Design for values in smart grid systems

An exploratory empirical investigation of the ethical values and their interrelationship that play a role in the British public debate on smart grid systems

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Challenge the future

Picture taken from: https://www.hectorschool.kit.edu/smart_energy.php

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“If there were only one truth, you could not paint a hundred canvases on the same theme”

Pablo Picasso

This thesis is dedicated to my family and my three angels in heaven (Cesar, Maria Trinidad, and Ivo) for their incomparable support and encouragement to realize this dream.

I love you endlessly!

Preface

In front of you lies my thesis about design for values in smart grid systems, written with a lot of dedication and sincere interest in order to realize the dream of obtaining my Master's Degree in Complex Systems Engineering and Management at Delft University of Technology. Moreover, this thesis embodies my passion for energy infrastructures, sustainable development, responsible innovation, and ethics of engineering design. The focus of this research project is to empirically investigate the normative stances (i.e. ethical values) that are put forward in the public debate as arguments/statements regarding smart grid systems in the United Kingdom for the past 10 years. This was very challenging! But I hope that the findings can contribute significantly to both science and society.

I would like to express my immense gratitude to my entire Graduation Committee for their excellent guidance and support during this thesis life. I admire each one of you! And it was an honour to collaborate with you in this research project. I feel very lucky. Especial thanks go to Christine Milchram for her outstanding supervision and support, especially during difficult times. Your great interest in this research topic was contagious and you proved to be a true mentor, providing me with inspiration and encouragement to move on. I would also like to thank you for willing to perform the tedious inter-coder reliability check (i.e. validation of coding), your time and the nice debates on ideas regarding this research, which were very helpful to me. Furthermore, I am very grateful to Dr. Geerten van de Kaa for his motivation, trust and especially his feedback when the results appeared to be too complex for interpretation. Thank you so much for the brainstorming session we had with Christine on how to tackle the complexity of my findings. That was a very fruitful meeting and made me realize even more the added value of working in interdisciplinary teams and sharing thoughts. In addition, I wish to thank Drs. Jolien Ubacht for her indispensable academic insights that helped me structure this thesis, keep focused, be more specific, and improve my work. I am also grateful for offering your help anytime, especially regarding the software for data analysis (ATLAS.ti) and for introducing me to the world of blockchain. My sincere gratitude also goes to my Committee Chair, Prof. Dr. Sabine Roeser, for her valuable insights and feedback on the ethics aspect of my research. I have a great esteem for your work on risk and emotions and it made me realize even more the importance of pursuing value-robust designs. I would also like to thank you for helping me to narrow down the scope of my research, for motivating and giving me confidence. Special thanks also go to Prof. Dr. Ir. Ibo van de Poel, Dr. Theo Fens, and Tristan de Wildt for validating my codebook and their valuable suggestions that have contributed to achieve credible results. Also, many additional thanks to Dr. Theo Fens for validating my network of related values, his noteworthy observations, and interest in this research. Furthermore, I wish to thank my student counsellor Drs. Marja Brand for her advice, support and motivation during my academic career and for guiding me in attaining the scholarship for my masters.

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Daniela Maxouri
Amsterdam, February 2018

Summary

Technology used to be perceived as value-neutral and simply instrumental practical objects (van de Poel, 2009; Winner, 1980). Nowadays, technology is perceived as strongly value-laden objects that incorporate values whilst failing in representing other values (Correljé, Cuppen, Dignum, Pesch, & Taebi, 2015; Dignum, Correljé, Cuppen, Pesch, & Taebi, 2016; Taebi, Correljé, Cuppen, Dignum, & Pesch, 2014; van den Hoven, Lokhorst, & van de Poel, 2012). It is generally claimed that there is a growing interest and challenge to address ethical values in the design of technology. As such, it is acknowledged that values play a role in engineering design and are thus intrinsic to technological objects (van de Poel, 2009) because they might affect human well-being (Roeser, 2006, 2012). This means that technologies, such as smart grid technologies, have desirable as well as undesirable effects other than the main purpose they were designed for (van de Poel, 2009). Therefore, these novel energy technologies imply burdens and gains that come forward as controversies among different stakeholders when they feel that their values are not considered in the design of innovative technologies (Correljé et al., 2015; Taebi et al., 2014) such as smart grid systems (SGSs). Furthermore, SGSs might give rise to the emergence of *"new types of behaviour, and with that they also lead to new expectations and new sets of values"* (Correljé et al., 2015, p.186). Hence, it is reasonable to assume that values are embedded in 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 United Kingdom (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 research project 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 leads to the following research question:

What ethical values underlie the British public debate on smart grid systems and what relationships among the values can be identified?

First of all, SGSs (i.e. smart grids) are conceptualized as electricity networks enhanced with ICT that allow the secure connection of decentralized generation sites of intermittent renewable energy and facilitate 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, Thuss, & Guenther, 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 modern electricity network is intended to aid in meeting climate goals, allowing the creation of new jobs and empowering/incentivising consumers to manage their demand accordingly and adopt smart grid technologies in order to realize economic savings for themselves and the energy system (Government, 2014b). Furthermore, smart grids are designed to facilitate the integration of the actions and behaviour of users (e.g. electricity producers, consumers, and prosumers) (Darby, Strömbäck, & Wilks, 2013). Therefore, development of smart grids in the UK is studied in order to understand their emergence in the British society and the key players (as that specific public debate is assumed to be more mature compared to that of other European nations), which are needed to better understand the empirical data of this research.

After gaining insight into the field of ethics of technology, a literature review is performed on Value Sensitive Design (VSD) and SGSs. This resulted in an initial set of values conceptualized in the context of SGSs, serving as input for the empirical data analysis. For this purpose, the identified values were considered as sensitizing concepts. This means that the predefined values were considered to be open to any possible future changes that come along with the empirical data analysis (e.g. new values, values that are not mentioned in the literature, and different conceptualizations of values). In order to uncover what ethical values play a role in the British public debate as a matter of fact, a qualitative content analysis is carried out of 127 British national newspaper articles. Thereby, values are inferred from stakeholders' normative stances (i.e. value-laden statements) using a protocol

for the content analysis (i.e. coding and recording principles). This resulted in the following values at stake for SGSs according to the public debate in the UK and based on the notion of sensitizing concepts: *Accountability/traceability, Autarky, Calmness, Control/Autonomy, Courtesy, Distributive justice, Economic development, Environmental sustainability, Health and Safety, Honesty/Integrity, Legitimacy, Ownership/property, Privacy, Procedural justice, Quality of life/Well-being/Comfort, Reliability, Security, Security of supply, Transparency/Accuracy, Trust,* and *Universal usability/Inclusiveness.* Furthermore, the public debate shows that the most prevalent stakeholders are energy consumers, governmental bodies and policy-makers, the media, and energy companies since they are the ones bringing forth the majority of arguments about SGSs. Thereafter, these 21 identified values are differentiated per valence (i.e. positive/neutral/negative) in order to determine the degree of value contestation or whether they are recognized as clear barriers or drivers for SGSs. The results show that 72% of the identified values are contested, 14% are perceived as barriers and 14% as drivers. Additionally, values are differentiated per smart grid technology and stakeholder group in order to gain insight into stakeholder interpretations and understandings of values. This reflects that dissimilarities in value perception can potentially fuel the public debate and the emergence of conflicts.

Integration of the literature review and content analysis results allows the creation of a network of related values that maps the type of relations among values that can be associated with SGSs. The nature of these relations might be supporting or conflicting. This network shows that there is a clear division of mutually reinforcing and counteracting values, which depends on which actor perspective is taken. Hence, the degree of reinforcement/opposition depends on the perspective of the relevant actor. This provides an indication on how complex such value networks are. However, it 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. To conclude, this research project delivers empirical information on stakeholders' normative stances about SGSs. This can serve as input for ethical deliberation of these novel energy technologies. Besides, this information contributes to the applicability of the VSD approach to the energy domain, as it used to be mainly deployed in the ICT domain. Moreover, the identification and conceptualization of ethical values in the context of SGSs contributes to further specification of values that come forth in the VSD literature about values that generally might play a role in engineering design. Lastly, this research contributes to raise awareness on the importance of designing for values and pursuing value-robust smart grids and related technologies.

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List of abbreviations

ABM – Agent-based Modelling
BWM – Best-Worst Method
CoSEM – Complex Systems Engineering and Management
DCC – Data and Communications Company
DECC – Department of Energy and Climate Change
DNOs – Distribution Network Operators
LCN – Low Carbon Networks Fund
Ofgem – Office of Gas and Electricity Markets
SD – System Dynamics
SGSs – Smart Grid Systems
SNA – Social Network Analysis
TSOs – Transmission System Operators
UK – United Kingdom
VSD – Value Sensitive Design

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1. Introduction

Our energy based society and economic development have led over the years to issues related to climate change and resource depletion due to a growing energy consumption and demand. In order to cope with these problems, governments around the globe have adopted a low carbon regime. In line with this, the European Union (EU) established the 2012/27/EU Energy Efficiency Directive, which entails a set of binding measures that require all member states to reach an efficient energy use from production to consumption (EC, 2017c). The aim is to help the EU reach the 30% energy efficiency target by 2030, which is key to the transition to a sustainable European energy system (EC, 2017c). As such, the United Kingdom (UK), among other nations, established the following objectives to ensure that their current energy 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). This type of policy focuses on sustainable development and energy efficiency (Chou et al., 2015). Therefore, the introduction of renewable energy (e.g. solar and wind) and new loads (e.g. heat pumps and electric vehicles) have gotten a lot of attention in the recent years (Verbong, Beemsterboer, & Sengers, 2013). However, this poses great challenges to the existing electricity grid because of the intermittent character of sustainable energy sources and the necessary balancing of power demand and supply when new loads are being actively used. This additional stress on the existing electricity grid and its ageing as well as the urge to realize a decarbonized economy create the need to change existing electricity networks. A potential solution is to upgrade the current electricity grid with information and communication technology (ICT), resulting in so-called smart grid systems (SGSs) (DECC, 2015; Dincer & Acar, 2016; Verbong et al., 2013). SGSs are perceived as a potential solution because they support the integration of rising shares of renewable energy in the power network and allow accounting for volatility in electricity supply as well as rising number of decentral power generation sites through digitalization of the electricity grid (Mathiesen et al., 2015; Milchram & van de Kaa, 2017; Muench et al., 2014).

SGSs can be defined as a container notion that refers to the addition of ICT to electricity networks, crucial to advance towards a clean energy transition (Milchram & van de Kaa, 2017). Examples are smart meters and technologies applied in smart homes (Balta-Ozkan, Davidson, Bicket, & Whitmarsh, 2013; Buchanan, Banks, Preston, & Russo, 2016; Tuballa & Abundo, 2016). The general aim of SGSs is to account for higher intermittency and decentralized energy production due to a larger share of renewable energy (Mathiesen et al., 2015; Muench et al., 2014). Moreover, SGSs can be seen as complex socio-technical systems since it implies technological innovations linked to institutions and social development where different stakeholders play a role, usually with divergent interests. Considering human agency as the main driver of this development, smart grid technologies, stakeholders, and institutions mutually influence and continuously reconstitute each other, thereby influencing the performance of the power network (Scholten & Künneke, 2016). Additionally, another aspect of complexity regards unpredictable outcomes and thus uncertainty in this type of socio-technical systems (Williams, 1999). This means that stakeholders in SGSs can show unpredictable behaviour, especially in situations of social interactions with conflicts of interests (Hu, 2014). Since SGSs can be distinguished as socio-technical systems, it can be said that social acceptance is important for their successful implementation and adoption in society and that can be affected by stakeholder values.

1.1. Research problem

As aforementioned, a sustainable energy system can be reached through the implementation of SGSs. However, there are ethical concerns related to their use. In general, the introduction of new technologies into society might not be aligned with the inclusion of social values, leading to public resistance due to the perceived societal impact (Dignum et al., 2016). In the UK, moral concerns such as mistrust, privacy invasion, fear for loss of control, and lack of knowledge are among the strongest features of public discussions about SGSs (Balta-Ozkan et al., 2013). For instance, regarding privacy, the notion of "big brother is watching you" is addressed by several scholars. In addition, consumers are concerned of energy suppliers managing their energy use through dynamic pricing (consumers pay the fluctuating market rate for their electricity) which could result in disruption of household routines (Buchanan et al., 2016; Verbong et al., 2013). Furthermore, Krishnamurti et al. (2012) and Buchanan et al. (2016) show that the majority of the British public does not know what a smart meter is. Besides, scholars show that mistrust appears to dictate the negative and/or neutral behaviour of consumers. Another example is the delayed smart meter roll-out in the Netherlands because the stakes of households (a key stakeholder) were not sufficiently considered and required changes in the initial legislative proposals (Ligtvoet et al., 2015). Apparently, consumers and SGSs have a kind of uneasy relationship, mostly because the role of consumers has been often neglected whilst consideration of the moral issues they relate to these novel energy systems can hamper their social acceptance (Chou et al., 2015; Correljé et al., 2015; Verbong et al., 2013). Consumers are known as the neglected side of the energy system during the energy transition (Blok, 2015). Even if the energy suppliers roll out SGSs with the aid of the government, consumers actually have a say in whether or not they want to accept and adopt these innovations. Therefore, it is important to consider the stakes of consumers in the design of SGSs.

Nevertheless, consumers also believe that SGSs offer benefits such as monetary and intellectual rewards, innovation and environmental awareness. Financial incentives (e.g. lower energy bills) are a means to seduce consumers in acquiring a more positive attitude towards SGSs (Buchanan et al., 2016; Muench et al., 2014; Verbong et al., 2013). Moreover, consumers are willing to suffer the inconvenience of not being able to use energy when it suits them best to their needs in order to contribute to the alleviation of environmental issues (Buchanan et al., 2016). Besides, innovation is also considered as a driver, especially when the emerging smart grid technologies serve the well-being and stakes of the society. For instance, assisted living is made possible due to the development of smart home technologies (an innovation) e.g. by providing elderly or disabled households greater independence by monitoring their activities inside the house (Balta-Ozkan et al., 2013).

According to Milchram and van de Kaa (2017), social values can be considered as characteristics of smart grid technologies that might be among factors for its acceptance and adoption. This means that the moral concerns and benefits related to SGSs mentioned above can be considered as values. Furthermore, for an innovation to be responsible it is essential to identify and consider public values (Taebi et al., 2014). Dignum et al. (2016) suggest that stakeholder participation in decision-making processes might lead to more social support of novel energy technologies. Hence, effective and transparent energy policy can be considered as another driver because the institutions in which SGSs are embedded play an important role in the deployment and adoption of these novel energy systems since a strong, trustworthy, and transparent governance can ensure and provide guidance in the linkage between stakeholder values and energy policy goals. Thus, there is urgency for a more explicit focus on considering ethical values for the deployment and adoption of SGSs on the level of consumers, the energy industry, and policy-makers.

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 of SGSs. Furthermore, *"values emerge and evolve during the development and implementation of technologies"* (Taebi et al., 2014, p.119). According to Taebi et al. (2014), Correljé et al. (2015), and Dignum et al. (2016), 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. 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 to better understand social repercussions and controversies about these emerging innovations. This can serve as an input for the British government and energy industry when devising policies and strategies to design for values in SGSs. Consequently, insights into the values that are at stake can potentially help to enhance the design of SGSs by embedding ethical values in their functional requirements and targeting the values in a more focused way through e.g. enhanced energy policy.

According to the European Commission (2013), smart grid projects and investments are geographically not uniformly distributed across Europe. In comparison to other European countries, the UK stands out as a leading nation in terms of investments for SGSs R&D and smart grid demonstration projects, with an expenditure of €280 million (EC, 2013). In addition, the smart grid development in the UK has been endorsed by the national smart meter roll-out, which is about to be completed in two years from now (Government, 2014b). This implies that the UK is a leading nation in Europe with regard to smart grid development and as this development is advanced compared to other European nations, it is reasonable to assume that the public debate is also more advanced. This allows the availability of research resources such as scientific and governmental publications as well as empirical data over a long period of time (10 years) required for this research.

Given that ethical values are among factors that play a role in the acceptance and adoption of SGSs, the problem statement for this thesis is defined as follows:

There is a lack of understanding of ethical values as held in the British society, from an empirical perspective, that can be associated with smart grid systems. Thus, there is no study that has empirically uncovered them and their interrelations for the British public debate.

The importance of this problem statement to consumers, energy industry, policy-makers, and scientists is that it addresses ethical considerations to come to socially better and more ethically acceptable SGSs, as these innovations are meant to primarily serve social needs. This implies that studying the normative stances of stakeholders regarding SGSs provides valuable insights into values that can be associated with these emerging innovations and allows understanding, considering and prioritizing those values in their technological and institutional design.

1.2. Research objective

In order to study the British public debate on SGSs in terms of ethical values, the research aim of this thesis is *to empirically uncover what ethical values underlie the British public debate on smart grid systems and whether those values have supporting and conflicting relations in order to provide input for design for values of these emerging innovations.*

In other words, the focus of this research lies between ethical acceptability and social acceptance as empirically studying the normative stances (i.e. ethical values) of stakeholders in the UK regarding SGSs is not solely a normative study, neither just a descriptive study on social acceptance. Ethical acceptability and social acceptance are notions that can be defined in several ways depending on the context (van de Poel, 2016) and have been used in different senses through a rich literature body of social sciences and psychology (Taebi, 2016). However, an analytical (thus not a practical)[1] distinction can be made between the descriptive and normative character of these notions (van de Poel, 2016). Therefore, it is important to emphasise that this thesis follows the line of argumentation of Taebi (2016) in distinguishing social acceptance as a descriptive notion, which in this case refers to the fact that SGSs are being accepted (or merely tolerated) as novel energy systems by the public and include stakeholder opinions. Ethical acceptability is distinguished as a normative notion that refers to the extent to which values are embedded in SGSs and that considers moral issues that can emerge from its implementation.

As can be derived from this research objective, the deliverable of this research is a systematic overview of the empirically identified ethical values and their interrelations that stimulate or hamper

[1] According to van de Poel (2016), descriptive and normative judgements cannot be neatly separated in practice, as acceptance and acceptability are so-called thick concepts since they contain both descriptive and normative elements. However, for analytical purposes it is possible to distinguish acceptance as descriptive and acceptability as normative (Taebi, 2016; van de Poel, 2016).

the deployment and adoption of SGSs in the UK. These insights are relevant as values play an important role in the ethical acceptability of SGSs and influence their social acceptance. Furthermore, the deliverable provides insights on what values are relevant to be embedded in the design of this specific socio-technical system and what conflicting values require trade-offs (i.e. prioritization of values). To conclude, the outcomes of this thesis can contribute to the development of smart grid technologies that are ethically as well as socially acceptable. If that is not the case, this thesis strives to contribute to critical thinking to redesign these technologies in order to tackle associated ethical problems of SGSs and facilitate its ethical and social desirability.

1.3. Scientific relevance

From a scientific perspective, the contribution of this thesis is to explore, through an empirical study, what ethical values as a matter of fact play a role in the public debate about SGSs in the UK, where conflicts can occur. Social acceptance of SGSs can be driven by benefits of these emerging innovations or can be hindered by public value concerns related to their ethical acceptability and thus are an important aspect to be studied.

In order to explore the knowledge gap, a literature search is conducted using the databases Web of Science, Science Direct, and Scopus as well as (combinations of) the following keywords: smart energy systems, values, consumers, and adoption. In the consulted databases, the search is refined to the following article types: review articles and original research. Besides, the content of the articles had to be related with the non-technical side of SGSs. Another criterion used is recent publication years, ranging from 2012 to 2017. The selection of the scientific articles was based on the title and abstract. By doing so, the following literature is chosen: Buchanan et al. (2016); Chou et al. (2015); Dincer and Acar (2016); Krishnamurti et al. (2012); Muench et al. (2014); Tuballa and Abundo (2016); Wilson, Hargreaves, and Hauxwell-Baldwin (2017) and Künneke, Mehos, Hillerbrand, and Hemmes (2015). Further literature was found by consulting the reference list of these articles, resulting in Balta-Ozkan et al. (2013); Correljé et al. (2015); Paetz, Dütschke, and Fichtner (2012); Taebi et al. (2014); Verbong et al. (2013). When opening a source, Science Direct automatically popped up a window stating, "other users also reviewed these articles". This suggestion resulted in the selection of Dignum et al. (2016) and Xenias et al. (2015). The majority of these studies focus on understanding consumer perception of SGSs through barriers/pitfalls/risks/threats and drivers/benefits/opportunities retrieved through empirical research. Table 1 provides a general overview of some examples of social barriers (red) and social drivers (green) than can be associated with SGSs. The second column in the Table 1 provides information about which reviewed scientific sources confirm that consideration of public values is relevant for social acceptance of SGSs. The previously mentioned academic studies on SGSs do not provide a conscious investigation of values, rather values emerge (without being made explicit) while their studies have a different purpose. Moreover, there seems to be limited research on values and SGSs and especially the relationship amongst those values. Therefore, the following knowledge gap is addressed in this research project:

So far there have been no studies that identified empirically, and for a British context, the values at stake and their relations (supportive or conflicting) in the public debate on smart grid systems, whilst understanding and consideration of public values (i.e. values that are held in society) is important for the ethical acceptability of smart grid systems and affects the societal acceptance needed for technology adoption.

Social concerns related to SGSs and benefits that come forth in the public debate underlie ethical values. Therefore, research is needed that addresses what ethical values play a role for the British public concerning SGSs and how those values affect each other. The contribution of this thesis to the knowledge gap and literature is that it empirically studies the normative stances of different smart grid stakeholders in the UK, rather than focusing on the consumers only. By doing so, ethical values are retrieved and specifically conceptualized for SGSs. Furthermore, the relation amongst the identified values is established, which has not been done before in previous studies and thus adds to the literature. In addition, this empirical study can provide valuable insights as input for the reflection on

Table 1: Social barriers (red) and drivers (green) associated with SGSs from scientific literature

Authors	Considering values from the public debate is important	Lack of knowledge	Lack of trust	Fear for loss of control	Privacy invasion	Rewards	Environmental awareness	Innovation	Effective & transparent energy policy
Balta-Ozkan et al. (2013)		√	√	√	√	√	√		
Buchanan et al. (2016)	√	√	√	√	√	√	√		√
Chou et al. (2015)	√				√	√	√	√	√
Correljé et al. (2015)	√						√		√
Dignum et al. (2016)	√						√	√	√
Dincer et al. (2016)			√			√	√		√
Krishnamurti et al. (2012)	√	√		√	√	√			√
Künneke et al. (2015)	√		√			√	√		√
Muench et al. (2014)					√	√	√		
Paetz et al. (2012)		√	√		√	√	√		√
Taebi et al. (2014)	√							√	
Tuballa et al. (2016)		√			√	√	√		√
Verbong et al. (2013)	√	√		√	√	√	√	√	
Wilson et al. (2017)		√		√	√	√	√		√
Xenias et al. (2015)		√	√		√	√	√	√	√

the ethical acceptability of SGSs. Moreover, this thesis applies the Value Sensitive Design (VSD) approach to the case of SGSs in the UK, which has not been done before. The VSD approach aims to incorporate stakeholder values in the design of technology (Correljé et al., 2015; Dignum et al., 2016; Taebi et al., 2014; van de Poel, 2009). This contributes to the research on SGSs by allowing an analysis on preferred aspects (value trade-offs) of SGSs by the public and what ethical values underlie the technical and institutional design of these socio-technical systems. Moreover, the use of the VSD approach in this thesis provides a set of empirical data and an exploratory analysis that contribute to the existing theory on VSD and the field of ethics of technology. This emphasizes the academic contribution of linking the VSD approach to the case of SGSs in the UK. As the VSD approach does not provide a fixed methodology to identify and assess values, it allows for own choice of methods. This research complements this aspect of VSD through performing a qualitative content analysis of national newspaper reports to identify and infer values from the written statements with the aid of the Value Hierarchy approach by van de Poel (2013). Thus, this thesis contributes to design for values within the energy domain, expanding the application of the VSD approach to SGSs.

1.4. Societal relevance

As the public debate reflects a wide variety of opinions (Taebi et al., 2014) its analysis to uncover ethical values associated with SGSs adds to the social relevance of this research. From van de Kaa, Rezaei, Kamp, and de Winter (2014) it can be inferred that a lack of knowledge of decision- and policy-makers about the relative importance of factors determining the dominance of technological systems, such as SGSs, in society hampers the successful rollout of these novel energy systems and its components. Therefore, the results of this research can serve as insights and input for the industry and policy-makers to increase their understanding, consideration, and prioritization of stakeholder values associated with SGSs. By doing so, more ethical and social desirable SGSs can be realized through designing for values in their technical and institutional design. Then, it can be assumed that it is more likely that the public will not exert resistance to SGSs in a great extent and thus a higher social support can be achieved. Seemingly, this can reduce problems and delays during the implementation of SGSs. Furthermore, the findings of this research can also aid these stakeholders to reform the current policies, strategies, and products in order to accommodate consumer and thus public values. Insights in the values that are at stake for consumer adoption of SGSs are important for fighting climate change, which also adds to the social relevance of this thesis. Moreover, insights in the values at stake for SGSs might be informative for social network analysis (SNA) as well as modelling and simulation studies such as system dynamics (SD) and agent-based modelling (ABM) in this domain, which can aid to develop, assess or reform policies related to SGSs.

1.5. Research questions

Based on the aim of this thesis (§1.2), the main research question is defined as follows:

What ethical values underlie the British public debate on smart grid systems and what relationships among the values can be identified?

In order to answer the main research question, a set of sub-questions are formulated as follows:

1. How can the concept of smart grid systems be described?

Currently, it is known that SGSs can be considered as enablers to the transition to a sustainable electricity system and economy due to the addition of ICT to conventional power networks. However, the assumption seems to be that SGSs are synonymous with a low carbon regime (Verbong et al., 2013). It appears that there is still no certain description in the literature of what SGSs are and which 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 et al., 2012; Verbong et al., 2013). Therefore, it is important to explore the different definitions of SGSs in order to determine its conceptualization and components for this research. Moreover, determining which technology components are comprised by SGSs allows studying which ethical values can be associated with specific SGSs components.

2. *What ethical values are associated with smart grid systems in the current academic literature?*
As presented in §1.1 and Table 1, there are several academic studies (both empirical and normative) that include drivers and barriers of smart grid technologies. The review of literature about SGSs and public perception (normative stances of stakeholders) can provide insights of what ethical values might be associated with SGSs and how those values can be conceptualized. This serves as an input for the empirical analysis of British national newspaper reports about SGSs in order to identify the values at stake within the data. Hence, an initial set of values and their conceptualization needs to be established based on the scientific literature, before starting the empirical analysis.

3. *What ethical values are associated with smart grid systems in the UK according to the empirical data?*
In order to study which ethical values underlie the British public debate on SGSs, the values at stake embedded in the empirical data need to be uncovered with the aid of the values defined with the aid of literature in the previous research question. In this research British national newspaper reports serve as the empirical source to identify value-laden statements of the public debate on SGSs and derive ethical values that can be associated with these innovations in the UK according to stakeholder perspectives provided in this type of media.

4. *How are the identified values related to each other?*
Studying how values are related is important for the technical and institutional design of SGSs as a value can be strived for the sake of other values or can be in conflict with other values, creating difficulty to accommodate indifferent values in the same technological or institutional design of SGSs. The latter implies that conflicting values require value trade-offs in order to find consensus on the design, whilst striving for a value can come at the cost of other (Keeney, 2002). Insights in the way values are related can contribute to design for values in SGSs and provide information of what value trade-offs seem necessary for socially desirable SGSs.

1.6. Research design

This section introduces the research design used to conduct this research, which is depicted in Figure 1. As this figure shows, this research is conducted following five consecutive phases with the aid of three different research methods (literature study, desk research, and qualitative content analysis). The research approach of this thesis is qualitative data analysis, used to explore empirical data (national British newspaper reports) of the British public debate on SGSs. More details follow in the remainder of this section.

Phase 1: Research Domain

The first phase of this research has the goal of delineating the research domain and answering the first sub-question: *"How can the concept of smart grid systems be described?"* A literature study and desk research is conducted on SGSs in order to gain insights into their definition and what technological components they imply. This conceptualization scopes SGSs for this research. Besides, this phase also provides insights into the development of SGSs in the UK through consultation of public available documents from British government agencies. This is important as insights into milestones of smart grid development in the UK and the stakeholders involved can aid in the empirical data analysis and interpretation of the research results. Moreover, the SGSs technology components and stakeholders serve as input for the codebook needed to perform the empirical data analysis.

Phase 2: Theoretical Background

The second phase of this research has the purpose of providing the theoretical pillar of this research and an initial codebook for qualitative data analysis in a later phase. Thus, this phase aims at answering the second sub-question: *"What ethical values are associated with smart grid systems in the current academic literature?"* For this purpose, a literature study and desk research is performed

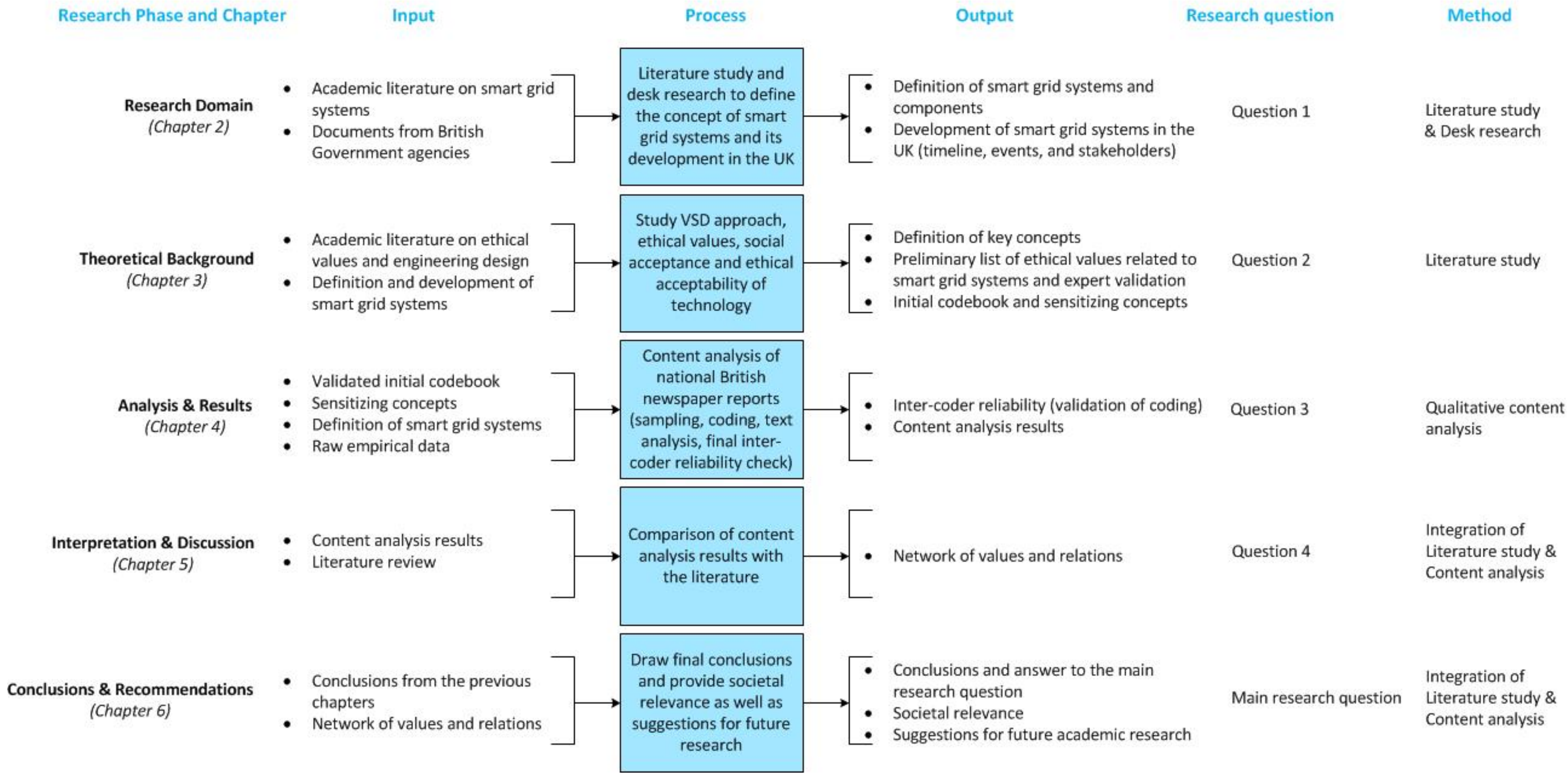

Figure 1: Research design diagram

in order to gain insights into ethics of technology. This is necessary in order to study ethical values in engineering design and to explore a definition of ethical values, value conflicts and how values are embedded in technological designs. Besides, ethical acceptability and social acceptance as well as their relation are addressed in this research phase because the focus of this thesis lies between these two notions. This all will jointly result in the definition of the key concepts of this research, which together with the concepts of phase 2, aid in setting up a search strategy to retrieve the data needed for an exploratory empirical analysis of the British public debate on SGSs.

In addition, this phase results in a preliminary list of ethical values and their conceptualization that can be associated with SGSs. This preliminary list of values is the input for the codebook needed to perform the empirical data analysis. In order to uncover the values that are stake for SGSs, VSD literature is consulted. As aforementioned, the main purpose of VSD is to account for a diverse range of human values in the design of technologies or systems (Correljé et al., 2015; Friedman, Kahn, Borning, & Huldtgren, 2013). The list of values and conceptualizations established with the aid of academic literature is validated by three experts on design for values in order to add objectivity to the researcher's interpretations. In addition, this research 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). 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, values that are not mentioned in the literature, and different conceptualizations of values). Thus, the predefined values, sub-systems, and stakeholders (i.e. sensitizing concepts of this research) are subject to change during the content analysis.

Phase 3: Analysis & Results

The third phase of this research has the goal of answering the third research sub-question: *"What ethical values are associated with smart grid systems in the UK according to the empirical data?"* This sub-question is answered performing a qualitative content analysis of national British newspaper reports on SGSs. In order to gather these newspaper reports, the database Factiva[2] is used. 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 can be said that newspaper publications contain value-laden statements of different stakeholders, which are suitable for deriving relevant social values (Correljé et al., 2015; Dignum et al., 2016; Taebi et al., 2014). Therefore, a qualitative content analysis is chosen as a research method to analyse British national newspaper reports on SGSs. Moreover, this research method is used to systematically extract inferences from text and has been used for more than 60 years in different disciplines for the purpose of organized analysis of messages (Krippendorff, 2004; Neuendorf, 2017; Weber, 1990). Hence, qualitative content analysis is considered as a suitable research method for this thesis as making inferences from newspaper texts fits the objective of this research, namely understanding and systematically uncovering ethical values that underlie the British public debate on SGSs and their relations.

For this thesis, a qualitative content analysis is chosen as it goes beyond assigning numbers to predefined statements in the text (as the quantitative counterpart does) and allows the understanding of the content in a subjective but scientific manner. Quantitative content analysis is known as deductive, intended to test general statements or hypothesis merely generated from theories or previous empirical research in order to reach a logical conclusion (Bradford, 2017; Zhang & Wildemuth, 2009). On the other hand, qualitative content analysis is mainly inductive, making broad generalizations from specific observations in the text and grounding the examination of themes, topics and the inferences drawn from them in the empirical data (Bradford, 2017; Zhang & Wildemuth,

[2] At first instance the databases Factiva and LexisNexis were consulted to explore the availability and access to British newspapers. As Factiva offers data (UK newspaper reports) in a greater extend compared to LexisNexis, it is chosen as the database for this research.

2009). Hence, a qualitative content analysis serves reaching the objective of this research through the creation of units and categories of the newspaper texts while reading it. For this purpose, ATLAS.ti is used as a data analysis tool to perform the qualitative content analysis. In addition, Excel served as a tool to clean and prepare the data. More details on the empirical data analysis can be found in Chapter 4. The results of this research phase are values that as a matter of fact play a role in the British public debate on SGSs, relevance of these values, stakeholder interpretations of the values, and relevance of smart grid technologies. This serves an input for the following research phase.

Phase 4: Interpretation & Discussion

The fourth phase of this research aims at answering the fourth research sub-question: *"How are the identified values related to each other?"* This sub-question is answered through integration of the content analysis results and the literature review, in which the findings of both research methods are compared in order to establish the type of relations (i.e. supporting or conflicting) among related values. For instance, this phase explores whether values are shared among smart grid technologies in order to establish whether value conflicts emerge or rather supportive relations are in place amongst the values. The same is also done for values that are shared among different stakeholder groups. Moreover, by linking the findings of the content analysis back to the literature, empirical proof can be provided (based on the UK case considered in this thesis) for what is being mentioned in scientific work about smart grids in the UK. This phase results in a network of related values and explanation of the links.

Phase 5: Conclusions & Recommendations

The last research phase aims at answering the main research question: *"What ethical values underlie the British public debate on smart grid systems and what relationships among the values can be identified?"* This is done jointly with the previous research phases in order to draw conclusions and provide suggestions for future academic research.

1.7. Thesis outline

As depicted in the left part of Figure 1, this thesis comprises six chapters divided in four research phases. Chapter 1 is of an introductory nature and delineates the problem at hand. Thereafter, this thesis starts with the first research phase in which SGSs are conceptualized in Chapter 2 and their development in the UK is explored in order better understand the emergence of SGSs and the stakeholders involved. This will aid in better understanding how to code the stakeholders and SGSs sub-systems (i.e. technology components) in the text of the newspaper reports. Subsequently, Chapter 3 provides the theoretical foundations of this thesis, addresses the main concepts of this research and serves as the basis for the initial codebook (needed for the empirical data analysis), completing the second research phase. Next, Chapter 4 presents the protocol, empirical data analysis (i.e. qualitative content analysis of national British newspaper reports on SGSs) and the results, completing the third phase. Thereafter, Chapter 5 entails interpretation of the findings and a critical discussion of the content analysis results by comparing it to the findings of the literature review. This is done in order to establish the type of relation among related values that are associated with SGSs. Thereby, the fourth research phase is completed. Lastly, the fifth research phase and thus Chapter 6 entails final conclusions to answer the main research question and achieve the objective of this thesis. Additionally, Chapter 6 provides suggestions for future academic research based on the limitations of this research project.

2. Smart grid systems

The previous chapter introduced the problem at hand in this research. In order to appropriately address the key concept of this thesis as the object of study, this chapter aims at conceptualizing SGSs through a literature study, thereby answering the first research sub-question: *"How can the concept of smart grid systems be described?"* In addition, a desk research is conducted of documents from British government agencies in order to gain insights into the development of SGSs in the UK (e.g. triggering events and stakeholders), being the case study of this research. As shown in Figure 2, the sub-deliverable of this chapter is the definition of SGSs and its components as well as the description of its development in the UK. Thus, the result of this research phase is a description of the research domain, necessary for the next research phases.

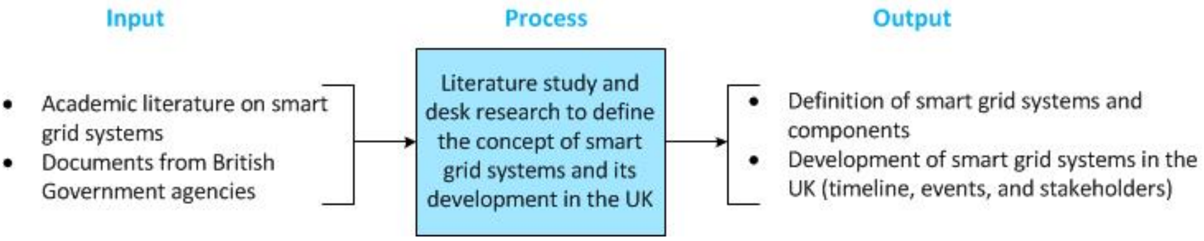

Figure 2: Research flow of the first phase (domain description)

2.1. The concept of smart grid systems

The development of SGSs is believed as a potential solution to take the UK a step further towards an affordable and low carbon energy system that allows *"the integration of renewable energy and green technologies while benefiting customers in cost savings through efficient energy use at home and in the electricity system"* (Government, 2014c, p.2). 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 (DECC, 2015; Dincer & Acar, 2016; Verbong et al., 2013). Currently, there is still no consensus in the academic body of knowledge about the exact definition of SGSs and the technologies they comprise (Buchanan et al., 2016; Connor et al., 2014; Krishnamurti et al., 2012; Muench et al., 2014; Paetz et al., 2012; Verbong et al., 2013). Therefore, a literature review is conducted in order to explore the definition of SGSs and its technology components. The results from the literature review are presented in Table 13 of Appendix A. Based on these results, the definition of SGSs and its components is determined for this research.

SGSs can be defined as a container notion that refers to the digitalization of electricity networks by addition of ICT (Milchram & van de Kaa, 2017). Hence, this research focuses on SGSs as being a smart electricity grid (from now on called smart grid) that is comprised of sub-systems being smart grid technologies that facilitate the integration of renewable energy, cope with its intermittencies and an increase in decentralized energy production sites, and promote energy efficiency (Mathiesen et al., 2015; Muench et al., 2014). In this research, smart grids can be characterized as a:

- Complex socio-technical system: smart grids link technological innovations (i.e. smart grid technologies) with social development (i.e. stakeholders with different interests and institutions) considering human agency as the main driver of this development. Moreover, SGSs allow interaction among the stakeholders involved with each other, but also with its technological components (i.e. sub-systems). Besides, complexity plays a role as these interactions have an uncertain outcome (e.g. unpredictable behaviour of stakeholders). In this context, SGSs entail smart grid technologies and people that use and interact with those, but also interact among each other to pursuit a certain goal (as stakeholders have a choice) (Palensky, 2017; Ruijgh et al., 2013). Hence, SGSs is a complex socio-technical system in the sense that it is a large-scale system that involves technological components as sub-systems, institutions, and multiple actors, generally with divergent stakes. Thus, these technological innovations need to satisfy functional requirements as well as moral and legal requirements of society.

- Physical energy system: Smart grids are comprised of smart grid technologies that allow operation of this smart electricity network. This implies the sub-systems (i.e. smart grid technologies) that enable power generation, distribution, storage and use (Palensky, 2017). Hence, the physical digitalized power network (i.e. smart grid).
- Energy management system: Smart grids facilitate the integration of volatile renewable energy sources to the electricity network and aids in coping with a larger share of decentralized energy generation sites (Muench et al., 2014). In that sense, smart grids ensure reliability as well as security of supply by increasing energy efficiency on the demand side through empowering and incentivising consumers to manage their energy demand (Palensky, 2017; SmartGridForum, 2014). Thus, smart grids serve as an energy management system.

Within these three characteristics of smart grids, the following smart grid components are identified:

- Smart meters *(physical energy system):* Advanced and smart gas and electricity metering devices that enable recording and storing energy utilization 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 utility companies and consumers: the readings are remotely sent to the utility 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. However, utility companies 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 (Cuijpers & Koops, 2012; Darby, 2010). Besides, smart meters are recognized as an inherent part, i.e. the backbone or critical building block, of smart grids and thus SGSs (Darby, 2012; DECC, 2015).
- Smart homes *(physical energy system):* 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 et al., 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, Ligtvoet, 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). Next to enhanced energy management, smart homes provide services such as assisted living (e.g. for elderly, sick or disabled inhabitants), home entertainment, luxury life style and security (Balta-Ozkan et al., 2013; Missaoui et al., 2014; Paetz et al., 2012). However, the focus of this research lies solely on smart home energy management, electricity consumption, production and savings.
- Electricity storage *(physical energy system):* Devices that 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 research considers the following forms of electrical power storage: household electricity storage and vehicle-to-grid. In the case of micro-

generation[3] and thus households become 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 offer the possibility of power storage, known as the vehicle-to-grid concept. This implies that households owning an electrical vehicle (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).

- Demand response[4] *(energy management system):* 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 et al., 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). 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).
- Stakeholders and Institutions *(complex socio-technical system):* Stakeholders are people (any group or individual) who have an interest or concern in smart grids and who can affect or is affected by it (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, smart grids are pointless if they do not make part of society to operate. The interaction between smart grid technology and stakeholders is essential. Besides, institutions regarding smart grids 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. Institutions can include government policies, societal expectations and preferences, money, manners, standardisation of technologies, industry standards, law, and organizations (Hodgson, 2006; Wolsink, 2012). This research considers institutions as relevant because they can aid in justifying why certain values related to smart grids are important and why certain value conflicts occur (e.g. conflicts around privacy are often about data access and property rights, which are an institutional feature of smart grids).

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[3] Micro-generation is the production of energy by households typically from sustainable sources (e.g. from the sun or wind) in order to meet their own needs (Evans, 2017). Moreover, it adds to reduction of the household carbon footprint due to energy efficiency and renewable energy production. Examples of micro-generation technologies are solar PV and micro wind turbines, generally located on the rooftop of the households' residence (Sauter & Watson, 2007).

[4] Demand response is also known as demand-side response and demand-side management (Mahmood, Javaid, Khan, & Razzaq, 2015). Hence, according to some scholars these terms are overlapping concepts and can be used interchangeably. However, a review of the demand side management (DSM) concept by Warren (2014), points out that the definitions of DSM vary in what they include or exclude. DSM refers to *"technologies, actions and programmes on the demand-side of energy meters that seek to manage or decrease energy consumption, in order to reduce total energy system expenditures or contribute to the achievement of policy objectives such as emissions reduction or balancing supply and demand"* (Warren, 2014, p.943). This definition is considered in this research as it suits the British policy objectives for energy security, affordability, and emissions reduction of greenhouse gases. Following Warren (2014), DSM comprises policies (e.g. regulatory, market-based, financial), implementers (e.g. network operator, utility, consumer, government), and DSM categories such as demand side response (price-based, incentive payment-based), energy efficiency (efficiency, conservation), and on-site back-up (generation, storage). Hence, demand response is part of demand side management and both terms cannot be used interchangeably as they are not overlapping concepts. In the context of smart grid systems, demand response (among the other DSM categories) is the only one considered in this research as it deals with changing electricity behaviour on the demand side.

The aforementioned SGSs components are classified in the three categories previously presented and discussed. A graphical representation is provided in Figure 3 below.

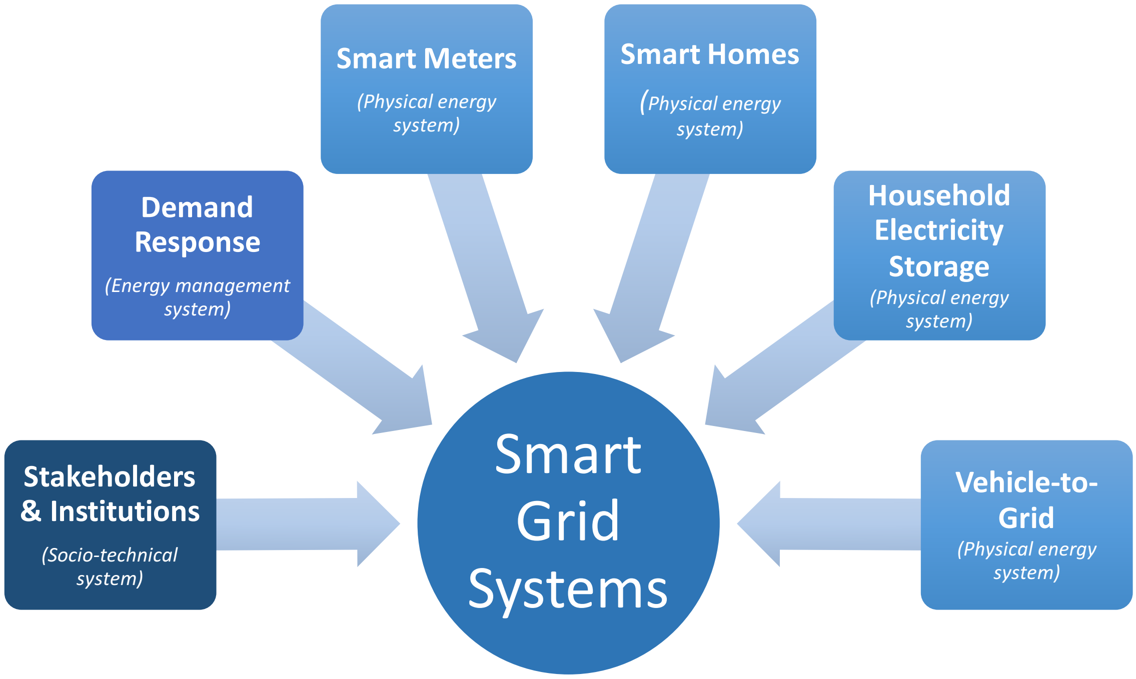

Figure 3: Smart grid systems and components

2.2. The case of smart grid systems in the United Kingdom

The definition of SGSs and its components address the fact that stakeholders play a key role in the development and deployment of smart grids. Hence, the introduction and adoption of smart grids considers social acceptance as a prerequisite (Sauter & Watson, 2007), which is influenced by their ethical acceptability. This section discusses the development of smart grids in the UK (§2.2.1) and presents a brief stakeholder analysis (§2.2.2). This is relevant in order to better understand the interaction between stakeholders and SGSs and its technologies and thus to gain insights into how these innovations have emerged in the British society. In addition, knowledge about the smart grid development in the UK and the stakeholders will aid in better understanding the empirical data of this research and it allows to better code the stakeholders and events during the content analysis.

2.2.1. Smart grid development in the UK

The UK has made significant progress to date in developing and modernising their electricity system into a smart grid. Figure 4 summarizes the milestones that will be described in the remainder of this section as a graphical representation of the UK timeline for smart grid development. More details about the timeline can be found in Appendix B.

