targets and to not rely upon energy Suppliers to head the process of demand reduction.

"*If you are reducing energy demand the costs are going to come down no matter what. You can change the emphasis of where you try and produce energy. The emphasis should not be on reducing costs, it should be on reducing energy consumption and CO2 goes with that. It's broken by having energy Supply companies trying to encourage the conservation of energy!"* (A1)

There were perspectives from the End-user sector (E6, E7) on how personal financial rewards from engaging in smart grids could be offered to maximise the sense of benefit. The psychology of feeling better from windfall gains was discussed from the perspective of (E7) who said it was important to separate perceptions of loss (from the electricity bill) with financial rewards in return for engaging in some form of electricity market activity such as deferred demand:

"*It's not enough to reduce your bill as a refund to be a benefit. It's not 'financial gain', it's just a 'reduction of loss'! A mitigation of loss. If you were to ask me would I rather get a £10 discount on my bill or find a tenner on the pavement, which one is going to give me a better feeling like - "Oh, that's lucky!" it would be the latter. That's the difference.*" (E7)

An End-user sector perspective from (E6) introduced gamification as a novel way to attract end-user interest and engagement in DSR activities.

"*End-user awareness is primarily about saying if you are aware you can be clever about your lifestyle and save money. It's also about making them aware of how they can make windfall gains from playing games. And we like playing games - we like taking risks, it's gambling isn't it? The dream of a big win.*" (E6)

Peak shifting, arbitrage and other forms of energy behaviour could also be amenable from this perspective (E6) to induce end-users to engage in an otherwise common place acceptance or passivity in respect of the electricity system.

"*[Corporates] will come up with all sorts of creative options if they've got a genuine financial incentive to reduce our energy use. Because I think yeah, all these things are good and people will sign up for it and take risks. Absolutely.*" (E6)

From this perspective, the emphasis for coming up with ideas to encourage engagement in end-user demand reduction was still upon the energy Suppliers but could highlight the conflicts of interest raised in the perspective addressing alignment of incentives (see above) from (A1).

6.8.4 Summary of perspective patterning

Approximately half (47%) of the Criteria composing the Finance Issue were from the End-user perspective, this is a very similar conclusion to the Inclusion Issue patterning, and reinforces the high degree of End-user concerns around these Issues. The Finance Issue addressed considerations of the cost of electricity and electricity system renewal, how these may be assessed in terms of least cost and how smart grids could facilitate new market configurations if they were opened to a wider range of stakeholders. Analysis of this Issue was approached by dividing Finance Issue Criteria into three sub-issue clusters summarised below:

1. The incremental nature of electricity system renewal was commented on from a Government perspective (G3). The high expense to end-users from an Academic perspective (A3), distinguished smart metering from other large singular electricity infrastructure developments (eg. a windfarm or transmission line) due to it being of a distributed, multiple asset configuration, which could support new energy markets from a Commercial perspective (C2). To support smart grid development there was concern from an End-user perspective (E6) about the large difference in level of financial subsidy still paid to the fossil fuel industry, who's view was that this conflicted with decarbonisation targets. This perspective was echoed by an Academic perspective (A1) in terms of alignment of incentives that included concerns about electricity Suppliers leading demand reduction efforts. The high cost of the smart metering rollout was reflected on from an NGO sector perspective (N1) and a perspective from the Utility sector (U3) saw that end-user bills would rise as a result, although this was still unclear from a Government perspective (G1). An academic perspective (A4) suggested that the presence of smart meters alone would reduce demand, and so the amount of their electricity bills.

2. It was important to pursue least cost methods in addressing the cost dimension of the energy trilemma from Academic (A4) and Government perspectives (G3), but this also entailed estimating the cost of not making interventions. One approach could be to break down their cost to different parts of the electricity system according to (G3) but such initiatives had encountered difficulties in practice partly

due to the market arrangements to accommodate novel energy saving practices at a system level (G3). This perspective aligned with comments from an Academic perspective (A1) of concerns about market sensitivity and flexibility to new energy market opportunities.

3. Commercial (C2) and Community energy perspectives (L1, L2) were shared concerning barriers that currently exist for smaller actors to enter electricity markets and compete fairly with the large established actors. (L2) said there was need for more Government leadership to open up these markets and (L1) outlined potentially viable business models that would favour community engagement if markets were opened. End-user (E3) and Academic (A1) perspectives aligned on the need for greater fairness in access to the potential benefits from new smart grid supported electricity markets. In this respect (A1) drew an analogy with the use made of the road network. The absence of regulatory facilitation of TOUTs through the proposed smart meter rollout was the concern of a perspective from the Utility sector (U2) that observed that this meant opportunities for demand response through exploitation of electricity spot price volatility were being lost. Demand reduction rather than cost should be the focus of incentives according to perspectives from Academic (A1) and End-user (E6) sectors as these could address both decarbonisation and cost in turn. Gamification and the form in which benefits paid to end-users engaging in electricity markets through smart metering systems were the subject of perspectives from the End-user sector (E6, E7). Windfalls would give more encouragement according to (E7). However there was a conflict in vision between perspectives from (E6) (advocating large energy companies) and (A1) (concerns over misaligned priorities) over who should be responsible for developing new ways of engagement in this way.

7. Exploring the performance of Options and Issue weights

The performance of Core and Discretionary Options is presented below for the sample of interviewees (n=15 out of 26) who assessed their chosen Options against the Criteria they created according to approach (1) described in Section 4.5. This set of interviewees was populated from all sectors (Table 7).

