Uncovering ethical values associated with smart grid systems in the British public debate: An empirical investigation of normative stances

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Abstract

Smart grid systems (SGSs) are often considered as enablers to the transition to a sustainable economy and power system, because they integrate ICT with renewable energy into the electricity grid. Seemingly, there are societal concerns regarding the impact of SGSs, which underlie ethical values. Due to a lack of understanding and thus consideration of public values in the design of SGSs, these emerging innovations are not adopted on a large-scale yet. This paper argues that public values can be acknowledged as relevant factors (i.e. social barriers and drivers) for the adoption of smart grid technologies. As such, contestation of public values might lead to deadlock of technology implementation. This paper aims to provide insights about ethical values that can be associated with SGSs. For this purpose, a literature review is carried out related to this topic in order to identify and conceptualize values at stake for smart grids and their related technologies. Thereafter, a qualitative content analysis of the British public debate on SGSs (assumed to be represented by national newspaper reports) is carried out in order to empirically uncover the normative stances (i.e. ethical values) of smart grid stakeholders and how those values are related. The result is a network of related values and conceptualizations. This network can be used by the energy industry and policy-makers to tackle challenges in designing for values in SGSs, from both a technical and institutional perspective. As a result, ethically and socially better energy systems can be reached. Additionally, the findings serve as a basis for future research regarding the relative importance of the identified values, the dynamics of the public debate, translation of values into design requirements, and to expand value sensitive design into the energy domain through case studies on SGSs in different countries.

Keywords: smart grid systems, value sensitive design, ethical values, content analysis, technology adoption

1. Introduction

Our economic development and growth have led over the years to a growing energy consumption and to issues related to climate change and resource depletion. In order to cope with these problems, governments worldwide have adopted a low carbon regime. As such, the United Kingdom (UK) established the following objectives to ensure that their current electricity system deals in the long term with peaks in demand and resource depletion: ensure security of supply, reduce the energy bills, and decarbonize in the most affordable way (DECC, 2015). Additionally, the UK aims to fulfil at least 15% of its total energy needs with renewables by 2020 (Parliament, 2016). However, a higher share of renewable energy (which has an intermittent character, e.g. solar and wind) and the introduction of new loads (e.g. electric vehicles and heat pumps) pose additional stress on the current electricity system in terms of balancing power supply and demand (Muench, Thuss, & Guenther, 2014; Verbong, Beemsterboer, & Sengers, 2013). Hence, for the achievement of a low-carbon and economic British transition changes in their current electricity system and the way energy is being supplied and used is recognized as important (DECC, 2012; Government, 2014). To cope with this challenge, a potential solution is to upgrade the current electricity grid with information and communication technology (ICT), resulting in so-called smart grids (Dincer & Acar, 2016; Milchram & van de Kaa, 2017; Verbong et al., 2013). These innovations are believed to take the UK a step further towards an affordable and low carbon electricity system that allows the integration of renewable energy (accounting for higher volatility and decentralized production), while benefiting energy consumers in cost savings through efficient energy use in the household and businesses as well as in the electricity system (Government, 2014; Mathiesen et al., 2015). Thus, upgrading the current electricity network with ICT results in a smart electricity grid, which is able to monitor and actively control generation and demand in (near) real-time (Verbong et al., 2013).

In general, the introduction of new technologies into society might not be aligned with the inclusion of social values, most likely leading to public resistance due to the perceived societal impact (Dignum, Correljé, Cuppen, Pesch, & Taebi, 2016). In the UK, moral concerns are among the strongest features of public discussions about SGSs (Balta-Ozkan, Davidson, Bicket, & Whitmarsh, 2013). For instance, 51% of the British public does not trust any energy supplier (Buchanan et al., 2016). They perceive that suppliers are not transparent about passing financial savings to consumers when smart grid technologies are adopted in a household. In addition, regarding control/autonomy consumers express displeasure about the idea of energy suppliers managing their energy use, e.g. through dynamic pricing (consumers pay the fluctuating market rate for their electricity) and particularly through cutting demand at peak times when prices and often CO_2-emissions are at their highest. This could result in disruption of household routines and even higher energy bills caused by strategic behaviour of energy suppliers (Buchanan, Banks, Preston, & Russo, 2016; Verbong et al., 2013). Regarding privacy, the notion of "big brother is watching you" is addressed by several scholars. This is related to monitoring daily habits in a household though information on energy consumption patterns (Balta-Ozkan et al., 2013).

Ethical values *"refer to what persons, either singularly or collectively, consider important to their lives"* (Ligtvoet et al., 2015, p.169). Moreover, ethical values play a role in the design of technology as well as in its deployment (Dignum et al., 2016). For instance, new technologies, such as smart grid technologies, "*can shape our practices, thereby promoting or undermining certain values*" (Taebi, Correljé, Cuppen, Dignum, and Pesch, 2014, p. 119). This implies that ethical values can form barriers and drivers for the social acceptance and adoption of SGSs (Milchram & van de Kaa, 2017). Currently, there is a lack of understanding on ethical values as held in the British society, from an empirical perspective, that can be associated with SGSs. Smart grid projects and investments are geographically not uniformly distributed across Europe (EC, 2013). In terms of spending for research and development of SGSs and specially for smart grid demonstration projects, the UK stands out compared to other European countries with €280 million investments (EC, 2013). Hence, the UK stands out as a leading nation in smart grid development in Europe. Therefore, this article considers the UK as a case study and aims to empirically uncover what ethical values underlie the British public debate on SGSs and how those values are related, in order to provide input for design for values of these emerging innovations. This is relevant as insights into ethical values aid to reach socially better and ethically acceptable SGSs. Moreover, these insights can serve as an input for the energy industry and policy-makers to increase their understanding, consideration, and prioritization of stakeholder values associated with SGSs and, if necessary, to reform the current policies, strategies, and products in order to accommodate public values.

Firstly, the concept of SGSs is defined in the next section. Secondly, section 3 presents the smart grid development in the UK. Subsequently, section 4 discusses the research approach. Thereafter, section 5 elaborates on the findings, being conceptualization of ethical values in the context of SGSs based on academic literature and a network of related values elicited from the British public debate. Besides, conclusions are drawn in section 6. Finally, suggestions for future research are provided in section 7.

2. Conceptualization of smart grid systems

It appears that there is still no certain description in the academic literature of what SGSs are and what technologies they comprise (Buchanan et al., 2016; Connor et al., 2014; Krishnamurti et al., 2012; Milchram & van de Kaa, 2017; Muench et al., 2014; Paetz, Dütschke, & Fichtner, 2012; Verbong et al., 2013). Therefore, this section focuses on defining SGSs as the object of study in order the determine what ethical values can be associated with these emerging innovations. Besides, insights into the SGSs components aid in establishing the search strategy for acquisition of empirical data.

This article defines smart grids as an electricity network enhanced with ICT that allows the secure connection of decentralized generation sites of intermittent renewable energy and facilitates the balance of energy supply and demand through real-time information sharing and advanced sensor and measurement technologies (Ellabban & Abu-Rub, 2016; Geelen, Reinders, & Keyson, 2013; Guerreiro, Batel, Lima, & Moreira, 2015; Muench et al., 2014). In addition, smart grids enhance security of supply through the management of peak demand, energy efficiency and improved reliability (e.g. reduction of blackouts) (Connor et al., 2014; Cuijpers & Koops, 2012; Kovacic & Giampietro, 2015). Besides, this digitalized electricity grid aids in meeting climate goals, allows the creation of new jobs and empowers/incentivises consumers to manage their demand accordingly and adopt smart grid technologies in order to realize economic savings for themselves and the energy system (Government, 2014). Furthermore, smart grids facilitate the integration of the actions and behaviour of users (e.g. electricity producers, consumers, and prosumers) (Darby, Strömbäck, & Wilks, 2013). The components of smart grids are illustrated in Figure 1 below.