The smart grid development in the UK is in parallel and partly triggered by European legislation and policies. In the pursuit of energy sustainability, environmental preservation, and tackling climate change, the European Council adopted the *20:20:20 package* in 2007 proposed by the leaders of the member states (as Great Britain used to be until the end of June 2016). The aim of this binding legislation was to ensure that member states would accomplish 20% cut in greenhouse gas emissions from 1990 levels, 20% of EU energy from renewables, and 20% improvement in energy efficiency (EC, 2017a, 2017b). These targets were enacted in legislation by the European Union in 2009 through the *Electricity Directive*, which required member states to implement smart metering by 2020 in 80% of households (EU, 2009). This Directive also aimed at encouraging the modernization of distribution networks through smart grids for the sake of decentralised power generation and energy efficiency (EU, 2009). Public concerns about meeting the future energy challenge and tackling climate change, caused the emergence of a policy 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 as well as on international level (DECC, 2015). In addition, the White Paper also established the following energy policy goals: reduction of UK's CO_2 emissions by 60% in 2050 (with real progress by 2020), promotion of UK (and beyond) competitive markets to increase sustainable economic growth and to improve the national productivity, to maintain the reliability of energy supply, and to ensure that every home in the UK is adequately and affordably heated (fighting fuel poverty[5]) (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). For these purposes, the government conducted a large-scale trial in 60,000 households in Great Britain to investigate how consumers reacted to improved information about their energy consumption over the long term (Government, 2014b; Ofgem, 2017c). This is called the *Energy Demand Research Project,* which took place from 2007 to 2010 and provided a combination of smart meters and real-time display devices to the households. This project successfully resulted in energy savings up to 11% (Ofgem, 2017c).

In order to identify and coordinate work to aid addressing key strategic issues that affect the British electricity network in the transition to a low carbon future, the Electricity Network Strategy Group (ENSG) was established as a consultation group facilitated by the Office of Gas & Electricity Markets (Ofgem) and the Department of Energy & Climate Change (DECC) (Government, 2017b). With the aim of fostering and facilitating the development of smart grids in the UK, in November 2009 the *ENSG vision and route map for smart grids* was published. ENSG's work is extended by the *Smart Grid Forum* (SGF), founded by DECC and Ofgem in 2011, with the aim to facilitate the deployment of SGSs in the UK as well as the exchange of information and knowledge between key parties, including those outside the energy sector (Ofgem, 2017a). The SGF served 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, particularly for electricity network operators (Ofgem, 2017a).

Between December 2010 and 2014, the *Low Carbon London Project* took place. This £28.3 million project was one of Britain's largest smart grid trials (UKPowerNetworks, 2014). The aim was to investigate the impact of a wide range of low carbon technologies, including intermittent local generation, smart meters, EVs, etc. on London's electricity distribution network and test how smart grid technologies can be used to manage these changes in a low-carbon economy (Government, 2014b). For instance, 6000 smart meters were installed throughout London to monitor changing consumer demand patterns in response to dynamic tariffs according to supply level and the subsequent effect on London's electricity network (UKPowerNetworks, 2014). In February 2014, the *SGF defined a clear vision of a British Smart Grid and a route map* of the ways in which the current power network could be transformed into a smart grid (SmartGridForum, 2014). In the same year, the *Low Carbon Networks Fund* (LCN) was led by Ofgem, consisting of a £500m budget to support projects sponsored by the Distribution Network Operators (DNOs) to try out new technology (such as EVs, heat pumps, micro and local generation, and demand side management), operations and commercial arrangements (Ofgem, 2017e; UKPowerNetworks, 2014). This type of projects aimed to aid DNOs in understanding how they can provide security of supply at value for money as the UK moves to a low carbon economy (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 optimising electricity generation and network management and thus moving towards a smart grid (Darby, 2012; DECC, 2015). Therefore, it can be seen from Figure 4 that the timeline mainly follows the smart meter development and deployment in

[5] A fuel poor household can be defined as one whose required fuel costs are above average (i.e. the national median level) and their expenditure in order to achieve a satisfactory heating regime and meet the energy needs, would be leave them with a residual income below the official poverty line (Darby, 2012; Government, 2017a). In the UK each nation has its own policy target and measurement of fuel poverty (Government, 2017a).

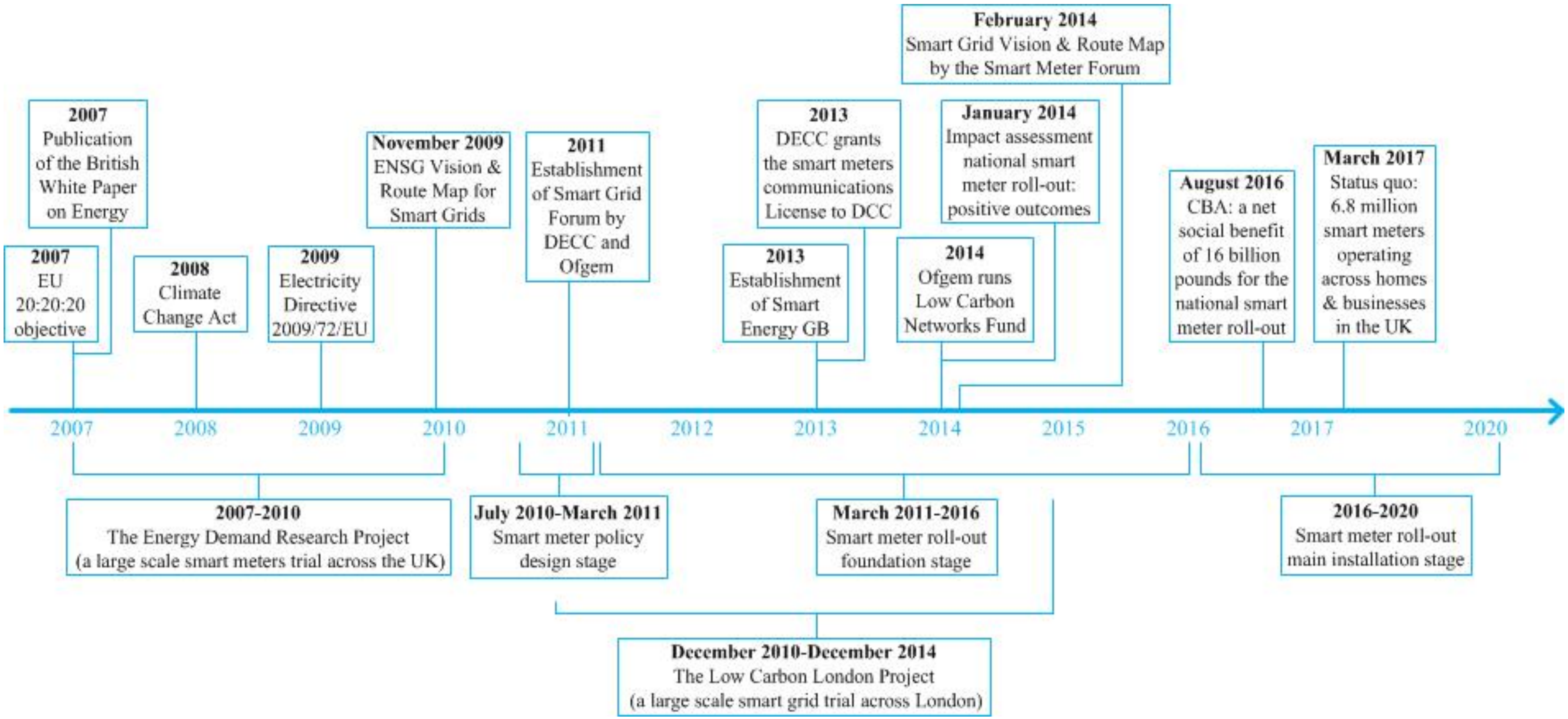

Figure 4: Timeline for the British smart grid development over the past 10 years

the UK as a representation of the smart grid development, which is justifiable as smart meters are key for the development of smart grids. Hence, another milestone in fostering the development of smart grids in the UK was the government's decision to perform a national smart meter roll-out. From July 2010 to March 2011, the *smart meter policy design stage* took place in order to establish policy to regulate the roll-out. The idea was that this policy would focus on regulating the replacement of approximately 53 million residential and non-domestic gas and electricity meters in Great Britain by smart meters through a supplier-led roll-out with a centralised data and communications company (Government, 2015). Subsequently, from March 2011 to 2016, the *foundation stage* took place, in which the government established the necessary commercial, regulatory, and technical framework for the smart meter roll-out. This stage is known as crucial as the industry built and tested systems, learned what works best for consumers and how to help people get the best from their new smart meters. Furthermore, in this phase the Data and Communications Company (DCC) was established to link the smart meters in homes and small businesses with the business systems of energy suppliers, network operators, and energy service companies (Government, 2015). Thereafter, the *main installation stage* began, in which most consumers will have smart meters installed. 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). In this phase, suppliers are obliged to complete the roll-out by the end of 2020 and they will decide how they deploy smart meters to their customers (Government, 2015).

In 2013, *Smart Energy GB* was established as the voice of the smart meter rollout. Their task is to help everyone in Great Britain understand smart meters, the national roll-out and how to use their new intelligent meters to get their electricity under control (SmartEnergyGB, 2016). In the same year, *DECC granted DCC a licence to establish and manage the data and communications network* to connect smart meters to the business systems of energy suppliers, network operators, and other authorised service users of the network (DCC, 2017; DECC, 2015). Then, in January 2014, an *impact assessment* was performed, which resulted in a net present value of £4.3 billion for the domestic roll-out of smart meters in the UK (DECC, 2014). As a result of consumers using energy more efficiently and suppliers passing through net cost savings, the roll-out is expected to reduce the average household electricity and gas bill by £26 in 2020 and by £43 in 2030 (DECC, 2014). Additionally, in August 2016, a cost-benefit analysis was performed, showing positive outcomes for the national smart meter roll-out: a net social benefit of £16 billion, with a net present value of £3.8 billion (Government, 2016). Moreover, the roll-out is expected to reduce the combined electricity and gas bill for the average household by £11 in 2020 and by £47 in 2030 (Government, 2016). 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, 2017c). The statistics of the first quarter of 2017 also show that a total of 1,027,7002 domestic smart meters were installed by large energy suppliers in this period (446,000 gas and 581,700 electricity meters) (Government, 2017c). This represents a 10% increase in domestic smart meter installations compared to the previous quarter and thus an on-going transition to digitalization of the British power network.

2.2.2. Smart grid stakeholders in the UK

Human action is the main driver of technology development (Ruijgh et al., 2013). As such, stakeholders strongly shape SGSs and the direction of the energy sector (Connor et al., 2014). Therefore, it is important to understand their perspectives as it has an impact on the future of smart grids. This section presents the most active smart grid stakeholders in the UK, being the ones having the most significant impact on the public debate about SGSs. Table 2 provides an overview of the stakeholders and their priorities. This overview is established with the aid of public available documents of the British governmental agencies (also used to study the development of SGSs in the UK) as well as with the work by Connor et al. (2014). The stakeholders are described in the remainder of this section.

Table 2: Overview of smart grid stakeholders in the UK

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 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

Environmental organizations

Their main purpose is environmental preservation and climate change mitigation to reach a healthy planet and a better standard of living. Furthermore, these organisations work closely with the British government to develop and implement energy policy (ENA, 2017c; FES, 2017). Environmental organizations also aids the industry to meet environmental goals through the provision of strategic advice (FES, 2017).

Governmental bodies and policy-makers

Their main purpose is to govern and regulate the energy sector for the sake of society. On the international level, the *European Union* has shaped national policies trough Directives, Regulations, and Acts (EU, 2017). On national level, the *Department of Energy & Climate Change* (DECC) is responsible for energy policy, especially in the case of smart grids (Connor et al., 2014). The energy regulator of the UK is known as the *Ofgem*, being an independent national Regulatory Authority (Ofgem, 2017f). Ofgem oversees the utilities that are responsible for delivering electricity in the UK, promotes security of supply and sustainability, protects the general interests of consumers, supervises the energy market and competition, and shapes the energy sector to meet the nation's energy needs (BEIS, 2017; Connor et al., 2014; ENA, 2017d; Ofgem, 2017f). The governing body of Ofgem is known as the *Gas and Electricity Markets Authority* (GEMA). Their main role is to provide Ofgem with strategic direction on how to perform their responsibilities (ENA, 2017d).

Supporting organizations for smart grid development

Their main purpose is to boost and facilitate the development of smart grids in the UK. For instance, *ENSG* is a consultation group that works to bring together government, energy companies, and trade associations to cooperate and devise strategies in order to reach a low carbon future (Connor et al., 2014). Besides, the *SGF* is a government-led cross-industry advisory group that aids in informing smart grid policy development, tackling and advising on issues ranging from regulations, market structure, commercial barriers to technology requirements of SGSs (Ofgem, 2017a). *Smart Grid GB* is an initiative led by the industry that works with the British government and the SGF to increase the public's understanding of smart grids as well as its challenges and benefits and to facilitate interaction between stakeholders (Connor et al., 2014). The technology developers (e.g. Itron, Elster, Amazon Alexa, and Utilita among others) are also considered as supportive organizations for smart grid development as they offer energy management solutions (i.e. software, services, smart grid technology) that drive energy efficiency and cost savings for energy companies and consumers.

Trade Associations

Their main purpose is to represent the interests of its members and to lobby in order to influence the regulatory frameworks that shape the sector in which their members operate. *Energy UK* represents the British energy industry, consisting of energy producers and suppliers, equipment providers, and network companies (Connor et al., 2014; EnergyUK, 2017a). The *Electricity Networks Association* represents transmission and distribution companies in the British energy sector and collaborates with SGF and Energy UK in smart metering and smart grid development (Connor et al., 2014). The *British Electro-technical and Allied Manufacturer's Association* represents the electro-technical industry (manufacturers of electrical infrastructure products and systems for transmission) in Great Britain to drive innovation of technologies and services (BEAMA, 2017; Connor et al., 2014). The *United Kingdom IT Association* represents the interests of the Small & Medium IT, Tech and Digital sectors and has successfully delivered projects for local authorities and projects funded by the European

Commission (UKITA, 2016). The *Association for Decentralised Energy* aims at securing energy efficiency and environmental enhancement through a widespread use of combined heat and power, demand response services as well as renewable energy (ADE, 2017).

Energy companies

This stakeholder group work in a competitive market where customers in the UK can choose any supplier to provide them with energy. The main purpose of the energy companies is to have a high market share for energy supply. Besides, this stakeholder group aims at continuity of their business and profit. In the UK, there are 36 energy suppliers differing in their fuel mix, prices and market dominance (Which?, 2017). Within this stakeholder group, *the Big Six* are known as the six largest energy suppliers in the UK that dominate 82% of the market (Ofgem, 2017b; SimplySwitch, 2015). This includes British Gas (22%), Scottish & Southern Energy (14%), Eon UK (13%), EDF Energy (12%), Scottish Power (11%) and RWE Npower (10%) (Ofgem, 2017b). Besides, the *middle-sized suppliers* have a market share of 10%. This includes First Utility (3%), Utility Warehouse (2%), OVO Energy (2%), Utilita (2%) and Cooperative Energy (1%). The *small suppliers*[6] are 25 energy companies that jointly hold a market share of 8% (Ofgem, 2017b).

Consumer organizations

This stakeholder group consists of the most prominent consumer organizations in the UK with the aim of representing and lobbying for consumers and their interests related to the development and implementation of new technologies (e.g. smart grid technologies). *Consumer Focus* (CF) is responsible for protecting consumers in the UK, concerning energy supply and any issues arising from the smart grid development (Connor et al., 2014). Since 2014, *Citizens Advice* took over the role and responsibilities of CF (Connor et al., 2014; Government, 2014a). In addition, Ofgem (as a regulatory body) protects the general interests of consumers by supervising the energy market and utility companies (Connor et al., 2014). Besides, *Community Energy* has become part of energy policy in the UK as local energy initiatives with the aim of creating renewable energy projects for and by local people or community (Walker & Devine-Wright, 2008). This means that these projects are driven, managed, and maintained by a group of local peopled and are supported by government funds and schemes such as the Community Renewables Initiative (Walker & Devine-Wright, 2008).

Energy consumers

The main purpose of this stakeholder group is to have secure and affordable energy supplied. This entails *domestic consumers* (households), *commercial consumers*, and *industrial consumers*, who withdraw electricity from the distribution network (Fare, 2016). Consumers are relevant for the development of smart grids as they are the ones creating the main challenge: technology adoption (Liu, Liu, & Pearson, 2011). The roles and interests of the different types of consumers are considered relevant in shaping the function of the liberalized British energy market and the realization of smart grid benefits (Kolk, 2012; Liu et al., 2011) such as integration of renewables, cost reduction, and effective network management (Government, 2014b; Xenias et al., 2015). As mentioned in §1.1, consumers perceive benefits as well as pitfalls of smart grids, resulting in contestation of these emerging innovations. Therefore, energy consumers can be considered as a critical actor in the realization of a smart power network in the UK. On the household level, a differentiation can be made between consumers and prosumers. This means that consumers can participate in energy generation and trading (thus becoming prosumers) and play an active role in managing and balancing energy use (e.g. in micro grids) by investing in decentralized energy systems (Kolk, 2012). Hence, the essence of prosumers coincides with that of smart grids: increase network control and support integration of renewable generation.

[6] These energy companies are known as the small energy suppliers in the UK: Airtricity, Atlantic, Better Energy, Budget Energy, Daligas, Ebico, Ecotricity, Extra Energy, Firmus Energy, Flow Energy, GB Energy, GnErgy, Good Energy, Green Energy UK, Green Star Energy, iSupply Energy, LoCO2, M&S Energy, Power NI, Sainsbury's Energy, Southern Electric, Spark Energy, Swalec, Woodland Trust Energy, and Zog Energy (Which?, 2017).

Distribution network operators

The UK privatized its electricity supply industry, opening generation for competition in 1990 and then supply in 1992 (Connor et al., 2014). Therefore, several DNOs are known in the UK, being companies licensed by Ofgem to distribute electricity in Great Britain in geographically defined areas as shown in Figure 5. In the areas covered by the DNOs, also Independent Network Operators (IDNOs) are present which own and operate smaller networks (Ofgem, 2017d). The main stake of IDNOs and DNOs is to ensure that electricity gets to the consumers by managing loads in the distribution network (which carries electricity from the high voltage transmission grid to the consumers). As the DNOs are natural monopolies, Ofgem regulates them in order to prevent abuse of their power position and get unreasonable profits from the consumers (Ofgem, 2017d).

Figure 5: Electricity distribution map of the UK (source: Fare (2016), p.4, based on ENA (2017a))

Transmission system operators

The grid plays an essential role in the British electricity system. Therefore, the main stake of the Transmission Systems Operators (TSOs) is to balance demand and supply since electricity is difficult and expensive to store (EnergyUK, 2017b). As such, their task is to manage the electricity flow across the entire electricity network. Each TSO owns and operates one of the four high voltage transmission networks in the UK, as illustrated in Figure 6.

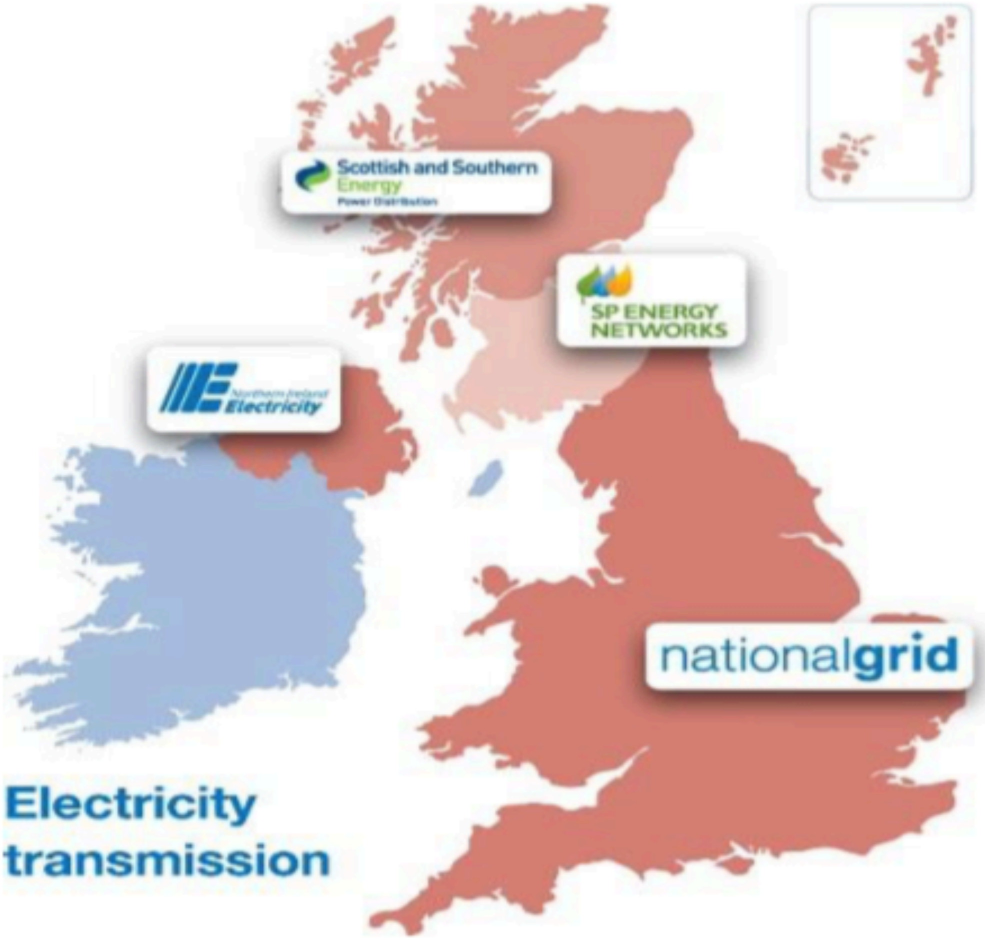

Figure 6: Electricity transmission map of the UK (source: Fare (2016), p.4, based on ENA (2017b))

2.3. Conclusion

This chapter introduced and conceptualized SGSs as well as its development in the UK and thereby answered the first sub-question of this research: *"How can the concept of smart grid systems be described?"* A literature study and desk research provided the following description of SGSs for this research: smart grid systems are the container notion for digitalization of conventional energy systems through application of innovative information and communication technology and smart grid technologies (i.e. smart grids, smart meters, smart homes, energy storage (e.g. batteries and vehicle-to-grid) and demand response) with the purpose of supporting and facilitating the integration of renewable energy sources into the power network, accounting for its volatility and larger number of decentral energy production sites. In addition, stakeholders and institutions make part of intelligent energy systems as these innovations aim at serving the public need of affordable and secure energy provision. In this context, consumers are the critical actor as they are the users and the ones creating the main challenge: technology adoption. Therefore, it is important to gain insights into their stakes and needs in order to embed those in the technological and institutional design of SGSs, aiming at the realization of ethically and socially better energy systems. Figure 3 graphically represents SGSs and its components. Figure 4 depicts the smart grid development in the UK and Table 2 provides an overview of relevant smart grid stakeholders. The findings of this research phase serve as input for elicitation of values from the academic literature, that can be associated with SGSs.

3. Theoretical background

General discussions on the benefits and pitfalls of smart grids have promoted the emergence of moral concerns (e.g. privacy invasion, mistrust, and fear for loss of control). These concerns can impede the widespread adoption of smart grids and achievement of climate goals as consumers have the freedom to decide whether or not smart grid technologies is extended into their household. This addresses the importance of studying the societal implications of SGSs through the empirical investigation of the normative stances (i.e. ethical values) that people hold in the UK about SGSs. Therefore, this chapter focuses on ethics of technology in order to answer the second research sub-question: *"What ethical values are associated with smart grid systems in the current academic literature?"*

In order to discover what ethical values are at stake for SGSs and its technology components, 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 SGSs is also reviewed in order to retrieve more specific values for the context of this research. As shown in Figure 7, the sub-deliverable of this chapter is a definition of values, social acceptance and ethical acceptability as well as a validated (preliminary) list of ethical values that can be associated with SGSs. These values are used as sensitizing concepts for the empirical data analysis and serve as an initial coding scheme of the British national newspaper reports on SGSs.

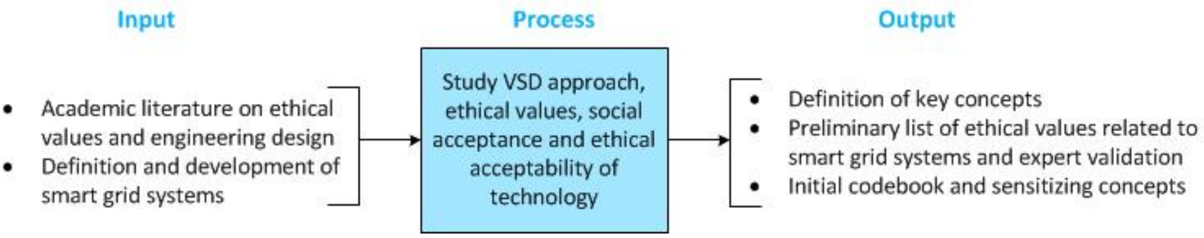

Figure 7: Research flow of the second phase (theoretical background)

3.1. Ethics of Technology

Technology used to be perceived as value-neutral and simply instrumental practical objects (Correljé et al., 2015; Dignum et al., 2016; van de Poel, 2009; Winner, 1980). Nowadays, technology is perceived as strongly value-laden objects that incorporate values whilst failing in representing other values (Correljé et al., 2015; Dignum et al., 2016; Taebi et al., 2014; van den Hoven et al., 2012). For example, Winner (1980) famously discussed that bridges serving as an overpass over the parkways on Long Island beach in New York, have been intentionally designed with a low height in order to achieve a particular social effect: excluding a certain societal group from visiting this beach. This social-class bias and racial prejudice implies that the overpasses are built too low for buses to get through. Hence, only automobile owners (merely the rich population) are able to cross the overpasses and make free use of the parkways for recreation and commuting purposes, while the poor population is discouraged and intentionally excluded from visiting the beach as they mostly do not own a car and use public transport (Winner, 1980). As this example shows, values can be at stake in the design of technologies as well as in the process of technology deployment, especially when it implies societal impact (Dignum et al., 2016; van de Poel, 2009).

Additionally, technology allows the emergence of new values as the interaction with the users raises new types of behaviour (Correljé et al., 2015). Furthermore, norms, perceptions, practices, and experiences are mediated by technology (Correljé et al., 2015). For instance, smart grids facilitate demand response to influence consumer behaviour on energy usage for the sake of environmental sustainability, cost savings, and security of supply. According to Steg, Perlaviciute, and van der Werff (2015), people are more likely to accept smart grids and related policies when these support and are aligned with their values. In this context, theory on ethics of technology provides a normative framework to infer arguments on the morality of smart grids, i.e. whether they are ethically right or wrong. Therefore, this section focuses on exploring and studying values, acceptability and acceptance of technology as well as risk perceptions and emotions in order to gain insights into the ethics of technology and how it affects/relates to SGSs.

3.1.1. Ethical values

In the context of SGSs, ethical values are related to the effects of smart grid technologies. In the context of environmental psychology, ethical values can be defined as desirable goals that differ in importance and guide the life of people (Steg, Bolderdijk, Keizer, & Perlaviciute, 2014). According to Künneke et al. (2015), values imply convictions about perceptions of good and bad associated with technological designs. Besides, Taebi et al. (2014) describe values as things that are worth striving for. Moreover, values are known as what is important in life of a person or a group of persons (Friedman et al., 2013). Based on the definitions of values by these authors, the following definition is established for this research:

Ethical values: convictions of a person or group of persons about matters that are important in life and worth striving for as well as the perception of what is good or bad.

The literature shows that ethical values can be distinguished in the following types:

- Intrinsic or final values: values that are good in themselves and are strived for their own sake (van de Poel, 2009, 2015; van de Poel & Royakkers, 2011). For instance, human well-being, environmental sustainability, safety, health, and fairness are examples of intrinsic values that can be related to the design of technology (van de Poel, 2015).
- Instrumental values: values that are a means to achieve intrinsic values (i.e. a good end) and are thus strived for the sake of other values (van de Poel, 2009, 2015; van de Poel & Royakkers, 2011). For instance, economic development, energy-efficiency, reliability, and maintainability are examples of instrumental values that can be related to the design of technology (van de Poel, 2015).

According to Friedman et al. (2013), values cannot be motivated by facts only as they basically depend on the interests and desires of humans[7]. This is known as naturalistic fallacy, meaning that value judgements (normative matters) cannot be logically derived from factual information only, rather, we need a genuinely normative perspective to assess values (Friedman et al., 2013; Moore, 1988 [1903]; van de Poel & Warnier, 2015). Values can be related in a positive manner, enforcing/supporting each other in balance or can be in conflict. A value conflict arises when *"(1) a choice has to be made between at least two options for which at least two values are relevant as choice criteria, (2) at least two different values select at least two different options as best, and (3) the values do not trump[8] each other"* (van de Poel & Royakkers, 2011, p.177). Value conflicts can contribute to moral problems when designers do not integrate values of ethical importance that motivate design requirements (van de Poel & Royakkers, 2011) in engineering or institutional design. Within value conflicts, two types can be distinguished: inter-value and intra-value conflicts. The notion of inter-value conflict is used when "*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). This refers to value pluralism in the public debate on SGSs that requires moral choice in order to reach common ground. For instance, the British smart meter roll-out can be the best option from an environmental sustainability point of view as it incentivises consumers to manage their electricity usage more effectively. Yet, it might not be best from the point of view of privacy as consumer data is being automatically shared between suppliers (who can show strategic behaviour) and authorized

[7] This view by Friedman et al. (2013) can be considered as a more specific interpretation of what normativity is. However, this is not shared by all philosophers who endorse the irreducibility of the normative.
[8] If values do not trump each other, it means that the conflicting values are worth equally (van de Poel & Royakkers, 2011).

third parties (e.g. for marketing purposes). Besides, the notion of intra-value conflict is used when stakeholders have different understanding and interpretations of the same value as well as different perceptions on which values could be best served (Dignum et al., 2016). For instance, a supportive argument from Public Health England regarding smart meters involving the value of *health and safety* is "*a substantial body of evidence showing smart meters are safe. She said the radiation was low compared to guideline levels*" (The Daily Telegraph, 25 April 2013) whereas an anti-smart meter stakeholder refers to the same value as follows: *"smart energy meters could be as dangerous as a bullet from a rifle because of the radiation they emit"* and *"evidence of harm could be acute, including cancer, infertility, dementia, genetic damage, immune system dysfunction and damage to foetuses"* (The Daily Telegraph, 25 April 2013). While health and safety was shared between these two different stakeholders, this shared value also fuelled the discussion on whether or not smart meters can be more or less safe to health.

According to Taebi et al. (2014) there are two ways to deal with value conflicts: adapt the technological design of SGSs components so it can accommodate the conflicting values (applicable to intra-value conflicts though designing for values) or perform a value trade-off that decides which of the conflicting values should have priority in the design of SGSs (applicable to inter-value conflicts). Hence, through a value trade-off can be suggested which preferences are better in distinguishing (policy or technological design) options (Ligtvoet et al., 2015).

3.1.2. Ethical acceptability and social acceptance in the context of smart grids

During the literature review, it was noticeable that scholars (especially philosophers, sociologists and psychologists) define the notions of acceptance and acceptability differently. A reason could be that these notions can be defined and operationalized in several ways depending on a specific context (van de Poel, 2016). Partially, this can be a matter of terminology that is common in a specific discipline. In order to avoid confusion, in this research ethical acceptability is defined as a normative notion that refers to people's reflection on smart grids and its related technologies, considering the moral issues that can emerge from its introduction in society (Taebi, 2016). This means that SGSs are ethically acceptable if they embed certain normative standards (van de Poel, 2009, 2016). The so-called normative standards refer to moral norms and values, implying moral judgements (van de Poel, 2016). On the other hand, social acceptance is defined as a descriptive notion (based on facts or how things are) that refers to certain states-of-affairs, typically in which stakeholders are in favour or against SGSs (van de Poel, 2009, 2016). Hence, in this thesis social acceptance is a descriptive notion that refers to the fact that society (being a community of people) accepts or merely tolerates[9] smart grids and its related technologies (Huijts et al., 2012; Taebi, 2016).

As aforementioned, this thesis acknowledges that social acceptance is important for the adoption of SGSs. Ethical acceptability is important too, as SGSs are intended to serve the social need of clean, secure, and affordable energy and have caused concerns, which reflect moral and social values that can hamper or drive social acceptance. People's judgement when they do or do not accept SGSs are likely to express moral concerns related to ethical values. However, this does not mean that acceptance is always based on moral concerns that make technology acceptable or not, but as long as technology includes moral judgements it deals with ethical acceptability (van de Poel, 2016). Since this thesis empirically investigates the normative stances of stakeholders on SGSs, the focus lies in between social acceptance and ethical acceptability as explained in §1.2. Based on Taebi (2016), social acceptance on its own cannot sufficiently capture the relevant moral aspects of SGSs and ethical acceptability on its own cannot capture the relevant empirical input (e.g. technology related facts, perceptions of stakeholders) necessary for an ethical evaluation of SGSs. Studying the social

[9] When people refuse to use a technology, they show resistance and perform protesting actions against the technology. On the other hand, when people are in favour of a technology but do not take any kind of action it can be said that they show tolerance (Huijts, Molin, & Steg, 2012).

acceptance of the ethical values that empirically as a matter of fact play a role in the British public debate on SGSs contributes to reflection on the ethical acceptability and thus provides input for ethical reflection and deliberation on moral issues related to SGSs. This serves the final goal of striving for ethically better smart grid technologies by addressing ethical considerations in the design of these innovations.

So far, it has been made clear that smart grids and its related technologies can create benefits such as integration of intermittent renewable energy in the power network and cost savings for the consumers due to promotion of energy efficiency, but also can entail risks that foster concerns about privacy, trust, (cyber) security, autonomy and control as well as affordability and informed consent among others. In this context, the question raises whether the concerns related to SGSs are actual risks or perceived risks rather than real. This is relevant as the different smart grid stakeholders may have different understanding and perception of risk and act accordingly by accepting or non-accepting SGSs (Taebi, Roeser, & van de Poel, 2012; Yesudas & Clarke, 2015).

Often, risk perceptions are seen as emotions being subjective or irrational (Roeser, 2006, 2012). Therefore, the public is sometimes neglected in the public debate about risky technologies since they are perceived as too emotional and incapable of engaging in a rational debate (Taebi et al., 2012). Emotions can be seen indeed as subjective since they belong to persons. However, it can be argued that emotions are not necessarily subjective; rather, they can provide insight into objective moral truths. According to Roeser (2006), the theory of moral realism holds that whether a moral judgment is true depends on the way the world is and not on the way people think the world to be. Realism in general means that "*the objects of our knowledge exist independently of our beliefs about them*" (Roeser, 2006, p.692). In the case of moral realism, this means that moral values are not constituted by people's preferences. Furthermore, Roeser (2006) argues that emotions can be perceptions of moral values. Thus, even if people's value judgments are based on emotions, they should be included in decision-making processes about risky technologies in order to achieve well-grounded judgements about the ethical acceptability of risks (Roeser, 2006). Hence, emotions about risky technologies (e.g. smart grid technologies) are indispensable to make well-grounded decisions as they offer a normative guide to judge the ethical acceptability of risky technologies (Roeser, 2006). This perspective addresses that quantitative risk assessment (i.e. calculation of the probability that risks or unwanted consequences will occur) and qualitative risk assessment (i.e. ethical acceptability of risks) complement each other (Roeser, 2006). These ideas can also be applied to SGSs. Besides, it is important to notice that next to assessing risks, misconceptions and misperceptions of stakeholders should be identified in advance in order to offer them aid in understanding the possible consequences of smart grids and its related technologies (Yesudas & Clarke, 2015) to prevent that SGSs might be socially accepted for reasons that are morally wrong, in the pursuit of ethically better energy systems. Hence, the acceptance of SGSs is affected by social norms as well as stakeholder's feelings and ethical values. Therefore, designers should take into account ethical considerations because the way technologies are designed determines, for better or for worse, its effects on people (Roeser, 2012).

3.1.3. Value Sensitive Design and the Value Hierarchy Approach

VSD specifically intends at diminishing the potential negative effects of technologies (Roeser, 2012). Therefore, it is chosen as a suitable approach for this research. Value Sensitive Design aims to identify values in technology and incorporate ethically justifiable stakeholder values in the design of morally responsible technologies (Correljé et al., 2015; Dignum et al., 2016; Taebi et al., 2014; van de Poel, 2009; van de Poel & Royakkers, 2011). Looking at the design of technology from an ethical perspective concerned with the manner in which values are facilitated or constrained, allows the incorporation of stakeholder values in the design of smart grid technologies (van den Hoven et al., 2012). Besides, as a theoretically grounded approach, VSD is as a tripartite iterative method that integrates conceptual, empirical and technical investigations (Correljé et al., 2015; Friedman et al., 2013). According to Ligtvoet et al. (2015), conceptual investigations have the purpose of clarifying what values are at stake for SGSs and how are those values related. In addition, empirical investigations involve social scientific research (e.g. the performance of a content analysis) to understand the perceptions of stakeholders affected by the design of smart grid technologies. Lastly, the technical investigations aim at analysing the technical design in order to assess how it supports relevant stakeholder values and if necessary find ways on how to ensure that the design of smart grid technologies supports those values (Ligtvoet et al., 2015). Hence, VSD will always need ethical theory and moral analysis. It is important to mention that next to the technological design of SGSs, VSD can also be applied to institutional design as well as to the design of public participation procedures (Correljé et al., 2015; Dignum et al., 2016; Taebi et al., 2014).

Thus, the VSD approach allows making relevant stakeholder values explicit in order to better embed them in the design of smart grid technologies and their related institutions, which actually is a challenge. Moreover, VSD identifies and considers two classes of stakeholders: direct and indirect. According to Friedman et al. (2013), direct stakeholders refer to individuals, groups or organizations who interact directly with SGSs. Indirect stakeholders refer to all other individuals, groups or organizations that are affected by SGSs. The VSD approach is open to be compatible with different research methodologies and thus provides no fixed methodology to identify stakeholders. Since stakeholder identification is indispensable to identify, assess, and incorporate values in the design of technology (Taebi et al., 2014), a literature study and desk research is performed as presented in §2.2.2. Besides, the VSD approach does not make clear how to specifically elicit values. When designing for values, a crucial step is to elicit values in order to translate them into design requirements of SGSs and its components. Therefore, the VSD framework is endorsed with the Value Hierarchy approach of van de Poel (2013) in this research, as suggested by Correljé et al. (2015) and Dignum et al. (2016).

As presented in Figure 8, the value hierarchy comprises three different levels: the values at the top, the norms in the middle, and the design requirements at the bottom of the hierarchy. As presented in §3.1.1, values are defined as convictions of a person or group of persons about matters that are important in life and worth striving for as well as the perception of what is good or bad. Norms can be defined as prescriptions or constraints on actions that support values (Dignum et al., 2016). Design requirements are defined as *"requirements that a good or acceptable design has to meet"* (van de Poel & Royakkers, 2011, p.166) and are very specific as they form the core of the SGSs design. According to van de Poel (2013), value hierarchies can be constructed bottom-up as well as top-down. Bottom-up construction is represented by the arrow on the right hand-side of Figure 8 named "for the sake of", being a type of relation that connects design requirements to underlying norms and values on which these design requirements may be based or to which they might contribute (van de Poel, 2013). This aids in understanding for the sake of what values certain design requirements or norms are desirable, which in turn aids in identifying stakeholder values that can be associated with SGSs. On the other hand, the top-down construction is represented by the arrow on the left hand-side of Figure 8 named "specifications", being a type of relation that translates values into design requirements for SGSs through translation into norms first (van de Poel, 2013). Here, it is important to define values before translating them into norms so it becomes clear how one should act to achieve certain values (van de Poel & Royakkers, 2011).

Dignum et al. (2016) observed that the public debate mainly addresses norms in the mid-level of the hierarchy, as norms can be made explicit in the form of arguments (i.e. normative statements) that come forth in the public debate. This means that norms are presented as arguments in the public debate and aid in gaining insight into the values at stake for SGSs in the UK, since arguments are assumed to be value-laden statements from which values can be derived. Hence, the value hierarchy approach is used to understand how to derive values from value laden-statements of smart grid stakeholders, presented in the newspaper reports. Figure 8 shows the position of arguments considered in this research. This figure emphasizes that stakeholder arguments expressed in the British public debate on SGSs mainly relates to the level of norms. Nevertheless, sometimes it might be the case that stakeholder arguments clearly specify design requirements or are very specific to explicit values. This justifies the overlap of arguments amongst the three levels of the value hierarchy, as illustrated in Figure 8 by the oval shape. Considering the value hierarchy approach, allows to grasp how to examine arguments from the British public debate in order to elicit and conceptualize values that can be associated with SGSs.

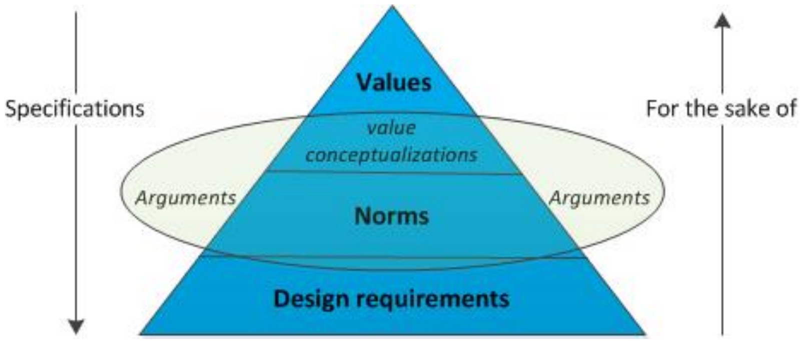

Figure 8: Value hierarchy (adapted from van de Poel (2013) and Dignum et al. (2016))

3.2. Ethical values associated with smart grid systems from the scientific literature

The scientific articles by Friedman and Kahn Jr (2003); Friedman et al. (2013); van de Poel (2015) and Ligtvoet et al. (2015) offer overviews of values that are often mentioned in the VSD literature and serve as a first step in exploring values that can be associated with SGSs. This contributes to establish the initial codebook for the qualitative content analysis of British national newspaper reports on SGSs. First of all, each VSD value conceptualization in the work of these authors was carefully evaluated. If a specific value could be related to SGSs, it was incorporated and conceptualized in Table 15 of Appendix C. Additionally, a literature review on SGSs is conducted in order to specify the broad and general sense of VSD values into the context of SGSs. For this purpose, Table 3 presents 48 reviewed scientific articles from which value statements about smart grids and/or its technology components were retrieved and if relevant added to Table 15. These articles did not explicitly mention values, but rather drivers (i.e. enablers/motivators) and/or barriers (i.e. concerns/threats). The search strategy used to retrieve these articles is the same as the one presented in §1.3.

Table 3: peer-reviewed scientific journal articles on smart grid systems and its components

#	Technology	Context	Source
1	Smart meter Energy storage	Measures to foster diffusion	Römer et al. (2015)
2	Smart meter Demand response	Consumer expectations and perceived risks	Krishnamurti et al. (2012)
3	Smart meter	Attitude of older people (consumers)	Barnicoat and Danson (2015)
4	Smart meter	Consumer engagement and acceptance	Buchanan et al. (2016)
5	Smart meter	Development and impact on privacy	Cuijpers and Koops (2012)
6	Smart meter	Consumer engagement	Darby (2010)
7	Smart meter	Social acceptance	Depuru et al. (2011)
8	Smart meter	Consumer acceptance	Guerreiro et al. (2015)
9	Smart meter	Factors for consumer adoption	Chou et al. (2015)
10	Smart meter	Design issues	Goulden et al. (2014)
11	Smart meter	Consumer concerns for acceptance	Yesudas and Clarke (2015)
12	Smart home Smart meter Demand response	Consumer perceptions	Paetz et al. (2012)
13	Smart home	Building Energy Management System to increase energy performance and comfort	Missaoui et al. (2014)
14	Smart home	Home energy management system and standard battles	van de Kaa et al. (2014)

15	Smart home	Expert views and public perception on social barriers for adoption	Balta-Ozkan et al. (2013)
16	Smart home	User needs and expectations	Bonino and Corno (2011)
17	Smart home	Users' perception, benefits and risks	Wilson et al. (2017)
18	Smart grid Smart meter Energy storage Demand response	Recommendations for the design of products and services in order to empower the end-user	Geelen et al. (2013)
19	Smart grid Smart meter	Social acceptance	Wolsink (2012
20	Smart grid Energy storage Demand response	Consumer engagement and participation	Sintov and Schultz (2015)
21	Smart grid Demand response	Preferences for domestic dynamic electricity tariffs in the US and EU	Buryk et al. (2015)
22	Smart grid Demand response	Consumer engagement and acceptance	Ellabban and Abu-Rub (2016)
23	Smart grid Demand response	Drivers, barriers, benefits, risks and expected functions	Xenias et al. (2015)
24	Smart grid	Consumer acceptance	Bigerna et al. (2016)
25	Smart grid	Barriers, drivers, and policies	Brown and Zhou (2013)
26	Smart grid	Policy and regulations in the United Kingdom	Connor et al. (2014)
27	Smart grid	Societal implications as challenges for engineering	Herkert and Kostyk (2015)
28	Smart grid	Privacy enhancement mechanisms of consumer data	Kessler et al. (2015)
29	Smart grid	Quality assessment to disentangle the ambiguity associated with the term smart grids	Kovacic and Giampietro (2015)
30	Smart grid	Barriers for adoption	Luthra et al. (2014)
31	Smart grid	Consumer and utility concerns related to load management techniques	Mahmood et al. (2015)
32	Smart grid	Barriers for implementation	Muench et al. (2014)
33	Smart grid	Consumer perceptions	Ponce et al. (2016)
34	Smart grid	Functionalities, history, issues and challenges	Tuballa and Abundo (2016)
35	Smart grid	Barriers and user engagement	Verbong et al. (2013)
36	Smart energy systems in general	Evaluation criteria to assess smart energy systems	Dincer and Acar (2016)
37	Smart energy systems in general	Instrumental, symbolic, and environmental attributes for consumer adoption	Noppers et al. (2016)
38	Renewable energy innovations	Social acceptance	Gross (2007)
39	Renewable energy innovations	Social acceptance	Huijts et al. (2012)
40	Renewable energy innovations	Purposeful design and social acceptance	Künneke et al. (2015)
41	Renewable energy innovations	Social acceptance	Wüstenhagen et al. (2007)
42	None	Democratic decision-making	Christiano (2004)
43	None	Framework for encouraging pro-environmental behaviour	Steg et al. (2014)
44	Energy system in general	Transformation of the energy system, public values and attitudes	Demski et al. (2013)
45	Energy storage	Theoretical results of simulation study regarding a specific system for household energy storage	Bianchi et al. (2014)

46	Energy projects in general	Responsible innovation; Values in the design of technologies and institutions	Correljé et al. (2015)
47	Demand response Energy storage	Demand side management policy in the United Kingdom	Warren (2014)
48	Contested technologies in general	Public values and responsible innovation	Dignum et al. (2016)

As can be seen from Figure 9, there is a clear difference in the groundedness (i.e. relevance) of the SGSs components (i.e. sub-systems) in the reviewed academic literature. Within the 48 scientific articles, it is noticeable that smart grids got the most attention (18 articles), followed by smart meters (14 articles). Besides, demand response was subjected to 8 articles and smart homes to 6 articles. The least mentioned sub-system (5 articles) is energy storage (i.e. household electricity storage and vehicle-to-grid). The literature review on VSD and SGSs jointly delivered an initial set of 38 values (see Table 15). In order to avoid redundancy, this initial set of values was critically revised once again after the literature review. This resulted in merging some values (e.g. synonyms or values complementing each other in the context of SGSs) into a single value and removing redundant values from the list. Consequently, this resulted in a list of 26 values unique to the context of SGSs. The conceptualizations and references to scientific literature are presented in Table 4. As aforementioned, these values are used as sensitizing concepts for the empirical data analysis. Therefore, validation of the values is performed though expert judgement of three scientists from the Faculty of Technology, Policy and Management of Delft University of Technology with a research interest in design for values and responsible innovation: Prof. Dr. Ir. Ibo van de Poel, Dr. Theo Fens, and Ir. Tristan de Wildt. The set of 26 values was provided to them in order to determine the degree to which the values and the perspective of the researcher could be confirmed or corroborated by the experts. All experts agreed on the set of values and provided some suggestions to strengthen the conceptualizations. When consensus was reached, the final set of validated values that can be associated with SGSs is established. Please note that the identified list of values (see Table 4) is not exhaustive, but illustrates typical values that can be associated with SGSs.