Table 7. Composition of interviewee sample used for Option performance analysis								Sample segment
Code	Sector	DO1	DO2	DO3	DO4	AO1	AO2	
G3	Government	✓		✓				4%
C1	Commercial		✓	✓				7.5%
C2	Commercial			✓	✓			
N2	NGO			✓	✓			4%
A1	Academic			✓	✓			15%
A2	Academic		✓		✓			
A3	Academic	✓			✓			
A4	Academic				✓	✓		
L1	Local	✓		✓				4%
U2	Utility			✓	✓			7.5%
U3	Utility		✓		✓			
E3	End-users		✓		✓			15%
E5	End-users		✓	✓				
E6	End-users	✓			✓			
E8	End-users	✓			✓			
TOTALS		5	5	8	11	1	0	61%

Option performance is a relative measure after taking into account the Weightings (see Section 4.6) applied to interviewee Criteria as a measure of their relative importance. Performance is expressed as a band on the x-axis to account for the range between minimum and maximum scores given to the Option when assessed against each Criterion. The results of this analysis are presented in Fig. 19.

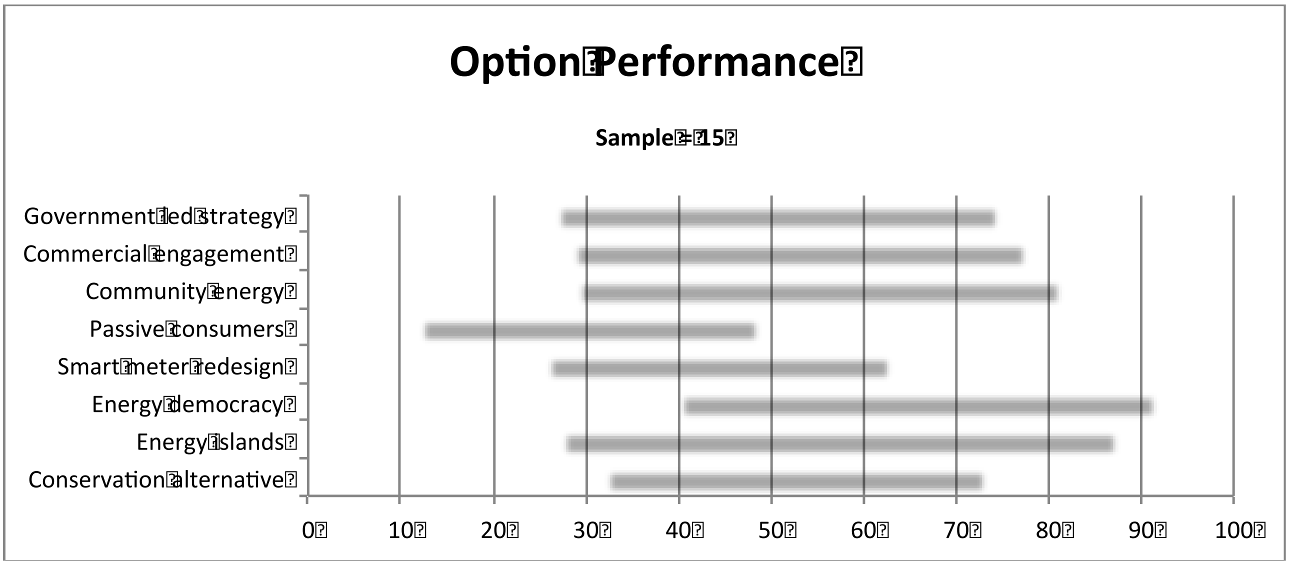


Fig. 19. Quantitative analysis of Option performance.

From Fig. 19 it is possible to get a sense of preferred Options as pathways for realising smart grids and to note the relative popularity of alternative models addressing them.

7.1 Issue weights

From the same sample of interviewees that were used to explore Option performance (where n=15) further analysis on the relative weighting of Issues is now discussed. This information reflects the relative weight given to the eight principal Issues described in Sections 6.1 to 6.8 from different interviewee and sector perspectives. In Fig. 20 the mean (represented by the thick black point) and range of weighting values (represented by the error bars) are presented for all the sectors in the sample. This graph indicates that after aggregating sectoral perspectives on Issue weights, the mean weights for the Technical feasibility and Governance Issues were highest.