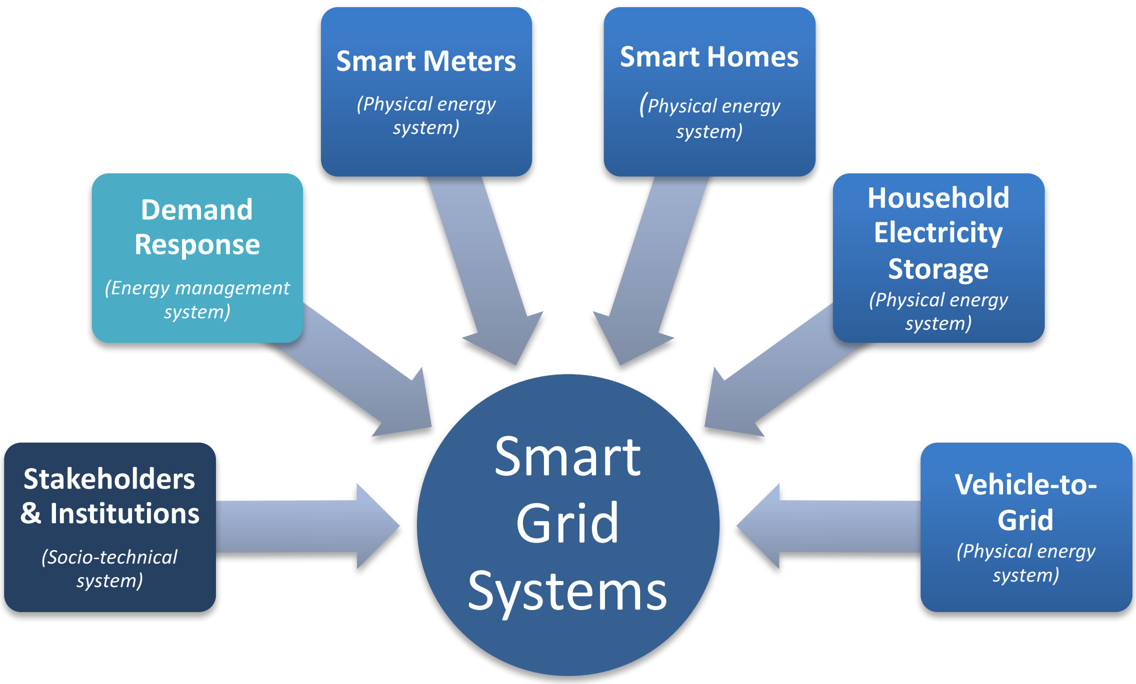

Figure 1: Smart grid systems and components

Stakeholders & Institutions: stakeholders are people (any group or individual) who have an interest or concern in SGSs and who can affect or is affected by SGSs (Freeman, 2010). This implies the interaction of different actors with smart grid technologies as energy has changed from a commodity to a basic human need (Ruijgh et al., 2013). Hence, SGSs are pointless if they do not make part of society to operate. This implies that the interaction between smart grid technologies and stakeholders is essential. Besides, institutions regarding SGSs are also part of this socio-technical system as the energy sector is heavily regulated. This implies that institutions structure collective behaviour (i.e. human interaction and activities) in the form of established formal or implicit social rules that matter in the social realm. Examples are government policies, societal expectations and preferences, money, manners, standardisation of technologies, industry standards, law, and organizations (Hodgson, 2006; Wolsink, 2012).

Demand response: instrument that controls the demand of electricity consumers (the demand-side) to shape the load profile by offering consumers tariffs that reward them for making changes in how they use their electricity and when (demand-side response) (Geelen et al., 2013; Mahmood, Javaid, Khan, & Razzaq, 2015). This way, loads are shifted from peak periods to periods of low demand by adjusting power demand instead of adjusting power supply (Darby et al., 2013; Verbong et al., 2013). Hence, demand response is an important tool of demand side management for a secure, affordable and sustainable electricity grid as it focuses on shifting energy consumption during peak times for the sake of balancing supply and demand (Warren, 2014).

Smart meters: advanced and intelligent gas and electricity metering devices that enable recording and storing energy use data of consumers in near real time in intervals of 30 minutes or less (depending on the settings and regulations) (Cuijpers & Koops, 2012; Guerreiro et al., 2015). Smart meters allow a two-way communication with the energy companies and consumers: the readings are remotely sent to the energy companies and other nominated parties if applicable (e.g. network operators and authorized third parties) and the consumers are shown change of tariffs (e.g. price increases or decreases) through an in-home display (Darby, 2010, 2012). This empowers consumers to control their energy use to save money and provides more accurate billing compared to the conventional energy meters. In addition, energy suppliers are also empowered as they have the control to remotely disconnect and reconnect consumers e.g. if peak demand is unbearable or if consumers do not pay their energy bills on time (Darby, 2010).

Smart homes: generic descriptor for the introduction of a high-tech network into homes (e.g. residences such as apartments, houses or social housing) with the purpose of managing the energy consumption in the domestic or small business environment (e.g. local store) (Balta-Ozkan et al., 2013; Missaoui, Joumaa, Ploix, & Bacha, 2014; van de Kaa, Ligtvoet, Fens, & Herder, 2014; Wilson, Hargreaves, & Hauxwell-Baldwin, 2017). Examples of (controllable) smart home appliances include lighting, washing machines, boilers, fridge, radiators, televisions, windows, air conditioners, garage doors, and curtains among others (Balta-Ozkan et al., 2013; Missaoui et al., 2014; Wilson et al., 2017). These smart appliances react automatically to trigger signals from the electricity grid (e.g. price signals, power system frequency, availability of renewable energy sources) and based on those signals they determine when the best time is to operate (e.g. the washing machines turns on when the electricity price is low) (Paetz et al., 2012; Wilson et al., 2017). Thus, the smart home energy management system is comparable to a local in-home smart grid that comprises sensors, monitors, interfaces, and appliances to facilitate the automation, access and control of the home's data and services (van de Kaa et al., 2014; Wilson et al., 2017). Hence, a smart home is a high-tech equipped home that has a network (the home energy management system) that connects and coordinates all information and technological components of the residence (Balta-Ozkan et al., 2013).

Electricity storage devices decouple the actual electricity consumption moment from the production of power (Ligtvoet et al., 2015). This means that consumers can use power at different times than when it is produced or bought from the grid (Geelen et al., 2013). For this purpose, this paper considers the following forms of electrical power storage: *household electricity storage* and *vehicle-to-grid*. In the case of micro-generation, e.g. when households have solar panels and/or micro wind turbines installed and are thus prosumers, they can store surplus power in home batteries. Besides, they can also store the energy produced in periods of low demand for later own consumption or to sell it back to the grid (Bianchi, Branchini, De Pascale, & Melino, 2014; Mathiesen et al., 2015). Furthermore, the batteries of electric vehicles (EV) offer the possibility of power storage, known as the vehicle-to-grid concept. This implies that households owning an EV can store electricity (from micro-generation surplus or from the grid off-peak hours) in their EV's battery and send the electricity back to the grid during demand peaks or to the households themselves when they need it (Geelen et al., 2013). Hence, electrical energy storage leads to higher reliability of the electricity network as it improves the grid stability (Bianchi et al., 2014; Mathiesen et al., 2015).

After conceptualizing SGSs, the research domain needs to be further delineated. This is done by examining the smart grid development in the UK, which is the subject of the next section.

3. Smart grid development in the United Kingdom

The UK has made significant progress to date in developing and modernizing their energy system into a smart grid. Figure 2 depicts the milestones achieved so far. Public concerns about meeting the future energy challenge and tackling climate change, caused the emergence of a public debate in the UK. Therefore, in 2007 the British government published the White Paper on Energy, containing an energy strategy to address the long-term energy challenges on national and international level (DECC, 2015). Then, in 2008, the Climate Change Act was published in order to give the UK a boost in reaching a low carbon economy and to mitigate climate change (Government, 2008). The smart grid development in the UK is in parallel and partly triggered by European legislation and policies,