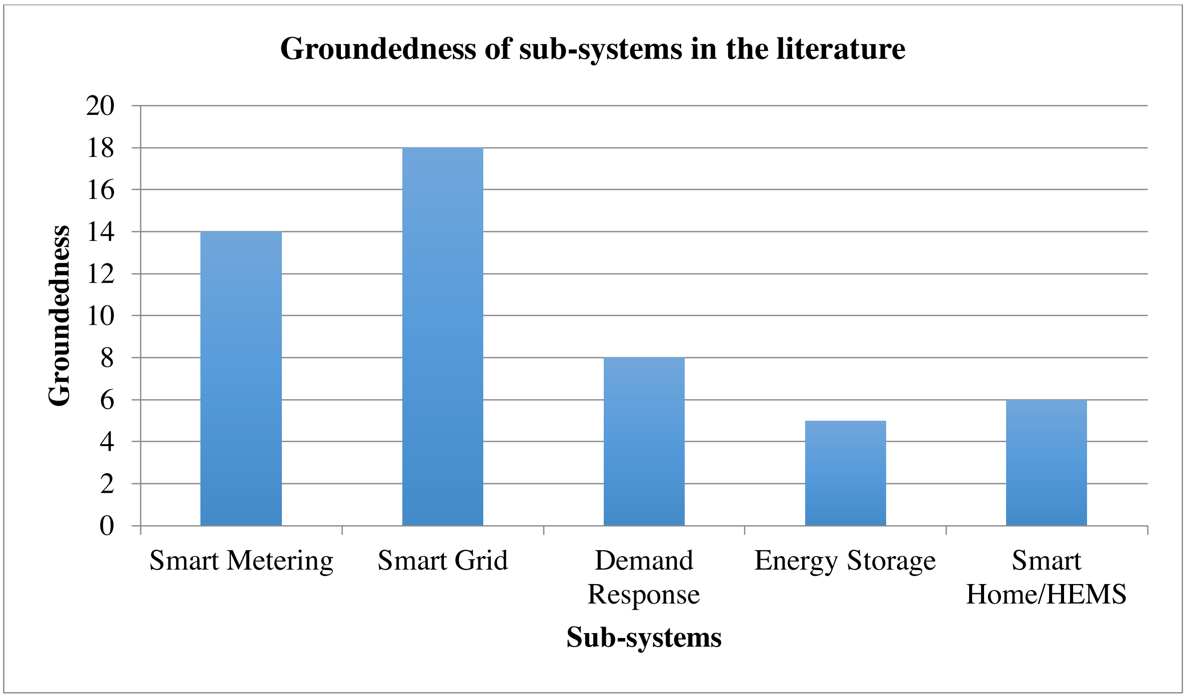

Figure 9: Groundedness of sub-systems in the literature

Table 4: Ethical values associated with SGSs (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 et al., 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, Ligtvoet, 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 et al., 2015; Steg et al., 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	(Dignum et al., 2016; Guerreiro et al., 2015; Ligtvoet et al., 2015; Yesudas & Clarke, 2015)

	social well-being and not merely the absence of infirmity or disease.	
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 et al., 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)

Besides, through the quotations retrieved from the literature (see Table 15 of Appendix C), values that are at stake for the specific sub-systems could be derived. For instance, from the quotation *"the full deployment of the smart grid would provide many potential benefits. The main benefits of the SG, include a more reliable, more economic, and more environmentally friendly grid"* (Ellabban & Abu-Rub, 2016, p.1287) it can be derived that smart grids can be associated with the values of reliability, economic development and environmental sustainability. Another example is *"energy consumption reveals details of personal life, in the most privacy-sensitive place – the home, and therefore smart metering has to strike a careful balance between detailed energy metering and privacy protection"* (Cuijpers & Koops, 2012, p.2), which implies that smart metering can be associated to the value of transparency/accuracy and privacy.

The co-occurrence between sub-systems and values are presented in Table 5. The co-occurrence shows when authors talk about value x, how many times do they specifically also talk about sub-system y. For instance, Table 5 shows that 10 different scientific articles discussed security while discussing smart grids. Overall, it was noticeable that privacy, security, control/autonomy and health/safety were mostly perceived as issues. On the other hand, environmental sustainability, economic development, security of supply, autarky, and quality of life/comfort/well-being were definitely perceived as drivers for SGSs.

Table 5: Co-occurrence of values and sub-systems in the reviewed literature

	Demand Response	Energy Storage	Smart Grid	Smart Home	Smart Metering
Autarky		1	2		
Control/Autonomy			2	1	4
Cooperation			1		
Economic Development	2		2	1	6
Environmental Sustainability	2		5	1	4
Health and Safety	1			1	3
Identity					2
Informed Consent					2
Ownership and Property			1		
Privacy	1		10	2	8
Procedural Justice					1
Quality of life/Well-being/Comfort	1		1	2	4
Reliability	1	2	2	1	2
Security			10	1	7
Security of supply	3	1	2		1
Transparency/Accuracy					3
Trust			2	1	2
Universal usability/Inclusiveness			2	1	

Demand response studies were presented from the focus on consumer expectations and perception, often combined with other smart grid technologies such as smart homes and smart meters (see Table 3). As presented in Table 5 demand response is related to economic development, and environmental sustainability. As dynamic pricing drives demand response, CO_2 emissions can be reduced because enhanced price signals can nudge consumers to shift energy demand away from peak times (Buryk et al., 2015). By doing so conventional generators (mostly gas power plants) meant to specially serve the system at peak can be avoided. Besides, balancing demand and supply through dynamic pricing for load shifting in order to reduce the strain on the grid adds to reliability of the system and security of supply. Privacy as well as health and safety seem to be concerns as demand response is achieved through implementation of smart meters for providing insights to energy consumers on energy pricing and energy consumption (Verbong et al., 2013). This detailed data entails information about consumer behaviour, which is vulnerable. In addition, the value of quality of life/well-being/comfort is at stake for this sub-system as smart appliances such as the dishwasher or washing machine turn on they receive a low energy price signal for now and e.g. the next hour, which aids consumers to adapt their consumption without losing comfort (Paetz et al., 2012).

Smart metering studies mainly focused on drivers and barriers i.e. benefits and risks for consumer acceptance. As can be seen from Besides, through the quotations retrieved from the literature (see Table 15 of Appendix C), values that are at stake for the specific sub-systems could be derived. For instance, from the quotation *"the full deployment of the smart grid would provide many potential benefits. The main benefits of the SG, include a more reliable, more economic, and more environmentally friendly grid"* (Ellabban & Abu-Rub, 2016, p.1287) it can be derived that smart grids can be associated with the values of reliability, economic development and environmental sustainability. Another example is *"energy consumption reveals details of personal life, in the most privacy-sensitive place – the home, and therefore smart metering has to strike a careful balance between detailed energy metering and privacy protection"* (Cuijpers & Koops, 2012, p.2), which implies that smart metering can be associated to the value of transparency/accuracy and privacy.

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Table 5, smart meters can be associated with transparency/accuracy, control/autonomy, economic development, and environmental sustainability. As smart meters provide insights into energy consumption patterns near real-time to consumers, they can be incentivised to be more aware and save energy where possible (Cuijpers & Koops, 2012). Moreover, the energy bills will no longer be estimated but based on actual consumption (Guerreiro et al., 2015). In the UK the installation of smart meters is not mandatory and thus legislation allows consumer to refuse installation of smart meters or have them removed once installed (Buchanan et al., 2016), also adding to the value of control/autonomy for example. Furthermore, smart meters allow consumers to keep their identity or adapt it if necessary and to freely make choices based on arguments (e.g. feedback from the smart meters) in order to play an active part in decision-making of their energy management (Buchanan et al., 2016), which refers to the values of identity and informed consent. Another value related to this sub-system is quality of life/well-being/comfort mainly due to the avoidance of meter reading's hassle as smart meters send the data automatically to the energy suppliers (Buchanan et al., 2016). Procedural justice, trust, privacy, and security appeared to be concerns or barriers for acceptance due to information communication and the strategic behaviour that parties can have due to its stake on energy consumption data (e.g. utility companies and other organizations wanting to sell their products to consumers).

Energy storage contributes to the value of autarky as renewable power generation and its storage can allow households to be self-sufficient and less dependent on the grid (Römer, Reichhart, Kranz, & Picot, 2012). However, a higher share of renewable energy and distributed generation can put additional strain on the grid and even threaten its stability (Brown & Zhou, 2013). However, energy storage in the batteries of electric vehicles support grid reliability by allowing energy discharge back into the grid especially during peak time (Sintov & Schultz, 2015). This also adds to the value of security of supply as increased grid stability can lead to a more reliable energy system in which the probability of power outages as well as blackouts is lower.

Smart grid studies mainly addressed barriers and drivers for development, implementation and adoption as well as consumer acceptance. As can be seen from Besides, through the quotations retrieved from the literature (see Table 15 of Appendix C), values that are at stake for the specific sub-systems could be derived. For instance, from the quotation *"the full deployment of the smart grid would provide many potential benefits. The main benefits of the SG, include a more reliable, more economic, and more environmentally friendly grid"* (Ellabban & Abu-Rub, 2016, p.1287) it can be derived that smart grids can be associated with the values of reliability, economic development and environmental sustainability. Another example is *"energy consumption reveals details of personal life, in the most privacy-sensitive place – the home, and therefore smart metering has to strike a careful balance between detailed energy metering and privacy protection"* (Cuijpers & Koops, 2012, p.2), which implies that smart metering can be associated to the value of transparency/accuracy and privacy.

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Table 5, the most repeating values are privacy and security, being the main concern of consumers. For instance, the digital technology applied in smart grids makes this sub-system prone to cyber-attacks, in which private consumer information can be acquired and sabotaged to facilitate delay or damage of grid response systems and even cause outages limiting power supply (a critical service) (Bigerna, Bollino, & Micheli, 2016; Herkert & Kostyk, 2015; Tuballa & Abundo, 2016). Besides, the value of environmental sustainability plays a role in this sub-system, as smart grids are believed to contribute to the reduction of GHG emissions through facilitation of renewable energy into the grid (Darby et al., 2013; Ellabban & Abu-Rub, 2016; Ponce et al., 2016; Tuballa & Abundo, 2016). Besides, universal usability/inclusiveness is relevant for smart grids as this complex system aims to make the users of the power grid successful users. Trust in the government and energy industry is also at stake for smart grids as it probably affects the public perception and debate on SGSs (Darby, 2012; Xenias et al., 2015).

Smart home studies focus on energy management, health care and entertainment as well as drivers and barriers for adoption. As given in Besides, through the quotations retrieved from the literature (see Table 15 of Appendix C), values that are at stake for the specific sub-systems could be derived. For instance, from the quotation *"the full deployment of the smart grid would provide many potential benefits. The main benefits of the SG, include a more reliable, more economic, and more environmentally friendly grid"* (Ellabban & Abu-Rub, 2016, p.1287) it can be derived that smart grids can be associated with the values of reliability, economic development and environmental sustainability. Another example is *"energy consumption reveals details of personal life, in the most privacy-sensitive place – the home, and therefore smart metering has to strike a careful balance between detailed energy metering and privacy protection"* (Cuijpers & Koops, 2012, p.2), which implies that smart metering can be associated to the value of transparency/accuracy and privacy.

The co-occurrence between sub-systems and values are presented in Table 5. The co-occurrence shows when authors talk about value x, how many times do they specifically also talk about sub-system y. For instance, Table 5 shows that 10 different scientific articles discussed security while discussing smart grids. Overall, it was noticeable that privacy, security, control/autonomy and health/safety were mostly perceived as issues. On the other hand, environmental sustainability, economic development, security of supply, autarky, and quality of life/comfort/well-being were definitely perceived as drivers for SGSs.

Table 5, privacy and quality of life/well-being/comfort are the most mentioned values for this sub-system according to the literature. Similar to the other sub-systems, privacy intrusion and data security is a concern for smart homes as well. The smart home's network that connects and coordinates all information and high-tech smart appliances of the residence can be associated to control/autonomy and comfort since households are not required to make day-by-day, minute-by-minute control decisions (Balta-Ozkan et al., 2013). Moreover, the smart appliances aim at minimizing the daily energy cost (Missaoui et al., 2014) and allow automatic shutter and windows operations, light regulation, space heating/cooling (Bonino & Corno, 2011), which adds to economic development. Besides, reliability is known as a concern as break down of the smart home's remote control units can cause malfunction of smart appliances, sensors wrongly going off and the house going limbo (Balta-Ozkan et al., 2013).

3.3. Conclusion

This chapter described the main concepts of this research next to SGSs: values (see §3.1.1) as well as ethical acceptability and social acceptance (see §3.1.2). This is done through a literature review on ethics of technology and SGSs, thereby answering the second research sub-question: *"What ethical values are associated with smart grid systems in the current academic literature?"* As presented in Table 4, 26 ethical values that can be associated with SGSs in general are inferred from the academic literature and conceptualized. In addition, the identified values are distinguished to specific smart grid technologies, as presented in Table 5. From the literature, it was noticeable that the consumers were addressed as the key stakeholder for the adoption of SGSs. Furthermore, the values were not explicitly mentioned in the journal articles but came forward as factors for technology adoption in the form of barriers/pitfalls/risks/threats or drivers/benefits/opportunities of SGSs. Besides, no values could specifically be associated with the stakeholders identified in §2.2.2, as the majority of the studies focused on understanding consumer behaviour and perceptions regarding the acceptance of different smart grid technologies. The findings of this research phase provide input for the empirical data analysis.

4. Qualitative content analysis

Content analysis *"classifies textual material, reducing it to more relevant, manageable bits of data"* (Weber, 1990, p.5). It can be defined as a *"research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use"* (Krippendorff, 2004, p.18). 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) using systematic and well-written rules (Krippendorff, 2004; Neuendorf, 2017; Weber, 1990). It can be seen as a scientific tool that requires and includes validity, reliability, objectivity (or inter-subjectivity), reproducibility, and sample representativeness (Krippendorff, 2004; Neuendorf, 2017). This thesis ensures that the empirical data analysis meets these requirements through retrieving the codes (e.g. values, stakeholders and sub-systems) from scientific literature and validating the predefined codes by expert judgment. These predefined codes serve as sensitizing concepts and initial input to analyse the empirical data. The aim is to gain insight into stakeholder values that play a role in the British public debate on SGSs according to newspaper reports and insights into the type of relations among the values. Therefore, this chapter focuses on performing the empirical data analysis of the British public debate on SGSs through a qualitative content analysis in order to answer the third research sub-question *"What ethical values are associated with smart grid systems in the UK according to the empirical data?"*

As shown in Figure 10, the sub-deliverable of this chapter entails content analysis results. These include values that as a matter of fact play a role in the British public debate on SGSs, relevance of these values, stakeholder interpretations of the values, and relevance of smart grid technologies in the public debate. The analysis and results of this research phase are necessary for the next research phase: interpretation and discussion.

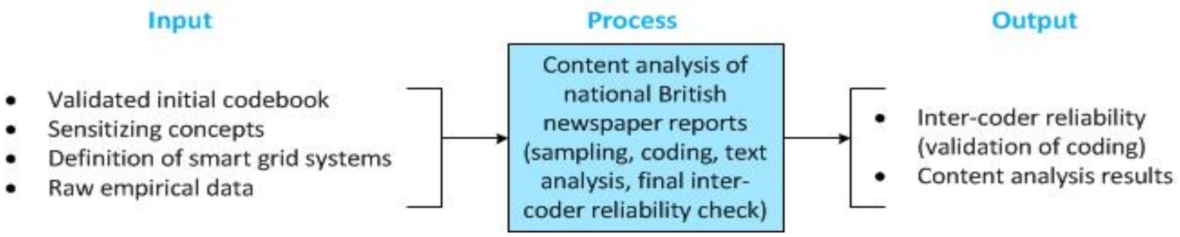


Figure 10: Research flow the third research phase (analysis and results)

4.1. Data collection

As generally acknowledged, data is the starting point of empirical research. In this research, the data is acquired from 21 British national newspapers. These are all national newspapers (still and no longer circulating in the UK) and are all considered in this research to avoid selection bias. The newspapers include both broadsheets (the quality press) and tabloids (the popular press) to be analysed. This provides a great contrast, which is interesting for this research as the type of the newspapers and their political orientation differ. An overview of the newspapers used for the content analysis is presented in Table 6 and Table 7. This information is retrieved from the British Audit Bureau of Circulations (ABC, 2017). The issue circulations presented in both tables are average figures until the 16^{th} of November 2017. The newspaper reports (empirical data) are acquired from the Factiva digital database. Factiva provides major regional and national news from different countries worldwide (Factiva, 2012).

Table 6: National distributed broadsheets (quality press) in the UK (source: (ABC, 2017))

Newspaper name	Political orientation	Circulation per issue
The Daily Telegraph	Centre-right, conservative	192,478
The Sunday Telegraph	Centre-right, conservative	344,758
The Times	Centre-right, conservative	444,493
The Guardian	Centre-left	146,766
The Observer	Centre-left	177,279
Financial Times	Economically liberal	193,029
i	Centrist	263,023

Table 7: National distributed tabloids (popular press) in the UK (source: (ABC, 2017))

Newspaper name	Political orientation	Circulation per issue
Daily Mail	Right-wing, conservative, populist	1,388,733
The Mail on Sunday	Right-wing, conservative, populist	1,195,035
The Daily Express	Right-wing, Eurosceptic	368,959
Sunday Express	Right-wing, Eurosceptic	323,474
The Sun	Right-wing, conservative, populist	1,517,314
The Daily Mirror	Centre-left, populist	603,629
The Sunday Mirror	Centre-left, populist	516,786
Daily Star	Largely non-political	406,864
Daily Star Sunday	Largely non-political	247,992
People	Centre-left, populist	206,593
Metro	Centre-right	2,027,892
The Independent	Liberal independent	No longer registered
Independent On Sunday	Liberal independent	No longer registered
The News of the World	Conservative	No longer registered

4.1.1. The search strategy

In order to retrieve the empirical data from the Factiva database, a search query is used that is based on the search terms (including wildcards) presented in Table 8. The chosen time span ranges from the 1st of January 2007 until the 30th of June 2017 being the date of the search. This timeframe is chosen since the policy debate leading up to the smart meter rollout in the UK started in 2007, as represented by the White Paper on Energy (DTI, 2007). As aforementioned, since smart meters are a critical building block towards SGSs, the start of its rollout can be considered as the start of making UK's current electricity system more intelligent (DECC, 2015). Taking smart meters as a proxy for the development of SGSs in the UK, it can be seen from Factiva that the earliest news publications on this topic started in 2007. In order to avoid redundancy, duplicates are excluded from the search results. The search summary (including the search query) can be found in Table 19 of Appendix D. The data was exported to Excel and screened before sampling. Thereby, further duplicates were identified and removed, resulting in 3,541 unique hits forming the newspaper population.

Table 8: UK search terms on SGSs

<table>
<tr><th>Technological Context / Broad Term</th><th colspan="2">Search Terms</th></tr>
<tr><td>Smart energy systems</td><td rowspan="6">Smart/Intelligent/Digital</td><td>Energy
Energy system*
Electricity system*</td></tr>
<tr><td>Smart grid</td><td>Energy network*
Energy grid*
Power grid*
Electricity network*
Grid*</td></tr>
<tr><td>Smart meter(ing)</td><td>Meter*
Energy meter*
Electricity meter*</td></tr>
<tr><td>Smart home/home energy management</td><td>Residence*
Home*
Building*
House*
Living space*</td></tr>
<tr><td>Smart energy regulation</td><td>Energy regulation*
Energy policy
Energy rule*
Energy arrangement*</td></tr>
<tr><td>Smart energy legislation</td><td>Energy legislation
Energy Act*</td></tr>
<tr><td>Smart EV charging</td><td>Smart/Intelligent</td><td>Charging AND electric car* OR electric vehicle*</td></tr>
<tr><td>Microgrid</td><td>--</td><td>Microgrid</td></tr>
</table>

Household storage	--	Home battery Home batteries Home storage
Demand side management	--	Demand side management Demand side response Demand response
Digitalization & energy Virtual power plants	--	Virtual power plant

4.1.2. Sampling of documents

Due to restriction of research resources a subset of newspapers needs to be drawn from the population in order to perform the content analysis. Therefore, for this research a limit of 150 newspapers articles is set to be studied. This thesis applies the notion of systematic sampling (Krippendorff, 2004; Neuendorf, 2017), consisting of selecting each *xth* case from the population following the equation:

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

After sorting the search results in Excel first by publication (i.e. newspaper) and then by date, every 25th article is subsequently selected for coding and recording. In this context, the following procedure is followed:

1. Check in the database whether the content of the selected newspaper article is relevant for this research or not. The relevance criteria are:
   - Is it really a British national newspaper publication?
   - Does the newspaper article have a relevant technological context (i.e. about energy and electricity)?
   - Is the content of the newspaper article relevant for the UK (i.e. not articles published in the UK but talking about smart grids and its related technologies in other nations)?
2. If the newspaper article is indeed relevant proceed to download it for the content analysis. The documents are subsequently subject to coding and recording (see §4.3)
3. If the article turns out not be relevant, simply select the next article and repeat from step 1 in this procedure

This procedure resulted in a total of 127 British national newspaper reports (i.e. articles) to be content analysed. A detailed example of application of this procedure is given in the next section, when explaining the coding and recording principles. A detailed example of application of this procedure is given in the next section, when explaining the coding and recording principles.

As shown in in Figure 11 below, the systematic sampling of documents is performed such that the distribution of articles per newspaper follows the same distribution of the population in order to avoid certain newspapers to be overrepresented and influence the results. The green bars depicted in Figure 11 represent the document count (in %) in the population and the blue bars represent that of the sample. In order to clearly examine whether the pattern of the sample follows that of the population, document count per newspaper in percentage is used for the sake of comparison. Hence, as Figure 11 illustrates, the pattern of document distribution per newspaper in the population is replicated by the sample.

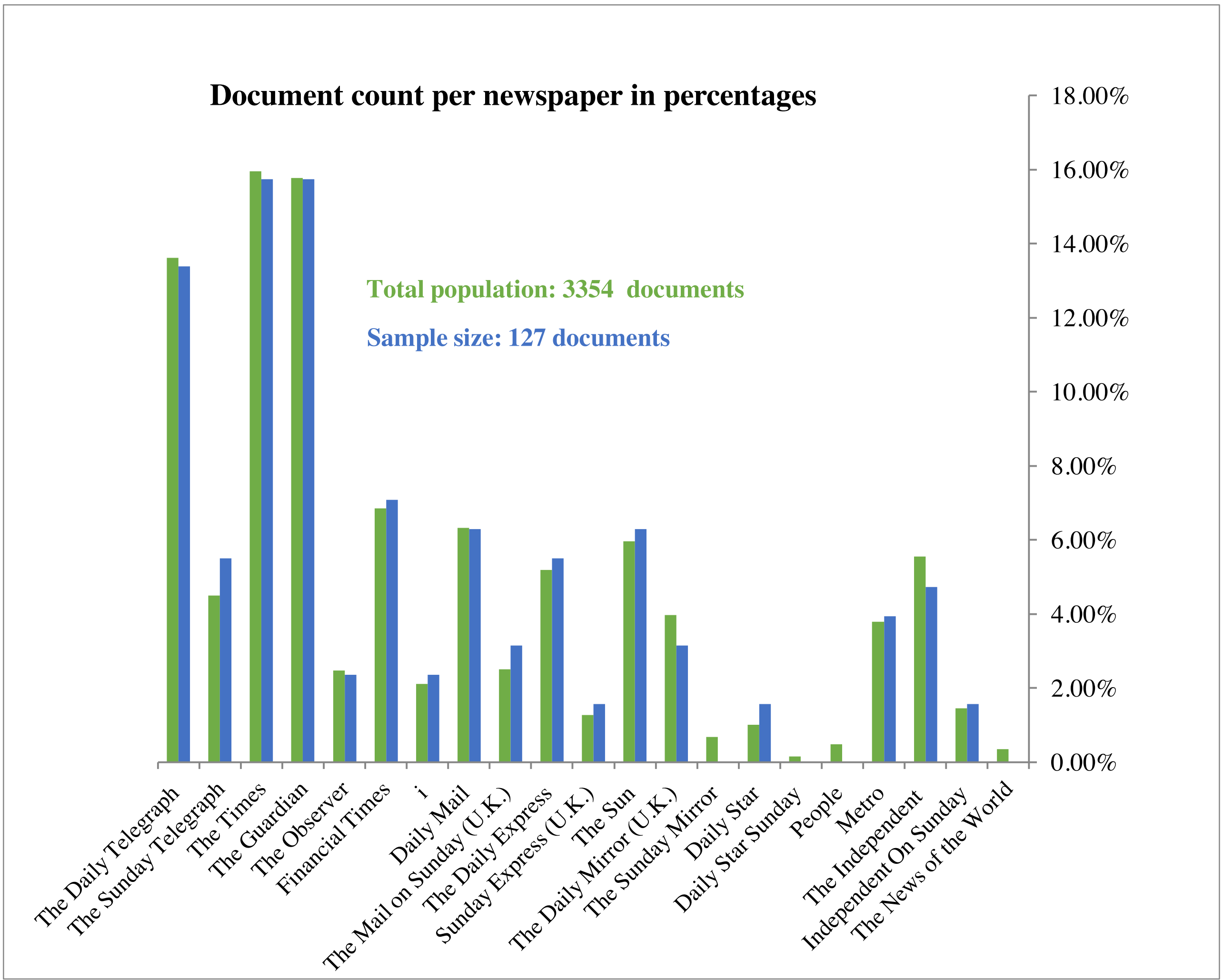


Figure 11: Document count per newspaper in the population and the sample in percentages

4.2. Qualitative text analysis with ATLAS.ti

As this research encompasses a large number of empirical data (127 newspaper articles from which 480 quotations are retrieved) and a large number of codes (26 value codes, 6 sub-systems codes, 40 stakeholder codes, 3 valence codes, and 45 event topic codes) it can be inconvenient and difficult to handle the data and keep track of it. Therefore, this research makes use of one of the well-known computer aided qualitative data analysis software: ATLAS.ti[10]. This specific software aims at aiding manual coding through allowing the combination of documents and management of codebook with different coding facilities. This means that ATLAS.ti allows the addition of documents, the definition of codes and relations between codes as well as assigning the codes to desired/selected parts of the imported documents, so-called quotations (Friese, 2014). As previously mentioned, the quotations in this research are value-laden statements in the articles text. Moreover, ATLAS.ti also allows for the creation of relations between quotations and codes (e.g. "is a", "expands", "contradicts"), which facilitates studying the relations between values by exploring whether there are overlapping value conceptualizations (e.g. evaluating whether one quotation is valid for several values) or values conflicts (e.g. a value is both used for pro and contra statements) through creating a network that shows the conceptualization links and see which values overlap or are in conflict. In addition, the software also facilitates to study what values are most prominent in the British public debate on SGSs by using the code manager and seeing how often selected codes come forth in the newspaper articles. Hence, ATLAS.ti is suitable

[10] The empirical data of this research is coded using ATLAS.ti version 1.6.0 for Mac with a full license (i.e. not a student license because it has limited functionalities)

software for the purpose of this research and makes it relatively easy to view and navigate to quotations that are linked to codes and find related codes as well (Friese, 2014).

4.3. Coding and recording principles

This section presents and elaborates on the protocol for empirical data analysis: the coding and recording principles. This aids in enhancing the reproducibility of the content analysis results. According to Krippendorff (2004), recording entails the content analyst's interpretation of what is read in the newspaper articles. Coding refers to analysing the content of newspaper articles and labelling the text with codes following observer-independent rules, instructions or principles. The protocol for analysing the content of newspaper articles, i.e. coding and recording principles, is important in order to ensure reproducibility, reliability, and validity of the content analysis results (Neuendorf, 2017). This protocol also clarifies the process of interpreting themes and patterns from the text, e.g. how values are inferred from statements in the text and under which conditions statements and newspaper articles are perceived as relevant. Besides, a coding scheme is developed, comprising a codebook that considers sensitizing concepts and presents as well as defines the codes that will label the text in the newspaper articles. The coding scheme is as follows:

- **Codebook** (see Appendix E)
- **Text data:**
    - Statements or arguments, representing the conception of the underlying value
    - Statements or arguments are full sentences, not single words or phrases
- **Coding units:**
    - Values
- **Additional recording/context units for each newspaper article:**
    - Source publication (not coded in ATLAS.ti, but indicated through the document name)
    - Publication date (not coded in ATLAS.ti, but indicated through the document name)
    - Reported event/topic of the article (coded in ATLAS.ti while making sure that the quotation overlaps all other codes in the article. This mainly means selecting the entire article as one quotation and then applying the event-topic code)
- **Additional recording/context units for value statements in the newspaper articles, i.e. each quotation that was coded with a value was also coded with the following codes:**
    - Statement valence:
        - Positive (the coded statement contains a pro argument or an advantage of the system)
        - Negative (the coded statement contains a contra argument or a disadvantage of the system or a challenge (things that have to be taken care of for the system to yield its benefits))
        - Neutral (the coded statement does not reflect a position pro or contra SGSs or the related value is not a barrier or disadvantage or negative valence)
    - Stakeholders:
        - Sender (stakeholder putting forward a statement)
        - Receiver (stakeholder who is affected by the statement)
    - SGSs sub-system/technology

The coding and recording principles are as follows:

- An initial coding scheme is established based on the literature review, which contains the list of values that can be associated with SGSs and their conceptualizations (definitions). The same is done for smart energy sub-systems, statement valence and stakeholders. Examples of codes are:
    - Value: Privacy→ Code: value_Privacy
    - Valence: Neutral → Code: valence_Neutral
    - Sub-System: Smart Metering → Code: sub-system_Smart Metering

- The notion of "sensitizing concepts" is used, meaning that the initially predefined coding scheme is open for new additions, changes in definitions, and changes in coding categories (e.g. splitting one value into two, merging separate values into one and/or adding new values, sub-systems and stakeholders). This is important to prevent precluding the possibility that there might be other values, sub-systems and/or stakeholders in the newspaper articles that did not emerge from the literature study and desk research.
- Statements or arguments in a newspaper article are examined and reflected with the aid of the coding scheme in order to identify which value underlies the respective statement or argument.
- A recorded statement from the text needs to be at least one full sentence in order to ensure that outside readers are capable of understanding the recorded statement when reading it independently from the main newspaper article.
- Statements that reflect values:
    - Are coded as positive, negative or neutral depending whether it is used in favour of, against or neutral to the smart grid development in the UK.
    - Stakeholders are assigned in two ways: The individual, group or organization that puts forward an argument is the "sender". The individual, group or organization that is affected by the statement is the "receiver". Please note that the two stakeholder classifications can be the same for one statement. If the recorded statement does not cite any individual, group or organization, the stakeholder classifications will be left empty. When the article puts forward a value-laden statement or advice from the journalist/newspaper perspective, the newspaper is the "sender" stakeholder.
    - Statements have to be explicitly in context with SGSs or their components. Statements that contain values but refer to main tasks of market actors, general energy generation or the energy transition in general are excluded. Additionally, conventional and renewable energy generation are excluded if not mentioned explicitly in relation with SGSs.
- Statements about smart homes need to be in relation with electricity consumption, energy savings, energy management or energy production to be included in the content analysis. Hence, smart home statements about health care, entertainment, and life style are excluded.
- To enhance the validity of the results, additional people need to code the statements with respect to underlying values (additional recording units do necessarily not need to be replicated as the values are the main focus of this research). The additional coding should be done by at least one more person, who will code the extracted statements from the newspaper articles independently of the initial coding. Discrepancies are solved through discussion and consensus.

An example of the application of this protocol for coding the empirical data in ATLAS.ti is depicted in Figure 18 of Appendix E. The example shows how value-laden statements from a newspaper article are coded in ATLAS.ti following the coding and recording principles and considering the codebook and coding scheme.

4.4. Validation of coding

In order to avoid the bias of being attached to a certain viewpoint (i.e. single coder subjectivity), this research applies to notion of "inter-coder reliability". This notion yields *"the amount of agreement or correspondence on a measured variable among two or more coders"* (Neuendorf, 2017, p.165). This implies that the process of making inferences from the text of newspaper articles as well as the attached codes to quotations are double checked by an additional independent coder as explained in the previous section. This means that the additional person will code the statements inferred from the newspaper articles independent of my initial coding. Then, my findings and that of the independent coder are compared. Any discrepancies will be solved through discussion until a consensus is found. Due to restriction of research resources just one independent coder could be involved in the inter-coder reliability test. For this purpose, an expert is needed that is familiar with the ATLAS.ti software and preferably SGSs and design for values. The expert who was willing to be the independent coder, is a member of the academic staff of the Faculty of Technology, Policy & Management of the TU Delft, being the third supervisor of this research: Christine Milchram, MSc. Her expertise is chosen for validation of the coding, as she is a PhD researcher in the field of moral values and acceptability of SGSs. The validation of the coding is done with ATLAS.ti and all discussions are recorded there. To summarize, at first in 14% of the coding discrepancies were found by the independent coder. These inter-coder discrepancies were dealt by discussion until consensus is reached. Thereafter, the ATLAS.ti project is adapted accordingly in order to retrieve the content analysis results.

4.5. Content analysis results

This section presents the findings of the empirical data analysis. As aforementioned, 127 articles are sampled to be content analysed, published between the 1st of January 2007 and the 30th of June 2017. Some articles focused on a single SGSs component (i.e. sub-system), whilst sometimes several components were the subject of one article at the same time. It is important to notice that the groundedness (i.e. relevance) of sub-systems is consistent through all newspaper articles. For instance, if an article is about smart metering and demand-response, both sub-systems are coded only once in the article with an overlapping quotation (i.e. selecting the entire article text as a single quotation and then adding the specific sub-system codes). As Figure 12 shows, there is a clear difference in the groundedness of the SGSs components in the newspaper articles. Within the data, it is noticeable that smart metering got the most attention (109 articles), followed by smart grids (18 articles). Besides, demand response was subjected to 15 articles and smart homes to 8 articles. As aforementioned and presented in the codebook (see Appendix E), this thesis considers energy storage as consisting of household electricity storage (in batteries) and vehicle-to-grid. As depicted in Figure 12, each of these power storage technologies is subjected to 8 articles.

Figure 13 illustrates the relative frequency of smart grids and sub-systems in the newspaper reports, per publication year. This entails information on the relevance of SGSs in the public debate. For instance, in 2007 10% of the articles were subjected to demand response, 10% to smart grids, and 80% to smart metering. In 2008, 11% of the newspaper reports were focused on smart homes and 89% on smart metering. Besides, Figure 13 shows that in 2009 5% of the articles discussed demand response, 35% smart grids, and 60% smart metering and so on. According to the empirical data, the major events that fuelled the public debate on SGSs over the last 10 years are billing problems (i.e. estimated bills that were not accurate), increase in energy price and fuel poverty, home energy efficiency need, and the energy transition.

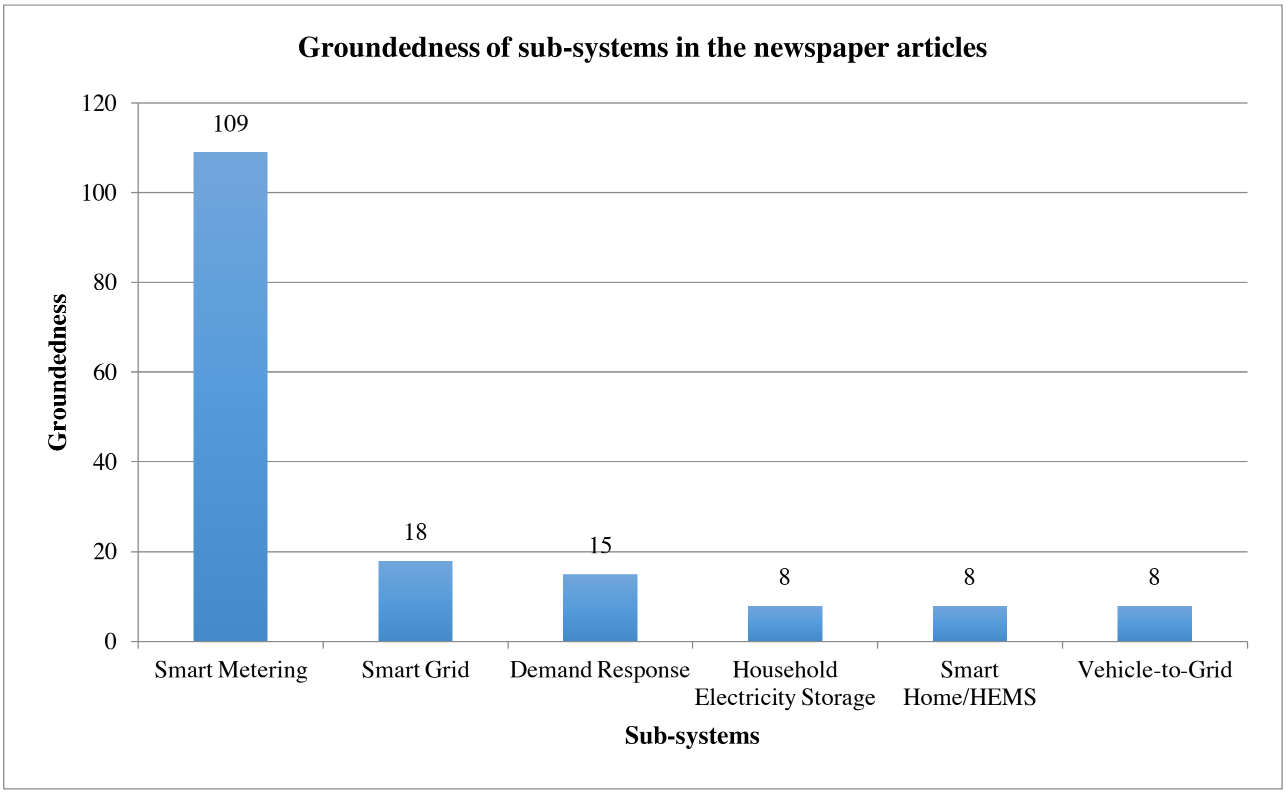


Figure 12: Groundedness of sub-systems in the newspaper reports

As illustrated by Figure 13, over the years smart metering is the most discussed sub-system compared to the others, followed by smart grids (the system). This can be justified as the smart meter roll-out is considered a key development in the deployment of smart grids in the UK. Moreover, the smart meter policy design stage took place from 2010 until 2011, the foundation stage lasted from 2011 until 2016 and the main installation stage lasts from 2016 until 2020 (see Figure 4 in §2.2.1). From 2007 until 2010, the energy demand research project took place in Great Britain as a test pilot for smart meters and real-time display devices. Besides, in 2009 the first smart grid route map and vision was published addressing smart meters as a critical building block for smart grid development in the UK. Figure 13 also shows that in the course of time, especially in the past 3 years, the amount of sub-systems that come forth in the public debate has grown. This can be justified as UK's smart meter roll-out is coming to an end (currently halfway) and new technological advancements have emerged such as the rise of electric vehicles and enhanced batteries for electricity storage. Besides, the population and energy consumption continue rising. This adds importance to the need for demand side management to ensure security of supply, specifically through demand response so consumers can make significant contributions to energy system management, often at lower cost and lower carbon emission than traditional approaches, such as subsidies, energy efficiency measures and temporary large-scale energy storage (currently very expensive).

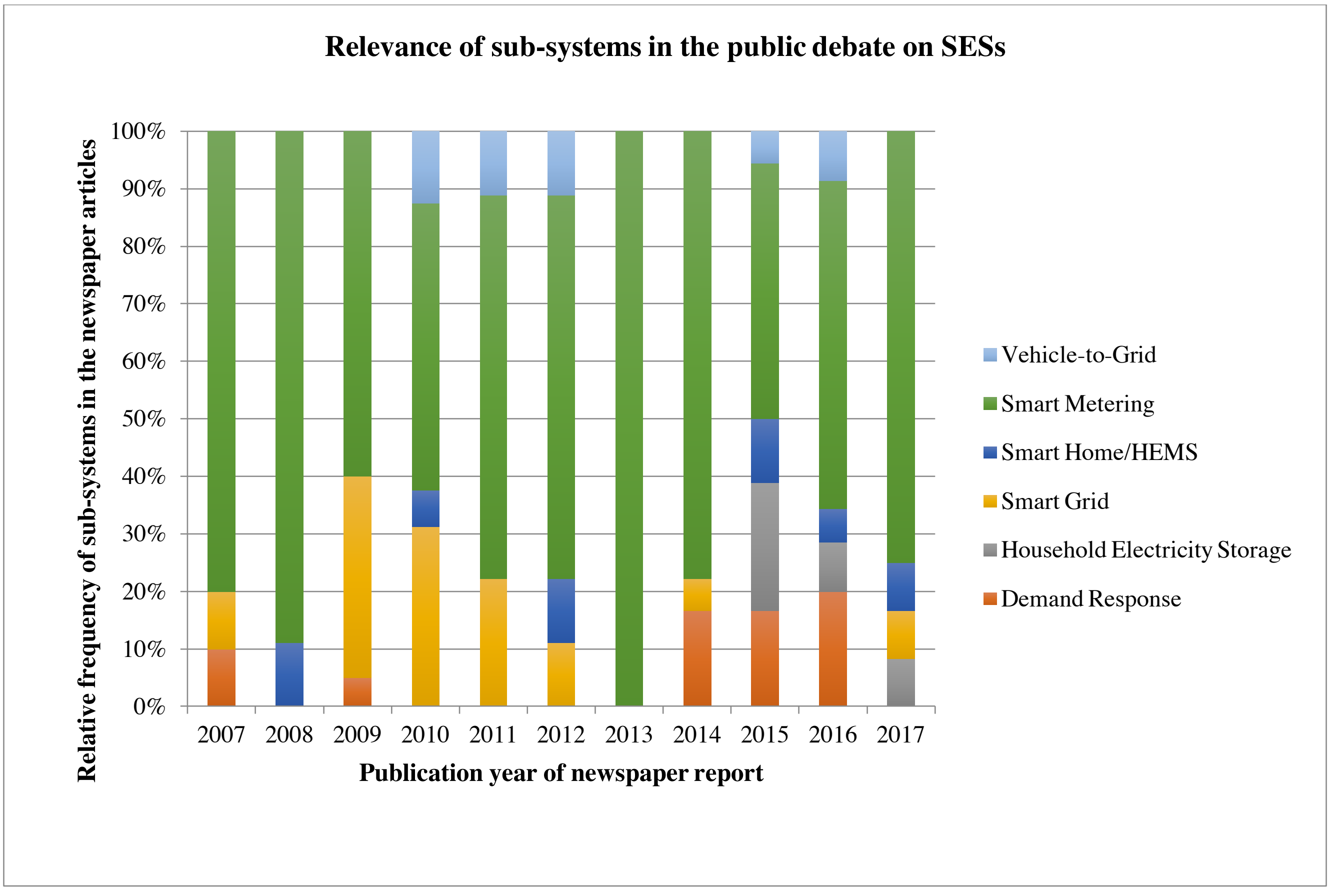


Figure 13: Relevance of SGSs in the public debate over time

4.5.1. Ethical values and valence in the public debate

The content analysis of British national newspaper reports reveals that 21 ethical values can be associated to SGSs and thus play a role in the public debate. This is depicted in Figure 14. On a general level, Figure 14 also shows that the most prominent values are Economic Development, Transparency/Accuracy, Environmental Sustainability, Control/Autonomy, and Distributive Justice. The least prominent values are Honesty/Integrity, Calmness, Accountability/Traceability, Ownership/Property, and Courtesy.

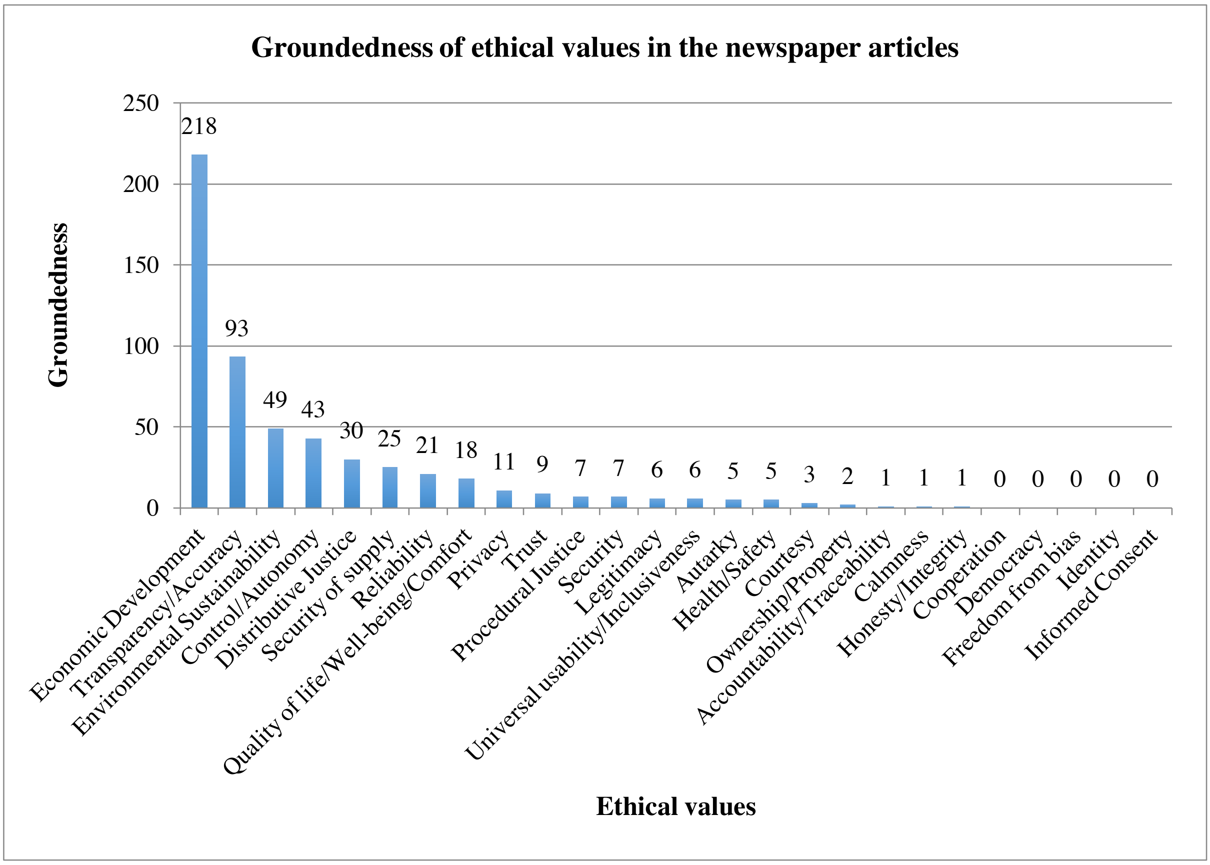


Figure 14: Relevance of ethical values in the public debate on SGSs

In order to determine whether values can be considered as drivers, barriers or as contested in the public debate, the code co-occurrence is used between values and the 3 types of valence (negative, positive and neutral). This is presented in Table 9 below and shows the number of quotations from the newspaper articles in which the value codes and valence codes are co-occurring. As presented in Table 9, three drivers are recognized. To start with, Autarky is perceived as a driver since it allows independency of (frequent) power cuts because the consumer generates and stores its own power, thereby contributing to security of supply and the ability of being off-grid. This energy self-sufficiency means that renewable energy is produced by the consumer itself, which contributes to environmental sustainability as renewable energy production contributes to lower GHG emissions. Moreover, autarky contributes to economic development as prosumers can sell their excess power to the grid, allowing them to make profit. Furthermore, cheaper energy can be produced (sun and wind are natural resources for free) and own production for own consumption and the ability to sell it can bring monetary savings for the prosumers. Regarding Honesty/Integrity, energy companies being honest and integer, thus not misleading consumers with sales tricks to sign up to their tariffs, can contribute to the willingness to accept and adopt SGSs (e.g. smart meters). Accountability/Traceability is perceived as a driver of SGSs since smart meters allow customers to track in real-time their energy consumption and energy bill at home. Some smart meters allow users to track the carbon generated from their energy use and send excess energy back into the grid. Moreover, the government and energy industry believe that the large-scale roll-out of this smart grid technology into people's homes in the UK will lead to significant reductions in consumption, which contributes to emission reduction and thus environmental sustainability.

Besides, as presented in Table 9 above, three barriers are recognized in the British public debate. First of all, regarding Calmness appeared from the empirical data that smart meters were in some cases not properly installed or not installed on time (meeting the government's deadline) provoking stress to consumers. Besides, it appears that the customer service of energy companies was not satisfactory. For these reasons, calmness was not ensured and has a negative valence. Regarding Courtesy, the public debate shows that a review from the energy regulator Ofgem into the prepay market revealed poor customer service, high costs and lack of choice. This, whilst some energy suppliers made a commitment to reduce prepay prices when they roll out smart meters as the most vulnerable consumers are the ones using prepay services in the UK. However, energy suppliers are seen as greedy and as having a cheek asking customers to get smart, while they are failing to wise up to their most vulnerable customers' needs (e.g. reasonable prices). With this behaviour, energy suppliers are not having consideration for vulnerable consumers and are not helping to tackle fuel poverty in the UK. In 2015, 2,5 million households lived in fuel poverty in England alone. Besides, whilst is known that millions of people are struggling to pay their bills in the UK, the government planned the energy firms to be in charge of deciding the costs of smart meters. Lastly, for Procedural Justice the empirical data shows that consumers feel not getting enough opportunities to participate in decision-making processes about SGSs, whilst they have decision rights as being affected by the roll-out of smart grid technologies. Moreover, there appears not to be enough transparency in energy pricing decisions (which include the price of smart grid technology being passed to the consumers).

Table 9: Ethical values and valence

	Negative valence	Neutral valence	Positive valence	Outcome
Accountability/Traceability	0	0	1	Positive
Autarky	0	0	5	Positive
Calmness	1	0	0	Negative
Control/Autonomy	5	0	38	Contested
Courtesy	3	0	0	Negative
Distributive Justice	26	1	2	Contested
Economic Development	81	8	129	Contested
Environmental Sustainability	4	3	42	Contested
Health/Safety	3	0	2	Contested
Honesty/Integrity	0	0	1	Positive
Legitimacy	4	2	0	Contested
Ownership/Property	1	0	1	Contested
Privacy	7	0	4	Contested
Procedural Justice	7	0	0	Negative
Quality of life/Well-being/Comfort	7	0	11	Contested
Reliability	16	1	4	Contested
Security	5	0	2	Contested
Security of supply	2	1	22	Contested
Transparency/Accuracy	13	4	76	Contested
Trust	6	1	2	Contested
Universal usability/Inclusiveness	2	0	4	Contested

Furthermore, as can be derived from Table 9 most of the values are perceived with different types of valence at the same time. This means that those values are still contested and cannot yet be considered as a driver or barrier. Concerning Control/Autonomy, smart grids and smart meters are believed to aid in energy saving, as they give consumers control over their appliances to curb energy waste and save money (i.e. reducing their energy bills by controlling their energy use): *"Smart meters put power into the hands of consumers, bringing an end to estimated billing and helping people understand their energy use. The nationwide roll-out is part of the Government's complete overhaul of the UK's energy infrastructure, which will revolutionise the market and support the development of smarter electricity grids. It will help reduce consumer bills, enable faster, easier switching and give households control at the touch of a button"*. However, precise meter readings and thus insights into the household's energy consumption patterns are believed to allow energy suppliers to control the energy supply to a home: *"Energy firms support the technology because it can supply precise meter readings automatically over the mobile phone network, thereby allowing them to lay-off thousands of meter readers and billing staff. It will also allow them to cut off homes at the click of a mouse"*. Moreover, it seems that some consumers will not like the idea of adjusting their consumption pattern and automation of appliances (e.g. at the most cost-effective times of a day): *"The prospect of behaviour change will not be welcome for many consumers, and the idea of intelligent appliances making their* *own decisions about when to run may be even less so"*. With respect to Distributive Justice, smart grids are believed to *"allow energy groups to manage sources of renewable energy, such as wind and tidal energy farms and biomass plants. An underlying "intelligent infrastructure" helps to reduce wasted power generation and network losses by automatically distributing power optimally*". On the other hand, concerns emerged as consumers, especially vulnerable (low income) households, will not benefit from smart grid technologies as intended, since energy suppliers probably will: *"Consumers will benefit from smart meters only if they understand the opportunity to reduce their energy bills and change their behaviour. So far, the evidence on whether they will do so has been inconclusive. Otherwise, the only people who will benefit are the energy suppliers. Consumers will have to pay suppliers for the costs of smart meters through energy bills and no transparent mechanism exists for ensuring savings to the supplier are passed on. The MPs are also worried about the cost to poor families. There is a risk that they may end up paying more through their bills where the costs of installing the meters outweigh the savings they make, they say"*.