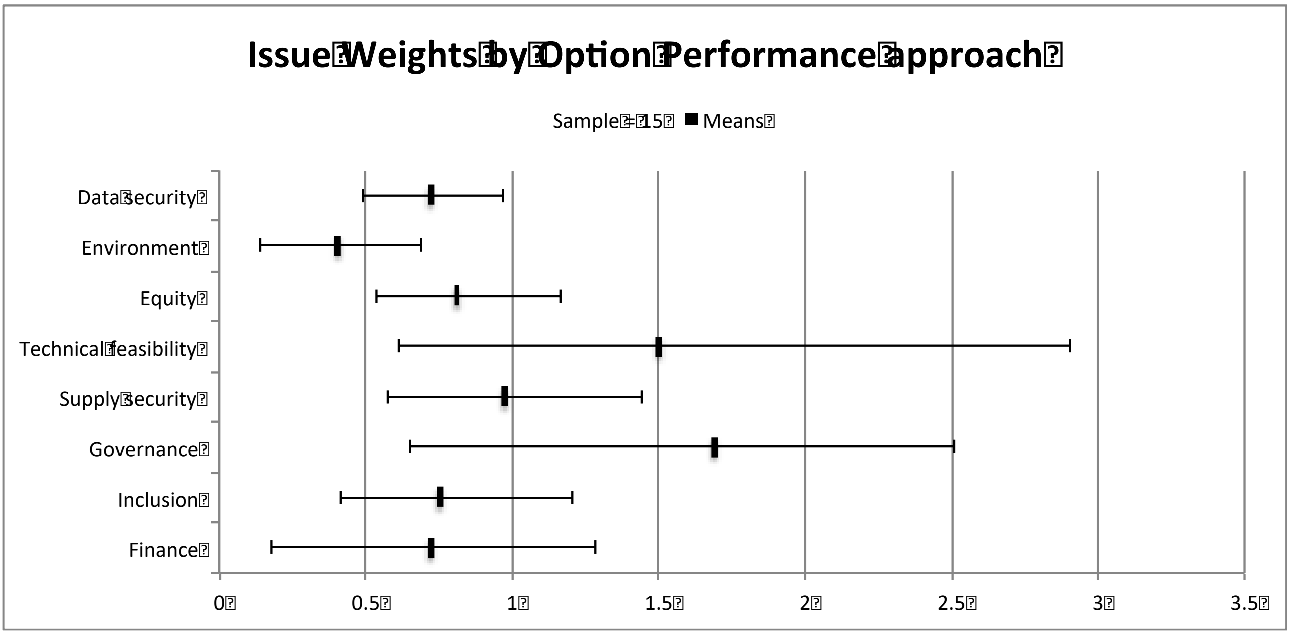


Fig. 20. Issue weighting across all sectors from sample (n=15).

A further breakdown of Issue weightings by sector representation from the (n=15) interviewee sample is presented in Figs. 21.1 to 21.7. These Figures give a detailed view of the relative weighting applied by the interviewees sampled. Where means are scoring zero on the X-axis, there was no Criterion submitted to that Issue. Where there was no range in weighting values to consider, a single point without error bars is shown. This would occur when a singular Criterion was submitted to an Issue.

Patterning from this data reveals the relative weight from a possible weighting value greater than 1, of the following Issues to each interviewee sampled from a given sector:

Government - Technical feasibility.
Commercial - Governance, Technical feasibility.
NGO - Technical feasibility.
Academic - Governance, Technical feasibility, Equity, Supply security.
Community energy - Technical feasibility, Supply security.
Utility - Governance, Technical feasibility, Inclusion.
End-user - Governance, Supply security, Finance, Inclusion, Equity.

Fig. 21.1. (n=1).

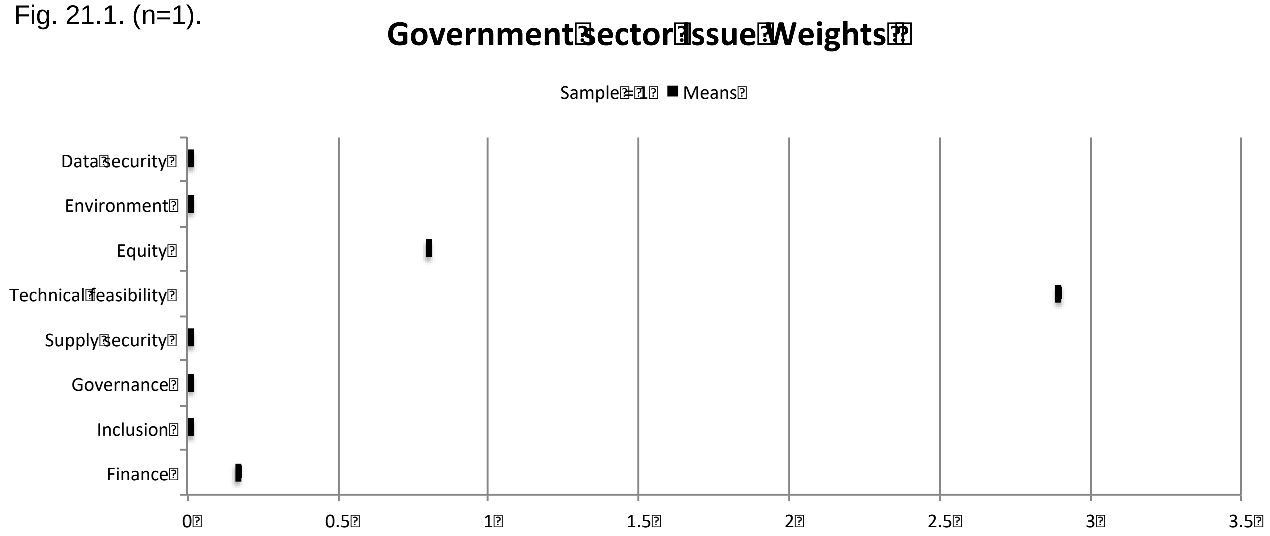


Fig. 21.2. (n=2).