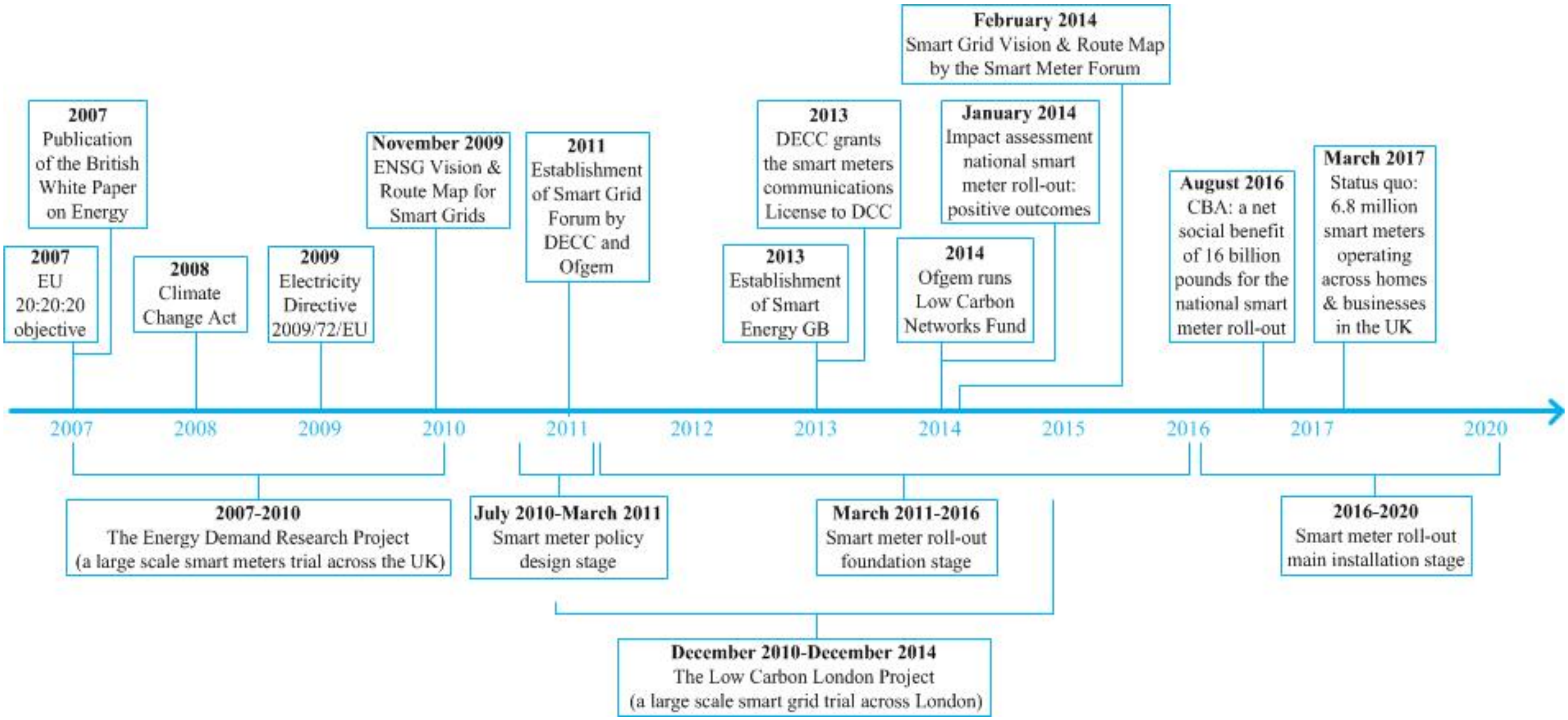

Figure 2: Timeline for the British smart grid development over the past 10 years

such as the 20:20:20 package from 2007 and enacted in legislation by the EU in 2009 through the Electricity Directive, which required member states to implement smart metering by 2020 in 80% of the households (EU, 2009). This Directive also aimed at encouraging the modernization of distribution networks through smart grids for the sake of decentralized power generation and energy efficiency (EU, 2009).

With the aim of fostering and facilitating the development of smart grids in the UK, in November 2009 the Electricity Networks and Strategy Group's vision and route map for smart grids was published on how to develop a smart grid in the UK. Their work was extended by the Smart Grid Forum (SGF) (established in 2011), which serves as a platform for industry, government and other key stakeholders to engage on the significant challenges and opportunities posed by UK's transition to a low carbon energy system (Ofgem, 2017a). In February 2014, the SGF defined a clear vision of a British Smart Grid and a route map of the ways in which this SGSs could be delivered (SmartGridForum, 2014). In the same year, the Low Carbon Networks Fund was led by the Office of Gas and Electricity Markets (Ofgem), consisting of a £500m budget to support projects sponsored by the Distribution Network Operators to try out new technology (e.g. EVs, heat pumps, micro and local generation, and demand side management), operations and commercial arrangements (Ofgem, 2017c; UKPowerNetworks, 2014). In order to investigate how consumers reacted to improved information about their energy consumption over the long term, the Energy Demand Research Project took place from 2007 to 2010 and provided a combination of smart meters and real-time display devices to the households in the UK (Government, 2014; Ofgem, 2017b). This project successfully resulted in energy savings up to 11% (Ofgem, 2017b). Additionally, to study the impact of a wide range of low carbon technologies, such as intermittent local generation, smart meters, and electric vehicles on an electricity distribution network and test how smart grid technologies can be used to manage these changes in a low-carbon economy, the Low Carbon London Project took place between December 2010 and 2014 (Government, 2014). This £28.3 million project was one of Britain's largest smart grid trials (UKPowerNetworks, 2014).

In the UK, smart meters are recognized as an inherent part, i.e. the backbone or critical building block, of smart grids as they offer benefits for optimizing electricity generation and network management and thus moving towards a smart energy system (Darby, 2012; DECC, 2015). Therefore, it can be seen from Figure 2 that the timeline mainly follows the smart meter development and deployment in the UK as a representation of the smart grid development. This is justifiable as smart meters are key for the development of smart grids. Hence, another milestone in the development of SGSs in the UK was the decision of the British government to perform a national smart meter roll-out that would be managed by the Ofgem on behalf of DECC to foster the smart grid development (Government, 2015). This consists of a smart meter policy design stage (July 2010-March 2011), foundation stage (March 2011-2016), and main installation stage (2016-2020). The aim is to install 53 million smart meters in the UK, including replacement of the conventional energy meters for gas and electricity (Government, 2015). The status quo shows that there are over 6,783 million smart and advanced meters operating across homes and businesses in Great Britain, by both large and small energy suppliers (Government, 2017) and that there is an on-going transition to digitalization of the British power network.

The milestones achieved by the UK in terms of smart grid development have shown that the national smart meter roll-out is about to be completed in two years from now (Government, 2014). This emphasizes that the UK is a leading nation in Europe with regard to smart grid development. As this development is advanced compared to other European nations, it is reasonable to assume that the British public debate on SGSs is also more advanced. This allows the availability of empirical data over a long period of time (10 years) required for this article.

4. Research approach

Social values can be elicited from the public debate because it reflects stakes, opinions, and expectations about issues that concern the society as a whole but still require ethical assessment (Correljé, Cuppen, Dignum, Pesch, & Taebi, 2015; Dignum et al., 2016; Taebi, Correljé, Cuppen, Dignum, & Pesch, 2014). Therefore, it is reasonable to assume that the public debate serves as an empirical source to qualitatively infer social values related to SGSs and to gain insights into better understanding social repercussions and controversies about these emerging innovations. Since the media (e.g. newspapers) plays a key role in informing the public, it also shapes the public debate in terms of setting agendas and focusing the public interest on particular aspects of SGSs (Happer & Philo, 2013). Hence, it is reasonable to assume that newspaper publications contain value-laden statements of different stakeholders, which are suitable for deriving relevant social values.