Economic development is another contested value. With the emphasis on energy savings, this value is perceived with a positive valence as it results in electricity costs savings as well as accurate billing and the possibility for prosumers to sell their excess energy back to the grid: *"Smart meters that show energy use will lead to less usage of energy and give accurate billing information for the first time"* and *"Householders who chose to have wind turbines or solar panels installed on their roofs could produce enough energy to power their homes and even sell spare electricity back to the National Grid at a profit"*. However, the negative valence attached to this value mainly relates to the high cost of technology deployment being put on consumers, which people can ill afford: *"smart meters can also be read remotely, so companies can see how much energy people are using. But they will be costly. It is estimated their installation will put an extra 40 pounds a year on the average home's energy bills"* and *"Officials and campaigners have also warned that companies will pass on the costs of their installation to consumers by hiking utility bills again"*. Benefits on Environmental sustainability are mainly focused on energy efficiency in order to reach a sustainable energy system in the future. For instance, *"Smart meters, home and grid-scale batteries that store and release excess renewable power, and other modern solutions would be cheaper and more efficient than building new power stations to meet extra demand during relatively short periods. Moreover, they're much less polluting and more climate-friendly"*. Moreover, *"the Internet for electricity using smart grids would allow demand and supply to be managed in an intelligent and environmentally friendly way"*. The idea is a more thoughtful energy use, which will save money and help the environment due to reduction in carbon emissions. Next to energy costs and consumption information, some smart meters can even display the carbon footprint of users in order to encourage greater environmental awareness. On the other hand, this energy saving initiative is opposed due to *"their high cost and the fact there is not a standard technology accepted by the industry"*. Opponents think, *"Smart utilities meters will not help stop climate change. A revision of the charging system for use of energy would be more effective. If the standing charges were eliminated and the payment system started at a low threshold increasing incrementally with the amount of energy consumed, the economical user would benefit and the "gas guzzler" pays heavily*".

With regard to Health and Safety, the automation of smart appliances to run when the electricity cost is low seems controversial as that moment can be at night: *"fire experts have serious concerns about the idea. The Chief Fire Officers Association says it was never consulted on whether it is safe to do so. It warns that running electrical appliances while you are asleep will put your family at greater risk of being trapped by fire. Andy Reynolds, electrical safety expert for the association, says: 'Never leave a tumble dryer, washing machine or dishwasher running when you have gone to bed or have left the house unoccupied. If it is absolutely necessary to run one of these appliances during sleeping hours, then there should be sufficient working smoke alarms correctly sited to alert sleeping occupants. Everyone in the household should know what the escape plan is in the event a fire breaks out"*. Besides, *"smart energy meters could be as dangerous as a "bullet from a rifle" because of the radiation they emit"* and *"evidence of harm could be acute, including cancer, infertility, dementia, genetic damage, immune system dysfunction and damage to foetuses"*. On the other hand, it seems that the emitted radiation of wireless devices such as smart appliances and smart meters do nor form a threat for health: *"Dr Jill Meara, of Public Health England, said she was aware of the concerns but cited a "substantial body of evidence" showing smart meters are safe. She said the radiation was low* *compared to guideline levels"*. Regarding, Legitimacy the government established a legally binding deadline for energy suppliers to install smart meters in British homes and businesses. This, in order to boost energy efficiency and modernise the power grid. However, it appeared that different suppliers did not put effort in taking the necessary steps to roll-out the smart meters: *"Ofgem said: The supplier did not take all reasonable steps to fulfill the rollout, as it was legally required to do. The £4.5 million fine will be paid to the Carbon Trust, which will use it to help businesses to save energy through energy efficiency measures"*. It is perceived unacceptable that consumers were prevented from timely receiving information about energy consumption and lost the opportunity to control costs due to energy suppliers not meeting the deadline. On the other hand, "*Energy Retail Association (ERA), which represents the major gas and electricity suppliers, called on the Government to turn its commitment to smart meters into firm policy decisions and clear action"*. Consumer group Which? demanded *"the Government to buy meters centrally to drive down costs. One of the biggest smart meter programme costs is the meters themselves, but currently each supplier has its own purchasing plan, it points out*", which is not in the benefit of the consumer as energy suppliers can decide how much this smart grid technology will cost.

Regarding Ownership and Property, the positive valence regards the possession of micro-generation: *"On a traditional grid, managing a proliferation of small generation sources is very difficult. A fully smart grid would help consumers to sell power to the network, increasing incentives for them to invest in small-scale generation"*. The negative valence concerns monetizing personal data from smart meters: *"Evidence of the race to monetise the data from smart meters is already emerging. A video on the website of Onzo, a British analytics company, says: "We take energy consumption data from smart meters and sensors. We analyse it and build a highly personalised profile for each and every utility customer." It will have "the ability to monetise their customer data by providing a direct link to appropriate third-party organisations based on the customer's identified character." Last year Onzo was at a "consumer goods hackathon" hosted by Procter & Gamble to help sell more detergent, shampoo and toiletries"*. However, it appears that *"your supplier can't use any data from your smart meter for sales and marketing purposes unless you give them permission to do so"*. Additionally, Table 9 shows that Privacy is a contested value too, as it is connoted with different types of valence. The concern is that *"smart meters may give energy suppliers and government agencies too much information about how we live our lives"*. For instance, *"smart meters take an electricity reading every 30 minutes. I find this level of surveillance worrying. Different household items use different amounts of electricity for different lengths of time. It will be easy to know when the TV is on, a kettle is being boiled, the occupants go to bed and get up and even when you go to the bathroom during the night. It will not be long before a complete profile is made of each household's routine"*. This shows an unfortunate "Big Brother" undertone. On the other hand, *"the information is reported back to suppliers and won't be passed on without your permission"* and *"people trust their energy supplier with their data. They will always have complete control - you don't have to give others access unless you want to*". Moreover, *"your smart meter stores and transmits simple information on how much energy your home has used. Personal details like your name, address and bank account details are not stored on or transmitted by the meter"*.

Quality of life/Well-being/Comfort mainly focuses on avoiding the hassle of meter readings and inaccurate bills for both consumers (i.e. enhanced ability to budget bills and not being overcharged) and energy suppliers (i.e. not sending staff to read old meters and not having to handle as many customer calls mostly with billing complaints): *"Sit back, relax and never worry about supplying your meter readings or letting a stranger into your home to take them. Your smart meter handles everything, sending the latest readings to your supplier, so you'll receive hassle-free, accurate bills"* and *"These meters accurately measure your exact gas and electricity usage so there are never any estimated bills. I like the fact that we pay only for the energy we use. In the past, we were often overcharged by our energy company and it was a hassle to get those credits back"*. An example of the energy suppliers' positive valence: *"The energy suppliers are keen to accelerate the smart meter roll-out. They stand to save about £9 billion, half the program's total estimated savings, by not sending staff to read old meters and not having to handle as many customer calls"*. However, a negative valence is connoted to discomfort for the inconvenience of not being able to consume energy at any desired time due to demand response costs constraints: *"Hi, there! This is your smart meter speaking. Please don't turn on the dishwasher because it will cost you £30. Just wait a couple of* *hours, will you? This is already no joke for what is left of Britain's heavy industry. Between 4pm and 6pm in midwinter, Tony Pedder of Sheffield Forgemasters reckons it can cost £27 to boil a kettle. His workers huddle in one room to keep warm while they wait for the demand peak to pass and thus avoid the "congestion charge" imposed by the company's supplier*". A concern regarding Reliability is that the *"technology could be out of date by the time the roll-out is complete"* and that *"Consumers will have to pay for smart meters even though they might already be out of date"*. Moreover, *"Difficulties in making the meters work in tall buildings and when customers switch supplier have not yet been resolved"* and *"Hard-to-treat households won't be able to get a meter immediately. Some flats, for instance, may be unsuitable because the meters cannot communicate with the in-home display unit if it is several floors away. Homes where a gas or electricity meter is situated in the garage, for example, may also be considered hard to treat"*. On the other hand, *"new technologies, such as smart grids and meters, are expected to play an increasingly important role, with the aim of delivering a more responsive energy system that would prevent blackouts by more effectively managing existing energy capacity rather than creating more"* and *"Once the national communications network is up and running, and existing meters are enrolled into it, they will be able to deliver the full range of functionality: accurate bills and visibility of what we're spending in near real-time in pounds and pence"*.

Besides, Table 9 shows that Security is also subject to contestation. For example, "*security experts think that the Internet of Things opens up horrendous vulnerabilities for our networked society. Hackers in Azerbaijan could get control of our "smart" electricity meters and shut down the whole of East Anglia with the click of a mouse"*. Moreover, *"an £11billion Government plan to put "smart meters" into every British home will be launched this week despite fears they may not work and could open the national grid to cyber–terrorists"*. On the contrary, it is claimed that security is at the heart of the smart meter roll-out, as *"Data from smart meters is never transmitted over the internet, unlike social media or email Your personal data is not stored on your and the energy use data that is sent from your meter is all encrypted"* and *"Energy data is transmitted via a custom-built network that covers 99.3% of the population and has GCHQ*[11]*-developed security"*. In terms of Security of supply, smart grids are perceived as having the ability of *"managing the flows of high volumes of intermittent power on new routes, which will require a more flexible and responsive network that can maintain steady supplies to consumers"*. Moreover, vehicle-to-grid technology *"allows electric car owners to not only plug into the grid to charge their vehicles, but also feed and sell energy back at times of high demand. It means idle cars in a future city could act as a giant battery, helping to stabilise the energy supply and even provide backup power during blackouts"*. In addition, *"owners of home battery packs who generate energy from roof-mounted solar panels or other renewable sources would be able to sell the electricity they generate to the grid or to other homes. Meanwhile, energy companies hope that home and industrial batteries will reduce spikes in demand at peak times because they could be used to store power when demand is lower"*. On the other hand, it is being argued that *"the people who foisted dependence on renewables on us say the answer is to make the energy system flexible. They say smart grids, smart meters, smart markets, smart everything are the answer"*. *"A significant increase in low-carbon energy generation — either nuclear or renewables, millions of charging points and a transition to a smart network able to cope with fluctuating demand — will be required",* but some people are sceptical whether the smart power network will be able to perform its intended function and adapt accordingly to surges in demand.

Transparency/Accuracy is another contested value. For example, smart meters provide instant updates of how much power a house is using: *"These meters give householders a clear display of how much energy they are using - and how much it costs - at any given moment"* and *"They would show exactly how much power appliances such as televisions left on standby were using"*. This accurate information is supposed to aid consumers to understand how much energy they are using and the associated costs in order to incentivise them to save energy and become more environmental aware. Moreover, it is argued that *"Consumers might be prepared to pay a little extra to finally get the accurate and reliable bills they deserve"*. On the contrary, some claim that *"A more serious problem is the erroneous belief, which the Government is encouraging, that smart meters will provide*

[11] GCHQ stands for Government Communications Headquarters. It is Britain's electronic intelligence agency and aims at defending Government systems from cyber threat (GCHQ, 2017).

consumers with additional information about their energy usage. That is not the case. By itself smart metering is nothing more than a new billing process that does away with meter readers and the need for estimated bills. This does bring some benefit to the customer, but that benefit is far more limited than ministers claim. If the introduction of smart meters is to be anything other than an expensive way of making life easier for the suppliers, more is necessary". With regard to Trust, it can be claimed that the government hesitates whether consumers can be truly trusted to adapt their energy consumption behaviour for the sake of society: *"Amyas Morse, head of the audit office, said: There is limited evidence of how much and for how long British consumers' behaviour might change, and costs could escalate"* and *"The committee said that the Government is relying too much on its hope that consumers will become more savvy, and therefore save cash through using smart meters. It also warned that the process puts too much reliance on the energy giants, which have consistently let consumers down in the past"*. Besides, the energy regulator Ofgem *"noted that the DECC was assuming that suppliers would automatically pass through the savings to consumers"*, which appeared not to be the case as *"No transparent mechanism presently exists for ensuring savings to the supplier are passed on to consumers, and the track record of energy companies to date does not inspire confidence that this will happen"*. On the other hand, *"Ms Maugham said she 'rarely hears about concerns' over data sharing from consumers and that 'people trust their energy supplier with their data'"*.

Lastly, Universal usability/Inclusiveness is presented as disputable in Table 9. For example, *"Homeowners are expected to be included in the roll-out of technology that will allow users to see "real time" digital displays of their energy consumption"* and with the introduction of smart meters *"we have the opportunity, for the first time, of customers becoming fully engaged in the market. We will all, through new contracts with our suppliers, be able to choose whether to contribute further to peak demand or adjust some of our activities (e.g. dishwasher overnight) to benefit from lower prices"*. Moreover, First Utility (an energy supplier) announced *"customers on the new iSaveV3 tariff will be offered a free smart meter in coming months, with the aim of nationwide coverage by the end of the year. Only households in the Midlands presently have access to these"*. On the other hand, it is noticed that *"many people struggle to engage with their energy use, which can lead to higher bills than expected. There are already devices on smartphones, but only the bill payer sees the information"*. This excludes engagement of the rest of the family, especially children and elderly who could also contribute in the household's energy management. In addition, *"The audit office also warned that studies showed that vulnerable people, such as those on low incomes and pensioners, were less likely to take advantage of cheap tariffs offered on smart meters. However, they would still have to shoulder their share of the costs"*. Besides, "*The MPs are also worried about the cost to poor families. 'There is a risk that they may end up paying more through their bills where the costs of installing the meters outweigh the savings they make,' they say"*.

4.5.2. Ethical values associated with smart grids and its sub-systems

From the empirical data, it was possible to retrieve the values that are at stake for smart grids and its related technologies. This is done through establishing the code-co-occurrence between values and sub-systems. This is presented in Table 10 below and shows the number of quotations from the newspaper articles in which the value codes and sub-system codes are co-occurring. This can aid in understanding whether there are different interpretations of a value per sub-system and if so, why these differences occur. Overall, it was noticeable that *control/autonomy, economic development, environmental sustainability*, and *transparency/accuracy* are values that come forth in smart grid as a system and all its sub-systems (i.e. technology components).

Smart grid

Smart grids are mentioned with a positive valence regarding economic development, environmental sustainability, and security of supply. These values are also the most occurring values regarding smart grids, as shown in Table 10. Economic development includes savings in grid investment, as it is believed that the grid will become more flexible and efficient when it gets "intelligent". Besides, smart grids allow the integration of renewable energy in the power network, which positively affects

Table 10: Co-occurrence of values, smart grids and sub-systems in the newspaper articles

	Demand Response	Household Electricity Storage	Smart Grid	Smart Home/HEMS	Smart Metering	Vehicle-to-Grid
Accountability/Traceability					1	
Autarky		2	1	1		2
Calmness					1	
Control/Autonomy	3	1	3	6	34	2
Courtesy					2	
Distributive Justice	1		2		26	
Economic Development	14	8	15	5	183	10
Environmental Sustainability	3	3	13	1	32	8
Health and Safety	2				5	
Honesty/Integrity					1	
Legitimacy			1		5	
Ownership/Property			1		1	
Privacy				1	10	
Procedural Justice					7	
Quality of life/Well-being/Comfort	3		1		16	
Reliability	1		2		19	1
Security					7	
Security of supply	5	3	8		4	10
Transparency/Accuracy	3	1	1	4	88	1
Trust					9	
Universal usability/Inclusiveness				1	5	

the values of economic development, autarky, and environmental sustainability: *"Renewable energy will give us energy independence, cheaper energy production and underpin future economic prosperity"*. The value of Control/Autonomy is contested as smart grids allow integration of novel energy technologies into the electricity system, which aid consumers to choose control of their energy use. On the other hand, there is fear that the automated smart grid technologies will exert control over the household by making their own decision e.g. on when to run smart appliances.

Reliability is perceived with a positive valence regarding smart grids, as it is able to cope with fluctuating demand and to effectively manage existing energy capacity rather than creating more. Besides, Distributive Justice is also perceived positively, as the underlying *"intelligent infrastructure helps to reduce wasted power generation and network losses by automatically distributing power optimally"*. Moreover, smart grids are perceived as fair since they *"will deliver for energy consumers today and in the future"*. With regard to Legitimacy, smart grid development relates to binding smart grid policy. On a traditional grid, managing a proliferation of small generation sources is perceived as very difficult. However, *"a fully smart grid is believed to help consumers to sell power to the network, increasing incentives for them to invest in small-scale generation"*. This positively adds to the values of Ownership/Property. The value of Quality of life/Well-being/Comfort regarding smart grids is contested, as it requires consumer behaviour change, which can be uncomfortable for some consumers not fully willing to adapt their energy consumption habits. On the other hand, as previously explained, smart grids add to environmental sustainability and a sustainable future is perceived a positive for human well-being. Lastly, Transparency/Accuracy relates to insights of energy use in the home, which aids in effectively managing the power network, but also makes it prone to cyber-attacks. Therefore, this value is perceived as ambiguous for smart grids.

Smart metering

With smart metering as the most mentioned sub-system in the public debate (see Figure 12), it also has the most co-occurrences with the values. As can be seen from Table 10, smart metering can be associated with all SGSs values except autarky, according to the empirical data. Accountability/Traceability, Calmness, Courtesy, Honesty/Integrity, Procedural Justice, Security, and Trust are only affected by this sub-system. Accountability/Traceability is positively denoted as it "*allow customers to track real-time their energy consumption, and their bill, at home. Some may allow individual users even to track the carbon generated from their use, and send excess energy back into the grid"*. Calmness is a negatively connoted value as it is being affected by installation problems with some smart meters such as not being installed on time, not properly functioning due to network coverage issues, and out-of-date technology in some cases. Courtesy is also denoted with a negative valence as energy suppliers put strain on the consumers due to high costs, poor customer service, and lack of choice: *"Some suppliers have made a commitment to reduce prepay prices when they roll out smart meters. But greedy utility suppliers have a cheek asking customers to get smart while they are failing to wise up to their most vulnerable customers' needs"* and *"When I phoned them the next day they claimed it had been connected and was up and running. They said I had been out, but I was not and both gas and electric meters are inside my property"*. Besides the government allowing the energy suppliers to decide the costs of smart metering affects this value: *"The Government must not write a blank cheque on behalf of every energy customer, especially at a time when millions of people are struggling to pay their bills"*.

Another value that is only being affected by smart metering is Honesty/Integrity, which has a positive valence as another energy mis-selling scandal has been averted by the government: *"Providers were gearing up to use the installation of 50-million- plus smart meters in British homes over the next decade to sell their wares and sign people up to their tariffs"; "Given the track record of the industry for pushy marketing, confusing terms and conditions, and for signing people up without permission"*. Additionally, Procedural Justice has a negative valence due to the forced smart meter roll out plans in which consumers were not sufficiently considered: *"But these devices should stand or fall on their own merits. Making every household in the country have one installed is simply not justified"*. Besides the roll-out appeared to cost more than it is supposed to save and therefore decisions ware purposefully unfairly made: *"The audit office was particularly scathing* *about a five-year, £10 million trial the department ran to justify the outlay. It said that findings from the trial, which was a year late, were not representative of the population as the 50,000 households who took part were volunteers and so were more engaged about saving energy than most. It wrote: 'The validity of some results has been constrained by design flaws, such as self-selection by participants and inconsistencies in the use of control groups, data collection and the documentation of results'. Outside experts were hired to try to sort out mistakes"*. Security and trust are both contested values for this sub-system due to the connotation with different types of valence. Regarding Security it is believed that the *"£11billion Government plan to put 'smart meters' into every British home will be launched this week despite fears they may not work and could open the national grid to cyber–terrorists"*. On the other hand, it is believed that there should be no security concerns as "*The information is reported back to suppliers and won't be passed on without your permission. Energy data is transmitted via a custom-built network that covers 99.3% of the population and has GCHQ-developed security"*. Trust is contested regarding the technology itself as well as energy suppliers and the government. For example: *"While surcharging at the peak makes obvious economic sense in terms of efficient use of expensive plant, it would make far more sense to impose a marginal inconvenience on consumers than to impose swingeing costs on industry. This requires smart meters that tell you the instantaneous cost of the current kilowatt-hour. Unfortunately, the electricity suppliers are in such bad odour with domestic customers that we would view any such move as a plot for further price gouging. And we would probably be right"*.

The rest of the values (except autarky) are shared with at least one of the other sub-systems: Control/Autonomy, Distributive Justice, Economic Development, Environmental Sustainability, Health and Safety, Legitimacy, Ownership/Property, Privacy, Quality of life/Well-being/Comfort, Reliability, Security of supply, Transparency/Accuracy, and Universal usability/Inclusiveness. Control/Autonomy is mostly perceived as positive because the national roll-out allows consumers to choose whether they want a smart meter installed or not. Moreover, smart meters enable consumers to control their appliances, choose to save energy and control their bills. However, consumers have the concern of energy suppliers having more control over households in terms of *"cut off homes at the click of a mouse"* and putting barriers for consumers to control costs. Distributive justice is mainly perceived with a negative valence as it relates to the distribution of burdens and gains amongst consumers and energy companies. Economic Development mainly relates to monetary savings in consumer electricity bills due to energy saving and grid investment costs. However, consumers' bearing the costs for smart meter installation is perceived as unacceptable as the energy price is already high and many people in the UK are struggling to pay their energy bills. Environmental Sustainability with regard to smart meters is mainly perceived as positive as this sub-system enables energy savings which aids in fighting climate change. However, *"Smart meters have been championed by environmentalists, but opponents highlight their high cost and the fact there is not a standard technology accepted by the industry"*. Health and safety is contested, as some believe that the emitted radiation could cause great harm to health (e.g. cancer, infertility, genetic damage) but others believe that the radiation is not of harm at all and complies a legally binding threshold, which adds to the value of Legitimacy as well as the deadline imposed to energy suppliers by the government to install smart meters.

Ownership/Property and Privacy are mainly related to energy suppliers being able to derive income from consumer personal data on consumption patterns, with or without consumers' knowledge. This could negatively affect the consumers' Quality of life/Well-being/Comfort, but on the other hand smart meters avoid the hassle of meter readings, which is generally considered as benefit and adds to this value. Reliability is mainly considered as negative due to the delay of the smart meter roll-out and the belief that the technology will be out of date when installed. In addition, there were some issues with the network coverage on flats. On the other some statements pointed out that the technology complies with requirements set by the government in cooperation with the energy industry and will work as intended. Security of supply is mainly denoted with a positive valence, as smart meters are essential in building a responsive energy system that prevents blackouts and thus a more secure grid in terms of energy supply. However, some people believe that smart meters cannot contribute to security of supply on its own and thus that this sub-system does not necessarily positively affects this value. Transparency/Accuracy due to smart meters refers to frequent feedback regarding energy consumption, but some statements hesitate the sufficiency of this transparency and accuracy, mostly raising privacy and control concerns: *"They are the mini-computers being installed in 30m UK homes and businesses in an £11bn programme that will allow the energy companies to remotely monitor our gas and electricity usage. But could also become the new spies in our homes, raising fresh fears about a surveillance society as they track our daily activities?"* Universal usability/Inclusiveness is contested as the government in first instance aimed at providing installation of smart meter for free specially to the poorer, but eventually it appeared that they had to bear the costs, which might exclude fuel poor households from managing their energy usage. Lastly, as Table 10 shows, the most prominent values for smart metering are Economic Development, Transparency/Accuracy, and Control/Autonomy.

Demand response

The most prominent values related to demand response are Economic Development and Security of supply. To start with, Economic Development is perceived as positive for this sub-system as demand side management and flexible tariffs are perceived as cost efficient for both consumers and energy suppliers. However, charging consumers with different rates at different times of a day by energy suppliers *"has also raised concerns that tariffs will become so confusing that customers will be left unable to compare suppliers to make sure they are on the cheapest deal"*, negatively affecting Control/Autonomy. On the other hand, this value is perceived as positive, since *"time-of-day pricing could save money if you can programme your dishwasher or washing machine to run at night, for instance, or if you have storage heating that is switched on overnight. But it could potentially lead to higher prices for essential energy use, such as cooking in the evening"*. This means that consumers are free to make up their own minds and choose by their own whether they use one of these tariffs. Furthermore, "Time-of-use tariffs will be an essential part of managing our future national energy supply by enabling energy use at off-peak times", which positively affects Security of supply. In terms of Distributive Justice and Quality of life/Well-being/Comfort, surcharging at the peak is beneficial for the energy suppliers as it allows efficient use of expensive power plants, but on the other hand it can put a burden on the consumers as they can be forced not to consume energy when it fits them best due to the high energy prices at peak times. On the other hand, consumers can program their household appliances to run at low cost, when demand for energy is low and energy is the cheapest. Therefore, these values are contested for demand response. The value of Health and Safety is perceived with a negative valence for this sub-system due to fire risks when household appliances run at off-peak hours, which is mostly at night when people are sleeping or during the day when people are usually not home.

Furthermore, the price signals belonging to demand response can aid in adjusting consumers consumption accordingly and prevent polluting power plants to operate: *"Proper information about energy use will allow both consumers and suppliers to change their behaviour to save energy, and particularly to cut demand at peak times when prices - and often carbon dioxide emissions - are at their highest"*. Hence, demand response is positively associated with the values of Environmental Sustainability and Transparency/Accuracy. In addition, this sub-system aid in enhancing the energy management in the grid, as supply and demand can be better matched, adding to Reliability of the grid as power outages and blackouts can potentially be prevented.

Smart home/HEMS

The most prevalent values for this sub-system are Control/Autonomy, Economic Development, and Transparency/Accuracy. All statements regarding these values are perceived with a positive valence as smart home technologies allow to gain insights into energy consumption, control energy bills by saving energy costs but also household appliances: *"Home energy management company PassivSystems has developed an iPhone app, PassivEnergy, that allows consumers to manage domestic heating from any location, as well as a secure portal that calculates energy use and finds a tariff best suited to individual needs"* and *"The team believes that the system has many potential applications in consumer technology, smart homes and motoring. It would fit with the trend towards "invisible" technology, alongside devices such as Amazon's Echo smart speaker, which enables people to control entertainment systems and appliances using voice commands. Until now, large touch surfaces have been expensive and those with irregular shapes and flexible surfaces have been available mostly in research* *labs. Some other systems for large touch surfaces rely on cameras to track the user's movements, which means the camera must have line of sight".*

As smart homes allow people to save energy by letting them know how much they are consuming and by controlling the home environment accordingly, it enhances the value of Environmental Sustainability: *"Designed for family homes, the GreenEgg Smart Home Hub has a traffic light system that shows red when energy use is high. CEO Rob Merriman explains: "we noticed that many people struggle to engage with their energy use, which can lead to higher bills than expected. There are already devices on smartphones, but only the bill payer sees the information. With GreenEgg you access it with your remote control so it's on the TV. The whole family can engage with it, especially kids and older people".* This also contributes to the value of Universal Usability/Inclusiveness. However, Privacy concerns have also been raised about such smart home technologies, namely about privacy intrusions and the vulnerability of consumer data falling into wrong hands, making it a contested value. Lastly, Autarky is positively perceived for this sub-system. For instance 61% of a poll of 2,876 British homeowners believe that smart homes contribute to UK homes becoming more self-sufficient/independent.

Household Electricity Storage

Economic Development, Security of supply, and Environmental Sustainability are the most mentioned values for this sub-system with and are positively perceived as home battery packs for power storage enhance balancing of supply and demand without the need of building new power plants and allow prosumers to store and sell their excess renewable energy back to the grid (preventing energy waste) as well as save money on their energy bill: *"home and grid-scale batteries that store and release excess renewable power, and other modern solutions would be cheaper and more efficient than building new power stations to meet extra demand during relatively short periods. Moreover, they're much less polluting and more climate-friendly"* and *"Another interesting cost-saving product is a storage battery, made by start-up firm Powervault. These units, about the size of an average fridge, store cheap off-peak electricity for daily usage, saving up to two thirds on bills".* Moreover, *"Owners of home battery packs who generate energy from roof-mounted solar panels or other renewable sources would be able to sell the electricity they generate to the grid or to other homes. Meanwhile, energy companies hope that home and industrial batteries will reduce spikes in demand at peak times because they could be used to store power when demand is lower".*

The values of Control/Autonomy and Transparency/Accuracy are also perceived with a positive valence as the ability to store power enables consumers to think about how and when they consume energy. For instance, *"to store energy produced during the sunniest part of the day for use at peak times, when more people are at home but the sun is down".* In addition, Autarky is perceived as a value with a positive valence as energy self-sufficiency and being off-grid is becoming more achievable due to the possibility to store power: *"A brand-new market is growing for home batteries that make it possible for British homeowners to store energy generated by solar panels and other renewable sources".*

Vehicle-to-Grid

All statements regarding values and Vehicle-to-Grid (V2G) are perceived with a positive valence. The most prevalent values related to this sub-system are the same as for household electricity storage: Economic Development, Security of supply, and Environmental Sustainability. Regarding Economic development, V2G allows consumers to reduce costs by charging their electric vehicle (EV) batteries during off-peak times, (when energy is cheaper) and discharge it during peak times (when energy is expensive), known as peak-shaving and makes the motorist an energy trader. Moreover, EV owners can even decide to use the stored power in their car battery themselves, which adds to the value of Autarky *"being able to be grid independent for power if needed".* Environmental sustainability is enhanced as the intermittent character of renewable energy can be tackled though power storage in EV battery: *"The extra battery capacity will allow more renewable energy to be stored, with EVs taking up the slack when renewable production is high and demand low, and then feeding it back to the grid when conditions are reversed".* Furthermore, this sub-system relates to

Security of supply as *"It allows electric car owners to not only plug into the grid to charge their vehicles, but also feed and sell energy back at times of high demand. It means idle cars in a future city could act as a giant battery, helping to stabilise the energy supply and even provide backup power during blackouts"*. The value of Reliability is positively addressed by V2G, as the smart network this sub-system is part of is aid by this technology to perform one of its intended functions, namely being able to cope with fluctuating demand. The values of Control/Autonomy and Transparency/Accuracy relate to the ability of consumers to adapt their energy management and consumption though using their electric vehicle as a mobile power plant that additionally allows power storage.

4.5.3. Ethical values associated with smart grid stakeholders

In the British public debate on SGSs, different stakeholders can be traced as well as which values are relevant for which stakeholder groups and what valence stakeholders have expressed on these values. This is important in order to trace value conflicts between stakeholder groups. For this purpose, the code-co-occurrence between values and stakeholders is established. This is presented in Table 11 below and shows the number of quotations from the newspaper articles in which the value codes and stakeholder codes are co-occurring. The stakeholder groups are the same as those presented in §2.2.2. From the empirical data, it became clear that the media is crucial to diffuse key information about SGSs to the public in a neutral fashion or supporting an opinion. Moreover, making this key information publicly available on behalf of different stakeholders can help steer the public perspective on SGSs. As aforementioned, some information is presented neutrally and accurately whilst other is reflecting a certain opinion. This enables the media to drive the public debate, sometime further fuelling additional controversy on smart grid projects in the UK. Therefore, the media came forth as a key stakeholder for the British smart grid development and is acknowledged as a stakeholder consisting of the newspapers themselves sending messages to its readers as well as reporting on events and SGSs. Out of the 11 stakeholder groups (see Table 11), the most prevalent ones in the public debate are:

1. *Energy consumers* (552 value-laden statements)
2. *Governmental bodies and policy-makers* (166 value-laden statements)
3. *The Media* (162 value-laden statements)
4. *Energy companies* (74 value-laden statements)

Energy consumers

As Table 11 shows, the energy consumers are involved in value-laden statements regarding all values except Accountability/Traceability. Their most prevalent values are Economic development, Transparency/Accuracy, and Control/Autonomy, which are perceived with different types of valence by this stakeholder group. Implementation smart grid technologies enable the consumers to engage more in their energy management and better understand their daily consumption patterns primarily to save energy and thus realize costs reductions on their energy bills. However, some believe that smart grid technologies will not provide useful additional information about their energy consumption and that the information is not easy to understand, preventing consumers from accordingly control their consumption behaviour and save energy as well as costs. As consumers can be prosumers and/or owners of household battery packs and/or an electric vehicle, they are enabled to act as an energy source for themselves (making them self-sufficient) but also selling (excess) power back to the grid when demand is high as well as aiding in balancing supply and demand. This relates to the values of Autarky and Security of supply and is perceived with a positive valence only. Besides, Environmental sustainability has a positive attitudinal direction as this value is enhanced through energy savings and the consumption of renewable energy (and thus reduction of GHG emissions) made possible with the use of smart grid technologies. Calmness is only perceived by the energy consumers and has a negative valence due to the poor customer service of energy companies. This also relates to Courtesy as consumers feel that their interests are not being sufficiently considered by the energy companies and the government. With regard to Trust and Distributive Justice, consumers doubt that energy companies will act on their benefit and doubt the

Table 11: Co-occurrence of values and stakeholders in the newspaper articles

	Environmental Organizations	Governmental bodies and policy-makers	Supporting organizations for smart grid development	Trade Associations	Energy Companies	Consumer organizations	Energy consumers	Distribution Network Operators	Transmission System Operators	Knowledge institutions	Media
Accountability/ Traceability											1
Autarky			1				8				1
Calmness							2				
Control/Autonomy		10	8	1	5	1	46		1		11
Courtesy		1			1	1	4				1
Distributive Justice		17			7	4	27			2	7
Economic Development	1	68	13	1	35	10	213		5	14	65
Environmental Sustainability	1	16	4		1	2	36		2	4	12
Health and Safety		1	1			2	5				1
Honesty/Integrity							1				1
Legitimacy		6		1	3	1	3				
Ownership/Property							2		1	1	1
Privacy			3			1	14			2	3
Procedural Justice		4			1	1	8				1
Quality of life/ Well-being/Comfort		3			5	1	21				6
Reliability		7	1			1	23			4	6
Security			2				7			1	5
Security of supply		5	3	1	2		23		4	2	7
Transparency/Accuracy		20	5	1	9	5	95		2	3	31
Trust		5	1		3	1	7			1	2
Universal usability/ Inclusiveness		3	1		2		7				

fair distribution of burdens and gains. On the other hand, some believe that the Government acts on behalf of the consumer preventing energy companies from misleading consumers e.g. to sign up for their tariffs whilst there more economical options and to fully carry the costs of smart grid technology implementation. This positively contributes to the value of Honesty/Integrity. Moreover, the Government established legal binding deadlines for the roll-out of smart meters and regulates the prices the consumer has to carry for the roll-out. This positively contributes to Legitimacy, but energy companies missing the deadlines and not willing to pass on cost savings to consumers, is perceived with a negative valence by this stakeholder group. Regarding Health and Safety, consumers are concerned with the consequences of radiation emission by wireless devices such as smart meters and smart appliances. Privacy intrusion and Security issues are also a concern as some believe that personal data might fall in the wrong hands due to vulnerabilities of smart grid technology, but on the other hand people have the right to choose whether they share their data or not and high security standards are used on SGSs. Quality of life/Well-being/Comfort is contested since it is perceived as avoiding the hassle of meter readings and automation of appliances being convenient. However, this value is also related to not being able to perform energy consuming activities when it fits consumers best, e.g. due to high energy prices applied through demand response. Procedural Justice is perceived with a negative valence only since consumers feel that they have not enough opportunities to participate in decision-making processes on SGSs whilst they are the ones mostly being affected by smart grid technologies. The value of Ownership/Property regards the possession of small generation sources and personal data. Furthermore, consumers are concerned about the Reliability of smart grid technologies, especially smart meters. Some people believe they will work as intended, whilst others state that the technology will be out of date when the roll-out is complete. Lastly, Universal usability/Inclusiveness is perceived to be enhanced by smart grid technologies, as all households in the UK will have access to it. However, some believe that the technology is so complex, excluding elderly and computer illiterate from becoming successful users.

Governmental bodies and policy-makers

As can be seen from Table 11, the most prevalent values for *Governmental bodies and policy-makers* are Economic development and Transparency/Accuracy both perceived with a positive valence, followed by Distributive justice and Environmental sustainability. In general, this stakeholder group has ruled that energy companies and consumers have to bear a share of the costs of upgrading the power network into a low-carbon smart grid. Part of the price rises of energy *"will relate to building smart grids, enabling consumers to sell electricity generated by solar panels or wind turbines to the national network. The rest of the money will be spent on ensuring that the companies are investing in a low-carbon future",* enhancing the value of Quality of life/Well-being/Comfort. Besides, governmental bodies and policy-makers believe that smart grid technologies put power into the hands of consumers, bringing an end to estimated billing and helping people understand their energy use as well as engaging more in the energy market. This relates to Control/Autonomy. Regarding Trust and distributive justice, the government trusted energy companies passing on *"the savings made from no longer having to send staff to read meters manually"*. As this seemed not to be the case, the government took Legitimacy measures to ensure that energy suppliers would have to pay a fine and in extreme cases even receive a sales ban if smart meters were not installed on time: *"The supplier did not take all reasonable steps to fulfil the rollout, as it was legally required to do"* and *"Customers have lost out on receiving better information about their energy consumption and the opportunity to control costs"*. With regard to Courtesy, the government took the risk of letting the energy companies decide on the costs of smart meters, while people were struggling to pay their bills. The consumers did not appreciate this, as they felt not being considered. The value of Health and Safety is positively perceived by this stakeholder group as the radiation emitted by wireless devices such as smart meters and smart appliances is lower than guideline levels and not harmful at all with a substantial body of evidence proving it. Concerning Procedural justice, the government tries to enhance cooperation between stakeholders and engage them as much as possible in the decision-making process on SGSs. Reliability, especially of smart meters, is a concern as the roll-out is being delayed and energy companies are not always realizing the agreements made. For instance, there are fears that when the roll-out is complete, the technology is out of date. Besides, the government ensures Universal usability/Inclusiveness as they provide free smart meters to vulnerable consumers (e.g. fuel poor) in order not to exclude any societal group from being able to better manage their energy use. Lastly, Security of supply is ensured as the government *"want to build an "internet" for electricity using smart grids that would allow demand and supply to be managed in an intelligent and environmentally friendly way"*.

The Media

The majority of statements put forward by this stakeholder regard Economic development, Transparency/Accuracy, Environmental sustainability, and Control/Autonomy, perceived with different types of valence. The opinions presented regard households facing a rise in energy bills as the government apparently underestimated the costs of the smart meter roll-out, but on the other hand the technology records energy consumption allowing accurate billing and saving energy by adjusting their consumption behaviour and controlling household appliances (e.g. by automation). The media presented Security of supply with a positive valence, as smart grid technologies enhance efficient management of energy flows (i.e. energy capacity of the network) and effective balancing of supply and demand. Besides, Accountability/Traceability is positively perceived as smart meters allow tracking real-time households energy consumption, their bill, and some may allow tracking the carbon generated from energy consumption in the home. Reliability and Security are contested as smart grid technologies are expected to deliver a more responsive energy system with the aid of ICT, but this could open the national grid to cyber–terrorists and raise Privacy concerns. Additionally, the media presents Trust with different types of valence. On the one hand, smart grid technologies will aid restore the trust in the energy industry and strengthen the relationship between energy suppliers and consumers as they are provided tools to better manage their energy consumption. On the other hand, smart grid technologies are a window into consumers' personal life and the energy suppliers can show strategic behaviour by making energy expensive when it suits them best. Ownership/Property is presented with a negative attitudinal direction as it regards property of personal data that is being automatically transmitted to the energy suppliers and is vulnerable if it gets sold to third parties for marketing purposes or if it falls in the hands of hackers.

Furthermore, Procedural justice is presented in a negative statement that regards consumers not having the opportunity to get engaged in energy pricing decisions. Quality of life/Well-being/Comfort is contested. Smart grid technologies contribute to a less polluted living environment and allow direct communication with energy suppliers, e.g. *"so there is no need for homeowners to supply meter readings any more. And they could be linked to household appliances too, allowing them to operate when demand for energy is low"* and *"Sit back, relax and never worry about supplying your meter readings or letting a stranger into your home to take them"*. Distributive justice is mainly presented with a negative valence regarding the distribution of costs for smart meter instalment and energy companies not sharing the benefits with consumers. For instance, *"Your smart meter handles everything, sending the latest readings to your supplier, so you'll receive hassle-free, accurate bills"*, but inconveniences are being imposed to consumers as to when energy can be best consumed. There is only a single statement put forward by the media regarding each of the following values: Autarky, Courtesy, Health and Safety, and Honesty/Integrity. Autarky is perceived with a positive statement regarding energy self-sufficiency is becoming more achievable for British homeowners, especially due to energy storage possibilities and micro-generation. Courtesy has a negative valence as energy suppliers made the commitment to reduce prepay prices when smart meters get installed, but *"greedy utility suppliers have a cheek asking customers to get smart while they are failing to wise up to their most vulnerable customers' needs"*. Health and Safety is also negatively perceived due to smart appliances operating by night when the energy prices are low, being left unattended and creating fire risk. Lastly, the media positively presents Honesty/Integrity as the government managed to prevent an energy mis-selling scandal of energy companies misleading people with sales trick to sign them up for their expensive tariffs.

Energy companies

As Table 11 shows, Economic development is the outmost value from the energy suppliers, followed by Transparency/Accuracy. These values are positively perceived by this stakeholder group as insights into energy consumption behaviour of consumers enabled by smart meters, allow cost savings for energy companies and consumers as previously discussed. Furthermore, Control/Autonomy is contested as the consumers can easily switch providers affecting the revenue of the energy companies and but suppliers can also freely adapt their tariffs to meet the customer needs. Environmental sustainability regards the energy companies contributing to upgrade energy system into a low-carbon smart grid, which also adds to the value of security of supply as aforementioned. Regarding Courtesy and Trust, energy suppliers feel tensions from the consumer side but try to consider their needs in the service that is being offered and the price of it. Moreover, this stakeholder group positively perceives Procedural justice and Distributive justice. They claim that relevant stakeholders have a say in e.g. energy pricing decisions and that next to costs, benefits are being shared with the consumers: *"Consumers will benefit from smart meters only if they understand the opportunity to reduce their energy bills and change their behaviour"*. Besides, they claim that their actions comply with Legitimacy as those are established in (binding) agreements and contracts. In addition, the values of Quality of life/Well-being/Comfort and Universal usability/Inclusiveness are perceived with a positive valence since the roll-out of smart meters aims to include all households in the UK and automated transmission of consumption data allows hassle free and accurate bills, being also in the advantage of supplier's customer care.

The other stakeholder groups

- For the ***Environmental Organizations*** only the values of Economic development and Environmental sustainability matter, according to the empirical data. They perceive these values with a positive valence as investments in SGSs contribute to sustainable development and climate change mitigation.
- The ***Trade Associations*** state that demand response is important for managing the grid for Security of supply purposes, which should be more a priority that it already is. With respect to Control/Autonomy this stakeholder group claims, *"It is imperative that any agreements made with the industry are on a voluntary basis"*. Regarding Economic development, it is argued that competition is being promoted for the award of franchises for smart meter supply. This stakeholder group positively perceives Legitimacy as the government shows their commitment through firm policy decisions and clear action. Besides, Trade Associations claim that Transparency/Accuracy is no properly being addressed as research revealed that almost two-thirds of people in the UK had not heard of the devices that measure energy use in the home.
- The most prevalent values of ***Knowledge Institutions*** are Economic development, Environmental sustainability, and Reliability. It is easy to dismiss the smart meter roll-out (i.e. the start of smart grid development in the UK) as an inefficient way of saving a small amount of money on energy bills. However, major national benefits can be achieved, such as a more secure grid and reduced pollution. This also adds to the value of Security since secure grid safeguards sensitive systems of the smart grid. Furthermore, Distributive justice is perceived with a negative valence, as dubious benefits are offered to consumers, whilst they will pay for the smart meters through increased energy bills, especially the poor paying the most. Privacy is clearly a concern because *"Many people do not like the idea of utility companies having a permanent window on their private life"*. Besides, it seems that personal data can be monetized for marketing purposes, which relates to Ownership/Property and privacy issues according to this stakeholder group. Trust is presented with a negative valence in a statement that regards findings of a research group in which appears that smart meters can lose their smartness if customer switches from supplier and the government has known this for years but did not put the necessary efforts to tackle it. In addition, Transparency/Accuracy is contested as it opens up a window on households' private life but allow energy companies to better understand consumers' energy usage and allow them to make better decisions when buying energy wholesale. These costs savings should, in theory, be passed on to

households. Security of supply relates to smart grids being able to cope with fluctuating demand and is perceived with a positive valence.

- The most mentioned values by ***Consumer Organizations*** are Economic Development and Transparency/Accuracy. This stakeholder group claims that the Transparency/Accuracy offered by smart meters aid households to drive down their energy bills, but on the other hand they claim that the installation costs are too high. Regarding Legitimacy, they state that the government should establish installation guidance with reasonable steps that suppliers must consider at the roll-out. Regarding Courtesy, Control/Autonomy, Distributive justice, Reliability and Trust, the consumer organizations claim that people who have smart meters feel more in control of their energy use than those without, helping them to cut bills as well as bills being up to date and based on actual usage. Besides, the energy industry promised to pass on savings to consumers, considering their needs and crucial role for acceptance of SGSs. Driving bills down is possible due to smart meters being a power-saving initiative that adds to the value of Environmental sustainability. Besides, they claim that consumer should be offered more opportunities to engage and participate more in energy pricing decisions as well as decision on SGSs deployment, which relates to the value of Procedural Justice. Additionally, smart meters are perceived as highly surveillant in household routines and thus Privacy intrusive. This stakeholder group has Health and Safety concerns as well as that of Quality of life/Well-being/Comfort as they perceive the radiation emission of wireless devices (e.g. smart meters and smart appliances) dangerous for health and well-being. Lastly, Reliability is positively presented as accurate and reliable energy bills.
- According to the empirical data, Economic Development and Security of supply are the most prevalent values for the ***Transmission System Operators***. Realizing an agile and flexible smart grid enables consumers to shift energy demand and be paid to do so. Besides, managing a proliferation of small generation sources is made possible by smart grids, increasing incentives for consumers to invest in small-scale generation of renewable energy, contributing to Ownership/Property and Environmental sustainability (sustainable development). Besides, *"proper information about energy use will allow both consumers and suppliers to change their behaviour to save energy, and particularly to cut demand at peak times when prices - and often carbon dioxide emissions - are at their highest"*, which relates to Transparency/Accuracy and Control/Autonomy.
- The ***Supporting Organizations for Smart Grid Development*** put forth Economic development and Control/Autonomy as the most important values, perceived with a positive valence as well as Environmental sustainability. Overall, the statements of this stakeholder group regarding these values relate to investment in making homes more energy efficient and smart grid technologies that are critical to meeting energy demand while reducing cost and improving the environment. Besides, smart grid technologies aid engaging consumers in their energy use, which adds to the values of Transparency/Accuracy and Universal usability/Inclusiveness. In addition, Security of supply is positively perceived as SGSs aid effective energy management by better balancing supply and demand. With regard to Privacy and Security this stakeholder group has a positive valence. The main argument is that a smart meter *"stores and transmits simple information on how much energy your home has used. Personal details like your name, address and bank account details are not stored on or transmitted by the meter. Your supplier can't use any data from your smart meter for sales and marketing purposes unless you give them permission to do so"*. This also adds to the values of Trust as this stakeholder group states that people trust their energy supplier with their data because they always have complete control of it, i.e. consumers do not give others access to their personal data unless they want to. Furthermore, Autarky is put forth with a positive valence, as smart grid technologies enable households to be grid independent for power if needed. Besides, Reliability is positively perceived as smart meters will be able to deliver the full range of functionality as intended (i.e. accurate bills and visibility of consumers energy spending in near real-time in pounds and pence), even if consumers switch suppliers, when the national communications network is up and running, enrolling existing meters into it. The value of Health and Safety is positively perceived by this stakeholder group since at the installation of smart meters in a home, a free fire safety advice is provided to the household, including a free carbon monoxide check on all gas appliances in the home.
- The ***Distribution System Operators*** do not come forth in the empirical data at all (i.e. in the sample).

4.5.4. Initial exploration of interrelations between the identified ethical values

As aforementioned, studying how values are related is important for the technical and institutional design of SGSs as a value can be strived for the sake of other values (i.e. supporting relationship) or can be in conflict with other values when they cannot be embedded in the design to the desired degree (i.e. conflicting relationship). The latter can raise challenges in the design of SGSs and imply the necessity of value trade-offs. Moreover, the identification of the type of relationship between values is important for the energy industry and policy-makers regarding the trade-offs that design choices might imply and that might affect the social desirability of SGSs. After performing the content analysis, the output of ATLAS.ti only shows which values are related, but not in what way. This means the results only show the co-occurrence between values, as presented in Table 19 and Table 20 of Appendix F. This means that the co-occurring values are related as they share a value-laden statement (i.e. quotation) and thus have overlapping conceptualizations, which might result in a supporting or conflicting relationship.