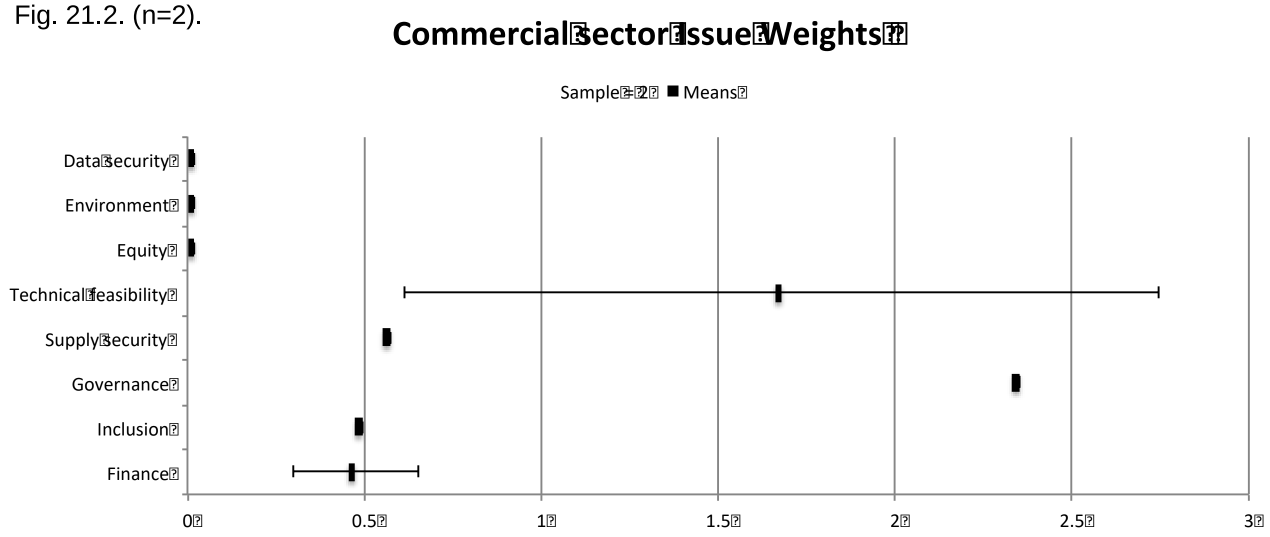
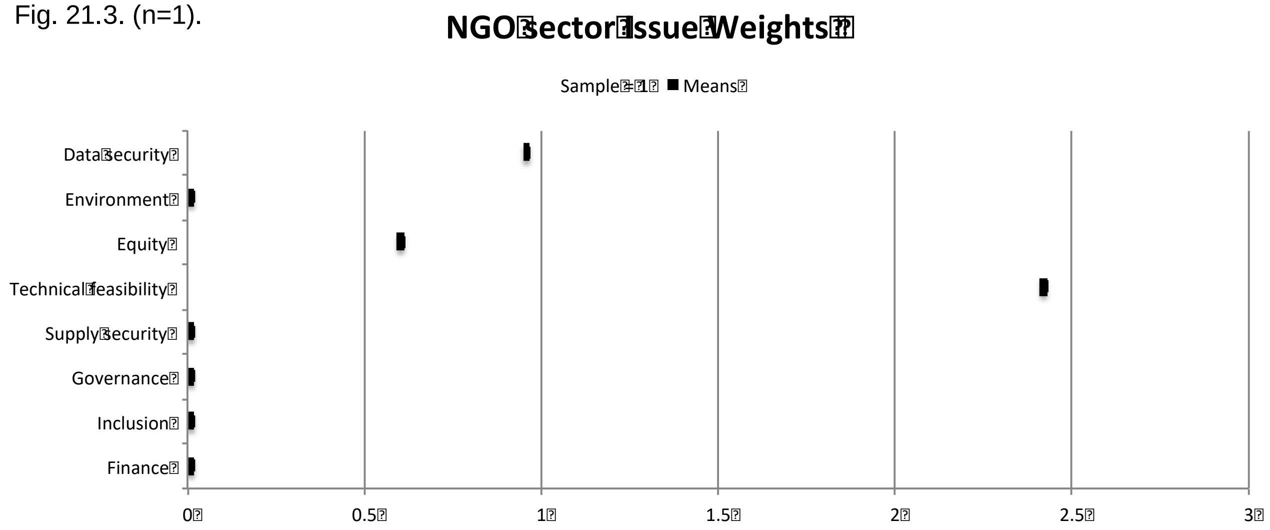


Fig. 21.3. (n=1).



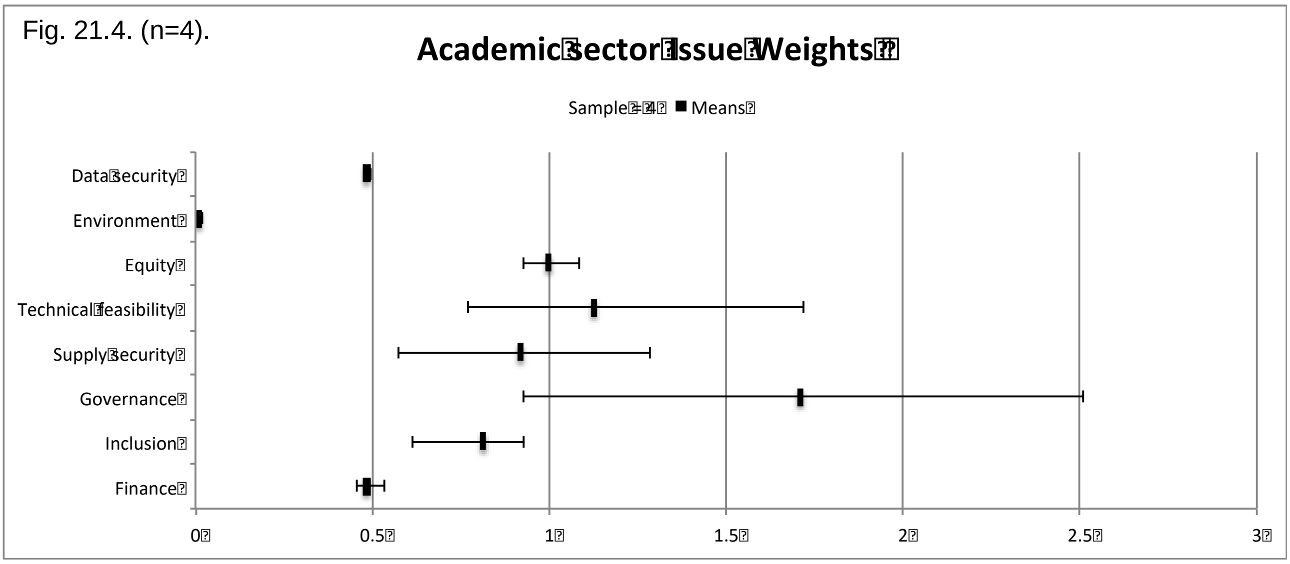


Fig. 21.4. (n=4).