The research approach used in this article is qualitative data analysis. First of all, in order to discover what ethical values are at stake for SGSs, a literature review is performed on Value Sensitive Design (VSD) as it is embedded in moral philosophy and serves as a rich source to retrieve values specifically related to technological objects and their use. Besides, as VSD uses a broad and general sense of values, academic literature on smart grids and its components is also reviewed. This allowed retrieving more specific values for the context of this study. For this purpose, a qualitative content analysis is performed of 21 British national newspaper reports on SGSs acquired from the Factiva digital database, including both broadsheets (i.e. the quality press) and tabloids (i.e. the popular press). This research method classifies and reduces textual material into relevant and manageable bits of data (Weber, 1990). Moreover, it aids in making valid and replicable inferences from texts (Krippendorff, 2004). The aim of content analysis is to identify and record (relatively) objective (i.e. inter-subjective) characteristics of messages through the creation of units for analysis (e.g. data segments) and categories (e.g. codes) (Krippendorff, 2004; Neuendorf, 2017; Weber, 1990). The data segments consist of arguments, i.e. value-laden statements, which were put forward in the newspaper articles by different smart grid stakeholders. An overview of these stakeholders and their priorities is provided in Table 1 of Appendix A. In addition, this article considers the notion of "sensitizing concepts" by Blumer (1954), who states that concepts in social theory are vague and thus sensitive rather than definitive. This means that concepts are indicative of the direction for theory exploration and can be modified by empirical data (Harvey, 2017). These are: values, stakeholders, and technology components of SGSs. As the literature review leads to implicit bias, the initial codebook (i.e. preliminary list of values and conceptualizations, stakeholders, and technology components of SGSs) serves as a means to make this unavoidable bias explicit, being open to any possible future changes that come along with the content analysis (e.g. new values/stakeholders/components, values that are not mentioned in the literature, and different conceptualizations of values). The analysed articles are published between the 1st of January 2007 and the 30th of June 2017. In total, 3,541 newspaper articles were retrieved from the Factiva database search. With a limit of 150 newspaper articles to be studied (due to time constraints of this study), this raw data is subjected to systematic sampling, consisting of selecting each *xth* case from the population following the equation:

$$xth\ case\ to\ be\ selected = \frac{Population\ size}{Limit} = \frac{3{,}541}{150} = 23.6$$

Hence, every 25th article is subsequently selected for coding and recording, after determining whether the article's content is relevant. In total 127 British national newspaper articles are content analysed with the software ATLAS.ti (Friese, 2014). From the empirical data, 480 value-laden statements are retrieved. In addition, an inter-coder reliability test is performed with an expert on designing for values in smart energy systems in order to validate the coding of values in the newspaper articles.

5. Results

First of all, the literature review resulted in 26 ethical values that can be associated with SGSs. Table 2 of Appendix B provides an overview of these values and their conceptualization. This overview serves as input for the empirical data analysis and therefore is validated by three experts[1] on design for values. Thereafter, the qualitative content analysis is performed in order to empirically study the normative stances of stakeholders in the UK regarding SGSs. This resulted in 21 ethical values that can be related to SGSs, which also came forth in the literature review. Hence, the following 5 ethical values from the literature have not been discussed in the empirical data: cooperation,

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[1] Prof. Dr. Ir. Ibo van de Poel, Dr. Theo Fens, and Tristan de Wildt (MSc). These experts are part of the academic staff of TU Delft's faculty of Technology, Policy, and Management.

democracy, freedom from bias, identity, and informed consent. This means that the newspapers did not present any statements regarding these values and thus did not report on any events, concerns or incidents with respect to this.

The analysis of the British public debate on SGSs resulted in three interesting findings: supporting relations, inter-value conflicts and intra-value conflicts. Supporting relations among values mean that values contribute to each other in a positive manner and a value is strived for the sake of other value. On the other hand, two types of conflicting relations are considered: intra-value conflicts (pertaining to different stakeholder interpretation and understanding of the same value) and inter-value conflicts (pertaining to values that, when considered in isolation, evaluate different options as best). Figure 3 presents the network of related values and depicts the ethical values that can be associated with SGSs as well as the type of relationship amongst them. The nature of these relationships is based on overlapping value conceptualizations within and between the newspaper articles and stakeholder interpretations according to the empirical data. The black arrows with a + sign in Figure 3 represent the supporting relationships, while the red arrows with a – sign represent inter-value conflicts. In addition, the purple coloured values are values that pertain an intra-value conflict.

5.1 Supporting relations

First of all, *Accountability/Traceability* contributes to Environmental Sustainability as consumers can track their energy consumption behaviour and energy bill and thereby can prevent wasting resources by sending excess energy back to the grid if they are prosumers. This means that this value contribution is highly dependent on consumers/prosumers willing to adapt their behaviour to alleviate environmental issues. Besides, *Autarky* is perceived to contribute to Economic Development as energy self-sufficiency can lead to monetary savings of consumers and cheaper energy production (e.g. micro-generation to meet own energy needs). Yet, these expected monetary savings will have to balance the investment in the micro-grid infrastructure and the operations and maintenance costs to get noticed. Autarky also contributes to Security of supply in terms of independency of (frequent) power cuts and to Environmental Sustainability in terms of lower GHG emissions (not in the case of micro combined heat and power generation as it needs gas). Yet, this contribution depends again on consumer/prosumer behaviour: willing to invest in the required maintenance to keep the micro-grid going.

Furthermore, *Control/Autonomy* contributes to Environmental Sustainability, Economic Development, and Security of supply as own choice to adjust energy consumption behaviour/activities accordingly leads to lower GHG emissions, monetary savings of consumers, and time-of-use tariffs (i.e. energy use at off-peak) respectively. These might seem automatic supporting relationships, but it cannot be neglected that consumers need to actively adapt their energy consumption behaviour accordingly, in order for Control/Autonomy to lead to the mentioned values. In terms of own choice to give others access to your personal data, this value also contributes to Economic Development (related to monetary savings of consumers) and Privacy. This might imply that fuel poor households who might not have the opportunity to become prosumers, might opt for this option to make some earnings from selling their consumption data. In addition, *Courtesy* contributes to Quality of life/Well-being/Comfort as considering consumers' needs in the energy market aids fighting fuel poverty. Moreover, Courtesy (in terms of claiming the truth and being polite) contributes to Calmness, but this is not necessary a pre-requisite.

As depicted in Figure 3, *Distributive Justice* contributes to Economic Development in terms of consumers not profiting as much as energy companies and thus most of the benefits for energy companies alone. Besides, Distributive Justice (in terms of reasonable prices for (vulnerable) consumers) is perceived to contribute to Courtesy. *Economic Development* contributes to Environmental Sustainability and Transparency/Accuracy as adoption of energy efficiency measures add to lower GHG emissions and data access of energy consumption. Yet, for these supporting relations to be realized, consumer adoption is required. Economic Development also contributes to Security of supply as businesses getting paid by the government to lower energy use aid to balance supply and demand. Yet, this depends on their willingness to do so. Moreover, Economic Development contributes to Universal usability/Inclusiveness and Transparency/Accuracy as the cost of smart grid technology for consumers add to consumers being less likely to profit from technology benefits, but enhance billing accuracy. *Environmental*