So far, potential value relations based on the different newspaper articles could not yet be retrieved. Due to the large number of quotations (480) and values (21), a very complex network raises showing the relation links between value codes and quotation, thus the overlapping conceptualizations of related values. This complex network is shown in Figure 19 of Appendix F. As it is not easy to see the type of relationship between the co-occurring values due to the high amount of quotation and thus links in the complex network, the value codes need to be semantically linked. This means that the overlapping quotations need to be grouped/summarized to reduce the amount of links into conception of the values, creating them as a new code right away in the network view of ATLAS.ti. Hence, the overlapping quotations are coded with high level value conceptions, staying very close to the text of the newspaper articles. Moreover, the high-level conceptions (i.e. the new codes) are linked to both the values and the quotations among different articles in order to justify the interpretations and determine potential value relations from different newspaper reports. An example is provided in Figure 20 of Appendix F. This process is carried out value per value, looking at each single quotation to determine whether values are related in a supporting or conflicting way. This results in the simplified network of all values and their relations presented in Figure 21 of Appendix F. However, the "simplified" network is still quite complex and thus needs further simplification to determine the type of relation among the related values. This can be done by linking the content analysis results with the literature through interpretation, as will be discussed in the next chapter.

4.6. Conclusion

This chapter presented the protocol for the empirical data analysis (see §4.1 until §4.3) and the results through performing a qualitative content analysis of British national newspaper reports on SGSs (see §4.5). Thereby, answering the third research sub-question *"What ethical values are associated with smart grid systems in the UK according to the empirical data?"* As discussed in §4.5.2 and presented in Table 9, 21 ethical values can be associated with SGSs in general, according to the empirical data. The conceptualization of these values is the same as that presented in Table 4 of §3.2. Additionally, the identified values can be specifically related to the different smart grid technologies. This is presented in Table 10 of §4.5.2. Furthermore, it was noticeable from the empirical data that the consumers are a key stakeholder for the adoption of SGSs, followed by governmental bodies and policy-makers, the media, and the energy companies. Besides, it was possible to specifically relate ethical values to stakeholder groups as presented in Table 11 of §4.5.3. However, it is remarkable that the DNOs did not come forth in the empirical data at all. Furthermore, from all TSOs only National Grid came forth in the empirical data (i.e. the taken sample). So far, it could be established which values are related but not though what type of relation. This is the subject of the next chapter.

5. Interpretation and Discussion

The previous chapter presented the results of the qualitative content analysis of British national newspaper reports on SGSs. In order to appropriately establish the type of relationship (i.e. supporting or conflicting) among interrelated values, this chapter aims at developing a network of related values based on both the integration of the content analysis and literature review results. Thereby, the fourth research question can be answered: *"How are the identified values related to each other?"* As Figure 15 shows, the sub-deliverable of this chapter is a network of related values that shows the type of relationship. In order to establish this network, three steps are taken. First of all, differences and similarities between the literature and newspaper reports are examined. This is done with the purpose of determining how sub-systems are subjected in both sources and whether there are differences or similarities in the values that are attributed to the sub-systems among both sources. Secondly, based on the findings of this comparison, it is examined whether there are dissimilarities in perception/interpretation of values relative to each sub-system and if so, whether those similarities are conflicting. As discussed in §3.1.1, dissimilarities in stakeholders' understanding and interpretation of values might lead to conflicts. Therefore, the third step taken to establish the network of related values is to examine the shared values among the stakeholder groups in terms of valence and interpretation.

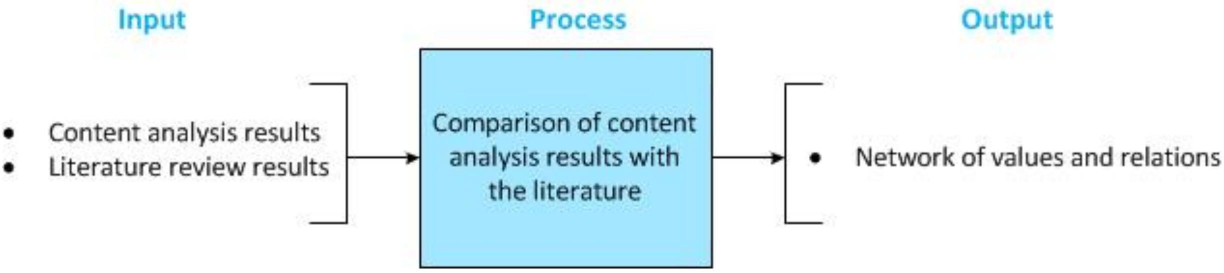


Figure 15: Research flow of the fourth research phase (interpretation & discussion)

5.1. Differences/similarities between the academic literature and British newspaper reports

This section focuses on examining differences and similarities related to values and sub-systems (i.e. SGSs components) that come forth in the literature and the empirical data. This includes examining the distribution of sub-systems as a topic in both sources and what values are attributed to the sub-systems. To start with, in comparison to the reviewed academic literature on SGSs (see §3.2), the British newspaper articles on SGSs (see §4.5) focus on more than one specific SGSs component at the same time within a publication and do include information about which values are relevant for the different stakeholder groups. As can be seen from Figure 16, the literature discusses smart grids the most, whilst the newspapers mostly discussed smart metering. Furthermore, demand response and energy storage are almost equally subjected within both sources. Smart homes are a bit more discussed in literature than in the newspaper articles. It is reasonable to assume that the differences of focus of both sources are in place due to newspapers paying more attention to components that are being physically installed at households and have more impact on the consumers' energy management (i.e. smart metering and energy storage facilities) as the media aims to inform the public on occurring events. The academic literature aims at diffusing knowledge and theory acquired through scientific research and therefore pays more attention at smart grids as a system and supporting technologies that are still under development, such as smart homes and demand response mechanisms (as there is currently not enough information of consumer's behaviour and consumption patterns). Probably as the smart meter roll-out is almost complete in the UK and technology has further advanced, the other smart grid technologies will be implemented and the newspapers will report on it on a greater extent, probably affecting stakeholder perspectives and contributing to the evolving character of ethical values related with SGSs.

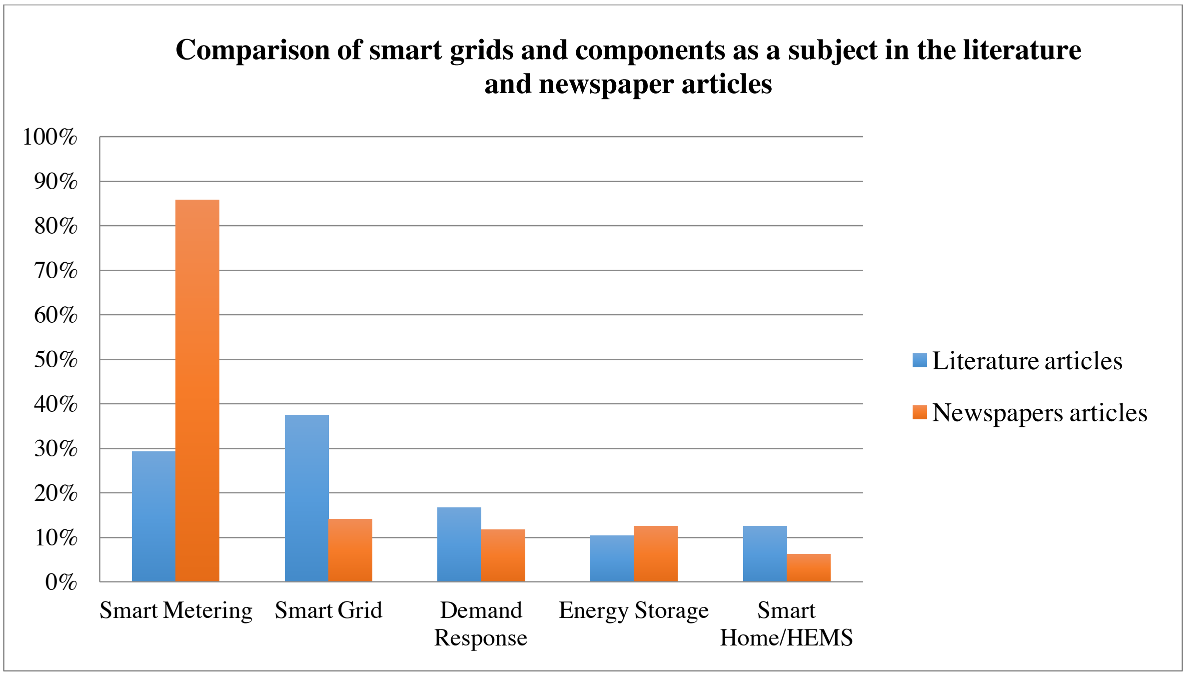


Figure 16: SGSs subjected to % of literature and newspaper articles

Further differences between the literature and newspapers articles is that the literature identifies 26 ethical values that can be associated with SGSs, whilst the newspapers only identify 21 ethical values. Hence, the following 5 values from the literature have not been discussed in the empirical data: cooperation, 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. In addition, when comparing the values relative to sub-systems according to the literature (see Table 5) and the newspapers (see Table 10) some small differences can be noticed. This comparison is summarized in Table 12 below. First of all, most of the identified values relative to sub-systems are shared by both sources, except for a few as will be discussed in the remainder of this section. Regarding demand response values, privacy is only mentioned in the literature, as demand response requires insights in energy consumption patterns of households, which might be intrusive. Besides, control/autonomy and distributive justice are only mentioned as values for this sub-system in the newspapers as households can control smart appliances to operate according to time-of-day pricing, but surcharging at peak is convenient for energy suppliers and can put a burden especially to vulnerable consumers not being able to consume energy when it suits them best. In addition to the shared values among the literature and newspapers for energy storage, the empirical data bring forward the following values: control/autonomy, economic development, and environmental sustainability. The reason is that triggering events of technology developers (e.g. Powervault and Tesla) delivering enhanced electric vehicle batteries and household battery packs for power storage has emphasized in the public debate that power storage enables consumers to decide when and how to consume energy and sell or use self-generated renewable energy through micro-generation.

Table 12 also shows that the values relative to smart grids mentioned by the newspaper only are: distributive Justice (regards automatic optimal distribution of power by the smart electricity infrastructure), legitimacy (regards smart grid policy), and transparency/accuracy (regards insights of households’ energy consumption, which allows effective management of the power network). For this system the following values are only mentioned by the literature: cooperation (in order to reach the targets of smart energy system policies, knowledge, resources, and technologies should be used in collaboration among smart grid stakeholders), privacy (consumers personal information gets vulnerable due to the digital technology applied in smart grids), security (regards vulnerability to cyber-attacks), trust (relates to the public perception on the government and energy industry acting in the benefit of society for smart grid development), and universal usability/inclusiveness (relates to making all users of the power grid successful users). For smart homes, autarky and transparency/accuracy are only mentioned in the newspapers as smart home technology contribute to households being energy independent by producing their own energy and effectively managing their energy use by insights into consumption patterns enabled by smart home technology.

Table 12: Values relative to SGSs according to the academic literature and newspaper reports

	Demand Response	Energy Storage	Smart Grid	Smart Home	Smart Metering
Accountability/Traceability					Newspaper
Autarky		Literature/ Newspaper	Literature/ Newspaper	Newspaper	
Calmness					Newspaper
Control/Autonomy	Newspaper	Newspaper	Literature/ Newspaper	Literature/ Newspaper	Literature/ Newspaper
Cooperation			Literature		
Courtesy					Newspaper
Democracy					
Distributive Justice	Newspaper		Newspaper		Newspaper
Economic Development	Literature/ Newspaper	Newspaper	Literature/ Newspaper	Literature/ Newspaper	Literature/ Newspaper
Environmental Sustainability	Literature/ Newspaper	Newspaper	Literature/ Newspaper	Literature/ Newspaper	Literature/ Newspaper
Freedom from bias					
Health and Safety	Literature/ Newspaper			Literature	Literature/ Newspaper
Honesty/Integrity					Newspaper
Identity					Literature
Informed Consent					Literature
Legitimacy			Newspaper		Newspaper
Ownership and Property			Literature/ Newspaper		Newspaper
Privacy	Literature		Literature	Literature/ Newspaper	Literature/ Newspaper
Procedural Justice					Literature/ Newspaper
Quality of life/Well-being/Comfort	Literature/ Newspaper		Literature/ Newspaper	Literature	Literature/ Newspaper
Reliability	Literature/ Newspaper	Literature/ Newspaper	Literature/ Newspaper	Literature	Literature/ Newspaper
Security			Literature	Literature	Literature/ Newspaper
Security of supply	Literature/ Newspaper	Literature/ Newspaper	Literature/ Newspaper		Literature/ Newspaper
Transparency/Accuracy	Newspaper	Newspaper	Newspaper	Newspaper	Literature/ Newspaper
Trust			Literature	Literature	Literature/ Newspaper
Universal usability/Inclusiveness			Literature	Literature/ Newspaper	Newspaper

In addition, Table 12 shows that the following values regarding smart grids are discussed in the literature only: health and safety (regarding assisted living and in-home health care, which is out of the scope of this research), quality of life/well-being/comfort (due to the convenience allowed by automation in the residence), reliability (relates to the functioning of smart home technology, sensors and systems), security (relates to personal data being prone to cyber-attacks die to the digital technology applied in the residence), and trust (relate of trust on the utility companies, about financial savings passed on to the consumers since they are the one taking action and adjusting their consumption behaviour and trust on the government regarding data protection and privacy measures). Lastly, Table 12 shows that for smart metering identity (relates to consumers maintaining their energy consumption behaviour, shaping it, or changing it if perceived as necessary) and informed consent (relates to providing the right information to consumers so they can better understand their consumption behaviour and make the right decision on how to be more energy efficient) are values only mentioned in the literature. Next to the values shared within both sources, the following values relative to smart metering are only discussed in the newspapers: accountability/traceability (relates to tracking energy consumption near real-time), calmness (relates to installation problems of smart meters), courtesy (regards customer service of energy companies), distributive justice (regards distribution of cost and benefits of the smart meter roll-out among energy companies and consumers), honesty/integrity (relates to selling tricks of energy companies to sign up consumers to their tariffs), legitimacy (obligatory smart meter roll-out following deadlines and smart grid policy), ownership and property (regards personal data on energy consumption patterns), and universal usability/inclusiveness (providing a smart meter in every household in the UK).

To conclude, values attributed to smart grids and its related technologies in the literature and newspaper reports might differ among these sources. For the values that are shared among two or more sub-systems it is important to examine whether the perception of these values actually differ and if so, whether it might lead to value conflicts. This is the subject of the next section.

5.1.1. Shared ethical values among smart grid systems

Table 12 shows that most of the values are shared among multiple sub-systems with each other and also with smart grids as a system. It can be justified that this is the case, as the different sub-systems are part of smart grid as a whole and thus have common goals and functionalities. Moreover, the sub-systems are interrelated. For instance, smart metering is needed to implement demand response mechanisms, especially on the level of domestic consumers. In addition, energy storage contributes to demand response, as power can be stored to reduce spikes in demand at peak times. Smart home can accommodate all these smart grid technologies in a residence due to the high technology and smart network that connects and coordinates all information and high-tech in the home. These components jointly build up a smart power network and thus an intelligent grid. Differences in values that can be associated to specific sub-systems only, can be in place due to differences in design requirements and functionalities of each SGSs component. Moreover, as can be derived from Table 12, the shared values among two or more sub-systems are: autarky, control/autonomy, distributive justice, economic development, environmental sustainability, health and safety, legitimacy, ownership and property, privacy, quality of life/well-being/comfort, reliability, security, security of supply, transparency/accuracy, trust, and universal usability/inclusiveness. Based Table 12, §3.2 and §4.5.2, it can be inferred that there are no differences among the sub-systems regarding autarky (energy self-sufficiency due to micro-generation of renewable energy), distributive justice (distribution of costs and benefits among smart grid stakeholders), environmental sustainability (GHG emission reduction through energy savings and integration of renewables into the power network), health and safety (radiation emission of wireless devices), legitimacy (smart grid policy), ownership and property (of personal data and small scale generation), privacy (personal data regarding household energy consumption patterns), security (vulnerability to cyber-attacks), security of supply (enhanced balancing of supply and demand), transparency/accuracy (frequent feedback regarding energy consumption), and trust (relates to the public perception on the government and energy industry acting in the benefit of society for smart grid development and also of these parties trusting in consumers willing to adapt their energy consumption behaviour). Some differences were derived regarding the following interpretations of a value per sub-system:

- ***Control/autonomy:*** regarding demand response, this value is about controlling energy use with variable tariffs. For energy storage, it relates to the ability of households to control when and how to use energy. Concerning smart grid and smart meters this value regards controlling energy use by the application of digital technology. Besides, smart homes are associated to this value as smart appliances can be controlled by automation to operate when consumers decide to.
- ***Economic development:*** with regard to demand response this value is about cost efficiency for both consumer and energy companies due to flexible tariffs. For smart home and smart metering this value is about monetary savings on energy bills due to saving energy. Besides, for smart grids it is about grid investments, thus investing in the physical energy infrastructure to make it

intelligent. For energy storage, this value relates to selling energy back to the grid and monetary savings on reducing energy consumption.

- ***Quality of life/well-being/comfort:*** For demand response, this value regards convenience of automated smart appliances to run when energy price is low. As smart grids contribute to a sustainable future, it is associated to this value. Regarding smart homes, this value relates to the convenience of automation in the residence. Besides, for smart metering this value relates to preventing the hassle of meter readings.
- ***Reliability:*** regarding demand response, this value relates to enhanced energy management in the grid. Moreover, for energy storage this value is about the ability to cope with fluctuating demand. With regard to smart grids, this value relates to effective management of energy flows in the energy system. Besides, for smart homes this value is about proper functioning of high-tech in the residence and the home energy management system. For smart metering, this value is about proper functioning of the smart meters.
- ***Universal usability/inclusiveness:*** for smart grids, this value relates to making all users successful users of the power grid. Besides, for smart homes this value is about allowing the whole family (especially children and elderly) to engage with energy management in the home. Regarding smart metering, this value relates to providing all households in the UK with smart meters.

These dissimilarities in perception of values relative to each sub-system are not conflicting, as the values mentioned above are specific to the SGSs components and this specification does not clash among interpretations of a value per sub-system.

5.1.2. Shared values among stakeholder groups

As can be seen from Table 11, all identified values, except for accountability/traceability and calmness, are shared among two or more stakeholder groups. The findings of §4.5.3 are summarized in Table 21 of Appendix G, which presents the valence and interpretation of shared values among the different stakeholder groups. The aim is to compare stakeholder interpretation of the values in the empirical data, which might lead to intra-value conflicts as explained in §3.1.1, and to link that to the reviewed literature on SGSs (see Appendix C). By doing so, the following is noticed for each of the shared values:

- ***Autarky:*** this value is shared among three stakeholder groups (supporting organizations for smart grid development, energy consumers, and the media), which all perceive this value with a positive valence and relate it to being grid independent and energy self-sufficient. This is in line with the findings of the literature review, namely with the ideas presented by Ellabban and Abu-Rub (2016) and Römer et al. (2015).
- ***Honesty/Integrity:*** this value is shared among energy consumers and the media and is positively perceived by both stakeholder groups. They relate it to the government acting on behalf of consumers to prevent energy mis-selling scandals by suppliers trying to sign up consumers to their expensive tariffs with sales tricks. In this case, this means that the government acts according to its norms and commitment, whilst the energy companies are not disclosing all relevant information to consumers to decide whether they sign up or not. This is in line with the notion presented by van de Poel and Royakkers (2011) regarding this value.
- ***Ownership/Property:*** this value is shared among four stakeholder groups. Energy consumers, TSOs, and knowledge institutions have the same interpretation and attach a positive valence 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 valence, as personal data is too vulnerable due to the digital technology used in smart grid technologies. This highlights an intra-value conflict. Moreover, this stakeholder interpretations are in line with the concern presented by Herkert and Kostyk (2015).
- ***Security of supply:*** this value is shared among eight stakeholder groups, all perceiving it with a positive valence. Governmental bodies and policy-makers, supporting organizations for smart grid development, trade associations, energy companies, energy consumers, and the media have the same understanding of this value and relate it to effective energy management and better

balancing of supply and demand due to smart grid technologies. The TSOs share this value interpretation and add management of proliferation of small-scale generation sources. Besides, knowledge institutions interpret this value as smart grids being able to cope with fluctuating demand. Thus, there are no significant differences in the understanding of this value among these stakeholder groups and no conflict is identified. Furthermore, these value interpretations are in line with the scientific work of Dincer and Acar (2016), Künneke et al. (2015), and Warren (2014).

- ***Control/Autonomy:*** this value is shared among eight stakeholder groups, some perceiving it with a different type of valence. Governmental bodies and policy-makers, supporting organizations for smart grid development, consumer organizations, and TSOs attach a positive valence 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 valence 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. Due to the latter, an intra-value conflict emerges. Moreover, these interpretations are in correspondence with the work of Buchanan et al. (2016), Ligtvoet et al. (2014), and Wilson et al. (2017).
- ***Courtesy:*** this value is shared among five stakeholder groups, some perceiving it with a different type of valence. The energy companies attach a positive valence 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. Hence, there is an intra-value conflict. Furthermore, this value interpretations are in correspondence with the conceptualization derived from Ligtvoet et al. (2015) and Friedman et al. (2013).
- ***Distributive Justice:*** this value is shared among six stakeholder groups, some perceiving it with a different type of valence. Governmental bodies and policy-makers as well as the energy companies attach a positive valence 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. This leads to an intra-value conflict. Moreover, these value interpretations are in line with Dignum et al. (2016), Künneke et al. (2015), and Steg et al. (2014).
- ***Economic development:*** this value is shared among all stakeholder groups, some perceiving it with a different type of valence. Environmental organizations, supporting organizations for smart grid development, energy companies as well as governmental bodies and policy-makers perceive this value with a positive valence 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, TSOs understand this value with a positive valence, 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 valences 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. Due to the differences in value understanding between some stakeholders, it is reasonable to assume that there is an intra-value conflict in this case. Furthermore, the presented stakeholder perceptions are in line with the ideas presented by Ellabban and Abu-Rub (2016); Geelen et al. (2013); Krishnamurti et al. (2012).

- ***Environmental Sustainability:*** this value is shared among all stakeholder groups, except the trade associations. All stakeholder groups that relate to this value perceive it with a positive valence, except the media as it contests it due to energy savings being highly dependent on consumers willing to adjust their energy usage for the sake of the environment. Overall this value is positively interpreted as improving the environment through energy efficiency and implementation of smart grid technologies that allow a higher share of renewables in the power network, contributing to climate change mitigation. This is in line with the scientific work of Darby (2010); Ellabban and Abu-Rub (2016); Noppers et al. (2016); Ponce et al. (2016); Tuballa and Abundo (2016). Despite the opinion of the media, no intra-value conflict is identified in this case.
- ***Health and Safety:*** this value is shared among five stakeholder groups, some perceiving it with a different type of valence. 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 valence 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. Clearly, the diverging value understandings lead in this case to an intra-value conflict. Furthermore, these interpretations are in line with Guerreiro et al. (2015) and Yesudas and Clarke (2015).
- ***Legitimacy:*** this value is shared among five stakeholder groups, some perceiving it with a different type of valence. 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 valence 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. In this case, the distinct value understandings lead to an intra-value conflict. The work of Dignum et al. (2016) is in line with these thoughts.
- ***Privacy:*** this value is shared among five stakeholder groups, some perceiving it with a different type of valence. 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. Due to the differences in value understanding between some stakeholders, it is reasonable to assume that there is an intra-value conflict in this case. Furthermore, the presented stakeholder perceptions are in line with the ideas presented by Balta-Ozkan et al. (2013), Chou et al. (2015), Cuijpers and Koops (2012), and Herkert and Kostyk (2015).
- ***Procedural Justice:*** this value is shared among five stakeholder groups, some perceiving it with a different type of valence. 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. This leads to an intra-value conflict. Furthermore, these perceptions are in line with Guerreiro et al. (2015), Steg et al. (2014), and Wüstenhagen et al. (2007).

- ***Quality of life/Well-being/Comfort:*** this value is shared among five stakeholder groups, some perceiving it with a different type of valence. 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 valence 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 valence 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. In this case, the distinct value understandings lead to an intra-value conflict. The work of Balta-Ozkan et al. (2013), Buchanan et al. (2016), and Paetz et al. (2012) is in line with these thoughts.
- ***Reliability:*** this value is shared among six stakeholder groups, some perceiving it with a different type of valence. 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 valence 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. Therefore, the differences in interpretations highlight an intra-value conflict. Moreover, these perceptions are in line with Chou et al. (2015), Darby (2010); Ellabban and Abu-Rub (2016), Krishnamurti et al. (2012), and Bianchi et al. (2014).
- ***Security:*** this value is shared among four stakeholder groups, some perceiving it with a different type of valence. Supporting organizations for smart grid development interpret this value with a positive valence, 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. This underlines an intra-value conflict. Furthermore, the different value interpretations are in line with the notions presented by Bigerna et al. (2016), Brown and Zhou (2013), Depuru, Wang, and Devabhaktuni (2011), Luthra, Kumar, Kharb, Ansari, and Shimmi (2014), and Xenias et al. (2015).
- ***Transparency/Accuracy:*** this value is shared among all stakeholder groups, except the environmental organizations, and some perceiving it with a different type of valence. 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 valence as insight into 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 valence to this value. On the contrary, TSOs understand this value as proper information about energy use. Knowledge institutions contest this value as insight into 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. Due to the differences in value understanding between some stakeholders, it is reasonable to assume that there is an intra-value conflict in this case. Furthermore, the presented stakeholder perceptions are in line with the ideas presented by Cuijpers and Koops (2012) and Guerreiro et al. (2015).

- ***Trust:*** this value is shared among seven stakeholder groups, some perceiving it with a different type of valence. 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 valence 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 valence 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). Therefore, the differences in interpretations highlight an intra-value conflict. Furthermore, these perceptions are in line with Wüstenhagen et al. (2007), Wolsink (2012), Buchanan et al. (2016), and Xenias et al. (2015).
- ***Universal usability/Inclusiveness:*** this value is shared among seven stakeholder groups, and is mainly perceived with a positive valence. 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. Due to the latter, an intra-value conflict emerges. Moreover, these interpretations are in correspondence with the work of Balta-Ozkan et al. (2013) and Ligtvoet et al. (2015).

Hence, as previously discussed, in some cases the stakeholder interpretations differ significantly and cause intra-value conflicts to emerge due to diverging understanding of the values they share among each other. This and linkage to the academic literature provides insights into the type of conflicting relationship among values at stake. Combining these insights with those gained in §4.5.4, allows to create a network of related values.

5.2. Network of related values

The purpose of this section is to provide a network of related values, based on the literature review and content analysis results. This network is presented in Figure 17 below and will be explained in the remainder of this section. As aforementioned, two types of value relations are considered in this research: supporting and conflicting. 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). Please note that the black arrows with a + sign in Figure 17 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.

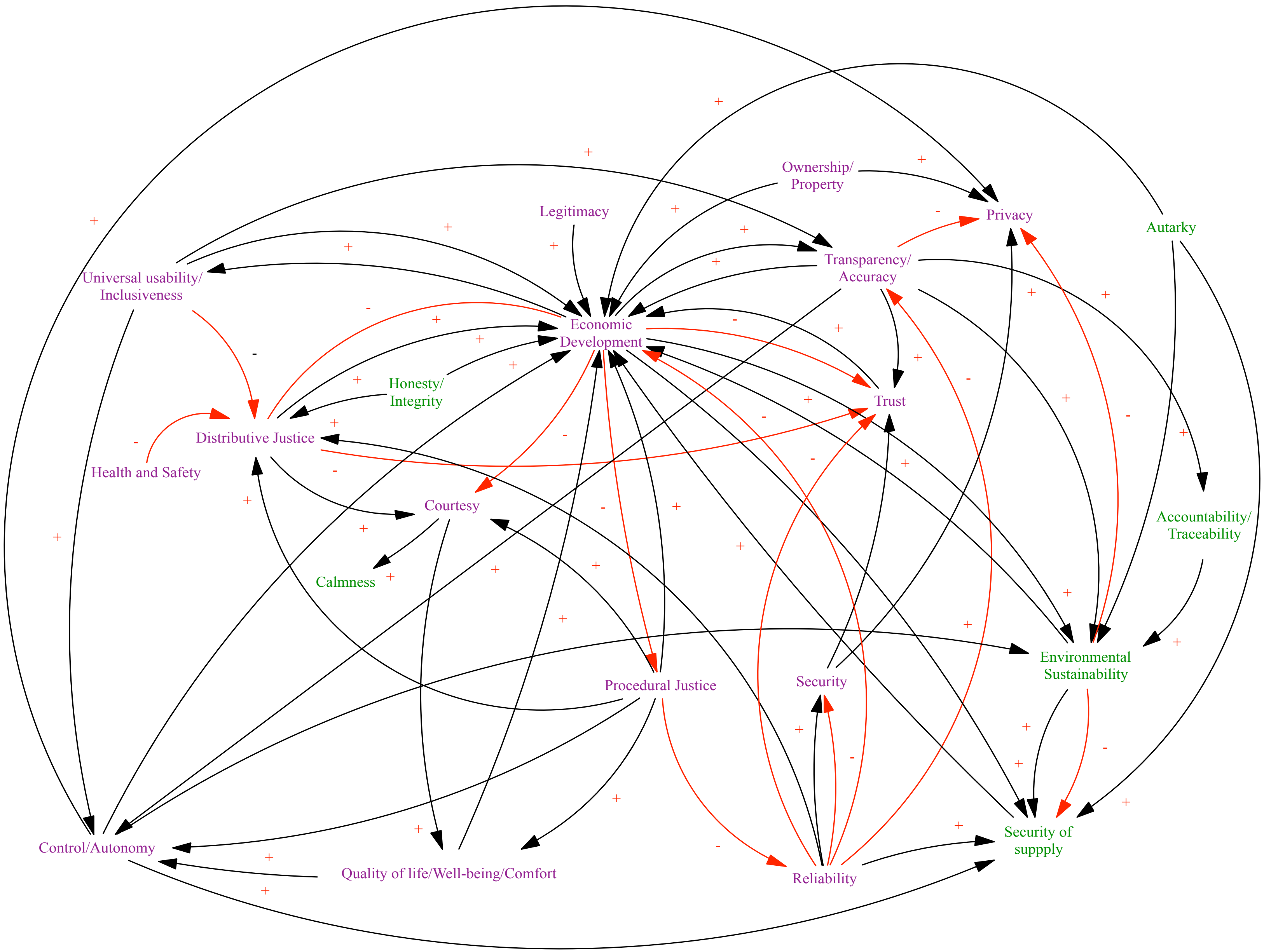


Figure 17: Validated network of related ethical values associated with SGSs

5.2.1. Supporting relationships

By semantically linking the value codes, i.e. summarizing/grouping overlapping quotations among values, the supporting relationships could be retrieved as presented in §4.5.4. 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. My impression is 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 17, *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 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 17, *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.

5.2.2. Conflicting relationships

As explained in §3.1.1, two types of conflicting relationships can be established among values: intra-value conflicts and inter-value conflicts. In §5.1.2 several intra-value conflicts are identified due to different stakeholder understanding and interpretations of the same value as well as different perceptions on which values could be best served (Dignum et al., 2016). For all values that are shared among two or more stakeholder groups, an intra-value conflict is recognized, except for Autarky, Environmental Sustainability, Honesty/Integrity, and Security of supply. Please note that Accountability/Traceability and Calmness are not considered, as they are not shared among stakeholder groups.

From the results presented in §4.5.4 and the §5.1, several inter-value conflicts can be identified between values, requiring a value trade-off. 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. Besides, *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. In my impression, 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 I believe 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. These value conflicts pertain clashing stakes and behaviour of different stakeholders. In order to at least reach reasonable disagreement and consensus it is paramount that the different smart grid stakeholders cooperate and understand their priorities. This cooperation might contribute to value-robust smart grids that integrate stakeholders' perspectives on what they find important and thus might contribute towards adoption of these emerging innovations by the public.

5.3. Validation of the values interrelations network

The established value relationships are direct interpretations from the newspaper articles. However, to confirm the validity of the results a face validation is performed with Dr. Theo Fens. The validation of the network has limitedly been done in this research project due to the time constraints and availability of experts. From this face validation, he deemed that the network of related values (see Figure 17) appears to be reasonable. The main discussion point regarded the intra-value conflicts where the TSOs were involved. According to Dr. Fens, TSOs deal with the high voltage network in the UK (above 70 kV). Small scale power generation generally feeds in at end-user level (low voltage network), which is the realm of the DSOs. However, in the empirical data only National Grid (a TSO) came forth and no DSO was mentioned in the newspaper articles. This could be a coincidence due to sampling a small number of articles compared to the large population. For the sake of clarity, the empirical data was examined considering the expert's feedback. Nevertheless, no DSO was mentioned indeed.

5.4. Conclusion

This chapter aimed to further uncover the relationship among ethical values, based on the findings of the literature review and content analysis results, by integrating both and thereby answering the fourth research question: *"Do the identified values relate to each other and how?"* Among the 21 ethical values associated with SGSs, both supporting and conflicting relationships are established. An overview of these relations is depicted in the network of Figure 17. Overall, all identified values deal with a supportive relationship with at least another value, except Health and Safety. Moreover, the divergent value understandings and interpretations of the different stakeholder groups lead to an intra-value conflict in 15 out of the 19 shared values, thus in 79% of the cases. In addition, the following values pertain inter-value conflicts and should be considered when making trade-offs regarding the institutional and technical design of SGSs: Economic development, Environmental sustainability, Courtesy, Distributive justice, Procedural justice, Privacy, Transparency/Accuracy, Security, Trust, Reliability, Security of supply, Health and Safety, and Universal usability/Inclusiveness.

Insights into the relationships between values are paramount as it can contribute to design for values in 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. The added value of the established network is that it promotes moral values as an integral part of the design of SGSs. So far, it could not yet be concluded what the identified value relations specifically mean for the technical design of SGSs and its institutions. Nevertheless, it can be concluded that 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.

6. Conclusion & Recommendations

The research objective of this thesis is to empirically uncover what ethical values underlie the British public debate on SGSs and whether those values have supporting and conflicting relations in order to provide input for design for values of these emerging innovations. The research methods used for reaching this goal are a literature study, desk research, qualitative content analysis, and integration of these all. This chapter concludes this research through recompiling the answers to the sub-questions (as presented in the previous chapters) and answering the main research question. Furthermore, this chapter elaborates on the scientific contribution and the societal relevance of this research project. In addition, this chapter provides suggestions for future academic research.

6.1. Answer to the research questions

This section presents the answers to the four sub-questions, which allow answering the mean research question of this thesis.

6.1.1. The sub-questions

1. *How can the concept of smart grid systems be described?*

Smart grid systems are the container notion for digitalization of conventional energy systems though application of innovative information and communication technology as well as smart grid technologies with the purpose of supporting and facilitating the integration of renewable energy sources into the power network, accounting for its volatility and larger number of decentral energy production sites. In addition, stakeholders and institutions make part of SGSs as these innovations aim at serving the public need of affordable and secure energy provision. Moreover, these technological innovations need to satisfy functional requirements as well as moral and legal requirements of society. Based on this research, the following SGSs components are identified:

- *Stakeholders & Institutions* (socio-technical system): Stakeholders are any group of people or individual who have an interest or concern in smart grids and who can affect or is affected by these emerging innovations. Institutions structure collective behaviour and the energy sector in the form of established formal or implicit social rules that matter in the social realm (e.g. organizations, policies, societal expectations, law, money, and standardisation of technologies)
- *Demand Response* (energy management system): Demand side management instrument that controls the demand of consumers to shape the load profile by offering consumers tariffs that reward them for making changes in how they use their electricity and when.
- *Smart Metering* (physical energy system): Advanced and smart electricity metering devices that enable recording and storing energy utilization data of consumers in near real-time.
- *Smart Homes* (physical energy system): 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.
- *Household electricity storage* (physical energy system): Electrical power storage in home batteries with the purpose of allowing consumers to use power at different times than when it is produced or bought from the grid.
- *Vehicle-to-Grid* (physical energy system): Electrical power storage in the batteries of electric vehicles (EV) with the aim of improving the grid stability. Households owning an EV can store power their car's battery from micro-generation surplus or from the grid off-peak hours and send the electricity back to the grid during demand peaks or to the households themselves when they need it.

2. *What ethical values are associated with smart grid systems in the current academic literature?*

Based on the literature review performed in this research, 26 ethical values that can be associated with SGSs in general are identified and conceptualized (see Table 4). This set of values is used as sensitizing concepts, meaning that they provide input for the empirical data analysis and at the same time are open to possible changes (e.g. new values and changes in conceptualization). The values are not explicitly mentioned in the literature, but came forward as factors for technology adoption in the form of barriers/pitfalls/risks/threats or drivers/benefits/opportunities of SGSs. Thus, according to the reviewed academic literature in this research, the following values are associated with SGSs:

1. Accountability/Traceability
2. Autarky
3. Calmness
4. Control/Autonomy
5. Cooperation
6. Courtesy
7. Democracy
8. Distributive justice
9. Economic development
10. Environmental sustainability
11. Freedom from bias
12. Health and Safety
13. Honesty/Integrity
14. Identity
15. Informed consent
16. Legitimacy
17. Ownership/property
18. Privacy
19. Procedural justice
20. Quality of life/Well-being/Comfort
21. Reliability
22. Security
23. Security of supply
24. Transparency/Accuracy
25. Trust
26. Universal usability/Inclusiveness

From the reviewed literature, no values could specifically be associated with smart grid stakeholders since it mainly focuses on consumer behaviour and perceptions regarding the acceptance of different smart grid technologies. Nevertheless, based on the literature consulted in this research, ethical values could be related to specific smart grid technologies:

- *Demand Response:* economic development, environmental sustainability, health and safety, privacy, quality of life/well-being/comfort, reliability, and security of supply.
- *Smart Metering:* control/autonomy, economic development, environmental sustainability, health and safety, identity, informed consent, privacy, procedural justice, quality of life/well-being/comfort, reliability, security, security of supply, transparency/accuracy, and trust.
- *Smart Homes:* control/autonomy, economic development, environmental sustainability, health and safety, privacy, quality of life/well-being/comfort, reliability, security, trust, and universal usability/inclusiveness.
- *Household electricity storage:* autarky, reliability, and security of supply.
- *Vehicle-to-Grid:* autarky, reliability, and security of supply.

3. *What ethical values are associated with smart grid systems in the UK according to the empirical data?*

In order to study what ethical values underlie the British public debate on SGSs, the values at stake embedded in the empirical data are uncovered with the aid of the values identified and defined based on the literature. Stakeholder perspectives in the newspaper articles are the source to identify value-laden statements of SGSs and derive ethical values that can be associated with these innovations in the UK. According to the empirical data, 21 ethical values can be associated with SGSs. These values are:

1. Accountability/traceability
2. Autarky
3. Calmness
4. Control/Autonomy
5. Courtesy
6. Distributive justice
7. Economic development
8. Environmental sustainability
9. Health and Safety
10. Honesty/Integrity
11. Legitimacy
12. Ownership/property
13. Privacy
14. Procedural justice
15. Quality of life/well-being/comfort
16. Reliability
17. Security
18. Security of supply
19. Transparency/Accuracy
20. Trust
21. Universal usability/inclusiveness

On a more specific level, ethical values can be related to specific smart grid technologies, based on the empirical data:

- *Demand Response:* control/autonomy, distributive justice, economic development, environmental sustainability, health and safety, quality of life/well-being/comfort, reliability, security of supply, and transparency/accuracy.
- *Smart Metering:* can be associated with all values identified in the empirical data, except autarky.
- *Smart Homes:* autarky, control/autonomy, economic development, environmental sustainability, privacy, transparency/accuracy, and universal usability/inclusiveness.
- *Household electricity storage:* autarky, control/autonomy, economic development, environmental sustainability, security of supply, and transparency/accuracy.
- *Vehicle-to-Grid:* autarky, control/autonomy, economic development, environmental sustainability, reliability, security of supply, and transparency/accuracy.

Besides, the empirical data allows to specifically relate ethical values to the different stakeholder groups:

- *Energy consumers:* can be associated with all values identified in the empirical data, except accountability/traceability.
- *Governmental bodies and policy-makers:* control/autonomy, courtesy, distributive justice, economic development, environmental sustainability, health and safety, legitimacy,

procedural justice, quality of life/well-being/comfort, reliability, security, security of supply, transparency/accuracy, trust, and universal usability/inclusiveness.

- *The media:* can be associated with all values identified in the empirical data, except calmness and universal usability/inclusiveness.
- *Energy companies:* control/autonomy, courtesy, distributive justice, economic development, environmental sustainability, legitimacy, procedural justice, quality of life/well-being/comfort, security of supply, transparency/accuracy, trust, and universal usability/inclusiveness.
- *Environmental organizations:* economic development and environmental sustainability.
- *Trade associations:* control/autonomy, economic development, legitimacy, security of supply, and transparency/accuracy.
- *Consumer organizations:* control/autonomy, courtesy, distributive justice, economic development, environmental sustainability, health and safety, legitimacy, privacy, procedural justice, quality of life/well-being/comfort, reliability, transparency/accuracy, and trust.
- *Supporting organizations for smart grid development:* autarky, control/autonomy, economic development, environmental sustainability, health and safety, privacy, reliability, security, security of supply, transparency/accuracy, trust, and, universal usability/inclusiveness.
- *TSOs:* control/autonomy, economic development, environmental sustainability, ownership/property, security of supply, and transparency/accuracy.
- *Knowledge institutions:* distributive justice, economic development, environmental sustainability, ownership/property, privacy, reliability, security, security of supply, transparency/accuracy, and trust.

4. *How are the identified values related to each other?*

The type of relationship (i.e. supporting or conflicting) is established through comparing and integrating the findings of the literature review and the content analysis. Integration of these findings regarding sub-systems (i.e. smart grid technologies) relative to values shows that dissimilarities exist in perception of values per sub-system. Even so, this does not cause any conflicting relations since the dissimilarities are specific to attributes of the sub-systems and do not clash among the different interpretations of a value per smart grid technology.

In addition, intra-value conflicts are identified between the shared values among stakeholder groups, as their understanding and interpretations differ significantly. These are presented in Table 21 of Appendix G, consisting of valence and value interpretations. The values pertaining an intra-value conflict are presented as purple coloured values in Figure 17, being the following:

- Ownership/Property
- Control/Autonomy
- Courtesy
- Distributive justice
- Economic development
- Health and Safety
- Legitimacy
- Privacy
- Procedural justice
- Quality of life/Well-being/Comfort
- Reliability
- Security
- Transparency/Accuracy
- Trust
- Universal usability/Inclusiveness

In addition, inter-value conflicts are identified addressing the need for value trade-offs to accommodate them in the technological and/or institutional design of SGSs. These conflicts are depicted in Figure 17 (see red arrows). The inter-conflicting values are the following:

- Universal usability/Inclusiveness and Distributive justice
- Health and Safety and Distributive justice
- Distributive justice and Economic development
- Economic development and Distributive justice
- Distributive justice and Trust
- Economic development and Trust
- Economic development and Procedural justice
- Economic development and Courtesy
- Procedural justice and Reliability
- Reliability and Economic development
- Reliability and Trust
- Reliability and Security
- Reliability and Transparency/Accuracy
- Transparency/Accuracy and Privacy
- Environmental sustainability and Privacy
- Environmental sustainability and Security of supply

Next to the conflicting relationships, also supporting relations are established. These are presented in Figure 17 (see black arrows). The following values entail supporting relations:

- *Accountability/Traceability* contributes to Environmental sustainability
- *Autarky* contributes to Economic Development, Security of supply, and Environmental Sustainability
- *Control/Autonomy* contributes to Environmental Sustainability, Economic Development, Security of supply, and Privacy
- *Courtesy* contributes to Quality of life/Well-being/Comfort and Calmness
- *Distributive justice* contributes to Economic Development and Courtesy
- *Economic Development* contributes to Environmental Sustainability, Transparency/Accuracy, Security of supply, and Universal usability/Inclusiveness
- *Environmental sustainability* contributes to Economic Development and Security of supply
- *Honesty/Integrity* contributes to Economic Development and Distributive Justice
- *Legitimacy* contributes to Economic Development
- *Ownership/Property* contributes to Economic Development and Privacy
- *Procedural justice* contributes to Courtesy, Quality of life/Well-being/Comfort, Distributive Justice, Economic Development, Control/Autonomy, and Distributive Justice
- *Quality of life/Well-being/Comfort* contributes to Control/Autonomy and Economic Development
- *Reliability* contributes to Security of supply, Distributive Justice, and Security
- *Security of supply* contributes to Economic Development
- *Security* contributes to Trust and Privacy
- *Transparency/Accuracy* contributes to Economic Development, Control/Autonomy, Accountability/Traceability, Environmental Sustainability, and Trust
- *Trust* contributes to Economic Development
- *Universal usability/Inclusiveness* contributes to Control/Autonomy, Economic Development, and Transparency/Accuracy

The validated network of related values is shown in Figure 17 and illustrates all related values and the type of relations.

6.1.2. The main research question

What ethical values underlie the British public debate on smart grid systems and what relationships among the values can be identified?

This research has shown that ethical values are intrinsic to the design of SGSs and that these novel energy systems are crucial to facilitate the transition to a low carbon electricity system. Furthermore, the findings indicate that ethical values can be characterized as relevant factors in the form of drivers and barriers for SGSs adoption. Therefore, designers should take into account ethical considerations because the way technologies are designed determines, for better or for worse, its effects on people (Roeser, 2012). Moreover, the lack of a serious consideration of ethical and societal concerns might fuel the resistance of stakeholders towards the implementation of SGSs and its emerging technologies. This seems to be a challenge, as there is currently limited attention paid to ethical values as factors for technology acceptance in general, and specifically to SGSs (Milchram & van de Kaa, 2017).

In this research, the media, specifically British national newspapers, represents the British public debate on SGSs. According to this empirical data source, the values that are at stake for SGSs and thus underlie its public debate in the UK are: *Accountability/Traceability, Autarky, Calmness, Control/Autonomy, Courtesy, Distributive justice, Economic development, Environmental sustainability, Health and Safety, Honesty/Integrity, Legitimacy, Ownership/property, Privacy, Procedural justice, Quality of life/well-being/comfort, Reliability, Security, Security of supply, Transparency/Accuracy, Trust,* and *Universal usability/Inclusiveness.* Their conceptualization is presented in Table 4. Furthermore, the public debate shows that the most prevalent stakeholders are energy consumers, governmental bodies and policy-makers, the media, and energy companies since they are the ones bringing forth the most value-laden statements about SGSs. It is also noticeable that value-laden statements from all stakeholder groups involved are often mentioned with both a positive and negative valence. This causes controversies on how ethical values are supported or hindered by smart grids and its components.

This research concludes that interrelations among values increases the complexity of determining their effect on SGSs adoption. The following values pertain a supporting relationship and thus contribute to one or more other values: *Accountability/Traceability, Autarky, Control/Autonomy, Courtesy, Distributive justice, Economic Development, Environmental sustainability, Honesty/Integrity, Legitimacy, Ownership/Property, Procedural justice, Quality of life/Well-being/Comfort, Reliability, Security of supply, Security, Transparency/Accuracy, Trust,* and *Universal usability/Inclusiveness.* In addition, conflicting value relationships are identified. To start with, 16 inter-value conflicts are identified between the values of *Universal usability/Inclusiveness and Distributive justice, Health and Safety and Distributive justice, Distributive justice and Economic development, Economic development and Distributive justice, Distributive justice and Trust, Economic development and Trust, Economic development and Procedural justice, Economic development and Courtesy, Procedural justice and Reliability, Reliability and Economic development, Reliability and Trust, Reliability and Security, Reliability and Transparency/Accuracy, Transparency/Accuracy and Privacy, Environmental sustainability and Privacy,* and *Environmental sustainability and Security of supply.* Besides, intra-value conflicts are identified due to significant differences in value understanding and interpretation amongst stakeholder groups, which give rise to concerns and controversies regarding the following values: *Ownership/Property, Control/Autonomy, Courtesy, Distributive justice, Economic development, Health and Safety, Legitimacy, Privacy, Procedural justice, Quality of life/Well-being/Comfort, Reliability, Security, Transparency/Accuracy, Trust,* and *Universal usability/Inclusiveness*.

The validated network of related values that can be associated to SGSs in the UK is presented in Figure 17. In this figure, values pertaining an intra-value conflict are presented as purple coloured values. Inter-value conflicts are depicted with red arrows and a - sign. Supporting relations are illustrated with black arrows and a + sign. The nature of these relationships is based on overlapping value conceptualizations in and among the newspaper articles and stakeholder interpretations. As can be seen from Figure 17, there is a clear division of mutually reinforcing and counteracting values, in addition to the intra-value effect, which depends on which actor perceives this. I emphasize that the degree of reinforcement/opposition depends on the perspective of the relevant actor. This provides an indication on how complex such value networks are.

6.2. Scientific relevance

This research has shown that social concerns related to SGSs and benefits that come forth in the public debate underlie ethical values. However, the majority of current literature (at least the one reviewed in this research) do not provide a conscious investigation of values; rather, values emerge (without being made explicit) as barriers/pitfalls/risks/threats or benefits/drivers/opportunities of different smart grid technologies. Therefore, the following knowledge gap is considered in this research:

So far there have been no studies that identified empirically, and for a British context, the values at stake and their relations (supportive or conflicting) in the public debate on smart grid systems, whilst understanding and consideration of public values (i.e. values that are held in society) is important for the ethical acceptability of smart grid systems and affects the societal acceptance needed for technology adoption.