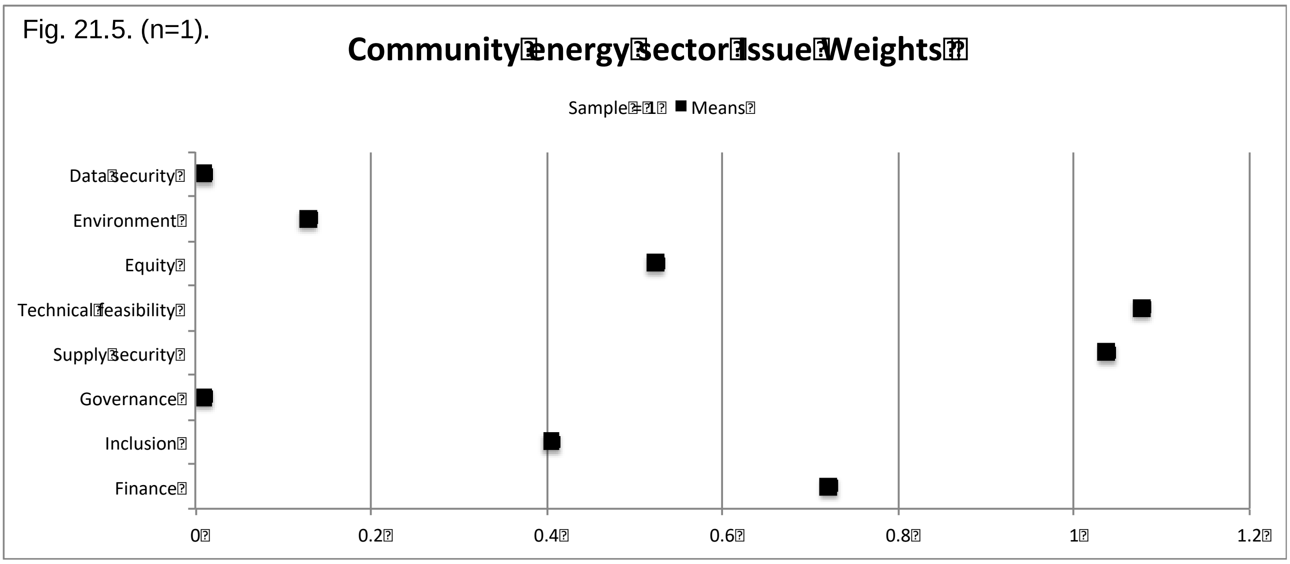


Fig. 21.5. (n=1).