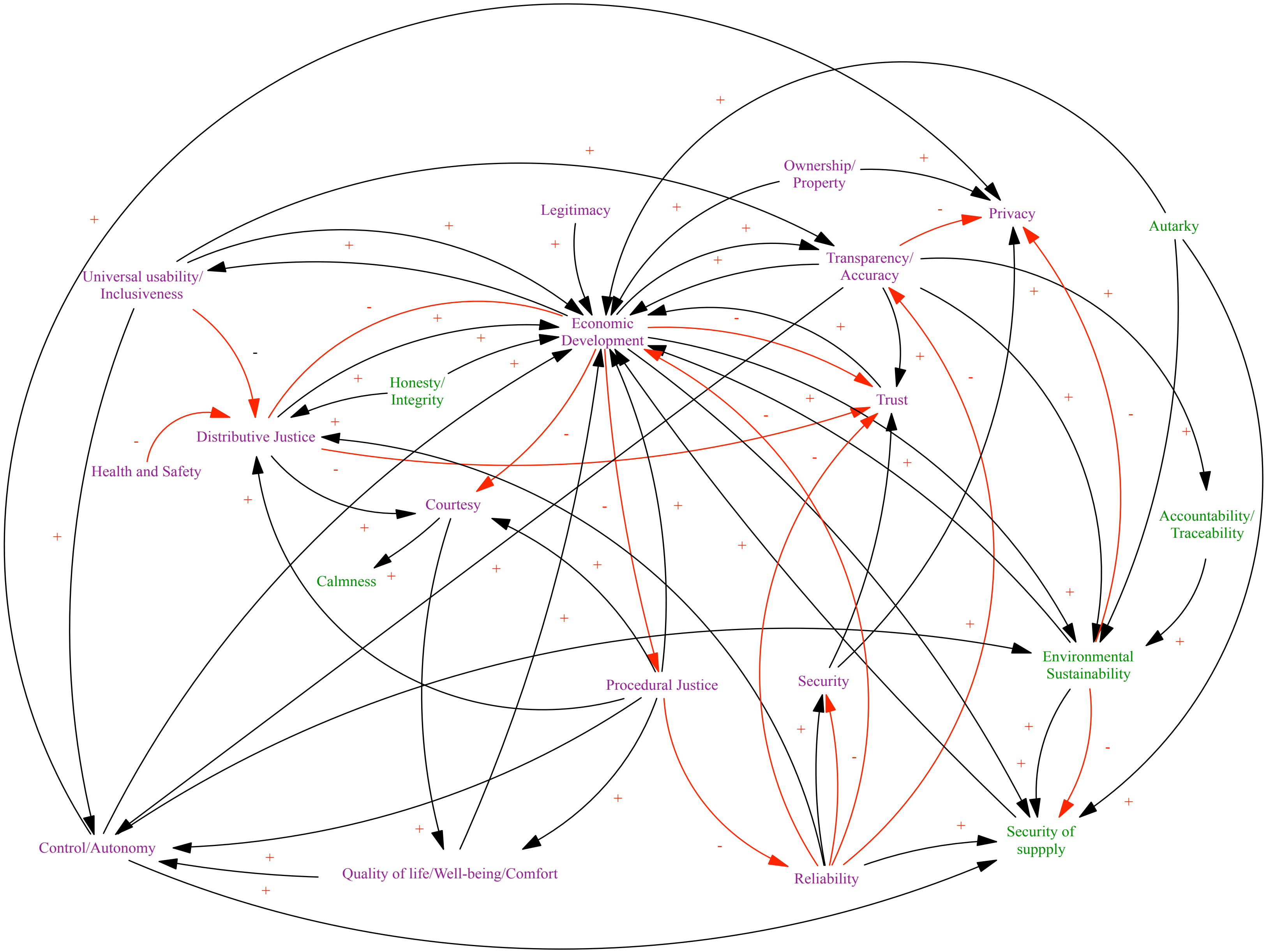

Figure 3: Network of related values associated with smart grid systems

Sustainability as in integration of renewables and preventing resource waste by sending excess energy back to the grid, contribute to Economic Development as in prosumers selling excess power (if that is the case) at a profit. This gives the impression that prosumers might overproduce in order to maximize their earnings. This could pose additional stress on de grid if energy demand is low compared to the supply. On the other hand, sending excess energy back to the grid if there is demand, contributes to Security of supply in terms of independency from (frequent) power cuts. Additionally, *Honesty/Integrity* contributes to Economic Development and Distributive Justice as energy companies misleading consumers with sales tricks adds to benefit for energy companies alone and consumers not profiting as much as energy companies. Furthermore, *Legitimacy* contributes to Economic Development as the legal binding deadline for the smart meter roll-out avoids disproportionate cost of roll-out plans. *Ownership/Property* regarding data property rights contributes to Privacy and Economic Development in terms of monetising consumer data. Besides, this value contributes to Economic Development as own power generation (i.e. possession of small-scale generation) adds to prosumers selling excess power with a profit and at the same time making them less prone to network power cuts.

From the empirical data also comes forth that *Procedural Justice* contributes to Courtesy, Quality of life/Well-being/Comfort, Distributive Justice, and Economic Development. The opportunity that consumers can participate in decision-making about SGSs adds to consideration of their needs, fighting fuel poverty, fair distribution of costs and benefits, and monetary savings for consumers. Besides, Procedural Justice in terms of decision rights that everyone should be able to contribute to Control/Autonomy. In addition, Procedural Justice in terms of transparency in energy pricing decisions contributes to Distributive Justice in terms of reasonable prices for (vulnerable) consumers. Furthermore, *Quality of life/Well-being/Comfort* contributes to Control/Autonomy and Economic Development since automation is convenient and adds to own choices to adjust energy consumption behaviour/activities and monetary savings by consumers. *Reliability* contributes to Security of supply as a network that is able to cope with fluctuating demand, balances supply and demand effectively. Additionally, Reliability contributes to Distributive Justice and Security since unreliable technology adds to consumers not profiting as much as energy companies and the national grid being open to cyber-terrorists. *Security of supply* contributes to Economic Development as effectively balancing supply and demand adds to monetary savings of consumers. Besides, *Security* of consumer data contributes to both Trust and Privacy.

As can be seen from Figure 3, *Transparency/Accuracy* in terms of billing accuracy contributes to Economic Development in terms of monetary savings for consumers. In terms of data access of energy consumption, Transparency/Accuracy contributes to Control/Autonomy (in terms of own choice to adjust energy consumption behaviour/activities and to give others access to your personal data), Accountability/Traceability (in terms of consumers being able to track their energy consumption behaviour and energy bill), Environmental Sustainability (i.e. prevention of wasting resources by sending excess energy back to the grid), Economic Development (i.e. monetary savings of consumers), and Trust. Additionally, *Trust* contributes to Economic Development in terms of monetary savings for consumers. Seemingly, trust from the domestic customers with the electricity suppliers might lead to a higher probability of smart meter adoption, which tells them the instantaneous cost of the current kilowatt hour. Furthermore, *Universal usability/Inclusiveness* contributes to Control/Autonomy (i.e. own choice to adjust behaviour/activities), Economic Development as monetary savings for consumers, and Transparency/Accuracy (i.e. data access of energy consumption). As the UK acknowledges fuel poverty issues, offering consumers a free smart meter, contributes to including all societal groups in the roll-out (especially vulnerable consumers), which contributes to monetary savings for households and data access of their energy consumption.

5.2 Inter-value conflicts

In addition, several inter-value conflicts are identified, requiring a value trade-off in the technical and/or institutional design of SGSs. This means that *"two or more values conflict in a specific situation if, when considered in isolation, they evaluate different options as best"* (van de Poel, 2009, p.977). To start with, *Distributive Justice* conflicts with *Economic Development* and *Trust*, as it seems that consumers do not profit as much as energy companies since they are the ones bearing the cost of SGSs technology. Besides, *Economic Development* conflicts with *Courtesy, Procedural Justice*, and *Distributive Justice* since consumers bearing the cost of SGSs technology contradicts consideration of their needs, consumers not sufficiently being able to participate in decision-making about SGSs, and no reasonable prices for (vulnerable) consumers. Furthermore, *Economic Development* in terms of rising energy prices contradicts *Trust*. Moreover, *Environmental Sustainability* conflicts with *Privacy* since smart meters are presented as an environmental and power-saving initiative, but it is a highly informative model that e.g. can tell how many showers are taken in a household, when are people cooking and when they are in and out of the home. This might imply that all these inter-value conflicts mainly concern the institutional design of SGSs. In terms of integration of renewables, *Environmental Sustainability* conflicts with *Security of supply* as the intermittent character of renewables puts an additional strain on balancing supply and demand.

Furthermore, *Health and Safety* is in tension with *Distributive Justice* due to radiation that can cause acute harm. Yet, in my opinion there is no scientific underbuilt proof that low frequency (50 Hz) electromagnetic radiation leads to health effects. For higher frequencies such as Wi-Fi this may be different, but as technology rapidly advances, this can be tackled in the technical design of SESs and should be addressed in their institutional design in the form of radiation thresholds specific to SGSs. *Procedural Justice* conflicts with *Reliability* as the government did not properly think about the costs to the consumer during the decision-making process about the smart meter roll-out, because it was mainly driven by the energy companies whilst the technology was unreliable (out-of-date). Moreover, *Reliability* in terms of unreliable technology conflicts with *Security* (of consumer data), *Trust, Economic Development* (in terms of cost of SGSs technology for consumers and monetary savings for consumers not always being possible due to marketing of third parties when consumer data is monetized), *Transparency/Accuracy* (i.e. data access of energy consumption and billing accuracy). In addition, *Transparency/Accuracy* in terms of data access of energy consumption conflicts with *Privacy*, as it can be intrusive in people's life. *Universal usability/Inclusiveness* conflicts with *Distributive Justice* in terms of vulnerable consumers being less likely to profit from benefits of SGSs implementation. This might be regulated in institutions to protect consumers.