The contribution of this thesis to the knowledge gap and literature is that it empirically studies the normative stances of different smart grid stakeholders in the UK, rather than focusing on the consumers only (as the majority of current literature does). By doing so, ethical values are retrieved (for different smart grid stakeholders) and specifically conceptualized for SGSs. These are valuable insights that can serve as input for implementing normative considerations into the technical and institutional design of SGSs. Thus, promoting ethical values as an integral part of the design of SGSs in order to pursuit value-robust smart grids and its related institutions. The conceptualization of SGSs entails a theoretical contribution as there is still no certain description in the academic literature of what SGSs are and which technologies they comprise (Buchanan et al., 2016; Connor et al., 2014; Krishnamurti et al., 2012; Muench et al., 2014; Paetz et al., 2012; Verbong et al., 2013). Furthermore, the relation amongst the identified values is established in this research project, which has not been done before in previous studies and thus adds to the literature. Moreover, the empirical information about the normative stances (i.e. ethical values) of stakeholders in this thesis contributes to the applicability of the VSD approach. This research applied this method to the energy domain while it used to be mainly deployed in the ICT domain regarding human and computer interaction (Friedman & Kahn Jr, 2003; Friedman et al., 2013). Additionally, the conceptualization of ethical values in the context of SGSs contributes to the specification of ethical values that come forth in the VSD literature. Furthermore, this research has proven that the application of the Value Hierarchy approach is an effective method with respect to identifying normative stances in newspaper articles related to the public debate in the UK on SGSs. Lastly, this thesis contributes to literature in the field of technology acceptance, as the findings enhance understanding of what normative stances motivate people's intention to adopt specific technologies such as SGSs. The outcomes of the British public debate regarding SGSs make relevant values explicit as well as their relation and necessary trade-offs, which can be subjected to the public discourse and drive the technological and institutional design of SGSs (and its redesign if necessary) to accommodate public values (Taebi et al., 2014).

6.3. Societal relevance

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). Innovations such as SGSs are meant to serve the needs of society (in terms of affordable and secure electricity supply) and therefore must reflect its values in order to be responsible. Therefore, it is imperative to identify values that can be associated with these emerging innovations to provide input to policy-makers and the energy industry and aid these stakeholders in identifying opportunities for value creation through innovative energy systems that are in the public interest and are pursuit to be responsible. Moreover, the governance framework of the British government and that of the energy industry can be shaped/enhanced based on insights into values and their interrelations in order to encourage responsible innovation of energy systems.

As this research has shown, ethical concerns regarding SGSs are mostly expressed in terms of social values. These values are at stake in the design of technologies as well as in the process of their deployment (Dignum et al., 2016), especially regarding major technological projects with significant societal impacts such as smart grid development. Therefore, it is urgent for policy-makers and the energy industry to consider social values in the institutional and technical design of SGSs. This, in order to develop and implement technology and related institutions that are ethically and socially acceptable. This also aids decision-makers on both governmental and industrial level to understand which value trade-offs certain decisions involve and which social cost/burden or social benefit might be linked to different design options of SGSs. Moreover, insights into social values related to SGSs allow policy-makers and energy industry to better understand social repercussions and controversies about SGSs. By doing so, value sensitive design of technology and institutions can be reached, but also the social perception can be positively influenced as some misunderstandings can emerge due to lack of knowledge or proper information. The initial expectations about SGSs that are held or developed by local people in the UK, might potentially shape the extent to which they seek more information on these emerging innovations, talk to others about it, read newspaper reports, become concerned in any way, and attend meetings e.g. on decision-making or information provision. Hence insights into social repercussions and controversies through value sensitive design can potentially aid these actors to shape initial expectations of the public about SGSs and collaboratively tackle challenges for implementation in the UK and jointly work towards public support.

From the research results appeared that SGSs are novel and therefore unfamiliar to some of the British public. For instance, the empirical study of Krishnamurti et al. (2012) shows that 70% of the respondents want a smart meter whilst 50% reported no prior knowledge of this smart grid technology. Furthermore, the content analysis results show that the majority of the identified values are contested. Therefore, policy-makers are suggested to provide the public with more clarity and details on how changes in the current electricity system will affect society and which changes are required now and in the future. Moreover, the government should take away regulatory barriers (if there are any) faced by the energy industry and provide signals to the energy market on the importance of SGSs, thereby unlocking further investment in this specific sector and providing legislative incentives as well as state support (e.g. subsidy frameworks). This might aid tackle concerns on fairness regarding distribution of smart grid technology costs amongst energy suppliers and consumers. Besides, this research shows that the willingness of consumers to adapt their behaviour and activities related to energy consumption are paramount to realize the benefits offered by SGSs. In this context, it is also paramount that the government shows best practices, for instance by demonstrating application of smart grid technologies in its buildings to motivate and inspire consumers to do so.

In addition, this research shows that the role of consumers has been often neglected during the energy transition (Blok, 2015). Therefore, the energy industry is advised to keep consumers close to their hearts and focus more on protecting them and their needs by ensuring sufficient investments in the power network to protect against potential risks, such as cyber-security and security of supply. This might restore trust and enhance cooperation between these key actors. In addition, both policy-makers and the energy industry should be more careful with their normative stance that smart grid systems are actually a good thing, because what if others are right about their concerns? This also addresses the need of close cooperation among the different stakeholders and greater engagement in order to jointly help ensure that the UK can make the most out of smart grids and its related technologies as well as institutions. This offers opportunities for the UK to become a world leader in climate change mitigation and smart grid development. Another opportunity that should be taken by the government and energy industry is to further invest and deploy energy storage technologies as it allows more connection to the current energy infrastructure and offers off-grid opportunities. It was noticeable that energy storage is one of the least mentioned smart grid components in both the scientific literature and newspaper articles, whilst it is in essence the security of supply lock to keep the energy system operating, especially now as the share of renewables and distributed generations have growth. One of the reasons might be that people are not familiar with it and do not know yet much about power storage technologies as it is recently being developed and up taking.

Furthermore, the network of related values (see Figure 17) serves as input for debate. 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. Moreover, the network of related values 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 established conflicting and supporting relations amongst values associated with SGSs, show the energy industry and policy-makers which values contribute to the enhancement or achievement of other values and which ones raise repercussions and controversies, needing value trade-offs. The network of values 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. In addition, the methodology used to establish this network of related values is universal and can be applied to other fields and socio-technical contexts. However, values (and thus this network) are specific to technological and institutional features of smart grid systems as the value conceptualisation (based on VSD and SGSs literature) highly depends on the socio-technical context and is thus specific to SGSs. Nevertheless, we should all strive for value-robust SGSs and keep in mind that ethics is not just a constraint but also a source of technological development and this technological progress can create moral progress rather than just moral issues (van den Hoven et al., 2012).

6.4. Limitations and suggestions for future academic research

Through reflecting on limitations of this research and identifying emerging research opportunities, suggestions for future academic research are provided in this section.

First of all, evolution in the electricity system is taking place, mainly due to sustainability policies and climate change concerns. As this research has shown, this is visible in the national commitment of the UK to reduce their carbon footprint and use energy efficiently with the aid of smart grid development and deployment. The findings for the UK case can deliver valuable insights for other countries (Buchanan et al., 2016; Muench et al., 2014; Römer et al., 2012), especially to those having well-developed electricity systems in a deregulated market (Xenias et al., 2015; Zhou & Brown, 2017). Of course, it has to be noticed that values and norms are subject to cultural differences (per country and even within a country) and form the basis of consumer motivation and behaviour towards SGSs and its components (Chou et al., 2015). Nevertheless, it is worthwhile for this research to take a first step in capturing social barriers and drivers in the form of ethical values, which underlie the British public debate on SGSs. Hence, the methodology used in this thesis is generalizable to any type of context. However, in terms of content, the case selection of the UK for this thesis might limit the findings of this research to developed nations with a liberalized energy market. Moreover, the outcomes of this thesis might only be generalizable (to a certain extent) for socio-technical systems similar to SGSs. As aforementioned, specific values belong to a specific context due to the influence of contextual factors on public engagement such as policy (international, national, regional, and local), business, places, and cultures (Walker et al., 2011). This means that values associated with SGSs emerge and evolve in a dynamic societal process in which SGSs are developed and implemented and in which stakeholders interact in specific contexts (Correljé et al., 2015). This is acknowledged by the VSD approach as the perception of what is acceptable can change over time (Correljé et al., 2015; Walker et al., 2011). Hence, the VSD approach is not a blueprint, but it rather targets a specific context (Correljé et al., 2015) as well as the degree of sensitivity to public responses regarding novel energy technologies (Walker et al., 2011). As the scope of this research solely lies on the British public debate on SGSs, 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. Thus, incorporating more case studies of SGSs, not only in the UK.

Another limitation is the time scope of this research, with empirical data form the period 2007-2017, as studying the public debate on SGSs for a longer period of time could lead to new insights into values and their interrelations. Moreover, it is recommended to take the dynamics of the public debate into consideration and study whether and how ethical values change over time. Morality has been subject to coevolution due to advanced intelligence, which has allowed humans to perceive the benefits that consideration of moral norms bring to society as a whole (Avise & Ayala, 2010). Following this reasoning, it can be argued that moral values have a dynamic and co-evolving character since *"values emerge and evolve during the development and implementation of technologies"* (Taebi et al., 2014, p.119). This implies that a shift in ethical values can occur over time in the British public debate on SGSs. According to Sauter and Watson (2007) and Walker et al. (2011), the public debate might constrain the implementation of technologies. Therefore, it is important 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.

This research is based on a content analysis of British national newspaper reports to investigate the public perspectives on SGSs and its related values. However, it can be questioned whether or not the media, and especially this type of media (i.e. newspapers), provides a proper representation of society and thus the public debate. It is generally acknowledged that news can and ought to be objective in order to reflect social reality (Hackett, 1984). Hence, newspapers seek to tell the truth. Yet, how objective are journalists and in what extent do they tell the truth in terms of social reality? In what extent are they biased by their own political attitudes or personal ideology? To what extent do journalists make efforts to verify the statements they make? For future research, it is recommended to also code the value-laden statements that come forth in the literature as well as that of governmental publications (from the desk research). This might make the analysis more representative of the actual public debate. In addition, it is suggested to investigate values relative to the newspaper types (i.e. popular and quality press) to see whether remarkable distinctions can be made, as the newspaper might differ in their political orientation. Besides, instead of a content analysis, a discourse analysis can be performed to study discourses between stakeholders in the public debate on SGSs as well as the life cycle of their arguments. This can contribute to study value conflicts more in detail. The source for performing the discourse analysis can be newspaper reports as considered in this research project. Alternative sources can be academic literature, documents from government agencies, mission statements, statutes and strategic plans. However, these alternative sources are not able to sufficiently capture public values that emerge during the process of innovation, development and implementation of technologies (Taebi et al., 2014). The reason is that innovative technologies, such as SGSs, can give rise to effects and consequences that have not yet been captured and discussed in such sources (Taebi et al., 2014).

Another limitation of this research is that it presents necessary value trade-offs for the design of SGSs, but it does not provide input on how these trade-offs actually can be made. Therefore, it can be suggested to investigate prioritization of the values among stakeholder groups in future research. For this purpose, the Best-Worst Method (BWM) by Rezaei (2015, 2016) can be applied or other multi-criteria decision-making methods in order to add importance in terms of "weights" to values per stakeholder group. Thereby, quantification of ethical values for the different stakeholders can be achieved. This could be done through e.g. consultation of stakeholders by means of workshops or interviews and then comparing their value preferences. This will contribute to trading-off values in the institutional and technical design of SGSs. Besides, a cost-benefit analysis can be carried out, which compares both costs and benefits for the UK in term of SGSs implementation. Building on the quantification of ethical values, game theory can be applied in future research. Game theory is defined as a bag of analytical tools designed to help us understand phenomena that we observe when decision-makers interact (Osborne & Rubinstein, 2000). Within game theory, coalitional games are distinguished, being a model of interacting decision-makers that focuses on the behaviour of groups of players. One of the purposes is to define the so-called core of the coalitional game. The core is the set of all stable actions (i.e. no coalition can break away and choose an action that all its members prefer) of the grand coalition (i.e. coalition of all the players) (Osborne & Rubinstein, 2000). With this in mind, future research is suggested to apply the notion of a coalitional game to the ethical values identified in this research project. This implies that after quantification of these ethical values (e.g.

through the BWM), these values could be considered as the players in a coalitional game. The game theoretical concept of the core can then be deployed in order to determine what the core ethical values are. This method allows to determine which ethical values would be considered essential to maximize the utility that SGSs design can offer to the smart grid stakeholders. As people have values or preferences that drive their action, the application of game theory to ethical values might result in a solid understanding of the most important/essential values for the technical and institutional design of SGSs.

Furthermore, it is worthwhile for future research to consider the findings of this research and apply the method of wide reflective equilibrium (WRE) as introduced by Rawls (1971) and developed by Daniels (1996). By doing so, the empirical findings of this research project can be merged with ethical analyses and deliberation related to SGSs. For instance, the values that are derived from the normative stances of smart grid stakeholders in the UK through empirical research can be presented to the smart grid stakeholders in order to acquire feedback on the identified values and perform an ethical deliberation. This implies working back and forth among judgements of the researcher (based on the findings of this research project) and the stakeholders. By doing so, input from stakeholders can be used for an iterative loop of ethical reflection. The aim is to achieve an acceptable coherence amongst the judgements and consensus, or at least reasonable disagreement on ethical values that are essential to be embedded in SGSs design.

This research has limited itself to identify and conceptualize ethical values that can be associated with SGSs and to establish the type of relations amongst these values. Yet, a further step needs to be taken in order to determine what these value relationships mean for the design of smart grids. Therefore, it is recommended for future research to use the identified values and their interrelations for translation into specific design requirements of SGSs. For this purpose, the Value Hierarchy approach by van de Poel (2013) can be used. Another interesting point in the future research agenda would be to study the impact of institutional changes in the public debate, as institutions address the importance of values. This research only considered major events in the newspaper articles' topics.
Regarding the validation efforts in this research, it can be recommended to extend those, as it was not possible due to time constraints and availability of experts. Moreover, the validation requires knowledge about SGSs and also preferably know-how related to the ATLAS.ti software to be able to dive into the data. One independent coder performed the validation of the coding, three experts validated the initial list of values and their conceptualization, and one expert validated the network of related values. Future research work should be devoted to further validation of the supporting and conflicting relationships among the identified values and to study whether the network actually changes depending on perspectives of different actors. The validation can be performed through consultation of more experts and stakeholders from the identified stakeholder groups for face validation purposes in the form an interview (as is done for this research with one expert) or a workshop. Besides, the inter-coder reliability could be extended to more than one independent coder.

Lastly, future research can focus on simulation and modelling of the acceptance of SGSs through e.g. agent-based modelling and system dynamics. Agent-based modelling can focus on (emergent) behaviour and attributes of individuals (i.e. agents) that take decisions and perform actions regarding the adoption of SGSs. The agents interact with their environment and take decisions to pursuit their own goals. The values discerned in this research project can provide input for ABM in terms of attributes of different agents. Then, experiments can be performed though ABM that help understand the complexity of SGSs in terms of interaction between the social network (i.e. agents) and the physical network (i.e. smart grids and related technologies as physical assets). Furthermore, this method could also cast some light into the relative impact of different ethical values on smart grid development processes in institutions. Moreover, ABM can provide decision support for steering this complex socio-technical system (van Dam, Nikolic, & Lukszo, 2012) for instance regarding redesign of the technical system, but also new policies, regulations and investment strategies that concern smart grid adoption. System dynamics (SD) can be used to explore the effects of different smart grid policy options under uncertainty. By doing so, the effectiveness of several policies that support smart grid development can be assessed though systematic inclusion of uncertainty in simulation models. This uncertainty concerns the evolving character of values and the dynamics of the public debate (i.e.

how stakeholder arguments change over time). The network of related values established in this research can be considered as the basic structure of a SD model, i.e. a causal loop diagram that is characterized by feedback loops amongst the ethical values. In addition, SD models might aid in identifying new policies or support policy interventions by analysing its long-term effects. Moreover, 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 in a certain environment. The aim is to analyse and determine social structures and to identify potential partnerships among smart grid stakeholders to effectively incorporate ethical values in SGSs.

6.5. Reflection on this research project and my MSc programme

During my masters, I followed the specialization *"Infrastructure and Environmental governance"*. Due to my interest in sustainability I followed the course *"Climate Change: Science and Ethics"*, which confirmed what type of thesis project I would love to do. My interest in sustainability relates to my concern of the public awareness on this topic. Moreover, I feel a responsibility for doing something about it with the resources (i.e. education) that I have in order to contribute to a better world. This is how I got very interested in several research projects that Dr. Geerten van de Kaa was supervising, especially this specific one. I argue that design for values in SGSs fits the MSc. programme Complex Systems Engineering and Management (CoSEM). First of all, this research project is centred around analysis of ethical values (as relevant factors for technology adoption) that might aid in enhancing the technical and institutional design of SGSs: a complex socio-technical system. For instance, our society depends on complex systems such as infrastructures for energy, e.g. the electricity grid. This research project focuses on a broader field than technology alone through studying the normative stances (i.e. ethical values) of different smart grid stakeholders. Furthermore, this research project can serve as input for modelling and simulations studies such as ABM and SD, as presented in the previous section. In addition, a game theoretical approach could also be used with the findings of this research. These methods are taught during the CoSEM programme and can be thus linked to the outcomes of this research. After all, this thesis has emphasized that when designing innovative technologies such as smart grids, we need to deal with institutions and human behaviour. These are aspects that should form the core of how to design socio-technical systems (as it is taught in the curriculum). Hence, SGSs are not only technologically complex, but also involve many parties that usually have divergent stakes, which can relate to ethical issues. This lies at the heart of the master programme. Therefore, this research project can be considered a typical CoSEM master thesis since it takes into account public values and looks at the physical energy system as well as the actor network. Hereby we confront not only technical challenges, but also ethical choices.

The reflection on the process and content of this research is presented in the previous section. However, I would like to emphasize that the process of gathering and preparing the empirical data was tedious due to restrictions and limitations of the Factiva digital database. For instance, Factiva does not facilitate any data export to e.g. Excel. For that reason, the documents needed to be downloaded in rich text format in order to copy/paste them in Excel for data cleaning purposes. Furthermore, this database does not allow the download of more than 100 newspaper articles at a time. Therefore, these had to be downloaded a set of 100 each time, until reaching the 3,546 articles needed for the content analysis. Another issue encountered was that similar duplicates were included in the data, being articles from the same date and newspaper, with the same content, only differing in the amount of words or headline. Due to these small differences Factiva did not remove them from the search results by applying the filter "Duplicates: Identical" and thus had to be identified and removed manually. While doing so, their content was checked in the database to ensure that they had indeed the same content. The article with the highest word count is kept for sampling. If the similar duplicates have the same word count, the one with the most complete headline is selected to be part of the population. This was a tedious but worthy work from which 3,354 unique newspaper articles are retrieved to be sampled.

This thesis has proven the value of working in inter-disciplinary teams. The different expertise, knowledge, and skills within my Graduation Committee helped me endorse my research project. I have learned many new things such as the importance of patience and perseverance as well as a new research method (qualitative content analysis) that I have not been taught during my curriculum. To conclude, I have been lucky to perform a research that I love with an incredible team of experts that offered their guidance and support throughout this research project.

References

ABC. (2017). Data search: National newspapers. Retrieved from British Audit Bureau of Circulations website: https://www.abc.org.uk/product?a=abc&search=national+newspapers

ADE. (2017). About ADE. Retrieved from Association for Decentralised Energy website: https://www.theade.co.uk/about

Avise, J. C., & Ayala, F. J. (2010). *In the Light of Evolution: Volume IV: The Human Condition* (pp. 428). Retrieved from https://www.nap.edu/catalog/12931/in-the-light-of-evolution-volume-iv-the-human-condition

Balta-Ozkan, N., Davidson, R., Bicket, M., & Whitmarsh, L. (2013). Social barriers to the adoption of smart homes. *Energy Policy, 63*, 363-374. doi:http://dx.doi.org/10.1016/j.enpol.2013.08.043

Barnicoat, G., & Danson, M. (2015). The ageing population and smart metering: A field study of householders' attitudes and behaviours towards energy use in Scotland. *Energy Research & Social Science, 9*, 107-115. doi:http://dx.doi.org/10.1016/j.erss.2015.08.020

BEAMA. (2017). About BEAMA. Retrieved from British Electrotechnical and Allied Manufacturer's Association website: http://www.beama.org.uk/about-beama.html

BEIS. (2017). Department for Business, Energy & Industrial Strategy. Retrieved from British Government website: https://www.gov.uk/government/organisations/department-for-business-energy-and-industrial-strategy

Bianchi, M., Branchini, L., De Pascale, A., & Melino, F. (2014). Storage Solutions for Renewable Production in Household Sector. *Energy Procedia, 61*(Supplement C), 242-245. doi:https://doi.org/10.1016/j.egypro.2014.11.1098

Bigerna, S., Bollino, C. A., & Micheli, S. (2016). Socio-economic acceptability for smart grid development – a comprehensive review. *Journal of Cleaner Production, 131*, 399-409. doi:http://dx.doi.org/10.1016/j.jclepro.2016.05.010

Blok, K. (2015). De verwaarloosde kant van het energiesysteem - Intreerede 16 september 2015. Retrieved from Delft University of Technology website: https://www.tudelft.nl/en/tpm/about-the-faculty/departments/engineering-systems-and-services/people/full-professors/profdr-k-kornelis-blok/

Blumer, H. (1954). What is wrong with social theory? . *American Sociological Review, 18*, 3-10.

Bonino, D., & Corno, F. (2011). What would you ask to your home if it were intelligent? Exploring user expectations about next-generation homes. *Journal of Ambient Intelligence and Smart Environment, 3*(2), 111-126. doi:10.3233/AIS-2011-0099

Bradford, A. (2017). Deductive Reasoning vs. Inductive Reasoning. Retrieved from Live Science website: https://www.livescience.com/21569-deduction-vs-induction.html

Brown, M. A., & Zhou, S. (2013). Smart-grid policies: an international review. *Wiley Interdisciplinary Reviews: Energy and Environment, 2*(2), 121-139. doi:10.1002/wene.53

Buchanan, K., Banks, N., Preston, I., & Russo, R. (2016). The British public's perception of the UK smart metering initiative: Threats and opportunities. *Energy Policy, 91*, 87-97. doi:http://dx.doi.org/10.1016/j.enpol.2016.01.003

Buryk, S., Mead, D., Mourato, S., & Torriti, J. (2015). Investigating preferences for dynamic electricity tariffs: The effect of environmental and system benefit disclosure. *Energy Policy, 80*, 190-195. doi:http://dx.doi.org/10.1016/j.enpol.2015.01.030

Chou, J.-S., Kim, C., Ung, T.-K., Yutami, I. G. A. N., Lin, G.-T., & Son, H. (2015). Cross-country review of smart grid adoption in residential buildings. *Renewable and Sustainable Energy Reviews, 48*, 192-213. doi:http://dx.doi.org/10.1016/j.rser.2015.03.055

Christiano, T. (2004). The authority of democracy. *Journal of Political Philosophy, 12*(3), 266–290. doi:10.1111/j.1467-9760.2004.00200.x

Connor, P. M., Baker, P. E., Xenias, D., Balta-Ozkan, N., Axon, C. J., & Cipcigan, L. (2014). Policy and regulation for smart grids in the United Kingdom. *Renewable and Sustainable Energy Reviews, 40*(Supplement C), 269-286. doi:https://doi.org/10.1016/j.rser.2014.07.065

Correljé, A., Cuppen, E., Dignum, M., Pesch, U., & Taebi, B. (2015). Responsible Innovation in Energy Projects: Values in the Design of Technologies, Institutions and Stakeholder Interactions. In B.-J. Koops, I. Oosterlaken, H. Romijn, T. Swierstra, & J. van den Hoven

(Eds.), *Responsible Innovation 2: Concepts, Approaches, and Applications* (pp. 183-200). Cham: Springer International Publishing.
Cuijpers, C., & Koops, B. J. (2012). Smart metering and privacy in Europe: lessons from the Dutch case. 269-293.
Daniels, N. (1996). *Justice and Justification: Reflective Equilibrium in Theory and Practice*. Cambridge: Cambridge University Press.
Darby, S. (2010). Smart metering: what potential for householder engagement? *Building Research & Information, 38*(5), 442-457. doi:10.1080/09613218.2010.492660
Darby, S. (2012). Metering: EU policy and implications for fuel poor households. *Energy Policy, 49*, 98-106. doi:https://doi.org/10.1016/j.enpol.2011.11.065
Darby, S., Strömbäck, J., & Wilks, M. (2013). Potential carbon impacts of smart grid development in six European countries. *Energy Efficiency, 6*(4), 725-739. doi:10.1007/s12053-013-9208-8
DCC. (2017). About DCC. Retrieved from Data Communications Company website: https://www.smartdcc.co.uk/about-dcc/
DECC. (2014). Impact Assessment: Smart meter roll-out for the domestic and small and medium non-domestic sectors (GB). Retrieved from British Government website: https://www.gov.uk/government/publications/smart-meter-roll-out-for-the-domestic-and-small-and-medium-non-domestic-sectors-gb-impact-assessment
DECC. (2015). *Towards a Smart Energy System*. (URN 15D/493). London: Department of Energy & Climate Change Retrieved from https://www.gov.uk/government/publications/towards-a-smart-energy-system.
Demski, C., Spence, A., & Pidgeon, N. (2013). *Transforming the UK Energy System: Public Values, Attitudes and Acceptability - Summary findings of a survey conducted August 2012*. Retrieved from London: http://www.ukerc.ac.uk/publications/transforming-the-uk-energy-system-public-values-attitudes-and-acceptability-summary-findings-from-a-survey-conducted-august-2012.html
Depuru, S. S. S. R., Wang, L., & Devabhaktuni, V. (2011). Smart meters for power grid: Challenges, issues, advantages and status. *Renewable and Sustainable Energy Reviews, 15*(6), 2736-2742. doi:http://dx.doi.org/10.1016/j.rser.2011.02.039
Dignum, M., Correljé, A., Cuppen, E., Pesch, U., & Taebi, B. (2016). Contested Technologies and Design for Values: The Case of Shale Gas. *Science and Engineering Ethics, 22*(4), 1171-1191. doi:10.1007/s11948-015-9685-6
Dincer, I., & Acar, C. (2016). Smart energy systems for a sustainable future. *Applied Energy*. doi:http://dx.doi.org/10.1016/j.apenergy.2016.12.058
DTI. (2007). *Meeting the Energy Challenge: A White Paper on Energy*. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/243268/7124.pdf.
EC. (2013). Smart Grid projects in Europe: Lessons learned and current developments. Retrieved from European Commision website: https://ec.europa.eu/energy/sites/ener/files/documents/ld-na-25815-en-n_final_online_version_april_15_smart_grid_projects_in_europe_-_lessons_learned_and_current_developments_-2012_update.pdf
EC. (2017a). 2050 Energy strategy. Retrieved from European Commission website: http://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2050-energy-strategy
EC. (2017b). Climate action: 2020 climate & energy package. Retrieved from European Commission website: https://ec.europa.eu/clima/policies/strategies/2020_en
EC. (2017c). Energy Efficiency Directive. Retrieved from European Commission website: https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive
Ellabban, O., & Abu-Rub, H. (2016). Smart grid customers' acceptance and engagement: An overview. *Renewable & Sustainable Energy Reviews, 65*, 1285-1298. doi:10.1016/j.rser.2016.06.021
ENA. (2017a). Electricity Distribution Map. Retrieved from Energy Networks Association (ENA) website: http://www.energynetworks.org/info/faqs/electricity-distribution-map.html
ENA. (2017b). Electricity Transmission Map. Retrieved from Energy Networks Association (ENA) website: http://www.energynetworks.org/info/faqs/electricity-transmission-map.html
ENA. (2017c). Environmental Organisations. Retrieved from Energy Networks Association (ENA) website: http://www.energynetworks.org/info/links/environmental-organisations.html

ENA. (2017d). Government. Retrieved from Energy Networks Association (ENA) website: http://www.energynetworks.org/info/links/government.html

EnergyUK. (2017a). About Energy UK. Retrieved from Energy UK website: http://www.energy-uk.org.uk/about-us.html

EnergyUK. (2017b). Network and supply. Retrieved from Energy UK website: http://www.energy-uk.org.uk/energy-industry/network-and-supply.html

ENSG. (2009). Electricity Networks Strategy Group: A Smart Grid Vision. Retrieved from The National Archives website: http://webarchive.nationalarchives.gov.uk/20100919181639/http://www.ensg.gov.uk/assets/ensg_smart_grid_wg_smart_grid_vision_final_issue_1.pdf

EU. (2009). Directive 2009/72/EC of the European Parliamnet and of the Council of 13 July 2009. Retrieved from European Union Law (EUR-Lex) website: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32009L0072

EU. (2017). Regulations, Directives and other acts. Retrieved from European Union (EU) website: https://europa.eu/european-union/eu-law/legal-acts_en

Evans, G. (2017). What is Micro-Generation? Retrieved from Energy Saving Community website: http://www.energysavingcommunity.co.uk/what-microgeneration.html

Factiva. (2012). Factiva inside out guide. Retrieved from Factiva website: http://factiva.com/en/cp/collateral/files/dj-factivacom-insideout-guide0312.pdf

Fare, X. (2016). Introduction to the UK Smart Grid Sector. Retrieved from Tech UK website: http://www.techuk.org/component/techuksecurity/security/download/325?file=Introduction_to_the_UK_Smart_Grid_Sector.pdf&Itemid=181&return=aHR0cDovL3d3dy50ZWNodWsub3JnL2luc2lnaHRzL3JlcG9ydHMvaXRlbS8zMjUtb3ZlcnZpZXctb2Ytb3VyLXNtYXJ0LWVuZXJneS1wcm9ncmFtbWU=

FES. (2017). About. Retrieved from Future Energy Solutions (FES) website: http://www.future-energy-solutions.com/html/about.htm

Freeman, R. E. (2010). *Strategic management: A stakeholder approach*: Cambridge university press.

Friedman, B., & Kahn Jr, P. H. (2003). Human values, ethics, and design. *The human-computer interaction handbook*, 1177-1201.

Friedman, B., Kahn, P. H., Borning, A., & Huldtgren, A. (2013). Value Sensitive Design and Information Systems. In N. Doorn, D. Schuurbiers, I. van de Poel, & M. E. Gorman (Eds.), *Early engagement and new technologies: Opening up the laboratory* (pp. 55-95). Dordrecht: Springer Netherlands.

Friese, S. (2014). *Qualitative data analysis with ATLAS.ti*: SAGE Publications Inc.

GCHQ. (2017). What we do. Retrieved from Government Communications Headquarters website: https://www.gchq.gov.uk/what-we-do

Geelen, D., Reinders, A., & Keyson, D. (2013). Empowering the end-user in smart grids: Recommendations for the design of products and services. *Energy Policy, 61*, 151-161. doi:http://dx.doi.org/10.1016/j.enpol.2013.05.107

Goulden, M., Bedwell, B., Rennick-Egglestone, S., Rodden, T., & Spence, A. (2014). Smart grids, smart users? The role of the user in demand side management. *Energy Research & Social Science, 2*, 21-29. doi:http://dx.doi.org/10.1016/j.erss.2014.04.008

Government. (2008). *The Climate Change Act 2008*. Retrieved from http://www.legislation.gov.uk/ukpga/2008/27/contents.

Government. (2014a). Consumer Futures closed in April 2014. Retrieved from British Government website: https://www.gov.uk/government/organisations/consumer-focus

Government. (2014b). *Factsheet on smart grid development in the UK*. Retrieved from https://www.gov.uk/government/publications/factsheet-on-smart-grid-development-in-the-uk.

Government. (2015). *Policy paper 2010 to 2015 government policy: household energy - Appendix 7: smart meters*. Retrieved from https://www.gov.uk/government/publications/2010-to-2015-government-policy-household-energy/2010-to-2015-government-policy-household-energy -appendix-7-smart-meters.

Government. (2016). Smart meter roll-out cost-benefit analysis. Retrieved from British Government website: https://www.gov.uk/government/publications/smart-meter-roll-out-gb-cost-benefit-analysis

Government. (2017a). Annual fuel poverty statistics report 2017 (2015 Data) - England. Retrieved from British Government website: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/639118/Fuel_Poverty_Statistics_Report_2017_revised_August.pdf

Government. (2017b). Electricity Networks Strategy Group. Retrieved from British Government website: https://www.gov.uk/government/groups/electricity-networks-strategy-group

Government. (2017c). Smart meters: Quarterly report to end March 2017 Great Britain. Retrieved from British Government website: https://www.gov.uk/government/statistics/statistical-release-and-data-smart-meters-great-britain-quarter-1-2017

Gross, C. (2007). Community perspectives of wind energy in Australia: The application of a justice and community fairness framework to increase social acceptance. *Energy Policy, 35*(5), 2727-2736. doi:http://dx.doi.org/10.1016/j.enpol.2006.12.013

Guerreiro, S., Batel, S., Lima, M. L., & Moreira, S. (2015). Making energy visible: sociopsychological aspects associated with the use of smart meters. *Energy Efficiency, 8*(6), 1149-1167. doi:10.1007/s12053-015-9344-4

Hackett, R. A. (1984). Decline of a paradigm? Bias and objectivity in news media studies. *Critical Studies in Mass Communication, 1*(3), 229-259. doi:https://doi.org/10.1080/15295038409360036

Happer, C., & Philo, G. (2013). The role of the media in the construction of public belief and social change. *Journal of social and political psychology, 1*(1), 321-336.

Harvey, L. (2017). Social Research Glossary: Quality Research International. Retrieved from http://www.qualityresearchinternational.com/socialresearch/blumer.htm

Herkert, J., & Kostyk, T. (2015). Societal Implications of the Smart Grid: Challenges for Engineering. In S. H. Christensen, C. Didier, A. Jamison, M. Meganck, C. Mitcham, & B. Newberry (Eds.), *Engineering Identities, Epistemologies and Values: Engineering Education and Practice in Context, Volume 2* (pp. 287-306). Cham: Springer International Publishing.

Hodgson, G. M. (2006). What Are Institutions? *Journal of Economic Issues, 40*(1), 1-25. doi:10.1080/00213624.2006.11506879

Hu, T.-W. (2014). Unpredictability of complex (pure) strategies. *Games and Economic Behavior, 88*, 1-15. doi:http://dx.doi.org/10.1016/j.geb.2014.08.002

Huijts, N. M. A., Molin, E. J. E., & Steg, L. (2012). Psychological factors influencing sustainable energy technology acceptance: A review-based comprehensive framework. *Renewable and Sustainable Energy Reviews, 16*(1), 525-531. doi:http://dx.doi.org/10.1016/j.rser.2011.08.018

Keeney, R. L. (2002). Common Mistakes in Making Value Trade-Offs. *Operations Research, 50*(6), 935-945. doi:https://doi.org/10.1287/opre.50.6.935.357

Kessler, S., Flath, C. M., & Böhm, K. (2015). Allocative and strategic effects of privacy enhancement in smart grids. *Information Systems, 53*, 170-181. doi:http://dx.doi.org/10.1016/j.is.2014.09.007

Kolk, A. (2012). The role of consumers in EU energy policy. *Carbon Management, 3*(2), 175-183. doi:10.4155/cmt.12.10

Kovacic, Z., & Giampietro, M. (2015). Empty promises or promising futures? The case of smart grids. *Energy, 93*, 67-74. doi:10.1016/j.energy.2015.08.116

Krippendorff, K. (2004). *Content analysis: An introduction to its methodology*: Sage Publications Inc.

Krishnamurti, T., Schwartz, D., Davis, A., Fischhoff, B., de Bruin, W. B., Lave, L., & Wang, J. (2012). Preparing for smart grid technologies: A behavioral decision research approach to understanding consumer expectations about smart meters. *Energy Policy, 41*, 790-797. doi:http://dx.doi.org/10.1016/j.enpol.2011.11.047

Künneke, R., Mehos, D. C., Hillerbrand, R., & Hemmes, K. (2015). Understanding values embedded in offshore wind energy systems: Toward a purposeful institutional and technological design. *Environmental Science & Policy, 53, Part B*, 118-129. doi:http://dx.doi.org/10.1016/j.envsci.2015.06.013

Ligtvoet, A., van de Kaa, G., Fens, T., van Beers, C., Herder, P., & van den Hoven, J. (2015). Value Sensitive Design of Complex Product Systems. In M. Janssen, M. A. Wimmer, & A. Deljoo (Eds.), *Policy Practice and Digital Science: Integrating Complex Systems, Social Simulation and Public Administration in Policy Research* (pp. 157-176). Cham: Springer International Publishing.

Ligtvoet, A., van de Kaa, G., Fens, T., van den Hoven, J., van Beers, C., & Herder, P. (2014). *Stakeholder values and platform wars: smart meters in the Netherlands*. Paper presented at the Proceedings of the 23rd International Management of Technology Annual Conference 2014.

Liu, W. H. E., Liu, K., & Pearson, D. (2011, 17-19 Jan. 2011). *Consumer-centric smart grid.* Paper presented at the ISGT 2011.

Luthra, S., Kumar, S., Kharb, R., Ansari, M. F., & Shimmi, S. L. (2014). Adoption of smart grid technologies: An analysis of interactions among barriers. *Renewable and Sustainable Energy Reviews, 33*, 554-565. doi:http://dx.doi.org/10.1016/j.rser.2014.02.030

Mahmood, A., Javaid, N., Khan, M. A., & Razzaq, S. (2015). An overview of load management techniques in smart grid. *International Journal of Energy Research, 39*(11), 1437-1450. doi:10.1002/er.3350

Mathiesen, B. V., Lund, H., Connolly, D., Wenzel, H., Østergaard, P. A., Möller, B., . . . Hvelplund, F. K. (2015). Smart Energy Systems for coherent 100% renewable energy and transport solutions. *Applied Energy, 145*(Supplement C), 139-154. doi:https://doi.org/10.1016/j.apenergy.2015.01.075

Milchram, C., & van de Kaa, G. (2017). *Moral values as factors for social acceptance: The case of smart energy systems*. Paper presented at the International Association for Management of Technology Conference.

Missaoui, R., Joumaa, H., Ploix, S., & Bacha, S. (2014). Managing energy Smart Homes according to energy prices: Analysis of a Building Energy Management System. *Energy and Buildings, 71*(Supplement C), 155-167. doi:https://doi.org/10.1016/j.enbuild.2013.12.018

Moore, G. E. (1988 [1903]). *Principia Ethica*: Promotheus Books, Buffalo, NY.

Muench, S., Thuss, S., & Guenther, E. (2014). What hampers energy system transformations? The case of smart grids. *Energy Policy, 73*, 80-92. doi:http://dx.doi.org/10.1016/j.enpol.2014.05.051

Neuendorf, K. A. (2017). *The content analysis guidebook*. Los Angeles: Sage publications.

Noppers, E. H., Keizer, K., Milovanovic, M., & Steg, L. (2016). The importance of instrumental, symbolic, and environmental attributes for the adoption of smart energy systems. *Energy Policy, 98*, 12-18. doi:http://dx.doi.org/10.1016/j.enpol.2016.08.007

Ofgem. (2017a). DECC and Ofgem Smart Grid Forum. Retrieved from Office of Gas and Electricity Markets website: https://www.ofgem.gov.uk/electricity/distribution-networks/forums-seminars-and-working-groups/decc-and-ofgem-smart-grid-forum

Ofgem. (2017b). Electricity supply market shares by company. Retrieved from Office of Gas and Electricity Markets website: https://www.ofgem.gov.uk/data-portal/electricity-supply-market-shares-company-domestic-gb

Ofgem. (2017c). Energy Demand Research Project. Retrieved from Office of Gas and Electricity Markets website: https://www.ofgem.gov.uk/gas/retail-market/metering/transition-smart-meters/energy-demand-research-project

Ofgem. (2017d). The GB electricity distribution network. Retrieved from Office of Gas and Electricity Markets website: https://www.ofgem.gov.uk/electricity/distribution-networks/gb-electricity-distribution-network

Ofgem. (2017e). Low Carbon Networks Fund. Retrieved from Office of Gas and Electricity Markets website: https://www.ofgem.gov.uk/electricity/distribution-networks/network-innovation/low-carbon-networks-fund

Ofgem. (2017f). Who we are. Retrieved from https://www.ofgem.gov.uk/about-us/who-we-are

Osborne, M. J., & Rubinstein, A. (2000). *A course in game theory*. Massachusetts: MIT Press.

Paetz, A.-G., Dütschke, E., & Fichtner, W. (2012). Smart Homes as a Means to Sustainable Energy Consumption: A Study of Consumer Perceptions. *Journal of Consumer Policy, 35*(1), 23-41. doi:10.1007/s10603-011-9177-2

Palensky, P. (2017, 9 June). *Introduction to the PowerWeb Conference 2017*. Paper presented at the PowerWeb Conference: Smart Grid Cyber Security, Delft University of Technology.

Ponce, P., Polasko, K., & Molina, A. (2016). End user perceptions toward smart grid technology: Acceptance, adoption, risks, and trust. *Renewable & Sustainable Energy Reviews, 60*, 587-598. doi:10.1016/j.rser.2016.01.101

Rawls, J. (1971). *A theory of justice*. Massachusetts: Harvard University Press.

Rezaei, J. (2015). Best-worst multi-criteria decision-making method. *Omega International Journal of Management Science, 53*, 49-57. doi:https://doi.org/10.1016/j.omega.2014.11.009

Rezaei, J. (2016). Best-worst multi-criteria decision-making method: Some properties and a linear model. *Omega International Journal of Management Science, 64*, 126-130. doi:https://doi.org/10.1016/j.omega.2015.12.001

Roeser, S. (2006). The role of emotions in judging the moral acceptability of risks. *Safety Science, 44*(8), 689-700. doi:http://dx.doi.org/10.1016/j.ssci.2006.02.001

Roeser, S. (2012). Emotional Engineers: Toward Morally Responsible Design. *Science and Engineering Ethics, 18*(1), 103-115. doi:10.1007/s11948-010-9236-0

Römer, B., Reichhart, P., Kranz, J., & Picot, A. (2012). The role of smart metering and decentralized electricity storage for smart grids: The importance of positive externalities. *Energy Policy, 50*, 486-495. doi:http://dx.doi.org/10.1016/j.enpol.2012.07.047

Römer, B., Reichhart, P., & Picot, A. (2015). Smart energy for Robinson Crusoe: an empirical analysis of the adoption of IS-enhanced electricity storage systems. *Electronic Markets, 25*(1), 47-60. doi:10.1007/s12525-014-0167-5

Ruijgh, T., van Daalen, E., Bots, P., Steenhuisen, B., Lukosch, S., Warnier, M., . . . van der Voort, H. (2013). Designing in socio-technical systems: Delft University of Technology.

Sauter, R., & Watson, J. (2007). Strategies for the deployment of micro-generation: Implications for social acceptance. *Energy Policy, 35*(5), 2770-2779. doi:https://doi.org/10.1016/j.enpol.2006.12.006

Scholten, D., & Künneke, R. (2016). Towards the comprehensive design of energy infrastructures. *Sustainability, 8*(12), 1291. doi:10.3390/su8121291

SimplySwitch. (2015). The Big Six Energy Suppliers. Retrieved from Simply Switch website: https://www.simplyswitch.com/energy/guides/the-big-six-energy-suppliers/

Sintov, N. D., & Schultz, P. W. (2015). Unlocking the potential of smart grid technologies with behavioral science. *Frontiers in Psychology, 6*(410). doi:10.3389/fpsyg.2015.00410

SmartEnergyGB. (2016). Latest findings on the impact of smart meters from Smart energy outlook. Retrieved from https://www.smartenergygb.org/en/resources/press-centre/press-releases-folder/smart-energy-outlook-august?tab=1&docspage=2

SmartGridForum. (2014). Smart Grid Vision and Routemap. Retrieved from British Government website: https://www.gov.uk/government/publications/smart-grid-forums-smart-grid-vision-and-routemap

Steg, L., Bolderdijk, J. W., Keizer, K., & Perlaviciute, G. (2014). An Integrated Framework for Encouraging Pro-environmental Behaviour: The role of values, situational factors and goals. *Journal of Environmental Psychology, 38*, 104-115. doi:http://dx.doi.org/10.1016/j.jenvp.2014.01.002

Steg, L., Perlaviciute, G., & van der Werff, E. (2015). Understanding the human dimensions of a sustainable energy transition. *Frontiers in Psychology, 6*, 805. doi:10.3389/fpsyg.2015.00805

Taebi, B. (2016). Bridging the gap between social acceptance and ethical acceptability. *Risk analysis*. doi:10.1111/risa.12734

Taebi, B., Correljé, A., Cuppen, E., Dignum, M., & Pesch, U. (2014). Responsible innovation as an endorsement of public values: the need for interdisciplinary research. *Journal of Responsible Innovation, 1*(1), 118-124. doi:10.1080/23299460.2014.882072

Taebi, B., Roeser, S., & van de Poel, I. (2012). The ethics of nuclear power: Social experiments, intergenerational justice, and emotions. *Energy Policy, 51*, 202-206. doi:http://dx.doi.org/10.1016/j.enpol.2012.09.004

Tuballa, M. L., & Abundo, M. L. (2016). A review of the development of Smart Grid technologies. *Renewable and Sustainable Energy Reviews, 59*, 710-725. doi:http://dx.doi.org/10.1016/j.rser.2016.01.011

UKITA. (2016). What is UKITA? Retrieved from UK IT Association website: http://www.ukita.co.uk/what-is-ukita/

UKPowerNetworks. (2014). DNO Guide to Future Smart Management of Distribution Networks - Summary Report. Retrieved from UK Power Networks website: http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL)/

van Dam, K. H., Nikolic, I., & Lukszo, Z. (2012). *Agent-based modelling of socio-technical systems* (Vol. 9). Dordrecht: Springer Science & Business Media.
van de Kaa, G., Ligtvoet, A., Fens, T., & Herder, P. (2014). *Home Energy Systems: the State of the Art*. Paper presented at the Proceedings of 23rd International Management of Technology Annual Conference 2014. https://pure.tudelft.nl/portal/en/publications/home-energy-systems-the-state-of-the-art(ef7fa784-5184-4c86-a4e3-459f990c8791)/export.html
van de Kaa, G., Rezaei, J., Kamp, L., & de Winter, A. (2014). Photovoltaic technology selection: A fuzzy MCDM approach. *Renewable and Sustainable Energy Reviews, 32*, 662-670. doi:http://dx.doi.org/10.1016/j.rser.2014.01.044
van de Poel, I. (2009). Values in Engineering Design A2 - Meijers, Anthonie *Philosophy of Technology and Engineering Sciences* (pp. 973-1006). Amsterdam: North-Holland.
van de Poel, I. (2013). Translating Values into Design Requirements. In D. P. Michelfelder, N. McCarthy, & D. E. Goldberg (Eds.), *Philosophy and Engineering: Reflections on Practice, Principles and Process* (pp. 253-266). Dordrecht: Springer Netherlands.
van de Poel, I. (2015). Design for Values in Engineering. *Handbook of Ethics, Values, and Technological Design* (pp. 667-690).
van de Poel, I. (2016). A Coherentist View on the Relation Between Social Acceptance and Moral Acceptability of Technology. In M. Franssen, P. E. Vermaas, P. Kroes, & A. W. M. Meijers (Eds.), *Philosophy of Technology after the Empirical Turn* (pp. 177-193). Cham: Springer International Publishing.
van de Poel, I., & Royakkers, L. (2011). *Ethics, technology, and engineering: An introduction*: John Wiley & Sons.
van de Poel, I., & Warnier, M. (2015). Design for values: Frontloading technology with Ethics - SPM4111 SEPAM Bootcamp. Retrieved from Blackboard TU Delft - Course SPM4111 website: https://blackboard.tudelft.nl/webapps/blackboard/content/listContent.jsp?course_id=_53431_1&content_id=_2529629_1
van den Hoven, J., Lokhorst, G.-J., & van de Poel, I. (2012). Engineering and the Problem of Moral Overload. *Science and Engineering Ethics, 18*(1), 143-155. doi:10.1007/s11948-011-9277-z
Verbong, G. P. J., Beemsterboer, S., & Sengers, F. (2013). Smart grids or smart users? Involving users in developing a low carbon electricity economy. *Energy Policy, 52*, 117-125. doi:http://dx.doi.org/10.1016/j.enpol.2012.05.003
Walker, G., & Devine-Wright, P. (2008). Community renewable energy: What should it mean? *Energy Policy, 36*(2), 497-500. doi:https://doi.org/10.1016/j.enpol.2007.10.019
Walker, G., Devine-Wright, P., Barnett, J., Burningham, K., Cass, N., Devine-Wright, H., . . . Heath, Y. (2011). Symmetries, expectations, dynamics and contexts: a framework for understanding public engagement with renewable energy projects. *Renewable Energy and the Public*, 1-14.
Warren, P. (2014). A review of demand-side management policy in the UK. *Renewable and Sustainable Energy Reviews, 29*(Supplement C), 941-951. doi:https://doi.org/10.1016/j.rser.2013.09.009
Weber, R. P. (1990). *Basic content analysis*: Sage Publications Inc.
Which? (2017). Energy suppliers A to Z. Retrieved from Which? Switch website: https://switch.which.co.uk/energy-suppliers/index.html
Williams, T. M. (1999). The need for new paradigms for complex projects. *International Journal of Project Management, 17*(5), 269-273. doi:http://dx.doi.org/10.1016/S0263-7863(98)00047-7
Wilson, C., Hargreaves, T., & Hauxwell-Baldwin, R. (2017). Benefits and risks of smart home technologies. *Energy Policy, 103*, 72-83. doi:10.1016/j.enpol.2016.12.047
Winner, L. (1980). Do Artifacts Have Politics? *Daedalus, 109*(1), 121-136.
Wolsink, M. (2012). The research agenda on social acceptance of distributed generation in smart grids: Renewable as common pool resources. *Renewable and Sustainable Energy Reviews, 16*(1), 822-835. doi:http://dx.doi.org/10.1016/j.rser.2011.09.006
Wüstenhagen, R., Wolsink, M., & Bürer, M. J. (2007). Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy, 35*(5), 2683-2691. doi:http://dx.doi.org/10.1016/j.enpol.2006.12.001

Xenias, D., Axon, C. J., Whitmarsh, L., Connor, P. M., Balta-Ozkan, N., & Spence, A. (2015). UK smart grid development: An expert assessment of the benefits, pitfalls and functions. *Renewable Energy, 81*, 89-102. doi:http://dx.doi.org/10.1016/j.renene.2015.03.016

Yesudas, R., & Clarke, R. (2015). Consumer Concerns About Smart Meters. In N. Streitz & P. Markopoulos (Eds.), *Distributed, Ambient, and Pervasive Interactions: Third International Conference, DAPI 2015, Held as Part of HCI International 2015, Los Angeles, CA, USA, August 2-7, 2015, Proceedings* (pp. 625-635). Cham: Springer International Publishing.