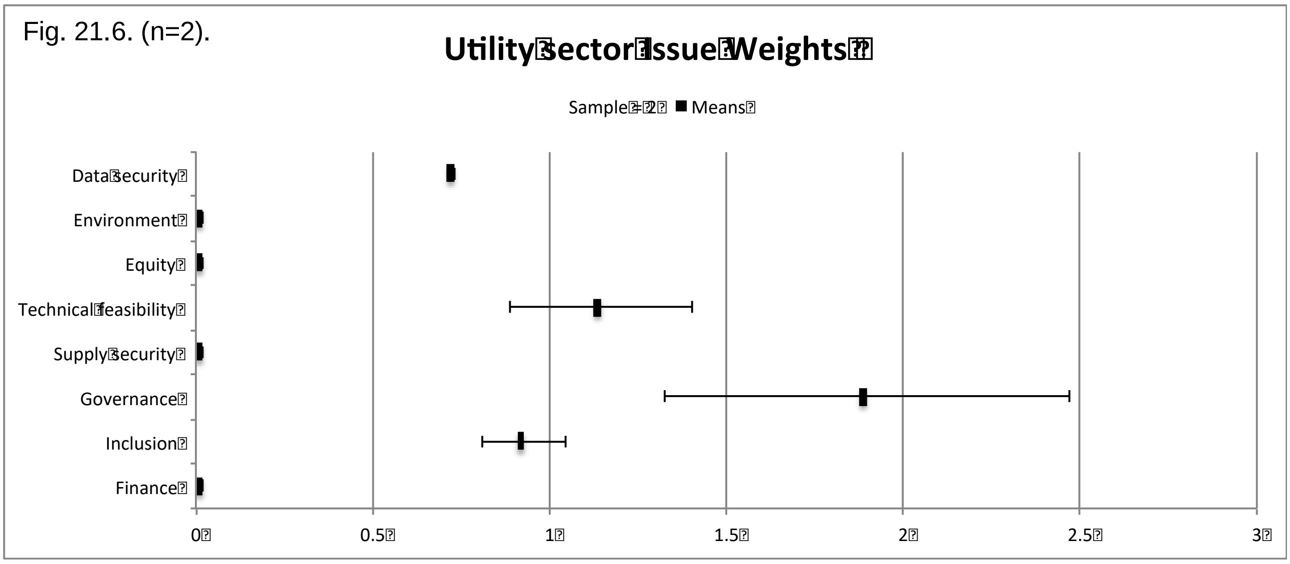
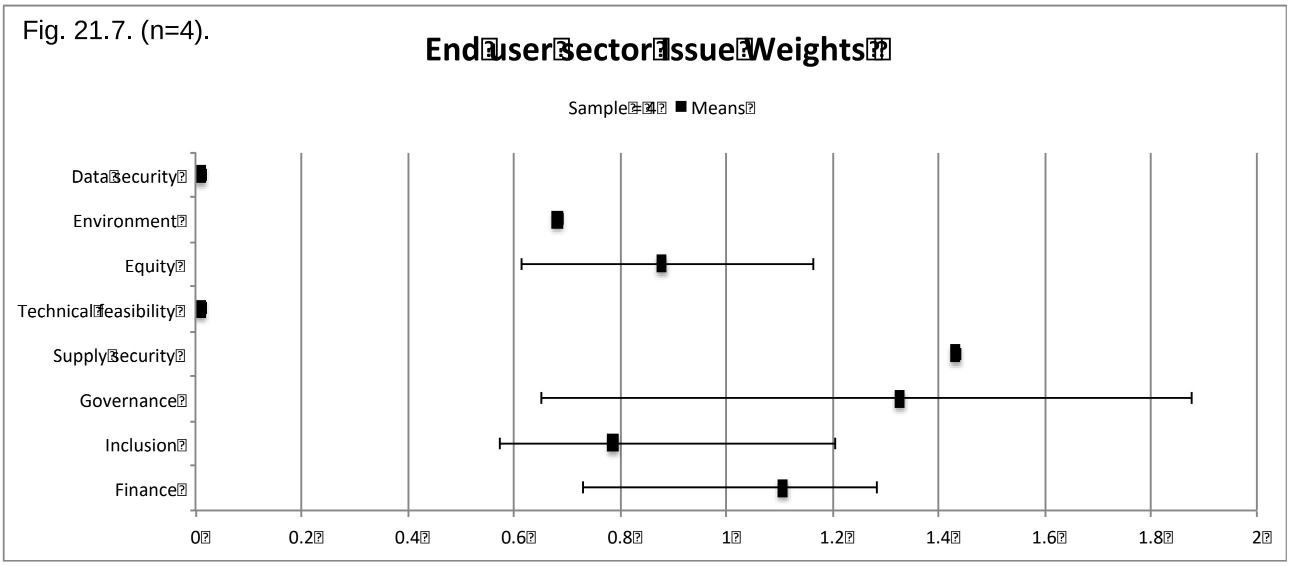


Fig. 21.6. (n=2).

Fig. 21.7. (n=4).


End user sector Issue Weights
Sample =4
■ Means
Data security
Environment
Equity
Technical feasibility
Supply security
Governance
Inclusion
Finance
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

8. Conclusions, Advice and Recommendations

This report has outlined the findings of a study that has attempted to push the boundaries and open up existing and future meanings of smart grid developments relating to the UK electricity system. Through drawing on the perspectives of diverse system-wide actors our analysis clearly demonstrates that the future success of interventions leading towards future smart grids is not only a technical matter, but crucially depends on them being *socially smart* as well. The report has begun to open up these dimensions which has important implications for:

1. Visions of how possible future smart grids will take shape and be viewed in the UK;
2. The significant considerations and matters of concern that will have to be taken into account for future smart grids to be successful;
3. Questions over the extent to which considerations of what it means to be socially smart are being recognised or excluded in existing energy governance arrangements;
4. How these criteria can be taken into account in the multiple distributed decisions that will contribute to the formation and reformation of future smart grids.

By way of conclusion we now take each of these implications in turn.

The first key message of the study is that possible future smart grids are not fully expressed by a single vision. They are subject to multiple perspectives, visions, hopes and concerns from different sectors and actors in society. We have shown how there are many different possible pathways and future trajectories down which a future smart grid may evolve. We have also seen how these different paths are judged differently by actors. For example, by referring to Fig. 6 (p. 36) it is possible to gauge the differences in perceptions of pathway viability from the sectoral make-up of choice involving the Options we proposed within this study.

From this we conclude that any attempts to govern and steer developments around a future smart grid will need to be more open and responsive to these diverse points of view and actions, not least because they could represent barriers to successful implementation otherwise. In addition, the diverse perspectives and expectations brought forward by the participants in this study emphasise how attempts to steer developments around future smart grids will not only be centralised; how they shape up will be formed my multiple distributed practices and actions across public, private, research and civil society sectors.

Further evidence of this conclusion can be drawn from the quantitative analysis presented in Section 7 (p. 99) where we have explored the performance of Options under a subset of our interviewees. Here we see emerging preferences for pathways embracing greater democracy in the energy system, community energy and new network architectures that are potentially more resilient under conditions of high renewable energy technology penetration and active demand response from a high levels of end-user engagement. Supporting this conclusion, the weight given to issues of technical feasibility and governance appear to be most pressing.

A second key contribution of our analysis has been the articulation, for the first time, of the considerations and matters of concern that different actors in society feel should be taken into account for future smart grids to be successful. The elaboration of these Criteria has formed one of the main parts of this report. Extensive qualitative analysis of the interview transcripts has been laid out in the guided commentaries describing these engagements in

Section 6. We have summarised the patterning of perspectives at the end of each Issue commentary and revealed where there is consensus and disagreement of viewpoints.