5.3 Intra-value conflicts

First of all, almost all identified values that are shared among two or more stakeholder groups (except for Autarky, Environmental Sustainability, Honesty/Integrity, and Security of supply) an intra-value conflict is recognized. This is due to significant differences in value understandings and interpretations of the different stakeholder groups in 79% of the cases. This means that the following values are contested:

- *Ownership/Property:* this value is shared among four stakeholder groups. Energy consumers, transmission system operators, and knowledge institutions have the same interpretation and attach a positive sentiment to it as it regards possession of small-scale generation sources and ownership of personal data on energy use. However, the media interprets this value with a negative sentiment, as personal data is too vulnerable due to the digital technology used in smart grid technologies.
- *Control/Autonomy:* this value is shared among eight stakeholder groups, some perceiving it with a different type of sentiment. Governmental bodies and policy-makers, supporting organizations for smart grid development, consumer organizations, and transmission system operators attach a positive sentiment to this value and interpret it as consumers having the power in their own hands to adapt their energy consumption to save energy and control costs. The energy companies share this value interpretation, but also attaches a negative sentiment to it as consumers (retail level) can easily switch suppliers. Trade associations positively interpret this value as agreements being made with the industry (wholesale level) on a voluntary basis. Besides, energy consumers and the media contest this value. On the one hand, they interpret it as control of consumption behaviour and control of appliances to operate when energy prices are low, but on the other hand there are fears that smart appliances will take control of the way a household operates.
- *Courtesy:* this value is shared among five stakeholder groups, some perceiving it with a different type of sentiment. The energy companies attach a positive sentiment to this value as they consider consumers' needs from their point of view. This is in direct tension with the value interpretation of energy consumers and the media, as they think that consumers' interests and needs are not being sufficiently considered by the suppliers and

sometimes even by the government. This is in line with the understanding of governmental bodies and policy-makers about this value, regarding the government letting suppliers decide the price of smart meters and thereby not properly considering that this could put a financial burden on consumers. In addition, the consumer organizations contest this value due to doubts on suppliers properly considering consumer needs.

- *Distributive Justice:* this value is shared among six stakeholder groups, some perceiving it with a different type of sentiment. Governmental bodies and policy-makers as well as the energy companies attach a positive sentiment to this value and interpret it as both consumers and suppliers bearing the costs of smart grid development and sharing its benefits. On the other hand, consumer organizations, energy consumers, knowledge institutions, and the media contest this value as they have doubts on fair distribution of costs and benefits between suppliers and consumers.
- *Economic development:* this value is shared among all stakeholder groups, some perceiving it with a different type of sentiment. Environmental organizations, supporting organizations for smart grid development, energy companies as well as governmental bodies and policy-makers perceive this value with a positive sentiment and understand it as investments in smart grid development and making homes energy efficient. Adding to this perception, governmental bodies and policy-makers also positively relate this value to prosumers selling power back to the national network and energy companies also relate it to cost savings for energy companies and consumers due to SGSs implementation. Moreover, transmission system operators understand this value with a positive sentiment as smart grids enabling consumers to shift demand and be paid to do so and also to invest in small-scale generation of renewable energy. Besides, trade associations positively interpret this value as competition in energy market regarding smart meter installation. Consumer organizations and energy consumer share understanding of this value and interpret it with mixed sentiments as smart meters aiding households to drive down their energy bills, but the installation costs are too high. Additionally, the media also contests this value as rise in energy bills are due to the government underestimating the costs of the smart meter roll-out, but even so smart meters allow accurate billing and energy saving through recording energy consumption and controlling household appliances through automation. Knowledge institutions, also contest this value since they perceive the smart meter roll-out as an inefficient way of saving small amounts of money on energy bills, but at the same time having major national benefits, such as a more secure grid and reduced pollution.
- *Health and Safety:* this value is shared among five stakeholder groups, some perceiving it with a different type of sentiment. Governmental bodies and policy-makers claim that radiation emission of wireless devices comply with guideline levels and are not harmful at all, while consumer organizations claim that it is dangerous for human health and well-being. The energy consumers share the value interpretation of both stakeholder groups and thus contest this value. The media perceives this value with a negative sentiment and interpret it as fire risk due to smart appliances being left unattended when operating at night, when the energy prices are low. Besides, supporting organizations for smart grid development positively interpret this value as a free fire safety advice and carbon monoxide check on all gas appliances in the home provided to households at the installation of smart meters.
- *Legitimacy:* this value is shared among five stakeholder groups, some perceiving it with a different type of sentiment. Governmental bodies and policy-makers, energy companies, trade associations, and energy consumers positively perceive this value and understand it as smart grid policy. However, energy consumers also attach a negative sentiment to it, as energy companies do not always comply with it (e.g. missing deadlines for the smart meter roll-out). In addition, consumer organizations have a negative perception of this value as the government has not established clear installation guidelines yet, with reasonable steps that suppliers must consider at the smart meter roll-out
- *Privacy:* this value is shared among five stakeholder groups, some perceiving it with a different type of sentiment. Consumer organizations relate this value to smart meters being privacy intrusive, whilst supporting organizations for smart grid development do not agree as only simple information on energy consumption is stored and transmitted, so not personal details at all, such as name, address, and bank account details. Energy consumers contest this value as smart meters are privacy intrusive, but necessary privacy measures are believed to be taken by the government. Besides, knowledge institutions contest this value as well since personal data can be monetized for marketing purposes having positive and/or negative effects (e.g. making profit or data being abused). The media also contests this value, as personal data is prone to fall in wrong hands, undesirably opening a window to peoples' private life.
- *Procedural Justice:* this value is shared among five stakeholder groups, some perceiving it with a different type of sentiment. Governmental bodies and policy-makers as well as energy companies positively interpret this value as being stakeholders having a say in energy pricing decisions and are offered the opportunity to engage as much

as possible in decision making processes on SGSs. On the other hand, consumer organizations, energy consumers, and the media negatively perceive this value as consumers not being offered enough opportunities to participate in decision-making procedures on SGSs and energy pricing.

- *Quality of life/Well-being/Comfort:* this value is shared among five stakeholder groups, some perceiving it with a different type of sentiment. Governmental bodies and policy-makers positively perceive this value as SGSs allow a low carbon future that enhances the quality of life and well-being of people. Energy companies also positively perceive this value as automated transmission of consumption data allows hassle free and accurate bills. The energy consumers share this interpretation too, but they also attach a negative sentiment to this value, as they are not able to consume energy when it fits them best due to high energy prices at peak times (i.e. demand response). Consumer organizations interpret this value with a negative sentiment as radiation emissions of wireless devices exacerbate human well-being. Besides, the media contests this value as smart grid technologies contribute to a less polluted living environment, but if automation of technology goes wrong it can affect users comfort and well-being.
- *Reliability:* this value is shared among six stakeholder groups, some perceiving it with a different type of sentiment. Supporting organizations for smart grid development, consumer organizations, and energy consumers positively perceive this value and understand it as smart meters delivering their full range of functionality. However, energy consumers also have a negative sentiment regarding this value, as some believe that the technology might be out-dated when the roll-out is complete. In addition, Governmental bodies and policy-makers contest this values since there are difficulties in making smart meters properly work (e.g. in tall buildings and when customers switch supplier, smart meters being out of date, and other technical issues), have not yet completely been resolved whilst the roll-out already started. Knowledge institutions claim that the digital technology of smart grids allows easily tracing and solving issues in the power network, ensuring that it properly functions. However, the media agrees that smart grid technology is advanced, but even so it could malfunction.
- *Security:* this value is shared among four stakeholder groups, some perceiving it with a different type of sentiment. Supporting organizations for smart grid development interpret this value with a positive sentiment, as permission is needed for sharing consumption data with third parties. Knowledge institutions also positively interpret this value as smart grids being secure and safeguarding its sensitive systems. On the other hand, the media contests this value as smart grids are expected to deliver a more responsive energy system with the aid of ICT, but this could make it prone to cyber-attacks. Energy consumers contest this value too since personal data is vulnerable due to SGSs digital technology and might fall in the wrong hands, but others acknowledge that high security standards are used for data protection.
- *Transparency/Accuracy:* this value is shared among all stakeholder groups, except the environmental organizations, and some perceiving it with a different type of sentiment. Governmental bodies and policy-makers, supporting organizations for smart grid development, energy companies, consumer organizations, energy consumers, and the media perceive this value with a positive sentiment as insight in energy consumption behaviour of households can be obtained. However, energy consumers and the media contest this value, as some believe that the energy consumption information is not useful and sometimes too complex to be understood. In addition, the trade associations emphasize that many people in the UK do not know about devices that measure energy use in the home and thus attach a negative sentiment to this value. On the contrary, transmission system operators understand this value as proper information about energy use. Knowledge institutions contest this value as insights in energy consumption behaviour of households opens up a window on their private life, but allows suppliers to better understand consumers' energy usage and allow them to make better energy decision when buying energy wholesale.
- *Trust:* this value is shared among seven stakeholder groups, some perceiving it with a different type of sentiment. Governmental bodies and policy-makers positively interpret this value as governmental trust in energy suppliers passing on the saving to consumers made on no longer having to send staff to read meters manually. Supporting organizations for smart grid development also perceive this value with a positive sentiment as consumers trust suppliers with their consumption data since they have complete control over it, because it cannot be shared with others without permission. However, energy companies negatively perceive this value since they understand it as tensions between suppliers and consumers regarding energy prices and customer service. Besides, consumer organizations and energy consumers contest this value due to doubts on energy suppliers acting for the benefit of consumers. The media also contests this values since energy suppliers provide consumers with tools to better manage their energy consumption, but those tools are a window into consumers' personal life and might aid suppliers in showing strategic behaviour, e.g. by making energy expensive when it suits them best. Moreover, knowledge institutions interpret this value with a negative sentiment since the government is trusted to tackle any

problems regarding smart grid technology, but it does not always do so (e.g. smart meters lose their smartness when consumer switch suppliers, the government knew this for a long time and did not take any action).