Zhang, Y., & Wildemuth, M. B. (2009). Qualitative Analysis of Content. In M. B. Wildemuth (Ed.), *Applications of Social Research Methods to Questions in Information and Library Science* (pp. 1-12). USA: Libraries Unlimited.

Zhou, S., & Brown, M. A. (2017). Smart meter deployment in Europe: A comparative case study on the impacts of national policy schemes. *Journal of Cleaner Production, 144*, 22-32. doi:http://dx.doi.org/10.1016/j.jclepro.2016.12.031

Appendix A: Definitions of smart grids and components from the scientific literature

According to several scientific studies, there is currently no consensus about the definition of smart grid systems (SGSs) and the technologies it comprises (Buchanan et al., 2016; Krishnamurti et al., 2012; Muench et al., 2014; Paetz et al., 2012; Verbong et al., 2013). Therefore, a literature review is conducted in order to explore the definition of SGSs and its sub-systems (i.e. technology components). The results are presented in Table 13 below. More details can be found in §2.1.

Table 13: Definition of smart grids and its components

SES component	Definition	Source
Smart grid	*"Smart grids have an essential role in the process of transforming the functionality of the present electricity transmission and distribution grids so that they are able to provide a user-oriented service, supporting the achievement of the 20/20/20 targets and guaranteeing high security, quality and economic efficiency of electricity supply in a market environment"*	Cuijpers and Koops (2012), p.2
	"An electricity network that can cost efficiently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety"	Cuijpers and Koops (2012), p.2
	"The European Commission Taskforce on Smart Grids defines a smart grid as 'an electricity network that can cost-efficiently integrate the behaviour and actions of all users connected to it—generators, consumers and those that do both—in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety"	Darby et al. (2013), p.725
	"The smart grid is a modern electric power grid infrastructure introduced for improved efficiency, reliability and security, with smooth integration of RES and energy storage devices, through smart energy management algorithms, automated control, and modern communications technologies. It systemizes the needs and cap- abilities of all power generators, grid operators, end-users, and electricity market stakeholders to operate all parts of the system as efficiently as possible with maximum system stability, reliability and resiliency"	Ellabban and Abu-Rub (2016), p.1286
	"The term smart grid refers to an electricity production and consumption infrastructure that is enhanced with information and communication technology (ICT) for improved monitoring and control of supply and demand balance in the electric power system. The smart grid is considered to be a requisite to accommodate an increasing amount of distributed and intermittent energy sources in electricity grids, as well as to reliably meet a growing overall electricity demand (International Energy Agency, 2011). ICT plays an important role in smart grids by enabling monitoring and control of the energy flows in the grid at every level in the system, from large scale generation and transmission to the low voltage distribution net- works in which residential end-users are located"	Geelen et al. (2013), p.152

	"Smart Grids are high- efficiency infrastructure for electricity transmission and distribution that employs automated and semi- automated consumption management, integrated communications, real-time information sharing, and advanced sensor and measurement technology"	Guerreiro et al. (2015), p.1150
	"The term "smart grid" was first introduced by Amin and Wollenberg to refer to the use of Information and Communication Technology (ICT) in electric grids. Within this vague umbrella, smart grids are defined as a way of matching electricity demand and supply in real time, of managing peak demand, of facilitating the transition towards renewable energies, of securing energy supply, of reducing blackouts, of increasing efficiency, and of guaranteeing universal access to electricity and a decentralised system of electricity generation where producers, distributers and consumers assume new roles"	Kovacic and Giampietro (2015), p.67
	"We define SG as an energy distribution system with the unique features (I1) to allow functional interaction of relevant market participants with the implementation of modern technologies such as information and communication technologies, (I2) to provide the capacity (in kW) that enables smart market applications (in kW/h), and (I3) to ensure the stability of distribution grids by securely connecting a large number of small points of intermittent consumption and production. Its actual design depends on (E1) whether transmission line expansions or the implementation of smart grid technologies is emphasised, (E2) which energy carriers will be included in the future energy system, and (E3) which users are suitable for the inclusion in a SG"	Muench et al. (2014), p.82
	"The Smart Grid is the concept of modernising the electric grid [...] the main focus is on an increased observability and controllability of the power grid"	Connor et al. (2014), p.270
Smart meter	*"Smart meters—the user's interface with smart grids—are innovative electronic meters, which provide consumers with more detailed information than traditional electricity meters. Bills are no longer based on estimates, but rather on actual consumption, improving the quality of billing that is often the target of customer complaints. There is a wide range of devices being used, which vary from simple displays that show consumers their consumption, to more advanced meters that automatically interact with the utility, sending readings remotely, and showing other types of consumption information such as the monetary costs or equivalent CO_2 emissions"*	Guerreiro et al. (2015), p.1150
	"A new generation of advanced and intelligent metering devices which have the ability to record the energy consumption of a particular measuring point in intervals of fifteen minutes or even less; communicate and transfer the information recorded in real time or at least on a daily basis by means of any communications network to the utility company; enable a two-way communication between the meter and the central system of the utility company, the so called distribution systems operator (DSO) al- lowing for remotely control functionalities of the meter such as switch off from the delivery of energy"	Cuijpers and Koops (2012), p.2
	"Taking the definition a little further, the literature shows general agreement that a fully smart meter is one that can (1) measure and store data at specified intervals and (2) act as a node for two-way communications between supplier and consumer and automated meter management (AMM). This allows for a radical change in customer – utility relations, with the possibility of remote disconnection and reconnection, remote change of tariff, and remote change in 'contractual power' (the peak electrical demand allowed for an individual customer, a familiar concept in Italy and France, for example)"	Darby (2010), p.445
	"Smart meters are installed in the homes of utility consumers, and are capable of two-way communication. They inform	

	consumers about the amount of energy they are consuming, and this information can also be sent to energy suppliers, and other nominated parties. The key feature of smart meters is that they provide the ability for these remote communications between the meter and authorized parties such as suppliers, network operators, and authorized third parties or energy service companies"	Darby (2012), p.99
	"Intelligent metering is usually an inherent part of Smart Grids"	Darby (2012), p.99
Smart home	*"The smart home, on the other hand, allows for remote electronic control and management of smart appliances (heaters, air conditioners, washing machines etc.) and represents the convergence of energy efficient appliances and real-time access to energy usage data, facilitated by a network of sensors and computers. Increased visibility of energy and cost information through interactive displays can enable consumers to proactively monitor and manage energy use in ways that are convenient, cost-effective, and environmentally beneficial. Smart homes can also deliver other services such as assisted living, home security or entertainment, as well as facilitating two-way communication between the grid and electric vehicles and any on- site micro-generation (e.g. rooftop solar panels). Finally, they can contribute to the delivery of social policy goals by helping provide better living standards for elderly, sick, and disabled homeowners"*	Balta-Ozkan et al. (2013), p.1
	"A smart home is a residence equipped with a high-tech network, linking sensors and domestic devices, appliances, and features that can be remotely monitored, accessed or controlled, and provide services that respond to the needs of its inhabitants. The term 'smart home' may, in principle, refer to any form of residence, for example, a standalone house, an apartment, or a unit in a social housing development. In the definition set out here, sensors may be used to detect the location of people and objects, or collect data about states (e.g. temperature, energy usage, open windows); domestic devices, appliances and features can include anything from washing machines or lighting to a user interface providing access to and control of smart home data and services; and smart home services are the benefits that the smart home provides to the user"	Balta-Ozkan et al. (2013), p.2
	The network, through which each of the technological components and information about them is connected and coordinated, is what distinguishes the smart home from simply the high tech-equipped residence"	Balta-Ozkan et al. (2013), p.2
	"The term "smart home" is generally used for linking separate devices of a household to a network and can therefore include aspects of ambient living, entertainment, and security. In our research we focus on aspects of energy management"	Paetz et al. (2012), p.24
	"The home energy management system essentially is designed to manage the energy use in a domestic environment or in a small business environment"	van de Kaa, Ligtvoet, et al. (2014), p.1
	"An important component of the smart grid is the smart home energy system (SHES). The smart home energy system essentially is the equivalent of the local in-home smart grid. Such systems are specifically designed to manage the energy use in a domestic environment, the house, or in a small business environment such as a local store"	van de Kaa, Ligtvoet, et al. (2014), p.1
	"Smart home technologies (SHTs) comprise sensors, monitors, interfaces, appliances and devices networked together to enable automation as well as localised and remote control of the domestic environment (Cook, 2012). Controllable appliances and devices include heating and hot water systems (boilers, radiators), lighting, windows, curtains, garage doors, fridges, TVs, and washing machines (Robles and Kim, 2010). Sensors and monitors detect environmental factors	Wilson et al. (2017), p.72

	including temperature, light, motion, and humidity. Control functionality is provided by software on computing devices (smartphones, tablets, laptops, PCs) or through dedicated hardware interfaces (e.g., wall-mounted controls). These different SHTs are networked, usually wirelessly, using standardised communication protocols. The diversity of available SHTs means the smart home has many possible configurations and by implication, smartness"	
	"Smart homes are used as a generic descriptor for the introduction of enhanced monitoring and control functionality into homes"	Wilson et al. (2017), p.72
	"A Smart Home is a residential dwelling equipped with sensors and possibly actuators to collect data and send control according to occupants' activities and expectations. Potential applications for Smart Homes are described in. The goal of these applications is to improve home comfort, convenience, security and entertainment"	Missaoui et al. (2014), p.155
	"Smart appliances are appliances that can be programmed and that communicate with energy management systems about appropriate hours to operate. Appliances in which the time of operation can be shifted and that consume a high amount of energy are most suitable for 'smart' operation. For example, white goods such as dishwashers, washing machines and refrigerators, as well as heating systems such as heat pumps, micro-cogeneration units and ventilation systems can be considered here"	Geelen et al. (2013), p.156
	"Smart appliances can decide for themselves or based on a trigger signal when the best time is to operate. The timing of the trigger signals may depend on the service that is contracted at a utility company, for example based on tariffs, availability of local renewable energy sources or power system frequency. The demand response of appliances may depend on factors such as convenience and safety, reducing flexibility in activation times. While a heat pump may be activated at any moment when energy can be stored, clean clothing may be desired at a rather fixed time"	Missaoui et al. (2014), p.155
	"White goods, such as dishwashers and washing machines, generally have a user interface through which one can control and plan when the appliance starts working in order to determine optimal results for the end-user (e.g. clean clothes at a given hour) and the management of the energy system. Heating system installations generally do not have such a user interface on the device. The interaction takes place through a thermostat or via a more elaborate home energy management system"	Geelen et al. (2013), p.156
	"Smart appliance is an electrical household device able to react automatically to external signals, e.g., turning itself following a signal from the electricity grid. These external signals can be price signals (i.e., variable tariff) or other signals sent by the utility depending on the current power supply and grid situation. In practice, this could mean that the dishwasher turns on automatically when receiving the signal that the electricity price is low now and for the next hour. This could support consumers in adapting their consumption to supply with little or no decrease in comfort"	Geelen et al. (2013), p.156
Demand response	*"Under this definition, technologies and actors are integrated by the use of information and communications technology—from refrigerators to electric vehicles and their drivers, wind turbines to coal plants and net- work operators. This allows demand to respond to generation (demand response)—a relatively new concept in systems that have historically operated on a 'predict and provide' basis, with generation following demand"*	Darby et al. (2013), pp.725-726
	"The contribution of end-users to balance supply and demand in smart grids is often referred to as demand response (DR).	Geelen et al. (2013), p.152

	Demand response refers to changes in electricity consumption by end-users in response to supply conditions (see e.g. Giordano et al., 2011). For example, end-users could permit utilities to automatically shut off their air-conditioning units or other appliances during peak demand periods provided that some financial incentives are offered. Also end- users could be encouraged by utilities to use energy feedback systems"	
	"The need to control the demand in order to shape the load profile was first realized in the 1970s. Now, it has evolved to the concept of demand side management (DSM) and is characterized by utility operations and incentives for the consumers in order to bring power usage at de- sired level at all times. Major objectives of DSM include peak clipping, valley filling, peak shifting, and deploying new efficient uses. DSM can help the consumers to lower their payments and utility to minimize the need of peaking plants. Obviously, the utility desires the shape of the load curve to be balanced with a reduced peak- to-average ratio (PAR) for all the hours while consumers want reliable energy supplies at minimum cost. In literature, LM, demand response (DR), and DSM are found as overlapping concepts and are used interchangeably"	Mahmood et al. (2015), pp.1437-1438
	"The social dimension of smart grids generally involves the introduction of some kind of Demand Side Management (DSM). Usually, smart grids are accompanied by the introduction of DSM to allow demand to follow supply. DSM is an old instrument developed to shift loads from peak periods to periods where demand is much lower. However, the use of DSM for households is relatively new. In order to make DSM work some form of flexibility has to be introduced"	Verbong et al. (2013), p.120
	"Energy efficiency generally aims to reduce overall energy demand, whereas demand response concentrates more on shifting energy consumption during peak times to help balance supply and demand"	Warren (2014), p.943
Energy storage	*"Renewable decentrals like PV, small scale wind (electricity) and solar boilers (heat) are non-steerable: the energy production is depending on weather conditions. This phenomenon is known as the intermittency effect. The consequence is that the energy has to be used at the time of production. This effect can be overcome by employing energy storage. With storage devices the actual usage moment can be decoupled from the production moment and as such the system could do away with the intermittency problem. By adding storage non-steerable production systems then become steerable. Presently this storage capacity is entering the market at acceptable economics. The main cause for this is found in developments in batteries for electric cars. Next to the car battery also stationary battery systems are now being developed. Another form of energy storage is heat/cold storage and is also fully steerable. Solar heat boilers can be used to collect heat during summer, which can be stored for usage in winter, these systems are often combined with heat pumps. In case of electricity storage systems it is observed that manufacturers of car batteries are setting the standard"*	van de Kaa, Ligtvoet, et al. (2014), p.5
	"The penetration of renewable sources, particularly wind and solar, into the grid has been increasing in recent years. As a consequence, there have been serious concerns over reliable and safety operation of power systems. One possible solution, to improve grid stability, is to integrate energy storage devices into power system network: storing energy produced in periods of low demand to later use, ensuring full exploitation of intermittent available sources. Focusing on stand-alone photovoltaic (PV) energy system, energy storage is needed with the purpose of ensuring continuous power flow, to minimize or, if anything, to neglect electrical grid supply"	Bianchi et al. (2014), p.242
	"Energy storage systems enable households to use energy at different times than when it was actually produced or purchased from the grid. Surplus energy can be stored as electrical energy in batteries and as heat in hot water tanks or	Geelen et al. (2013), p.155

	storage heaters. In the case of electrical storage, electricity can be delivered to and drawn from the grid at favourable times in terms of system balance and prices. Additionally, a household can avoid buying electricity from the main grid, for example during peak hours by using previously produced (and stored) electricity. As with micro-generation, storage can also be organized as a shared or collective facility. Electrical storage in batteries is not yet very common in households due to the related costs. Electric mobility is often mentioned in relation to electrical storage at the household level. The batteries of an electric vehicle can be charged with surplus electricity from micro-generation or from the grid during off-peak hours. When required, the car batteries can deliver power to the household or to the local grid. This concept is known as vehicle-to- grid (V2G)"	
	"The principle of electricity storage is to charge a storage facility when excess electricity production occurs and discharge the facility when a shortfall in electricity supply occurs. This ensures that supply and demand matches on the electricity side. At present however, there are only two types of large-scale electricity storage technologies that have been implemented (i.e. >100 MW): pumped hydroelectric energy storage (PHES) and compressed air energy storage (CAES). Both of these technologies lead to significant inherent energy losses, with the two having round-trip efficiencies of approximately 85% and 65% respectively"	Mathiesen et al. (2015), p.142
Stakeholders	*"A stakeholder in an organization is (by definition) any group or individual who can affect or is affected by the achievement of the organization's objectives"*	Freeman (2010), p.46
	"Socio-technical systems comprise people, their social interactions, the resources they use, and the technology that enables them to do so"	Ruijgh et al. (2013), p. 9
	"They also show that large-scale socio-technical systems such as cities, railroads, highways, power grids, and the internet all develop gradually over time, and that the continuous interaction between people and the system they are part of leads to remarkable technical artefacts like skyscrapers, miniature model trains, wildlife viaducts, HVDC cables, and webcams, and to no less remarkable social artefacts like Times Square Ball, train spotting, traffic flirting, Earth Hour, and flash mobs. Note that human agency is the main driver behind all this development. Without humans, the earth would still be a natural system"	Ruijgh et al. (2013), p. 12

Appendix B: The British smart grid development

To better understand the interaction between social and technical artefacts that belong to and have shaped smart grid systems in the UK, it is important to trace its development (Ruijgh et al., 2013). Therefore, a timeline is constructed based on publications of the British government and other regulatory bodies. The timeline is illustrated in Figure 4 (see §2.2.1) and is described in more detail in Table 14 below.

Table 14: Smart grid development in the UK over the past 10 years

Event	Year	Description	Source
EU 20:20:20 objective	2007	The European Council adopted the 2020 package, which is a set of binding legislation to ensure that the European Union meets its climate and energy targets for 2020: • 20% cut in greenhouse gas emissions from 1990 levels • 20% of EU energy from renewables • 20% improvement in energy efficiency The leaders of the member states set these targets in 2007 and were enacted in legislation by the EU in 2009 through the Electricity Directive.	(EC, 2017a, 2017b)
White Paper on Energy	2007	At this point the policy debate on meeting UK's energy challenge started. This White Paper sets out the Government's international and domestic energy strategy to address the long-term energy challenges and deliver the four energy policy goals: • Reduction of UK's CO_2 emissions by 60% in 2050, with real progress by 2020 • Promotion of UK (and beyond) competitive markets to increase sustainable economic growth and to improve UK's productivity • To maintain the reliability of energy supply • To ensure that every home in the UK is adequately and affordably heated	(DECC, 2015)
The Energy Demand Research Project	2007-2010	This is a large-scale trial conducted in 60,000 households in Great Britain to investigate how consumers reacted to improved information about their energy consumption over the long term. The combination of smart meters and real-time display devices consistently resulted in energy savings up to 11%. Ofgem oversaw the trials on behalf of the Department of Energy and Climate Change (DECC) and the following energy suppliers ran the trials: EDF Energy, E.ON, Scottish Power, and Scottish and Southern Energy. Independent analysis of the final data from the trials was carried out by consultancy Aecom.	(Government, 2014b; Ofgem, 2017c)
Climate change Act	2008	This Act aims at enabling the UK in reaching a low carbon economy and to mitigate climate	(Government, 2008)

		change. Furthermore, it a primary legislation and describes the duty of the Secretary of State regarding climate change.	
Electricity Directive 2009/72/EC	2009	This Directive requires all EU member states to implement smart metering in 80% of households by 2020. Furthermore, it encourages member states to the modernization of distribution networks through smart grids for the sake of decentralised generation and energy efficiency.	(EU, 2009)
Electricity Networks Strategy Group's Vision and Route Map for Smart Grids	November 2009	This document addresses the urge to develop the current British electricity network in order to efficiently facilitate low carbon developments in generation, supply and consumption, while ensuring security of supply. To this end, it sets out a vision and road map on how to develop a smart grid in the UK.	(ENSG, 2009)
Smart meter policy design stage	July 2010 -March 2011	This was the first stage of the national smart meter roll-out project in the UK, managed by the Office of Gas and Electricity Markets (Ofgem) on behalf of DECC. The aim was to establish a policy to regulate Great Britain's smart meter roll-out. This policy focuses on regulating the replacement of approximately 53 million residential and non-domestic gas and electricity meters in Great Britain by smart meters through a supplier-led roll-out with a centralised data and communications company.	(Government, 2015)
Foundation stage	March 2011 - 2016	At this stage, the British government established the necessary commercial, regulatory, and technical framework. This stage is crucial for the smart meter roll-out as the industry build and test systems, learn what works best for consumers and learn how to help people get the best from their meters. Furthermore, in this phase the Data and Communications Company (DCC) was established to link the smart meters in homes and small businesses with the business systems of energy suppliers, network operators and energy service companies.	(Government, 2015)
Establishment of the Smart Grid Forum	2011	The DECC/Ofgem Smart Grid Forum (SGF) is 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, particularly for electricity network operators. Besides, the SGF is a government-led cross-industry advisory group that aids in informing Smart Grid policy development, tackling and advising on issues ranging from regulations, market structure, commercial barriers to technology requirements of smart grid systems. Its main aim is to facilitate the deployment of smart grid systems in the UK as well as the exchange of information and knowledge between key parties, including those outside the energy sector.	(Ofgem, 2017a)
Establishment of Smart Energy GB	2013	Smart Energy GB is the voice of the smart meter rollout. Their task is to help everyone in Great Britain understand smart meters, the national rollout and how to use their new meters to get their electricity under control.	(SmartEnergyGB, 2016)

The Smart Meters Communications License was granted to the DCC	2013	DECC granted the Data and Communications Company (Smart DCC Ltd) a licence to establish and manage the data and communications network to connect smart meters to the business systems of energy suppliers, network operators and other authorised service users of the network.	(DCC, 2017; DECC, 2015)
Impact Assessment: positive outcomes	January 2014	This assessment resulted in a net present value of £4.3bn for the domestic roll-out of smart meters in the UK. As a result of consumers using energy more efficiently and suppliers passing through net cost savings, the roll-out is expected to reduce the average household electricity and gas bill by £26 in 2020 and by £43 in 2030. Hence, positive outcomes.	(DECC, 2014)
Smart Grid Vision & Route Map by the Smart Grid Forum	February 2014	The Smart Grid Forum defined a clear vision of a British Smart Grid and a route map of the ways in which this smart grid systems could be delivered.	(SmartGridForum, 2014)
Ofgem runs Low Carbon Networks Fund	2014	The LCN Fund consists of a £500m budget to support projects sponsored by the Distribution Network Operators (DNOs) to try out new technology (such as electric vehicles, heat pumps, micro and local generation, and demand side management), operations and commercial arrangements. The aim of the projects is to help all DNOs understand how they can provide security of supply at value for money as the UK moves to a low carbon economy.	(Ofgem, 2017e; UKPowerNetworks, 2014)
The Low Carbon London Project	December 2010-December 2014	This project is one of Britain's largest smart grid trials to investigate the impact of a wide range of low carbon technologies, including intermittent local generation, smart meters, electric vehicles, etc. on London's electricity distribution network and test how smart grid technologies can be used to manage these changes in a low-carbon economy. For instance, 6000 smart meters were installed throughout London to monitor changing consumer demand patterns in response to dynamic tariffs according to supply level and the subsequent effect on London's electricity network. The Low Carbon Networks Fund and UK Power Networks funded this £28.3million project.	(Government, 2014b; UKPowerNetworks, 2014)
Cost-benefits analysis: positive outcome	August 2016	The national smart meter roll-out delivers a net social benefit of £16bn, with a net present value of £3.8bn. As a result of consumers using energy more efficiently and suppliers passing through net cost savings, the roll-out is expected to reduce the combined electricity and gas bill for the average household by £11 in 2020 and by £47 in 2030. Hence, the CBA shows positive outcomes.	(Government, 2016)
Main installation stage	2016-2020	The main installation stage is the phase when most consumers will have smart meters installed. Suppliers are obliged to complete the roll-out by the end of 2020 and they will decide how they deploy smart meters to their customers. 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)

Status quo: 6.8 million smart meters operating across homes and businesses in the UK	March 2017	Since the smart meter roll-out project began, a quarterly release presents statistics on the roll-out in Great Britain. The statistics provide information on the number of smart meters installed in domestic properties and smaller non-domestic sites during a certain quarter of a certain year. According to the report of the first quarter on 2017, there are over 6.783,4 million smart and advanced meters operating across homes and businesses in Great Britain, by both large and small energy suppliers. The statistics also show that a total of 1,027,7002 domestic smart meters were installed by large energy suppliers in the first quarter of 2017 (446,000 gas and 581,700 electricity meters). This represents a 10 per cent increase in domestic smart meter installations compared to the previous quarter.	(Government, 2017c)

Appendix C: Definitions of initial set of values from the scientific literature

This appendix serves as supplement for §3.2. It shows how the ethical values that can be associated with smart grid systems (SGSs) are established with the aid of a journal articles. The initial set of 38 values is presented in Table 15 below. After establishing potential values that could related to SGSs, a critical revision took place in order to avoid redundancy and conceptualize these value definitions even more to the context of SGSs.

Table 15: Initial set of values and conceptualizations from the literature

Value	Definition	Sources
(Energy) Autarky	*"Energy independence"*	Ellabban and Abu-Rub (2016), p.1293
	"The concept of energy autarky is also referred to as energy autonomy, energy self-reliance, or energy self- sufficiency. It refers to an energy system that has the ability to fully function using only its own resources (e.g. renewable electricity generation, power lines, storage, and consumption devices"	Römer et al. (2015), p.51
(Privacy & Cyber) Security	*"The analysis of cyber security in relation to the digital technology focuses on the related possibility of cyber-attacks. The targets of these cyber-attacks are manifold. They can attempt to compromise and control monitoring devices on the grid d often as a first step of deeper and more complex attacks d or they can insert contradictory data traffic or edit or delete information to facilitate incorrect decisions from the response systems. Cyber-attacks can acquire private information from user data or sabotage the communications and data processing systems to facilitate delay or damage"*	Bigerna et al. (2016), p.405
	"Customer privacy is a new issue analyzed by the literature in connection with smart grids development. Indeed, the introduction of smart grids will lead to exponential growth of data from smart devices, and energy utilities will have the largest increase in data ever seen"	Bigerna et al. (2016), p.405
	"The major benefit provided by the Smart Grid, i.e., the ability to obtain richer data to and from customer meters and other electric devices, is also its 'Achilles' heel' from a privacy viewpoint". Smart meters read personal information and send all data to the utility companies. Experiments are conducted to investigate privacy concerns (i.e., illegal usage, commercial usage, usage by law enforcement agencies, usage by other parties for legal purposes, usage by family members and other co-inhabitants) that primarily affect household dynamics"	Bigerna et al. (2016), p.405
	"Many technologies that enable the deployment of smart grids, such as smart meters and sensors, can increase the vulnerability of the grid to cyber-attacks. As the number of participants and distributed generators in the electric system increases, so does the complexity of security issues.6 The tension between protection of consumer privacy and development of smart grid also imposes challenges on	Brown and Zhou (2013), p.

	privacy protection rules. It is essential for both customers and smart- grid service providers to have access to energy consumption data to optimize the use of smart-grid technologies. This can be difficult when incumbent utilities that are currently controlling the meters and data on electricity consumption create barriers to market entry for new smart-grid players"	
	"Ensure that control of the network's sensitive systems cannot easily be compromised"	Balta-Ozkan et al. (2013), p.366
	"Ensuring safety and security of private data, violations of privacy, data falling into wrong hands, combining two sets of innocent data leading to 'non-innocent' data, tension between interoperability and security. big brother-like monitoring as too intrusive, concerns over third parties knowing daily routines and occupancy, systems being compromised, companies responsible for smart home services selling on personal data, lack of perceived privacy would not worth it for lower bills, smart health services invading privacy by leading to consumers being bombarded with marketing"	Balta-Ozkan et al. (2013), p.371
	"I expect smart meter technology would resist cyber or physical attacks. I expect smart meter technology would detect crime and allowing the utility company to respond rapidly"	Chou et al. (2015), p.197
	"Collection and transmission of energy consumption data is a continuous process that is done automatically, but it is a tedious and expense job. In this context, a common notion might arise in several customers is that, smart meters they might essentially create some privacy and security risks as the data and signals are being transmit- ted. Additionally, this data might also reveal the information about presence of people at their residence, when they were present, and what appliances are in use"	Depuru et al. (2011), p.2739
	"Energy consumption data transmitted through public communication networks like cellular networks might involve security risk. Other possible security vulnerabilities might be weak authentication, quality of implemented software, error handling, weak protocols, and improper session management"	Depuru et al. (2011), p.2739
	"Apart from utility companies, there are certain sections of people who might be interested in collecting and analyzing the energy consumption data of a customer. They include revengeful ex-spouses, civil litigants, illegal consumers of energy, extortionists, terrorists, political leaders with vested interests, thieves, etc. for knowledge about people's presence at their homes"	Depuru et al. (2011), p.2739
	"Security and Privacy: the household activities can be figured out from detailed consumption information of the consumer, therefore, serious security and privacy issues may be resulted if a third party gets this information"	Ellabban and Abu-Rub (2016), p.1290
	"More than simple increased visibility, individual and community power generation shifts the public from a position of outsider upon which the system imposes change. It was from this position one participant responded 'Why should I change my routine? Because Big Brother wants me to? Go and take a flying leap'"	Goulden, Bedwell, Rennick-Egglestone, Rodden, and Spence (2014)
	"In the future, cyber-attacks such as denial-of-service or virus attacks could cause outages in the smart grid and limit electricity supplies, including critical services such as infrastructure and public safety"	Herkert and Kostyk (2015), p.298
	"But at the same time, the grid may to subjected to attack because many of the technologies being	

	deployed to support smart grid projects, like smart meters, sensors, and advanced communication networks, are interoperable and open. Frequent smart metering data collection and analysis may help in improving energy efficiency and framing future policy, however this comes at the cost of user privacy. Cyber systems may be vulnerable to worms, viruses, denial-of- service attacks, malware, phishing, and user errors that compromise integrity and availability. Analyzing and implementing smart grid security may be a challenging task, considering the scale of the potential damages that could be caused by cyber-attacks"	Luthra et al. (2014), p.559
	"Smart meters collect and transmit more information than the traditional Ferraris meters. A complex issue is how to treat the collected data in terms of privacy and data security without unsettling end users. In fact, end users and consumer associations are sceptical in regard to the collection and transmission of consumption data"	Muench et al. (2014), p.85
	"Increased hacking threats due to enhanced information flow among various stakeholders"	Mahmood et al. (2015), p.1447
	"Smart grid is Prone to security and privacy issue compared to the traditional grid"	Tuballa and Abundo (2016), p.713
	"Generators of renewable energy as well as consumers participate in such local markets and trade energy over short time intervals, e.g., 30 min or less. Transparency obligations like the EUC543/2013 mandate the publication of comprehensive market data. Market transparency is key to ensure market liquidity and hence market efficiency. Yet, fine-grained power consumption records contain sensitive personal information. For example, appliances have a characteristic power consumption pattern over time called the load signature. This facilitates the detection of appliances or even the currently selected TV channel"	Kessler, Flath, and Böhm (2015), p.171
	"These studies have confirmed interest in the energy management potential of smart homes, but have also identified potential market barriers to adoption including cost, privacy, security, reliability, and the interoperability of different technologies"	Wilson et al. (2017), p.73
	"Data protection/security and privacy were the most cited responses. There was concern of the limits that might apply to the volume and nature of data which Government/Ofgem allow to be collected, transmitted and stored outside consumers' control, and who would have access to this data. There was concern too that Government choices could affect the usefulness of the data to network operators, the services that thus might be offered to consumers, and consumers' level of control over their energy use and changes in their demand"	Xenias et al. (2015), p.93
	"Smart meters will provide insights into a household's living patterns to the extent that it could reveal the appliances used and activities conducted by the household"	Yesudas and Clarke (2015), p.628
Accountability	*"Refers to the properties that ensures that the actions of a person, people, or institution may be traced uniquely to the person, people, or institution"*	Friedman et al. (2013), p.58
	"Legal and practical arrangements for safe practice and the allocation of responsibility in case of accidents and incidents including (absence of) trust that arrangements will be followed and would prove	Dignum et al. (2016), p.1180

	to be adequate"	
	"The system allows for tracing the activities of individuals or institutions"	Ligtvoet et al. (2015), p.171
Affordability	*"A household is in fuel poverty if, in order to maintain a satisfactory heating regime, it would be required to spend more than 10% of its income (including Housing Benefit or Income Support for Mortgage Interest) on all household fuel use"*	Barnicoat and Danson (2015), p.109
	"Transaction costs to seek out price and consumer information, installation costs, high repair and maintenance costs"	Balta-Ozkan et al. (2013), p.371
	"When their profits are linked with sales, utilities have a financial incentive to maximize the throughput of electricity across their wires; hence, they are often reluctant to adopt technologies that improve the efficiency of power supply"	Brown and Zhou (2013), p.123
	"Dynamic pricing is a market-driven approach to boost demand response in electricity markets. The fundamental idea is to provide accurate price signals to customers, and let them decide whether to continue consumption at higher prices or to cut electricity us- age during peak times"	Brown and Zhou (2013), p.127
	"Smart meters enable dynamic electricity tariffs that allow customers to face the cost of procuring electricity in the wholesale market, which varies by time of day and season"	Buryk et al. (2015), p.190
	"The chance to save money (due to accurate billing)"	Buchanan et al. (2016), p.95
Autonomy	*"Refers to people's ability to decide, plan, and act in ways that they believe will help them to achieve their goals"*	Friedman et al. (2013), p.58
	"It is clear from the UK government's policy that there is some recognition of the importance of consumers' autonomy as legalisation states that smart meters are not mandatory and that consumers may have them removed once installed, providing they do so before a year has elapsed. While such information may provide reassurance to consumers with autonomy concerns, un- fortunately many energy suppliers have failed to successfully communicate this information in their nationwide campaigns"	Buchanan et al. (2016), p.97
	"Indeed, a common concern across interviews was loss of control, with some interviewees worrying about their electricity company using smart meters to act like 'big brother'"	Krishnamurti et al. (2012), p.793
	"The system allows for its users to make their own choices and choose their own goals"	Ligtvoet et al. (2015), p.171
	"Both prospective users and actual early adopters also express caution towards ceding autonomy and independence in the home for increased technological control"	Wilson et al. (2017), p.82
	"A representative national survey of UK homeowners (n=1025) finds prospective users have positive perceptions of the multiple functionality of SHTs including energy management. Ceding autonomy and independence in the home for increased technological control are the main perceived risks"	Wilson et al. (2017), p.73
Calmness	*"Refers to a peaceful and composed psychological state"*	Friedman et al. (2013), p.59

	"The system promotes a peaceful and quiet state"	Ligtvoet et al. (2015), p.171
Comfort	*"People don't want to be involved in having to make day-by-day, minute-by-minute, control decisions"*	Balta-Ozkan et al. (2013), p.369
	"Avoiding the 'hassle' of meter readings"	Buchanan et al. (2016), p.95
	"Represents comfort specific issues such as light regulation, environment heating/cooling, shutter and windows operations"	Bonino and Corno (2011), p.118
	"Furthermore, smart technologies are perceived to make already complicated lives even more complicated"	Muench et al. (2014), p.85
	"In practice, this could mean that the dishwasher turns on automatically when receiving the signal that the electricity price is low now and for the next hour. This could support consumers in adapting their consumption to supply with little or no decrease in comfort"	Paetz et al. (2012), pp.24-25
	"Different authors have pro- posed energy management algorithms for Smart Home that either integrates or not renewable energy. All these researches have the same general objective: minimizing the daily energy cost without affecting the comfort of occupants"	Missaoui et al. (2014), p.155
Control	*"In the short-term, it is anticipated that smart metering will put an end to estimated billing and give UK consumers control their energy bills by equipping them with an IHD that provides real-time information about their consumption, thus enabling them to switch suppliers more easily to secure better tariffs"*	Buchanan et al. (2016), p.88
	"Issues of control and autonomy emerged as a key theme throughout discussions in each of the focus groups. This was evident not only from the words that participants used in their discussions ("choice", "option", "power", "control", "consent") but also because participants openly ex- pressed their displeasure about the idea of energy suppliers managing their energy consumption for them"	Buchanan et al. (2016), p.94
	"Specifically, consumers are receiving a reduced bill, at a fair level, due to the inconvenience of handing control of their appliances to the energy suppliers while suppliers are equipped with the tools needed to reduce strain on their grid, thus reducing the need to invest in reinforcing existing energy infrastructures"	Buchanan et al. (2016), p.95
	"In the future, SHES may also take commands from the energy company, either directly (IP based), or via the smart meter. For example, the energy company or the network company may take decisions as to when certain appliances are allowed to run or not at specific times via so called time-of-use contracts"	van de Kaa, Ligtvoet, et al. (2014), p.2
	"At the same time, they believe that end-users should remain free to decide how to participate. Freedom includes the choice to maintain energy use in situations of shortage but also which data to communicate and at what moment. It is considered unlikely that end-users will trust an external party with control over home electrical appliances, yet, at the same time users might not want to manually have to switch off appliances whenever this is more efficient. In this context stakeholders mentioned the issue of control, the amount of control that users should have over the system"	Verbong et al. (2013), p.12

	"Throughout the marketing material, user control of smart home technologies is a central concern. As Philips assures prospective users, 'your home is as individual as you and the way you live should be determined by you, not the system'"	Wilson et al. (2017), p.79
Cooperation	*"Public responses to technology are produced in an interaction process between stakeholders with different backgrounds, interests, expectations and attitudes towards the technology"*	Correljé et al. (2015), p.191
	"Smart energy systems have smart targets that are multidimensional, multidisciplinary, complex, and dynamic. Therefore, in order to reach smart targets of smart energy systems, existing and future resources, technologies, knowledge, and policies should be used in collaboration"	Dincer and Acar (2016), p.4
	"The systems allow for its users to work together with others"	Ligtvoet et al. (2015), p.171
Correctness	*"The systems process the right information and performs the right actions"*	Ligtvoet et al. (2015), p.171
Courtesy	*"Refers to treating people with politeness and consideration"*	Friedman et al. (2013), p.58
	"The system promotes treating people with politeness and consideration"	Ligtvoet et al. (2015), p.171
Democracy	*"The system promotes the input of stakeholders"*	Ligtvoet et al. (2015), p.171
	"On the other hand, I argue that the democratic process has an intrinsic fairness. Here, I lay out the basic conception of justice, which is the principle of the public realization of equal advancement of interests"	Christiano (2004), p.269
	"I have argued that a fair way of making decisions in the light of disagreement which treats people's judgments and interests with respect without defeating the point of political society is to give each a reasonably equal say in the process of deciding. On this account, it is just to assure each robust opportunities to contribute to political discussions on controversial matters, resources for making compromises and coalitions with others who disagree, and finally, votes in the final decision-making about how shared aspects of social life are to be arranged. It is a robust way of taking people's views into consideration. This approach treats each publicly as an equal and respects each citizen's judgment without requiring that everyone agree to the outcome of the decision-making or be equally satisfied with the outcome"	Christiano (2004), p.284
Distributive justice	*"Refers to (questions regarding) patterns of distribution of an important good or commodity, 'distributive justice' is a procedural value. When it focuses on the unit of distribution; i.e. what is the entity or unit of benefit, good or commodity that is to be distributed, it is a substantive value"*	Dignum et al. (2016), p.1178
	"The fair distribution of costs, benefits, and other positive and negative external effects, including both spatial and temporal distributive justice. The spatial part refers to distribution of negative and positive consequences in a physical spatial sense. The temporal aspect includes intergenerational issues and includes exploitation of resources for future generations, as well as the environment we leave behind"	Dignum et al. (2016), p.1179
	"How are costs and benefits shared"	Wüstenhagen et al. (2007), p.2685

	"Distributive justice focuses on the equitable distribution of outcomes, which can be either public goods or public 'burdens', such as hazardous waste products"	Gross (2007), p.2729
	"Distributional justice, including a reasonable allocation of costs and benefits between the public and private sectors"	Künneke et al. (2015), p.120
	"Not only evaluations of costs and benefits per se, but also the extent to which costs and benefits are believed to be distributed fairly across groups in society, which reflects perceived distributive fairness, can influence acceptability"	Steg et al. (2014), p.364
Economic development/ Profitability	*"Energy bill cutback"*	Ellabban and Abu-Rub (2016), p.1293
	"Currently, smart meters are predominantly used by energy suppliers for more automated and accurate billing"	Geelen et al. (2013), p.156
	"Another potential benefit of smart meters is that they may help customers to save money"	Krishnamurti et al. (2012), p.791
	"The system is beneficial to the economic status/finances of its users"	Ligtvoet et al. (2015), p.171
Environmental sustainability	*"Refers to sustaining ecosystems such that they meet the needs of the present without compromising future generations"*	Friedman et al. (2013), p.59
	"Have a positive impact on the environment Learning how to reduce energy use"	Buchanan et al. (2016), p.91
	"Reduce carbon emissions"	Buchanan et al. (2016), p.95
	"Responsive demand driven by dynamic pricing can also reduce greenhouse gases and local pollutants. Enhanced price signals can cause customers to shift demand away from peak times, avoiding emission-intensive generators used to serve system peak in some regions. The CO_2 reductions of smart metering and dynamic pricing, and resulting demand response have been quantified in studies, some specific to the US, others global in scope. They show modest direct benefits, at maximum around 5% of total emissions in 2030. Renewable energy deployment in the 25–40% range supported by a smarter grid can deliver another 5– 10% of cuts in CO2 emissions"	Buryk et al. (2015), p.191
	"Most survey respondents would clearly favour a move away from fossil fuel energy production towards the use of other energy sources"	Demski et al. (2013), p.19
	"These findings confirm that reducing energy use is perceived to be a positive aspect of future energy transitions, and something to strive towards. In principle, over two thirds of respondents are willing to play a personal part in reducing energy use if supported in some way"	Demski et al. (2013), p.27
	"The UK and Irish governments have taken the idea of using smart meters as a tool for carbon reductions further than most, and both have decided to proceed with national rollouts of AMI, although many elements of equipment, procedures, and regulation remain to be decided"	Darby (2010), p.448
	"There are three principal ways in which smart grids are thought capable of contributing to achieving	Darby et al. (2013), p.726

	EU targets for greenhouse gas reduction and integrated renewable generation"	
	"The table shows substantial potential for percentage carbon dioxide reductions in four of the six countries, rising to 13 % in France, 8 % in Great Britain and Portugal and 7 % in Spain"	Darby et al. (2013), p.736
	"The full deployment of the smart grid would provide many potential benefits. The main benefits of the SG, include a more reliable, more economic, and more environmentally friendly grid"	Ellabban and Abu-Rub (2016), p.1287
	"As a result, successful demand response programs can provide consumers with more reliable service and decrease the need for new generation, which in turn could reduce energy waste and subsequent carbon emissions"	Krishnamurti et al. (2012), p.790
	"The system does not burden ecosystems, so that the needs of current generations do not hinder future generations"	Ligtvoet et al. (2015), p.171
	"Reduce consumers' fossil energy use and related emissions of greenhouse gases, by increasing their understanding of ways to reduce their fossil energy use and to make better use of self-generated renewable energy sources"	Noppers et al. (2016), p.12
	"Main motives for adopting smart home technologies is the lower ecological footprint"	Paetz et al. (2012), p.38
	"Since smart meters have advanced features that allow consumers to track their energy consumption over short and long periods, they are considered an essential part of the solution for achieving energy efficiency and sustainable development in smart grids"	Ponce et al. (2016), p.588
	"Global warming has been linked to the burning of crude oil and natural gas. Because SG technology helps increase the implementation of renewable energy in electric markets and alleviate the problem of global warming, it is a key technology for improving environmental and financial conditions for end users"	Ponce et al. (2016), p.588
	With large efforts put forth for Smart Grid research, the Smart Grid can be more effective in helping attain energy sustainability and environmental conservation and preservation.	Tuballa and Abundo (2016), p.720
	"Although environmental values play a role in engineering for quite some time, in the last decade this has been increasingly understood in terms of the broader value of sustainability. The most influential definition of sustainable development has been provided by the Brundtland Commission: 'Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs'"	van de Poel (2015), p.67
	"Social acceptance may be enhanced if consumers perceive smart meters to be useful for society and the environment"	Zhou and Brown (2017), p.28
Fairness/Justice	*"Justice is accepted as central to the well-functioning of society with fairness being an expectation in day-to-day interactions. Outcomes that are perceived to be unfair can result in protests, damaged relationships and divided communities, particularly when decisions are made which benefit some*	Gross (2007), p.2727

	sections of the community at the perceived expense of others"	
Freedom from bias	*"Refers to systematic unfairness perpetrated on individuals or groups, including pre-existing social bias, technical bias, and emergent social bias"*	Friedman et al. (2013), p.58
	"The system does not promote a select group of users at the cost of others"	Ligtvoet et al. (2015), p.171
Health	*"The fear of carcinogenic effects from radio frequency waves has created negative public opinion about the safety of Advanced Metering Infrastructures, demand– response end-use systems, electric vehicle charging stations, and other smart-grid technologies"*	Brown and Zhou (2013), p.123
	"Is defined by the World Health Organization (WHO) as 'state of complete physical, mental and social well-being and not merely the absence of disease or infirmity'. In engineering, the focus is usually on avoiding negative influences on human health. It is not obvious that there is a requirement for engineering to contribute positively to human health, with the exception perhaps of some specific domains like health technologies"	van de Poel (2015), p.673
Health and safety	*"[A] state of complete physical, mental and social well-being and not merely the absence of disease or infirmity''. An argument relates to the value of health when it compromises, or refers to, the state of well-being as defined by the World Health Organization or when it inhibits people from reaching this state"*	Dignum et al. (2016), p.1178
	"Considering smart meters, we envisage that these devices have certain features that can arguably be perceived as involving risk. First of all, it is a technology based on wireless networks, and the emission of remote signals may be perceived as risky, as it happens with other wireless devices, associated with exposure to radiation, and thus adverse health"	Guerreiro et al. (2015), p.1152
	"The system does not harm people"	Ligtvoet et al. (2015), p.171
	"Smart meters provide exposures to radio frequency waves causing electro hypersensitive (EHS)"	Yesudas and Clarke (2015), p.628
Honesty	*"Telling what one has good reasons to believe to be true and disclosing all relevant information"*	van de Poel and Royakkers (2011), p.38
Identity	*"Refers to people's understanding of who they are over time, embracing both continuity and discontinuity over time"*	Friedman et al. (2013), p.59
	"The system allows its users to maintain their identity, shape it, or change it if required"	Ligtvoet et al. (2015), p.171
Informed consent	*"Refers to garnering people's agreement, encompassing criteria of disclosure and comprehension (for 'informed') and voluntariness, competence, and agreement (for 'consent')"*	Friedman et al. (2013), p.58
	"Similarly, some participants expressed a preference to be given the information so that they could play an active part in making decisions about their energy management"	Buchanan et al. (2016), p.94
	"Utilities and policy makers could play important roles in defining and communicating any health and safety effects and the benefits of smart-grid systems to various stakeholders"	Brown and Zhou (2013), p.123

	"Based on the long-term power usage pattern, the feedback information from smart meter data analytics offers consumers a better understanding of their energy consumption and help them increase end-use energy efficiency"	Chou et al. (2015), p.193
	"The systems allow its users to voluntarily make choices, based on arguments"	Ligtvoet et al. (2015), p.171
Integrity	*"Living by one's own (moral) values, norms and commitments"*	van de Poel and Royakkers (2011), p.38
Legitimacy	*''Sound political and legal basis with a corresponding institutional framework''*	Dignum et al. (2016), p.1179
	"The system is deployed on a legal basis or has broad support"	Ligtvoet et al. (2015), p.171
Ownership and property	*"Refers to a right to possess an object (or information), use it, manage it, derive income from it, and bequeath it"*	Friedman et al. (2013), p.58
	"Collection and storage of data are only part of the issue. Ultimately, the privacy implications of the smart grid rest upon who owns consumer data"	Herkert and Kostyk (2015), p.294
	"The system facilitates ownership of an object or of information and allows its owner to derive income from it"	Ligtvoet et al. (2015), p.171
Participation/Inclusiveness	*"Instead of mere consent to an infrastructure project, domestic micro-generation requires active acceptance by homeowners, whereby individual households become part of the electricity supply infrastructure"*	Wüstenhagen et al. (2007), p.2688
	"Also, technology would exclude those who are not computer literate, notably older people"	Balta-Ozkan et al. (2013), p.370
	"Young people were seen to 'live' for technology, such as mobiles, and iPads, contrasting with the elderly who are less likely to own computers and would struggle unless devices had a more user-friendly design"	Balta-Ozkan et al. (2013), p.370
	"Consumer involvement in the energy system requires cooperation among the parties, i.e., the industry, regulators and consumers themselves, allowing innovative culture development and market interactions between owners and managers of electricity production and distribution sectors"	Bigerna et al. (2016), p.406
	"Consumers help balance supply and demand, and ensure reliability by modifying the way they use and purchase electricity. These modifications come as a result of consumers having choices that motivate different purchasing patterns and behaviour. These choices involve new technologies, new information about their electricity use, and new forms of electricity pricing and incentives"	Herkert and Kostyk (2015), p.291
	"The system promotes active participation of its users"	Ligtvoet et al. (2015), p.171
Privacy	*"Refers to a claim, an entitlement, or a right of an individual to determine what information about himself or herself can be communicated to others"*	Friedman et al. (2013), p.58
	"The industry faces the challenge of ensuring that personal data is adequately safeguarded"	Balta-Ozkan et al. (2013), p.366