Some clear themes have emerged, including the need for more to be done by Government to remove barriers to participation in smart grid markets, some of which may be unable to emerge until conditions exist that allow individuals and communities to engage with similar privilege to that currently exercised by large energy companies. Innovation and risk aversion to embracing new paradigms and possibilities afforded by smart grids were other points of contention. Frustration was expressed from Community energy and Commercial sectors at the need for new market and non-conventional business models to be admitted by regulators and for utilities to embrace innovation through emerging data-driven technologies. Academic and Utility sector interviewees aligned on the need for transparent long term energy planning incorporating overall smart grid architecture that could leverage integration of new social and technical pathways, as well as answer the call from End-user sector interviewees to address decarbonisation in respect to national targets. Heroic gestures were proposed by some End-user interviewees for greater emphasis on energy demand reduction and use of smart grids to create an energy aware culture. NGO sector interviewees recognised the need for new network configurations that not only could involve community management on a regional basis but in accord with perspectives from Utility and Commercial sectors, point to the possible creation of energy islands and smart cities in future.

As a quick reference we can see some striking patterns of interest emerge in Figures 9 and 9.1 (p. 40) but the reality of our findings show that there are subtle interconnected layers of nuancing behind these impressions when the detail of interview considerations, concerns and perspectives is explored. Nevertheless, these Figures show us how different Issues are regarded by interviewee sector and clearly how environment, inclusion and finance are most important issues from End-user sector perspectives. In contrast we can see Data security is the major concern of the Government interviewee sector while the Technical feasibility and Governance Issues are most prominent from the Commercial sector interviewees, for example.

What is particularly significant here is how the range of criteria developed by participants in our study emphasise that the success of future smart grids depends not only on technical considerations, but also a range of social, political and ethical considerations as well, including equity, inclusion, data security, finance and governance. Behind these clusters there are a wide spectrum of criteria expressing considerations such as trust, maintaining connection, fairness, affordable warmth, investing in people, education and awareness raising. In short, these considerations reflect back upon the framework that is generally accepted in technical circles for framing energy challenges, namely 'the energy trilemma'. What this research has shown is that, while this maybe sufficient to meet the needs of some incumbent, technologically-facing sectors in the energy debate, by excluding the concerns (as reported here) of other sectors it is an inadequate framework for integrating many of the meanings of social smartness with technical smartness. A working hypothesis for this work being, that smart grids require integration of both social and technical smartness to be successful. Reflecting this, we show our own version of the trilemma, drawn from our findings, in Figure 22, below.

As well as consensus there was evidence of difference in patterns of understanding and approach to some issues. For example, in how end-users may be encouraged to embrace and engage in smart metering systems. From the Government sector perspective this was much to do with education, protection of consumer rights and the use of mandate if

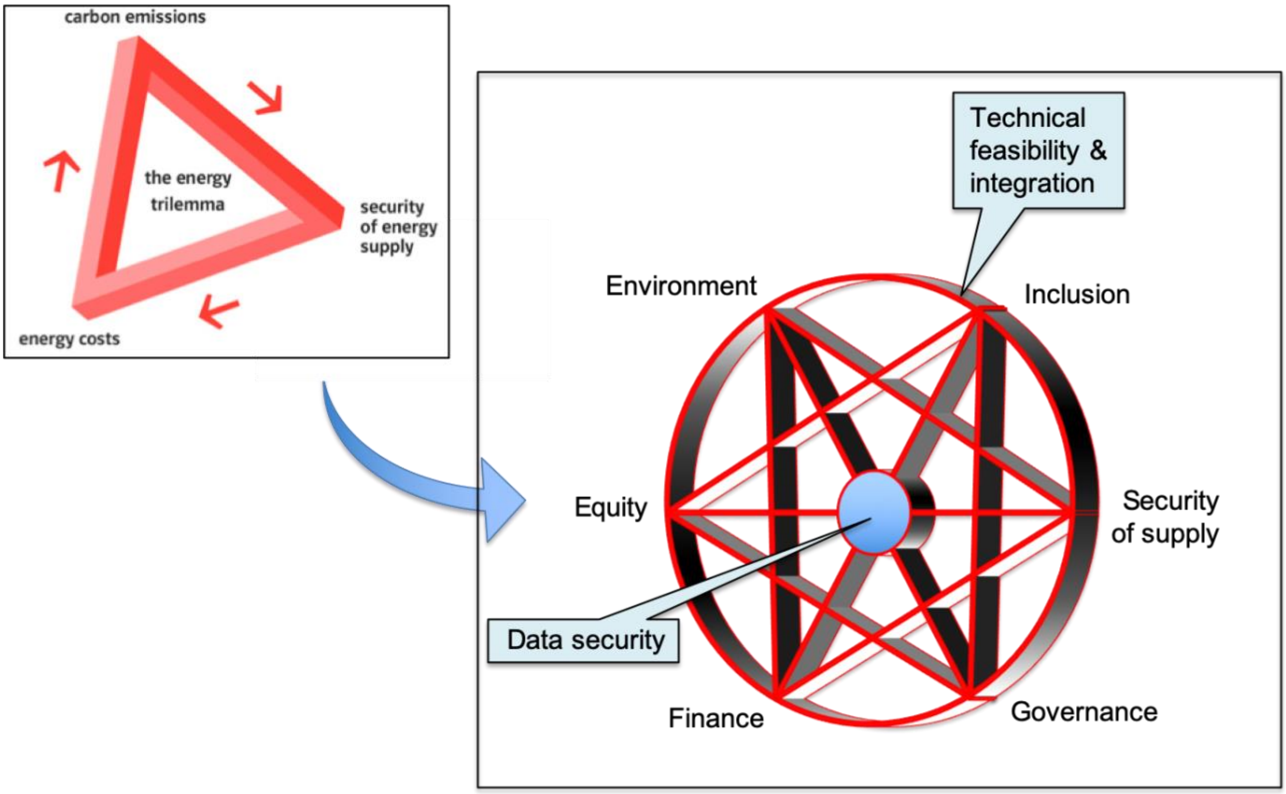


Fig. 22. The energy ‘trilemma’ transformed to be more socially smart.