- *Universal usability/Inclusiveness:* this value is shared among seven stakeholder groups, and is mainly perceived with a positive sentiment. Governmental bodies and policy-makers and energy companies understand this value as the smart meter roll-out including all households in the UK and thus not excluding any. Supporting organizations for smart grid development positively interpret this value too as smart grid technologies aid all consumers engaging more in their energy use. Besides, energy consumers contest this value since all households in the UK will have access to smart grid and smart meters, but the technology is so complex that some people believe elderly and computer illiterate will be excluded to become successful users.

The examination of values and the type of relationship (supporting or conflicting) among them is paramount as it can contribute to design for values in SGSs. This implies the ethical values that have been identified can be translated in design requirements to be embodied in the technical and institutional design of SGSs. Furthermore, those insights also provide information on necessary value trade-offs in case values are conflicting and cannot be both addressed in the design of SGSs. Identifying value conflicts is the first step towards resolving them or reaching reasonable disagreement. This is relevant as SGSs designs may not be adopted due to unresolved value conflicts.

6. Conclusion

Responsible innovation is increasingly receiving attention from policy-makers and the energy industry (Taebi et al., 2014), thereby demanding socially responsible development of energy projects through identification, consideration and accommodation of stakeholder values (Correljé et al., 2015; Taebi et al., 2014). This article has shown that ethical values are intrinsic to the design of SGSs as they can be characterized as relevant factors (i.e. barriers or drivers) for SGSs adoption. Furthermore, identification of values and insights into their interrelations provide information on necessary value trade-offs that certain decisions involve and which social cost/burden or social benefit might be linked to different design options of these emerging innovations. This is necessary in the pursuit of value-robust SGSs by better understanding its social repercussions and controversies.

The network of related values (see Figure 3) serves as input for the public debate on SGSs. For instance, putting all these values on the negotiation table in a decision-making arena can nudge other stakeholders to consider these social values as important, creating added value for society at large. Furthermore, this network also serves as input to identify emerging values, supporting, and conflicting relations from the perspective of new players in the energy market and smart grid development. Besides, the network also serves as input for modelling and simulation studies (e.g. agent-based modelling and systems dynamics) in order to examine long-term effects of smart grid policies for example. In addition, the network serves as a reference to grasp how changes in the design of smart grid components affect their associated values and consequently other values, thus which value trade-offs certain design choices might imply. The added value of the established network is that it promotes moral values as an integral part of the design of SGSs. The values and relations provide input for implementing normative considerations into the technical and institutional design of SGSs. Moreover, choices for specific design options of SGSs can be (normatively) justified with the aid of the network of related values. Hence, embedding values in the design of SGSs contribute to reach ethically acceptable and socially desirable smart grids.

7. Avenues for future research

First of all, it is recommended to consider other cases (i.e. public debate in other countries) to study whether values associated with SGSs differ per country and/or whether new values emerge. This contributes to further expanding VSD into the energy domain. Besides, it is advised to gain insights into the dynamics of the public debate in order to understand the co-evolving character of ethical values associated with SGSs and thus how they develop over time. Furthermore, it is worthwhile for future research to make efforts in translating the identified values into design requirements for SGSs. Moreover, the future research can focus on simulation and modelling of SGSs acceptance and policies through e.g. agent-based modelling and system dynamics. Additionally, future research can also focus on performing a Social Network Analysis in order to study the relationships between smart grid actor(s) with other actor(s) or organizations to identify potential partnerships among smart grid stakeholders to effectively incorporate ethical values in SGS. Lastly, it is suggested for future research to investigate prioritization of the values among stakeholder groups. For this purpose, multi-criteria decision-making methods can be applied (e.g. the Best-Worst method by Rezaei (2015, 2016) in order to add importance in terms of "weights" to values per stakeholder group through e.g. consultation of stakeholders by means of workshops or interviews and then comparing the preferences. Thereby, quantification of ethical values can contribute to trading-off values in the institutional and technical design of SGSs.

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Appendix A: Smart grid stakeholders and their priorities

Table 1: Overview of smart grid stakeholders in the United Kingdom

Stakeholder group	Stakeholder name	Priorities
Environmental Organizations	• Friends of the Earth • Future Energy Solutions • Energy Saving Trust	• Environmental protection • A better standard of living • Sustainable development • Climate change mitigation
Governmental bodies and policy-makers	• European Union • Department of Energy & Climate Change • Department for Business, Energy & Industrial Strategy • Environment Agency • Office of Gas and Electricity Markets • Gas and Electricity Markets Authority	• Sustainable development • Climate change mitigation • Environmental protection • Development of Energy Policy • Regulation of the Energy Industry • Cooperation between stakeholders • Provide strategic direction • Fight fuel poverty • Innovation
Supporting organizations for smart grid development	• The Electricity Network Strategy Group • The Smart Grid Forum • SmartGrid GB • Developers of technology	• Provide (expert) advise • Smart grid development • Realization of a low carbon future • Cooperation among stakeholders • Provide guidance to stakeholders • Identify the challenges and barriers to the adoption of SGSs
Trade Associations	• Energy UK • The Electricity Networks Association • The British Electro-technical and Allied Manufacturer's Association • UK IT Association • Association for Decentralised Energy	• Represent its members and their interests, also in the political agenda • Lobby to influence policy and decision-making processes
Energy Companies	• The Big Six suppliers • Middle sized suppliers • Small suppliers	• Supply of energy • Profit • High market share • Continuity of their business
Consumer organizations	• Consumer Focus • Citizens Advice • Community Energy	• Represent consumers and their interests, also in the political agenda • Lobby to influence policy and decision-making processes • Clean, healthy, and safe energy practices

Energy consumers	• Domestic consumers • Commercial consumers • Industrial consumers	• Secure and affordable energy supply • Accurate billing • Lower energy bills • Avoid fuel poverty
Distribution Network Operators	• Electricity North West • Northern Ireland Electricity Networks • Northern Powergrid • SP Energy Networks • Scottish and Southern Electricity Networks • UK Power Networks • Western Power Distribution • GTC • Inexus	• Ensure electricity gets to the consumers • Continuity of their business • Management of loads in the distribution network
Transmission System Operators	• National Grid Industrial • Scottish Power Energy Networks • Scottish & Southern Electricity Networks • Northern Ireland Electricity Networks	• Continuity of their role and responsibilities • Management of electricity flow through the entire transmission network • Balance supply and demand
Knowledge institutions	• Universities in the UK • Research institutes in the UK • Think tanks	• Perform research to contribute to the knowledge about SGSs • Share knowledge and solutions • Acquire funds to finance scientific research • Convening platforms for stakeholder engagement • Transition of the UK to a low carbon economy

Appendix B: Values associated to smart grid systems

Table 2: Ethical values associated with smart grid systems and their conceptualization in this context (after expert validation)