	"Making consumer information available to other parties may be fraught with difficulty. It is possible that data may fall into the 'wrong hands', or that one piece of 'innocent data' combined with a second piece of 'innocent data' becomes a piece of 'non-innocent' data"	Balta-Ozkan et al. (2013), p.369
	"Monitoring of daily habits was perceived as too intrusive, controlling, restrictive, 'big brother-like' and engendering paranoia"	Balta-Ozkan et al. (2013), p.369
	"A strong theme throughout the groups equated the household monitoring involved with smart technology with 'big brother' watching them. Smart home technology was often viewed as a further invasion of, or threat to, privacy in a society where already too much personal information is collected and stored. The 'Post- Family Town' group speculated over whether the companies responsible for smart home services would sell on personal data as they would be in receipt of 'all this free information from millions of homes every month'"	Balta-Ozkan et al. (2013), p.370
	"Believes regarding the processes, activities, systems, or tasks that protect the confidentiality, integrity, and accessibility of information or objects (Privacy/Safety Concern)"	Chou et al. (2015), p.197
	"I expect that my privacy would not be compromised by a smart meter in my house. I expect all information about my energy consumption would be protected. I expect all information about my profile would be protected"	Chou et al. (2015), p.197
	"Energy consumption reveals details of personal life, in the most privacy-sensitive place – the home, and therefore smart metering has to strike a careful balance between detailed energy metering and privacy protection"	Cuijpers and Koops (2012), p.2
	"Informational privacy concerns the protection of personal data. Because of the importance of data protection in current society, the concepts of privacy and data protection are often used as synonyms, in a sense that people speak of privacy when they mean informational privacy or the protection of personal data"	Cuijpers and Koops (2012), p.6
	"As is the case for many other modern ICT applications such as the Internet and geographical positioning system (GPS), ensuring consumer privacy will be a challenge for the smart grid"	Herkert and Kostyk (2015), p.293
	"The system allows people to determine which information about the is used and communicated"	Ligtvoet et al. (2015), p.171
	"In particular, privacy is considered an issue that can block successful introduction of smart grids and DSM. Detailed data on electricity consumption gives involved actors a lot of information on user behaviour"	Verbong et al. (2013), p.120
	"The issue of data protection and privacy is also raised in the UK Government proposals, which note the data might allow insight into the lifestyle of individual consumers and thus encroach on their privacy"	Connor et al. (2014), p.278
Procedural justice	*"Is there a fair decision-making process giving all relevant stakeholders an opportunity to participate"*	Wüstenhagen et al. (2007), p.2685
	"Transparency, honesty as well as timely, full, and unbiased information in the procedure of planning,	Dignum et al. (2016), p.1179

	exploratory drilling, and exploitation"	
	"Procedural justice is concerned with the processes by which decisions are made 'in pursuit of other societal goals, including either of the other types of justice'. Important elements in procedural justice include rights of participation, access to information, and lack of bias on the part of the decision-maker"	Gross (2007), p.2729
	"Procedural justice refers to the processes of decision making being fair and appropriate, which is often based on the fact that relevant stakeholders are able to participate in decision making. The theory of procedural justice proposes that if the decision process is perceived as being fair, people are more likely to accept the final, even if this is not what they wished"	Guerreiro et al. (2015), p.1152
	"The extent to which people believe that decisions regarding (implementation of) energy alternatives are taken in a fair way, namely perceived procedural fairness, has also been linked to (mostly community) acceptability"	Steg et al. (2014), p.364
	"Procedural justice that includes all societal groups affected by the wind energy system in the decision making"	Künneke et al. (2015), p.120
Quality of life/ Well-being/Welfare	*"Connecting with others, being active, taking notice of experiences and surroundings, learning and giving to others. Connect with the people around you. With family, friends, colleagues and neighbours. At home, work, school or in your local community. Building these connections will support and enrich you every day. Go for a walk or run. Step outside. Cycle. Play a game. Garden. Dance. Exercising makes you feel good. Take notice. Be curious. Catch sight of the beautiful. Remark on the unusual. Notice the changing seasons. Savour the moment. Be aware of the world around you. Reflecting on your experiences will help you appreciate what matters to you. Try something new. Rediscover an old interest. Sign up for that course. Take on a different responsibility at work. Fix a bike. Learning new things will make you more confident as well as being fun. Do something nice for a friend, or a stranger. Thank someone. Smile. Volunteer your time. Seeing yourself, and your happiness, linked to the wider community can be incredibly rewarding and creates connections with the people around you"*	Buchanan et al. (2016), p.88
	"The term social well-being is used in this research to encapsulate a community's ability to respond collectively to challenges"	Gross (2007), p.2728
	"The system promotes physical, psychological, and material well-being"	Ligtvoet et al. (2015), p.171
	"Human well-being. This value is being referred to under a number of headings like human welfare, happiness, quality of life, human flourishing, and good life. I will here use the term "human well-being" to refer to the value that is at stake in all these cases. Well-being does not just refer to feeling well here and now but it tells something about how someone's life is going for that person"	van de Poel (2015), p.673
Reliability	*"Tolerances for technical errors, malfunctions, inference in householder's desired outcome"*	Balta-Ozkan et al. (2013), p.366
	"Malfunctioning, inference of householders' desired outcome, avoiding unintended consequences. Behaviour recognition forming key aspect of smart homes, sensors going off by mistake. Due to break	Balta-Ozkan et al. (2013), p.371

	down of remote control units house going in limbo"	
	"The high-level penetration of distributed generation (DG) on existing infrastructure can threaten system stability"	Brown and Zhou (2013), pp.122-123
	"Price-responsive customers can produce efficiency gains for the electricity sector because they: require less infrastructure to generate and distribute power at peak times1; cut electricity procurement costs through lower peak prices; and reduce vulnerability to service failures, such as blackouts"	Buryk et al. (2015), pp.191-192
	"Using a smart meter would probably frustrate me because of its poor performance"	Chou et al. (2015), p.197
	"Reliability; by minimizing the cost of interruptions and power quality disturbances and decreasing the probability and outcomes of widespread blackouts"	Ellabban and Abu-Rub (2016), p.1287
	"One main benefit of smart meters is that they can improve the operational efficiency of the grid and allow for proactive maintenance. For consumers, the benefits of this improvement might be realized through the reduction of such adverse events as blackouts"	Krishnamurti et al. (2012), p.791
	"The system fulfils its purpose without the need to control or maintain it"	Ligtvoet et al. (2015), p.171
	"EV's offer potential for supporting grid reliability. Specifically, vehicle battery technologies that discharge energy back into the grid during high usage periods offer potential for distributed storage networks and a fundamentally new strategy for managing peak demand"	Sintov and Schultz (2015), p.5
	"Reliability, which might be understood as 'the ability of a product to perform its function adequately over a period of time without failing'"	van de Poel (2015), p.672
	"The penetration of renewable sources, particularly wind and solar, into the grid has been increasing in recent years. As a consequence, there have been serious concerns over reliable and safety operation of power systems"	Bianchi et al. (2014)
Risk perception/Uncertainty	*"Uncertainty that affects individual confidence in their decisions. Compared with other energy measurement technologies, a smart meter has more uncertainties"*	Chou et al. (2015), p.197
	"Uncertainty regarding the development of the energy system"	Muench et al. (2014), p.88
Safety	*"Safety refers to the situation in which the risks have been reduced in as far that is reasonably feasible and desirable"*	van de Poel (2015), p.673
Security of supply	*"A large majority is very or fairly concerned about more abstract, long-term future aspects of energy security including dependence on other countries (82%), and having alternatives in place when fossil fuels are no longer available (84%). Respondents are also very or fairly concerned about being able to afford electricity and gas (83%). Interestingly, concern over petrol prices (78%) is lower than for electricity and gas, although still notably high. Expressed concern is also found for items relating to the interruption of energy services although relatively speaking, this concern is lower than for the other energy security aspects. In this survey, 73% are very or fairly concerned about a national petrol*	Demski et al. (2013), p.12

	shortage, and a lower percentage (63%) are concerned about frequent power cuts in the next 10-20 years"	
	"Security of supply comprises: International stability: National and international stability in relation to energy supply, including concerns about import dependence, geopolitical tensions due to changes in energy reserves, and concerns of energy exporting countries regarding demand insecurity. Resource durability: Availability of resources for future generations. This may include the conservation of existing finite resources as well as the development of alternative resources to compensate for depleted resources"	Dignum et al. (2016), pp.1177-1178
	"This is basically about energy security. A smart energy system should be designed and implemented in a way by taking advantage of affordable, reliable, locally available, abundant and replenished sources. Such smart energy systems then become self-sufficient, safe, efficient and hence secure. With smart energy systems, end users have access to dependable, practical, safe, and efficient energy supply which eventually provides energy security"	Dincer and Acar (2016), p.2
	"Moreover, demand–response programs are expected to decrease utilities' capacity costs paid to energy suppliers to ensure availability during peak demand times"	Krishnamurti et al. (2012), p.790
	"Security of supply, or availability of power when needed. This includes sufficient power supply, and stability of the electric grid and auxiliary system services"	Künneke et al. (2015), p.120
	"As such smart homes are seen as an integral part of a future energy efficient system, helping to reduce overall demand as well as alleviating supply constraints during periods of peak load"	Wilson et al. (2017), p.72
	"Security of supply for electricity systems means that these have a low risk of supply interruption"	Römer et al. (2015), p.50
	"Energy efficiency generally aims to reduce overall energy demand, whereas demand response concentrates more on shifting energy consumption during peak times to help balance supply and demand"	Warren (2014), p.943
Technical complexity	*"Individual perception of the difficulty understanding and using new technology e.g. I would have no difficulty reading the information on smart meter in-house display"*	Chou et al. (2015), p.197
	"In a smart grid with time-based variable pricing, the management of energy consumption and production can become rather complex for a household"	Geelen et al. (2013), p.157
Tractability	*"The functioning of the system can be traced"*	Ligtvoet et al. (2015), p.171
Transparency/Accuracy	*"A new generation of advanced and intelligent metering devices which have the ability to record the energy consumption of a particular measuring point in intervals of fifteen minutes or even less; communicate and transfer the information recorded in real time or at least on a daily basis by means of any communications network to the utility company; enable a two-way communication between the meter and the central system of the utility company, the so called distribution systems operator (DSO) allowing for remotely control functionalities of the meter such as switch off from the delivery of energy"*	Cuijpers and Koops (2012), p.4

	"Another key functionality of smart meters is that they provide detailed feedback to consumers on their energy consumption, which raises awareness and should incite them to save energy where possible"	Cuijpers and Koops (2012), p.3
	"They share a need for accurately-measured and reliable energy systems, and they also have a shared interest in potential pitfalls, such as unwarranted direct load control, confusing tariffs, and invasion of privacy"	Darby (2012), p.104
	"Bills are no longer based on estimates, but rather on actual consumption, improving the quality of billing that is often the target of customer complaints"	Guerreiro et al. (2015), p.1150
	"This improved version of an electricity meter is seen as an important element for electricity grid optimisation that also allows for end-user efficiency through insight into consumption patterns"	Ligtvoet et al. (2015), p.158
Trust	*"Refers to expectations that exist between people who can experience good will, extend good will toward others, feel vulnerable, and experience betrayal"*	Friedman et al. (2013), p.58
	"Trust is a key issue in all facility siting issues. Siting decisions are always heavily loaded with risk components: environmental, economic, and social risks. The perceived fairness is to a large extent dependant on how potential risks are defined, how information about those risks is produced, and how and by whom they are managed"	Wüstenhagen et al. (2007), p.2687
	"Do potential investors trust authorities that they sustain their financial support instruments? In other words, do they trust the real commitment to the renewable energy policies of their policy makers that is still essential in market acceptance of renewable energy?"	Wüstenhagen et al. (2007), p.2688
	"Does the local community trust the information and the intentions of the investors and actors from outside the community"	Wüstenhagen et al. (2007), p.2685
	"It is essential to create trust to foster the involvement of public and private actors. Planning and decision-making overly focused on formal decisional competencies, and therefore without opportunities for meaningful deliberation, generally fuels conflict. Community members must have strong conviction that the new energy system will serve their benefit as well as that the organisation facilitating the process will act in their best interest. 'Trusting social relationships support and enable cooperation, communication and commitment such that projects can be developed and technologies installed in ways which are locally appropriate, consensual rather than divisive, and with collective benefits to the fore'"	Wolsink (2012), p.828
	"The degree of acceptance by key actors and the actors that ultimately should invest in the assets is also deter- mined by the level of trust they have of the institutions and the other actors that guide the transformation of the conventional energy grid into a 'smart grid'"	Wolsink (2012), p.826
	"The issue of cost also triggered broader discussions about trust in government and industry across the groups. Participants questioned whether smart technologies and services would really save customers money in the long run, since energy suppliers and technology producers would ultimately be motivated by profit and suspected that any financial savings made by utility companies would not be passed on to	Balta-Ozkan et al. (2013), pp.379-371

	the consumer: And being a bit cynical too, isn't there a vested interest on the part of energy companies to make money and yet we're told that they're trying to encourage us to use less energy? I don't think that's being particularly honest"	
	"Lack of trust that financial savings made by utility companies will be passed onto the consumers Prioritisation of issues by the UK Government"	Balta-Ozkan et al. (2013), p. 371
	"From the explanations given it was clear that participants found it difficult to comprehend how an energy provider would profit if they were encouraging consumers to use less energy"	Buchanan et al. (2016), p.94
	"'Big Brother'" to invoke a comparison of being watched by an unseen and invasive presence"	Buchanan et al. (2016), p.94
	"Trust in government and in the energy industry in a given context will affect the nature of the debate. For example, the UK regulator Ofgem, which held deliberative workshops on privacy with 100 customers chosen to be representative of the population, found that the main concern was that data would be shared with third parties, leading to unwanted commercial intrusions. However, most customers did accept that their data might be useful to government and suppliers in predicting demand; only a few were apprehensive of 'spying' on their lives"	Darby (2012), p.104
	"When people know little about a technology, acceptance may mostly depend on trust in actors that are responsible for the technology, as a heuristic or alternative ground to base one's opinion on. As yet, no agreement exists about the exact definition of trust and types of trust. A popular definition was proposed by Rousseau et al.: 'Trust is a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behaviour of another'"	Huijts et al. (2012), p.528
	"The system promotes trust in itself and in its users"	Ligtvoet et al. (2015), p.171
	"Development, production, distribution, and use of different energy alternatives are complex matters that can only be fully grasped by people with specific knowledge and expertise. This means that the public need to rely on other parties (e.g., energy companies, national and local governments, interest groups, knowledge institutes) when evaluating costs and benefits of energy alternatives. Hence, the extent to which people trust these parties is an important factor for acceptability. In the literature, trust has been defined as 'a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behaviour of another'. Trust is partly a personal predisposition and can also be defined by the context (e.g., which parties are involved with energy alternatives and how they perform). We classify trust as a general psychological factor that can make energy alternatives appear in an overly positive or a negative light"	Steg et al. (2014), p.368
	"Experts felt that consumer trust will in part be reliant on assurances that data protection and privacy measures are sufficient, along with increased transparency and benefit-sharing since the current public perception is that energy companies do not act in consumers' best interest"	Xenias et al. (2015), p.96
	"Clear regulation about ownership and liability is crucial to gain public trust for clean technology deployment"	Zhou and Brown (2017), p.28

Universal usability	*"Refers to making all people successful users of information technology"*	Friedman et al. (2013), p.58
	"The system can be easily used by all (foreseen) users"	Ligtvoet et al. (2015), p.171

Appendix D: Search summary

This appendix is a supplement of §4.1.1. Table 16 below presents the search summary of the search performed in the Factiva digital database.

Table 16: Search summary of the Factiva database

Search query	smart energy system* or intelligent energy system* or digital energy system* or smart electricity system* or intelligent electricity system* or digital electricity system* or smart grid* or intelligent grid* or digital grid* or smart electricity network* or intelligent electricity network* or digital electricity network* or smart power grid* or intelligent power grid* or digital power grid* or smart energy grid* or intelligent energy grid* or digital energy grid* or smart energy network* or intelligent energy network* or digital energy network* or smart energy or intelligent energy or digital energy or smart electricity or intelligent electricity or digital electricity or smart power or intelligent power or digital power or smart meter* or intelligent meter* or digital meter* or smart energy meter* or intelligent energy meter* or digital energy meter* or smart electricity meter* or intelligent electricity meter* or digital electricity meter* or smart residence* or intelligent residence* or digital residence* or smart home* or intelligent home* or digital home* or smart building* or intelligent building* or digital building* or smart house * or intelligent house * or digital house * smart living space* or intelligent living space* or digital living space* or smart energy regulation* or intelligent energy regulation* or digital energy regulation* or smart energy policy or intelligent energy policy or digital energy policy or smart energy rule* or intelligent energy rule* or digital energy rule* or smart energy arrangement* or intelligent energy arrangement* or digital energy arrangement* or smart energy legislation or intelligent energy legislation or digital energy legislation or smart energy Act* or intelligent energy Act* or digital energy Act* or ((smart or intelligent or digital) and charging and (electric car* or electric vehicle*)) or microgrid or home battery or home batteries or home storage or demand side management or demand side response or demand response or virtual power plant
Date	01/01/2007 to 30/06/2017
Source	The Daily Telegraph (U.K.) Or The Sunday Telegraph (U.K.) Or The Times (U.K.) Or The Guardian (U.K.) Or The Observer (U.K.) Or Financial Times (Available to Academic Subscribers Only) Or i (U.K.) Or Daily Mail (U.K.) Or The Mail on Sunday (U.K.) Or The Daily Express (U.K.) Or Sunday Express (U.K.) Or The Sun (U.K.) Or The Daily Mirror (U.K.) Or The Sunday Mirror (U.K.) Or Daily Star (U.K.) Or Daily Star Sunday (U.K.) Or People (U.K.) Or Metro (U.K.) Or The Independent (U.K.) Or Independent On Sunday (U.K.) Or The News of the World
Author	All Authors
Company	All Companies
Subject	All Subjects
Industry	All Industries
Region	United Kingdom
Language	English
Results Found	4,509
Timestamp	1 September 2017 17:59

Appendix E: The codebook

The codebook used for the qualitative content analysis of British national newspaper reports on smart grid systems is presented in Table 17 and Table 18. This codebook presents and defines the codes that label the text (i.e. value-laden statements) in the newspaper articles (i.e. the empirical data). More details on the codebook and coding scheme can be found in §4.3.

Table 17: Value codes and their definition

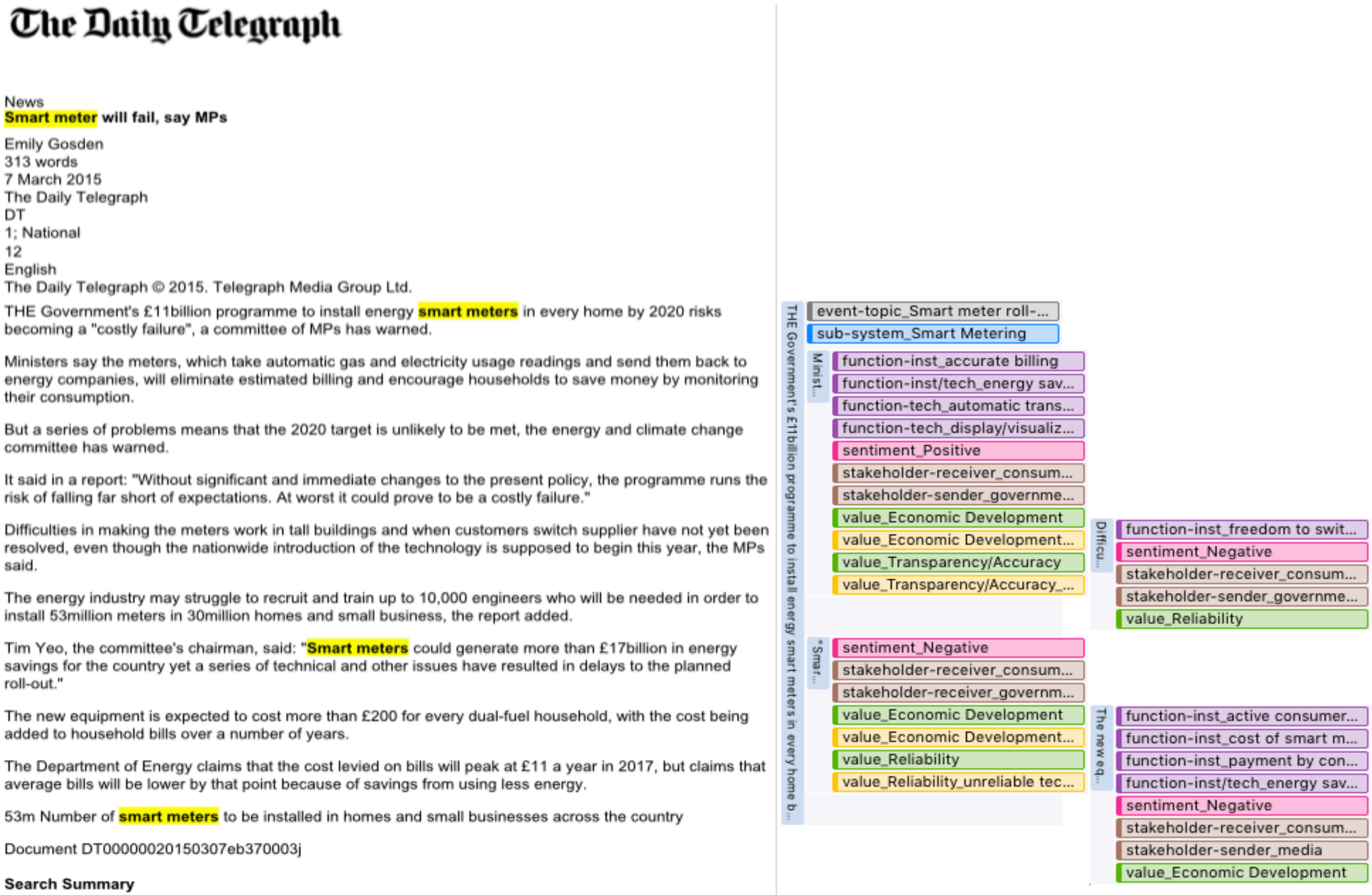
Value	Code	Conceptualization in smart energy context
Accountability	value_Accountability	Refers to the properties of smart grid systems that allows and ensures that the actions or activities of a person, people, or institution may be traced uniquely to that specific person, people, or institution. This 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.
Autarky	value_Autarky	Refers to smart grid systems allowing energy independence, energy autonomy, energy self-reliance or energy self-sufficiency.
Calmness	value_Calmness	Refers to smart grid systems promoting and allowing a peaceful and composed psychological state to its users and other stakeholders.
Control/Autonomy	value_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.
Cooperation	value_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.
Courtesy	value_Courtesy	Refers to smart grid systems promoting treating people with dignity, politeness, and consideration.
Democracy	value_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.
Distributive Justice	value_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.
Economic development	value_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.
Environmental Sustainability	value_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.

Freedom from bias	value_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.
Health and Safety	value_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.
Honesty/Integrity	value_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.
Identity	value_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.
Informed Consent	value_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.
Legitimacy	value_Legitimacy	Refers to smart grid systems being deployed on a sound political and legal basis or having broad support.
Ownership/ Property	value_Ownership/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.
Privacy	value_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).
Procedural Justice	value_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.
Quality of Life/Well-being/ Comfort	value_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).
Reliability	value_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.
Security	value_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).
Security of Supply	value_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.
Transparency/ Accuracy	value_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.

Trust	value_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.
Universal usability/ Inclusiveness	value_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.).

Table 18: Other predefined codes

Main category code	Subcategory	Code	Conceptualization
event-topic	…	event-topic_…	Refers to a specific event topic in the newspaper articles.
valence	Positive	valence_Positive	Refers to a coded statement that contains a pro-argument or an advantage related to smart grid systems.
valence	Negative	valence_Negative	Refers to a coded statement that contains a contra-argument or a disadvantage or a challenge (things that have to be taken care of for smart grid systems to yield its benefits).
valence	Neutral	valence_Neutral	Refers to a coded statement that contains a neutral argument (nor pro-argument or contra-argument) related to smart grid systems.
stakeholder-sender	…	stakeholder-sender_…	Refers to the stakeholder who sends/makes the coded statement (e.g. government talking about consumers, the sender is the "government").
stakeholder-receiver	…	stakeholder-receiver_…	Refers to the stakeholder who is affected/addressed by the coded statement (e.g. government talking about consumers, the receiver is "consumers").
sub-system	Smart Grid	sub-system_Smart Grid	Refers to smart grids as a sub-system i.e. technical component of smart grid systems (being the physical power network) and smart grid as a sub-system i.e. energy management system (e.g. facilitates the integration of the actions and behaviour of users (e.g. electricity producers, consumers, and prosumers)).
sub-system	Smart Metering	sub-system_Smart Metering	Refers to smart meters as a sub-system i.e. technical component of smart grid systems.
sub-system	Smart Home/HEMS	sub-system_Smart Home/HEMS	Refers to smart homes (in the context of home energy management systems) as a sub-system i.e. technical component of smart grid systems.
sub-system	Demand Response	sub-system_Demand Response	Refers to demand response (being part of demand response) as a sub-system i.e. technical component of smart grid systems.
sub-system	Household Electricity Storage	sub-system_Household Electricity Storage	Refers to household electricity storage (in the context of energy storage, e.g. in batteries) as a sub-system i.e. technical component of smart grid systems.
sub-system	Vehicle-to-Grid	sub-system_Vehicle-to-Grid	Refers to the notion of electric vehicles storing power as part of a smart grid i.e. vehicle-to-grid, being a sub-system i.e. technical component of smart grid systems.



The Daily Telegraph

News
Smart meter will fail, say MPs

Emily Gosden
313 words
7 March 2015
The Daily Telegraph
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12
English
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THE Government's £11billion programme to install energy **smart meters** in every home by 2020 risks becoming a "costly failure", a committee of MPs has warned.

Ministers say the meters, which take automatic gas and electricity usage readings and send them back to energy companies, will eliminate estimated billing and encourage households to save money by monitoring their consumption.

But a series of problems means that the 2020 target is unlikely to be met, the energy and climate change committee has warned.

It said in a report: "Without significant and immediate changes to the present policy, the programme runs the risk of falling far short of expectations. At worst it could prove to be a costly failure."

Difficulties in making the meters work in tall buildings and when customers switch supplier have not yet been resolved, even though the nationwide introduction of the technology is supposed to begin this year, the MPs said.

The energy industry may struggle to recruit and train up to 10,000 engineers who will be needed in order to install 53million meters in 30million homes and small business, the report added.

Tim Yeo, the committee's chairman, said: "**Smart meters** could generate more than £17billion in energy savings for the country yet a series of technical and other issues have resulted in delays to the planned roll-out."

The new equipment is expected to cost more than £200 for every dual-fuel household, with the cost being added to household bills over a number of years.

The Department of Energy claims that the cost levied on bills will peak at £11 a year in 2017, but claims that average bills will be lower by that point because of savings from using less energy.

53m Number of **smart meters** to be installed in homes and small businesses across the country

Document DT00000020150307eb370003j

Search Summary

Figure 18: Example of coding value-laden statements in ATLAS.ti

Appendix F: Exploration of value relations

This Appendix serves as a supplement for §4.5.4. Table 19 and Table 20 show which values are related as their codes are co-occurring. However, the information provided by these tables does not tell what type of relationships among the values are in place.

Table 19: Co-occurrence of ethical values (part I)

	Accountability/ Traceability	Autarky	Calmness	Control/ Autonomy	Courtesy	Distributive Justice	Economic Development	Environmental Sustainability	Health and Safety	Honesty/ Integrity
Accountability/ Traceability								1		
Autarky							2	1		
Calmness					1					
Control/Autonomy						1	27	4	1	
Courtesy			1			1	1			
Distributive Justice				1	1		27	2	1	1
Economic Development		2		27	1	27		32		1
Environmental Sustainability	1	1		4		2	32			
Health and Safety				1		1				
Honesty/Integrity						1	1			
Legitimacy							5			
Ownership/Property							2			
Privacy				3			2	1		
Procedural Justice				1	1	4	6			
Quality of life/Well-being/Comfort				2	1	1	16			
Reliability						1	5	1		
Security				2			1			
Security of supply		2		3			12	8	1	
Transparency/ Accuracy	1			20			65	11		

Trust				1		2	6			
Universal usability/ Inclusiveness				1		2	5			

Table 20: Co-occurrence of ethical values (part II)

	Legitimacy	Ownership/ Property	Privacy	Procedural Justice	Quality of life/ Well-being/ Comfort	Reliability	Security	Security of supply	Transparency/ Accuracy	Trust	Universal usability/ Inclusiveness
Accountability/ Traceability									1		
Autarky								2			
Calmness											
Control/Autonomy			3	1	2		2	3	20	1	1
Courtesy				1	1						
Distributive Justice				4	1	1				2	2
Economic Development	5	2	2	6	16	5	1	12	65	6	5
Environmental Sustainability			1			1		8	11		
Health/Safety								1			
Honesty/Integrity											
Legitimacy											
Ownership/Property			1								
Privacy		1					3		3	1	
Procedural Justice					1	1					
Quality of life/Well-being/Comfort				1		1			10		
Reliability				1	1		2	2	4	1	
Security			3			2				1	
Security of supply						2					
Transparency/ Accuracy			3		10	4				2	2
Trust			1			1	1		2		
Universal usability/ Inclusiveness									2		

Based on the value co-occurrence, the network of related values is established as depicted in Figure 19. The green boxes represent the values, the grey boxes represent the quotations, and the lines represent the links between the values and the quotations. Hence, if two or more values share the same quotation, it is reasonable to assume that they are related. However, as aforementioned, the type of relationship cannot be established yet.

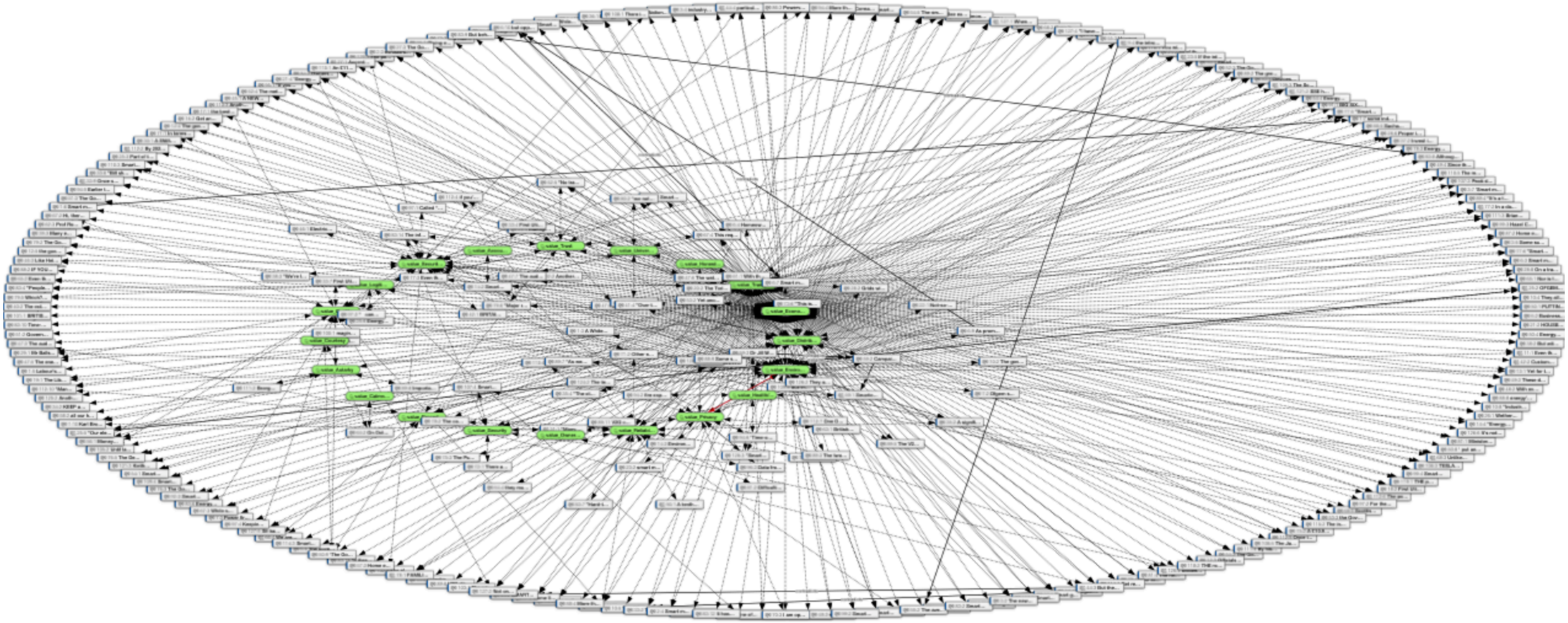

Figure 19: Complex network of overlapping value conceptualizations in the empirical data

To simplify this complex network, the data segments (i.e. quotations that represents a value-laden statement) need to be coded as high-level value conceptions. By doing so, the relations can be named in ATLAS.ti. In the network view of this software, I imported a value and all its quotations. Then, clicked on each quotation and imported codes. Thereafter, all codes except the value codes are deleted and non-overlapping quotations between values in the network. Each quotation was opened and conceptualized the value that is named in that specific quotation as a new code (coloured yellow to make it easier to distinguish). Then I linked it to the quotations (to retrieve them in a later stage in order to justify the chosen relations) and then link the new (yellow) codes to the (green) value codes and name the relation (extracted from the quotation/data segment). When the relations are determined, delete the quotations from the network view to only keep the value codes and new conceptualization codes. An example is provided in Figure 20, in which the value Autarky is imported, keeping only the two overlapping quotations with other value codes (see green coloured boxes), which are in this case Economic development, Environmental sustainability, and Security of supply. By looking at each quotation the value codes can be conceptualized into a higher-level code (see yellow coloured boxes). Then, the type of relationship between the high-level conception codes can be determined and named in the network. In this example only supporting relationships came forth and are characterized by a black arrow and are named "contributes to". The conflicting relationships are characterized by a red arrow and named "contradicts". The simplified network is presented in Figure 21.

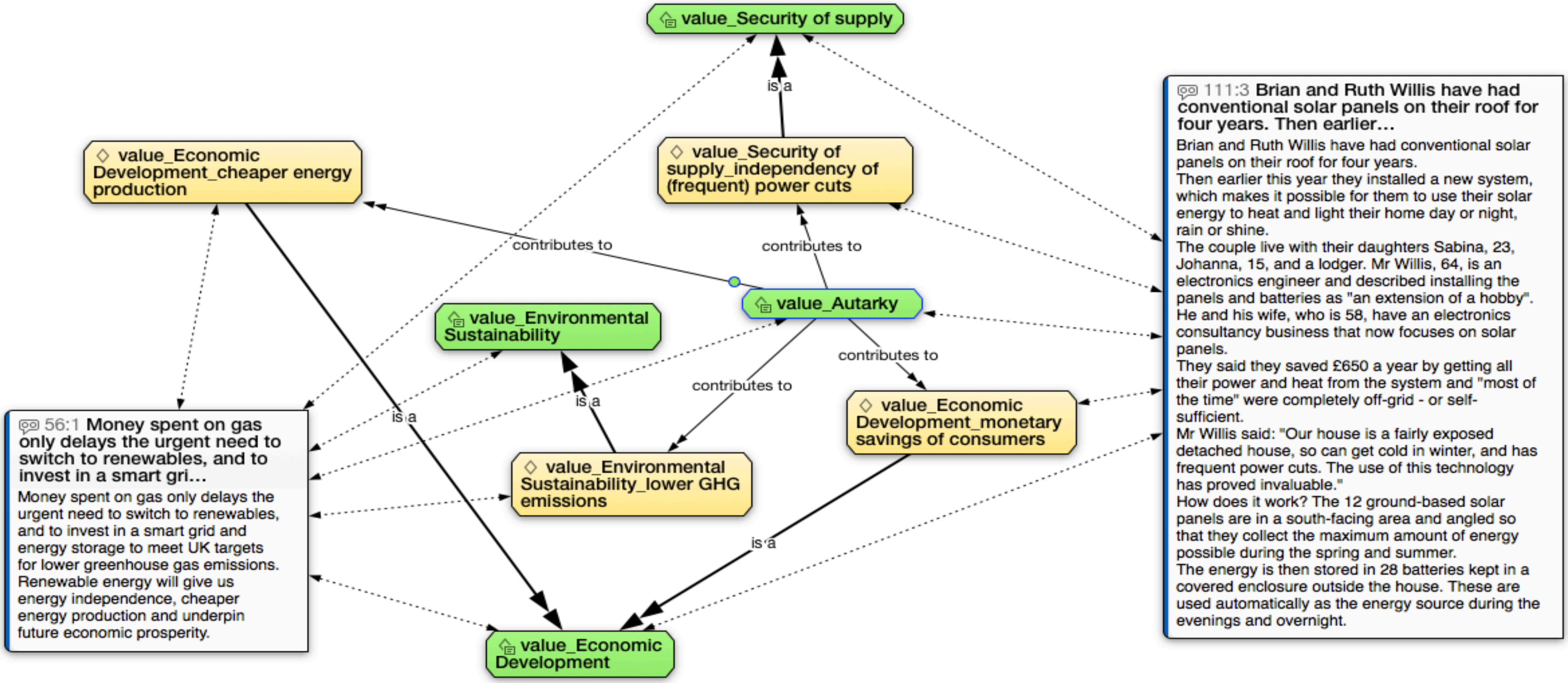

Figure 20: Example of summarizing quotations to higher level value conceptions

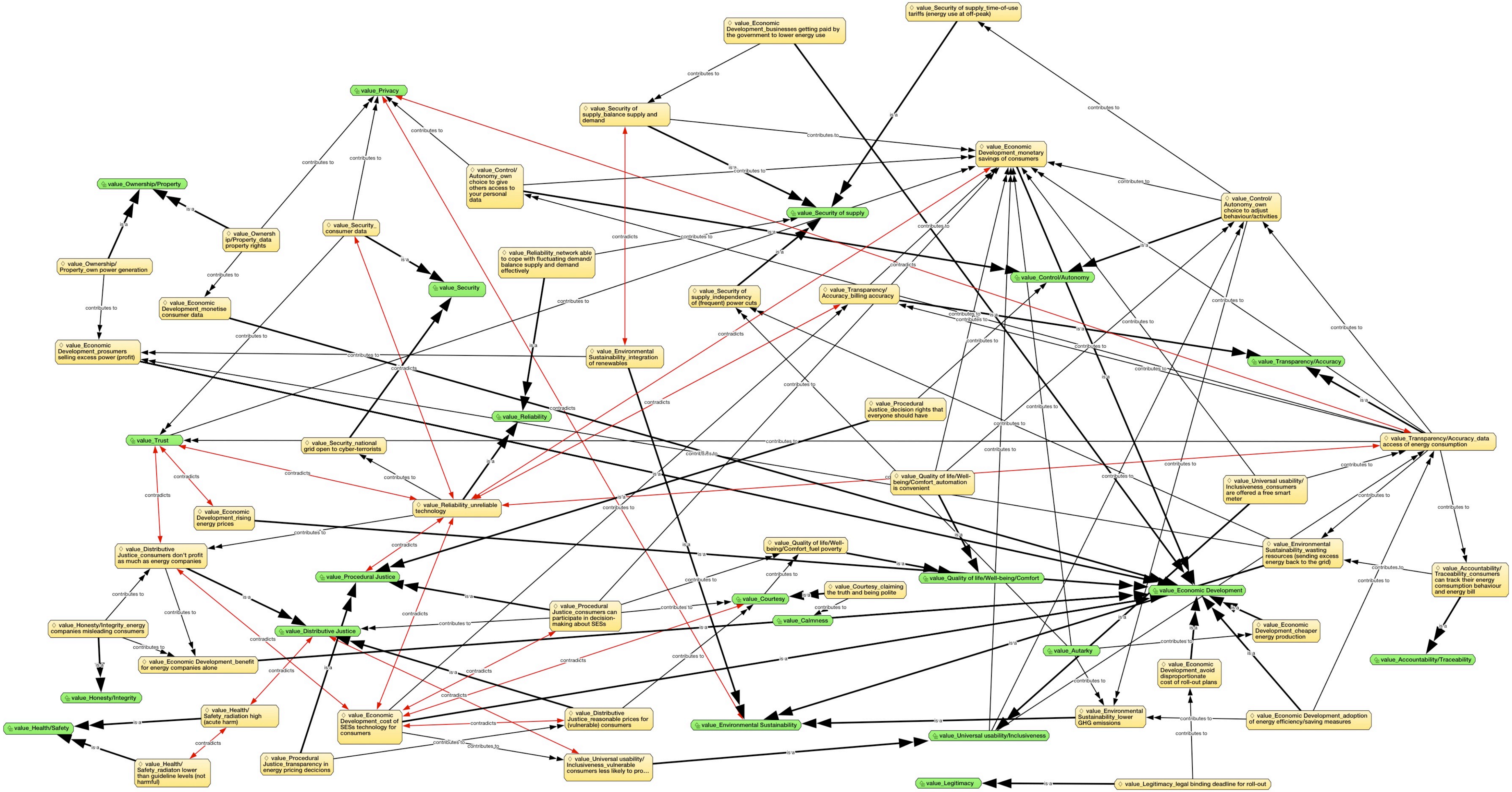

Figure 21: Simplified network of relations among values

Appendix G: Stakeholder interpretations of values

This appendix serves as input for determining the type of conflicting relations among shared values between stakeholder groups. Table 21 summarizes the findings of §4.5.3 and presents the valence (i.e. positive (+) or negative (-)) and interpretation of shared values among the different stakeholder groups. The aim is to compare these value understandings and identify intra-value conflicts. More details can be found in §5.1. Please note that Accountability/Traceability and Calmness are not incorporated in Table 21, as these values only pertain to one stakeholder (see Table 11).

Table 21: Value interpretations among stakeholder groups

	Environmental Organizations	Governmental bodies and policy-makers	Supporting organizations for smart grid development	Trade Associations	Energy Companies	Consumer organizations	Energy consumers	Transmission System Operators	Knowledge institutions	Media
Autarky			Smart grid technology allows households to be grid independent for power if needed (+)				Households act as an energy pack for themselves (i.e. being self-sufficient), but also for others by selling excess power back to the grid (+)			Energy self-sufficiency is becoming more available to households, especially due to energy storage and micro-generation (+)
Control/Autonomy		Consumers have the power in their own hands to adapt their energy consumption and engage more in the energy market (+)	Control of costs and energy consumption (+)	It is imperative that any agreements made with the industry are on a voluntary basis (+)	Consumers can easily switch suppliers (-) and suppliers can freely adapt their tariffs to meet consumer needs (+)	People who have smart meters feel more in control than those who does not (+)	Control of consumption behaviour and appliances controlling households (+/-)	Suppliers and consumers have the freedom to adjust their energy consumption behaviour to save energy (+)		Control of consumption behaviour and control of appliances to operate when energy prices are low, but there are fears that smart appliances will take control of the way a household operates (+/-)
Courtesy		The government lets suppliers decide the			Consumers needs are	Doubts on suppliers	Consumers' interests and			Suppliers fail to meet customer

		price of smart meters and thereby did not properly considered that this might put a burden on consumers (-)			being considered by the suppliers (+)	properly considering consumer needs (+/-)	needs are not being sufficiently considered by the suppliers and government (-)			needs because they are greedy for profit (e.g. they promised to reduce prepay prices when smart meters get installed but do not do so) (-)
Distributive Justice		Both consumers and suppliers bear the costs of smart grid development (+)			Costs and benefits are being shared with stakeholders such as consumers (+)	Doubts on fair distribution of costs and benefits between suppliers and consumers (+/-)	Doubts on fair distribution of costs and benefits between suppliers and consumers (+/-)		Dubious benefits are offered to consumers, whilst they pay for smart meters through increased energy bills, which puts a burden especially on vulnerable (fuel poor) consumers (+/-)	Doubts on fair distribution of costs and benefits between suppliers and consumers (+/-)
Economic Development	Investments in SGSs contribute to climate change mitigation (+)	Prosumers sell power to the national network; companies will invest in a low carbon future (+)	Investments in smart grid development and making homes energy efficient (+)	Competition in the energy market regarding smart meter installation (+)	Cost savings for energy companies and consumers as well as investments in smart grid development (+)	Smart meters aid households to drive down their energy bills, but the installation costs are too high (+/-)	Smart meters aid households to drive down their energy bills, but the installation costs are too high. Besides, prosumers can sell energy back to the grid and make profit (+/-)	Smart grids enable consumers to shift demand and be paid to do so and also to invest in small scale generation of renewable energy (+)	Smart meter roll-out is an inefficient way of saving small amounts of money on energy bills, but has major national benefits (e.g. more secure grid and reduced pollution)	Rise in energy bills as the government underestimated 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 (+/-)
Environmental Sustainability	SGSs contribute to sustainable development and climate change mitigation (+)	Integration of a larger share of renewables into the power network (+)	Improving the environment through energy efficiency and implementation of smart grid technologies (+)		Energy companies contributing to upgrade the into a low carbon smart grid (+)	Smart meters are a power-saving initiative (+)	Improving the environment through energy efficiency and implementation of smart grid technologies (+)	Higher share of renewable energy generation (due to micro-generation) and better integration in the power grid (+)	Improving the environment through energy efficiency and implementation of smart grid technologies (+)	Energy savings and higher share of renewables in the power system, but energy savings are highly dependent on consumers willing to adjust their energy usage for the sake of the environment (+/-)
Health and Safety		Radiation emission of wireless devices comply with guideline levels and is not harmful at all (+)	At the installation of smart meters in a home, a fire safety advice is provided as well as a free, including a carbon monoxide check on all gas appliances in the home (+)			Radiation emission of wireless devices is dangerous for human health and well-being (-)	Radiation emission of wireless devices might be dangerous for human health and well-being (+/-)			Fire risk due to smart appliances being left unattended when operating at night when the energy process are low (-)
Honesty/Integrity							The government acts on behalf of consumers to prevent energy mis-selling scandals by suppliers (+/)			The government acts on behalf of consumers to prevent energy mis-selling scandals by suppliers (+)
Legitimacy		Smart grid policy (+)		Smart grid policy (+)	Smart grid policy, agreements and contracts (+)	There is need of government establishing clear installation guidelines with reasonable	Smart grid policy is in place, but energy companies do not always comply with it (e.g. missing			

						steps that suppliers must consider at the smart meter roll-out (-)	deadlines for the smart meter roll-out) (+/-)			
Ownership/Property							Possession of small generation sources and ownership of personal data (+)	Possession of small generation sources (+)	Possession of small generation sources and ownership of personal data (+)	Personal data is too vulnerable due to the digital technology used in smart grid technologies (-)
Privacy			Only simple information on energy consumption is stored and transmitted, not personal details at all (e.g. name, address, bank account details) (+)			Smart meters are privacy intrusive (-)	Smart meters are privacy intrusive, but necessary privacy measures are believed to be taken by the government (+/-)		Personal data can be monetized for marketing purposes (+/-)	Personal data is prone to fall in wrong hands, undesirably opening a window to peoples' private life (+/-)
Procedural Justice		The government tries to enhance cooperation among stakeholders and engage them as much as possible in decision making processes on SGSs (+)			Stakeholders have a say in energy pricing decisions (+)	Consumers are not being offered enough opportunities to participate in decision-making procedures on SGSs and energy pricing (-)	Consumers are not being offered enough opportunities to participate in decision-making procedures on SGSs and energy pricing (-)			Consumers have not enough opportunities to get engaged in energy pricing decisions (-)
Quality of life/ Well-being/Comfort		Low carbon future enhances the quality of life and well-being of people (+)			Automated transmission of consumption data allows hassle free and accurate bills (+)	Radiation emission of wireless devices exacerbate human well-being (-)	Automation is convenience and no more hassle of manual meter readings. However, due to demand response consumers are not able to			Smart grid technologies contribute to a less polluted living environment, but if automation of technology goes wrong it can affect users

							consume energy when it fits them best due to high energy prices at peak times (+/-)			comfort and well-being (+/-)
Reliability		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, even though the nationwide introduction of the technology has already started but the government is tackling this (+/-)	The national communications network enables smart meters to deliver their full range of functionality (+)			Smart meters deliver their full range of functionality (+)	Some consumers believe that the technology might be out-dated when the roll-out is complete, whilst others believe that they will function properly (+/-)		The digital technology of smart grids allows to easily trace and solve issues in the power network, ensuring that it properly functions (+)	Smart grid technology is advanced, but even so it could malfunction (+/-)
Security			Permission needed for sharing consumption data with third parties (+)				Personal data is vulnerable due to digital technology and might fall in the wrong hands, but others acknowledge that high security standards are used for data protection (+/-)		The smart grid is secure and safeguards its sensitive systems (+)	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 (+/-)
Security of supply		Smart grid technologies support targets for	Effective energy management and better balancing of	Effective energy management	Effective energy management		Effective energy management	Management of proliferation	Smart grids being able to cope with	Effective energy management and better

		increasing renewable energy (i.e. intermittent sources), and adapt better to surges in demand ensure security of supply Moreover smart grid technologies (+)	supply and demand (+)	and better balancing of supply and demand (+)	and better balancing of supply and demand (+)		and better balancing of supply and demand (+)	of small-scale generation sources, effective energy management and better balancing of supply and demand (+)	fluctuating demand (+)	balancing of supply and demand (+)
Transparency/Accuracy		Insight into energy consumption behaviour of households (+)	Insight into energy consumption behaviour of households (+)	Many people in the UK do not know about devices that measure energy use in the home (-)	Insight into energy consumption behaviour of households (+)	Insight into energy consumption behaviour of households (+)	Insight into energy consumption behaviour of households , but some believe that this information is not useful and sometimes too complex to be understood (+/-)	Proper information about energy use (+)	Insights into energy consumptio n 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 decisions when buying energy wholesale (+/-)	Insight into energy consumption behaviour of households , but some believe that this information is not useful and sometimes too complex to be understood (+/-)
Trust		Government trusted energy suppliers passing on the saving to consumers made on no longer having to send staff to read meters manually (+)	Consumers trust supplier with their consumption data as they have complete control of it because it cannot be shared with other without permission (+)		Tensions between suppliers and consumers regarding energy prices and customer service (-)	Doubts on suppliers acting for the benefit of consumers (+/-)	Doubts on suppliers acting for the benefit of consumers (+/-)		The government is trusted to tackle any problems regarding smart grid technology	Energy suppliers provide consumers with tools to better manage their energy consumption,

									but it does not always do so (e.g. smart meters lose their smartness when consumer switch suppliers) (-)	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 (+/-)
Universal usability/ Inclusiveness		Provision of smart meters to all households in the UK, not excluding any (+)	SG tech aid all consumers engaging more in their energy use (+)		Smart meter roll-out aims to include all households in the UK (+)		All household 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 (+/-)			