voluntary means failed. From a Commercial perspective the challenge was more to do with openness and access to data and willingness for new technology to be embraced through innovation. The Academic sector interviewees viewed alignment of incentives and intelligibility of systems and interfaces as key pathways to engagement. From within the End-user sector there were differing responses to such suggestions that ranged from the desire for less technology intruding upon their lives, to the desire for their own raw data to be first hand. There was also sensitivity to being treated as 'non-experts' in energy matters parodied by cartoon figures such as 'Gaz' and 'Leccy'. Particularly, as visions of engagement through being local energy system co-managers and personal power plant operators were all future possibilities given the right conditions within governance and financial incentives.

On the basis of our analysis we would contend that these dimensions of what it means to be socially (as well as technically) smart have not been acknowledged enough in energy research, policy and practice to date.

This forms the focus of the third main implication of our study that concerns how many of the Criteria offered for consideration within the meaning of 'smart' in our study are not currently being addressed, or in some cases may even be actively resisted by the largest and dominant energy system actors. There is a clear theme running through these criteria calling for inclusion and equity, supportive financial measures (in addition to market barrier removal) and concern for the natural and personal environment. Visions for smart grids may collide over these issues if End-user, Community energy and NGO aspirations (that actually do align with some elements of Commercial, Government and Local Government visions) are compared to a more technically manifested, centrally controlled, and top-down market-dominated future energy system. The point here is whether new paradigms from 'distributed stakeholder sectors' are entertained and smart grids develop in cooperation with a wider range of consultation to become facilities in support of greater equity and fairness. Or, whether the status quo is maintained by the dominant players who's perspectives often seemed to shutdown debate and discussion about what smart grids should be for and more hurriedly attend to how it might be practically realised.

This brings us to the final main implication of our study. If current governance arrangements struggle to acknowledge what it means to be socially smart this raises important questions for how these criteria can be taken into account in the multiple distributed decisions that will contribute to the formation and reformation of future smart grids. These big questions cannot be resolved here but can be answered and addressed through future research and interventions in practice that flow from our study. Our overall message is that because the processes of policy-making, decision-making, design and innovation that will lead to future smart grids will be distributed and multiple, then strategies for accounting for the social dimensions of these processes will themselves have to be diverse rather than prescriptive. Having said this, there is a clear need for tools, devices, procedures and ways of being that build-in ‘real time’ reflection over what it means to be socially smart - including concerns over equity, inclusion, directionality, privacy and trust - to bring into smart grid design and innovation processes. These could include (but are not limited to):

- Discursive spaces (e.g. workshops) where smart grid decision-makers and innovators interact with social scientists and/or actors in wider society to reflect on what it means to be socially (as well as technically) smart, consider future social and unintended consequences of smart grid developments, and so on.

- Online tools that allow distributed decision makers to go through similar process of reflection over the social dimensions of their innovations and decisions in ‘real time’.

- Check lists and sensitising questions that can circulate in networks relating to smart grid developments that allow actors to consider socially smart criteria in their work.

- Processes of organizational learning and capacity building that help raise awareness and develop cultures that are more reflective over the social meanings of smart and are able to incorporate such considerations into everyday and ongoing smart grid related practices and decisions.

- Forms of anticipatory governance and upstream engagement that open up emerging visions, purposes and directions of smart grid developments to wider public debate and allow the criteria developed in this study to be continually scrutinised, developed and refined (thus enriching the above suggested interventions).

Returning to the central question of this exploration, "What’s the meaning of 'smart’?" we put forward in summary some of key findings as follows:

a) There is no singular meaning of 'smart' as it is seen differently by different people. Crucially, this leads us to the understanding that smart grid development will not and indeed cannot be centrally controlled (by projecting a singular meaning) but will inevitably and unavoidably involve distributed decisions from a range of actors across society.

b) Many of these different understandings (and other 'outsider' actors) are currently not being adequately incorporated in current discussions about smart grid development. In particular, those relating to being 'socially smart' are being excluded, which is a marker for greater inclusion.

c) As a result, current visions of smart grids are very narrow - exclude too many perspectives and, perhaps most notably, fail to really open up debate to questions about what the energy system might actually be able to deliver for society beyond a reliable supply of kWh. Here we can emphasise that many perspectives - especially end-users, Community energy groups and NGOs - were interested as much in changing the current system to place control in the hands of people (even if this meant suffering power cuts) as they were in technical feasibility or awareness raising. In short, they were seeing the smart grid as an opportunity to 'open up' wider debate about what the energy system is or could be for, whereas dominant discussions shut this out

d) Therefore, future work and smart grid development should place more emphasis on what it means to be 'socially smart' and how this intersects with well-established technical understandings. Here, the list of suggested processes above provides a starting point for debate about how to boost 'social smartness' within the GB electricity system but that this is a concern that requires considerable further attention.

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