Value	Conceptualization	Source
Accountability/Traceability	Refers to the properties of smart grid systems that allows and ensures that the actions or activities of a person, people, or institution may be traced uniquely to that specific person, people, or institution. This also refers to explaining, in the sense of giving reasons, for one's actions. Moreover, this also encompasses a form of "making up for the damage", thus compensation, reimbursement in terms of actions or financial settlement.	(Friedman, Kahn, Borning, & Huldtgren, 2013; Ligtvoet et al., 2015)
Autarky	Refers to smart grid systems allowing energy independence, energy autonomy, energy self-reliance or energy self-sufficiency.	(Ellabban & Abu-Rub, 2016; Römer, Reichhart, & Picot, 2015)
Calmness	Refers to smart grid systems promoting and allowing a peaceful and composed psychological state to its users and other stakeholders.	(Friedman et al., 2013; Ligtvoet et al., 2015)
Control/Autonomy	Refers to smart grid systems (and its components) enabling its users to pursuit their own goals and decide, plan, act, and make their own choices in the ways they believe will help to achieve their goals.	(Buchanan et al., 2016; Friedman et al., 2013; Ligtvoet et al., 2015; Wilson et al., 2017)
Cooperation	Refers to smart grid systems allowing its users to interact and collaborate with each other and other stakeholders, even if they have different interests, expectations, backgrounds, and attitudes towards smart grid systems.	(Correljé et al., 2015; Dincer & Acar, 2016; Ligtvoet et al., 2015)
Courtesy	Refers to smart grid systems promoting treating people with dignity, politeness, and consideration.	(Friedman et al., 2013; Ligtvoet et al., 2015)
Democracy	Refers to a process of collective decision-making that enables equal advancement of public interests in a fair way by promoting the input from the members of society and by giving them an equal say in the decisions to be taken.	(Christiano, 2004; Ligtvoet et al., 2015; van de Kaa et al., 2014)
Distributive justice	Refers to the equitable and reasonable distribution and allocation of outcomes, such as public goods, opportunities, welfare and/or public burdens (negative effects) across individuals or groups in society. In the context of smart grid systems, the public goods relate to energy supply, opportunities relate to innovation (upgrade of the current energy infrastructure with ICT) and the opportunity of consumers to become prosumers achieving economic welfare out of own energy production. In addition, public burdens related to social values being at risk or not being considered in the design of smart grid systems.	(Dignum et al., 2016; Gross, 2007; Künneke, Mehos, Hillerbrand, & Hemmes, 2015; Steg, Bolderdijk, Keizer, & Perlaviciute, 2014)
Economic development	Refers to smart grid systems being beneficial to the future finances/economic status of its users, market participants, and other relevant stakeholders as well as smart grid systems having a positive business case.	(Ligtvoet et al., 2015)

Environmental sustainability	Refers to smart grid systems allowing and fostering the contribution to climate goals through the reduction of greenhouse gas emissions from the energy sector as well as promoting reduction of consumers' energy use and allowing the integration of renewable energy into the electricity network, these all for the sake of environmental conservation and preservation for current and future generations.	(Buchanan et al., 2016; Buryk, Mead, Mourato, & Torriti, 2015; Darby, 2010; Darby et al., 2013; Friedman et al., 2013; Krishnamurti et al., 2012; Ligtvoet et al., 2015; Noppers, Keizer, Milovanovic, & Steg, 2016; Ponce, Polasko, & Molina, 2016; Tuballa & Abundo, 2016; van de Poel, 2009; Zhou & Brown, 2017)
Freedom from bias	Refers to smart grid systems promoting the absence of systematic unfairness perpetrated on individuals or groups in society, including pre-existing social bias, technical bias, and emergent social bias. This also includes that smart grid systems should not promote a select group of stakeholders at the cost of others.	(Friedman et al., 2013; Ligtvoet et al., 2015)
Health and safety	Refers to smart grid systems not harming people and their health due to the emission of remote signals and thus people's exposure to effects such as electromagnetic radiation (the entire spectrum: not only high frequency radio waves but also extremely low frequency (hence 50/60 Hz) electromagnetic fields) possibly causing electro hypersensitivity. Smart grid systems should not inhibit people from reaching a state of complete mental, physical, and social well-being and not merely the absence of infirmity or disease.	(Dignum et al., 2016; Guerreiro et al., 2015; Ligtvoet et al., 2015; Yesudas & Clarke, 2015)
Honesty/Integrity	Refers to smart grid systems being transparent and honest/integer; designed to prevent abuse of e.g. consumer data. This also refers to smart grid systems promoting smart grid stakeholders to have the quality of being honest and telling the truth and being able to be trusted and not likely to lie or cheat.	(van de Poel & Royakkers, 2011)
Identity	Refers to smart grid systems promoting people's understanding of who they are over time and allowing its stakeholders to preserve their identity, shape it or change it if necessary.	(Friedman et al., 2013; Ligtvoet et al., 2015)
Informed consent	Refers to garnering people's agreement, encompassing criteria of disclosure and comprehension (for "informed") and agreement, competence, and voluntariness (for "consent") for the implementation of smart grid systems. This implies that reliable information is provided to and shared between smart grid stakeholders so they can make choices based on arguments.	(Buchanan et al., 2016; Friedman et al., 2013; Ligtvoet et al., 2015)
Legitimacy	Refers to smart grid systems being deployed on a sound political and legal basis or having broad support.	(Dignum et al., 2016; Ligtvoet et al., 2015)
Ownership and property	Refers to smart grid systems facilitating the ownership of an object or of information and allowing its owner to use it, manage it, bequeath it and/or derive income from it.	(Friedman et al., 2013; Ligtvoet et al., 2015)
Privacy	Refers to smart grid systems allowing people to determine which personal information can be collected, stored, used, and shared with others (e.g. monitoring of daily habits, energy consumption data).	(Balta-Ozkan et al., 2013; Friedman et al., 2013; Ligtvoet et al., 2015; Xenias et al., 2015)

Procedural justice	Refers to fairness in the process of decision-making, giving all relevant stakeholders the opportunity to participate in the process, especially the ones that are being affected by decisions on smart grid systems.	(Gross, 2007; Guerreiro et al., 2015; Künneke et al., 2015; Wüstenhagen, Wolsink, & Bürer, 2007)
Quality of life/Well-being/Comfort	Refers to smart grid systems facilitating a sufficient state of convenience and comfort (e.g. avoiding the hassle of meter readings, light and heating control in a home environment, etc.) and promoting human well-being (e.g. physical, psychological, and material well-being).	(Bonino & Corno, 2011; Buchanan et al., 2016; Ligtvoet et al., 2015; van de Poel & Warnier, 2015)
Reliability	Refers to the ability of smart grid systems and its components to adequately perform its function over a period of time without failing. This implies the reduction/avoidance/prevention of vulnerabilities for failure, adverse events, malfunctions, unintended consequences, and inference in the desired outcomes of a household concerning smart grid technology use.	(Balta-Ozkan et al., 2013; Buryk et al., 2015; Krishnamurti et al., 2012; Ligtvoet et al., 2015; van de Poel, 2015)
Security	Refers to the protection and safeguard of personal data and sensitive systems of smart grids and its components against (external) malicious attacks (e.g. cyber attacks).	(Balta-Ozkan et al., 2013; Chou et al., 2015; Muench et al., 2014)
Security of supply	Refers to smart grid systems promoting a low risk of interruptions in power supply and thus ensuring that power is available when needed (even during peak demand times.	(Demski, Spence, & Pidgeon, 2013; Krishnamurti et al., 2012; Künneke et al., 2015; Römer et al., 2015)
Transparency/Accuracy	Refers to smart grid systems providing information and insights on (actual) consumption patterns of energy consumers e.g. to consumers, energy suppliers and/or the government.	(Cuijpers & Koops, 2012; Guerreiro et al., 2015; Ligtvoet et al., 2015)
Trust	Refers to a state of mind that entails expectations that exist between people who can experience good will, extend good will toward others, feel vulnerable, and experience betrayal. Hence, the intention to accept vulnerability based upon positive expectations of the intentions or behaviour of another. Smart grid systems promote trust in itself and in its stakeholders.	(Friedman et al., 2013; Huijts, Molin, & Steg, 2012; Ligtvoet et al., 2015; Steg et al., 2014)
Universal usability/ Inclusiveness	Refers to smart grid systems providing different individuals or groups in society the opportunity to become (successful) users and not excluding anyone (e.g. people who are not computer literate, elderly, etc.).	(Friedman et al., 2013; Ligtvoet et al., 2015)