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Review

Moral Values as Factors for Social Acceptance of Smart Grid Technologies

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Abstract: Smart grid technologies are considered an important enabler in the transition to more sustainable energy systems because they support the integration of rising shares of volatile renewable energy sources into electricity networks. To implement them in a large scale, broad acceptance in societies is crucial. However, a growing body of research has revealed societal concerns with these technologies. To achieve sustainable energy systems, such concerns should be taken into account in the development of smart grid technologies. In this paper, we show that many concerns are related to moral values such as privacy, justice, or trust. We explore the effect of moral values on the acceptance of smart grid technologies. The results of our systematic literature review indicate that moral values can be both driving forces and barriers for smart grid acceptance. We propose that future research striving to understand the role of moral values as factors for social acceptance can benefit from an interdisciplinary approach bridging literature in ethics of technology with technology acceptance models.

Keywords: smart grid; smart energy; sustainability; values; technology acceptance; technology adoption

1. Introduction

Driven by climate change mitigation and transition to low carbon energy systems, governments worldwide have set targets to increase the use of renewable energy sources. The 2030 European energy targets include a minimum 27% share of renewable energy consumption [1]. Growing shares of renewables, particularly from wind and solar energy, lead to rising intermittencies of energy supply and to a larger number of small and decentralized generation sites. Growing intermittencies and decentralization, however, lead to challenges for balancing supply and demand in networks that were designed for relatively few large and controllable power plants [2,3].

Smart grid technologies are praised as one solution to support the integration of rising shares of renewable energy sources into power networks and are thus seen as essential in the transition to sustainable energy systems [2,4]. They allow accounting for higher supply intermittencies and decentralization by using innovative information and communication technologies (ICT). For consumers, they contribute to increased information and awareness of energy use, potentially enabling energy savings [5]. As such, smart grids can be a promising solution to reducing greenhouse gas emissions in the electricity system while at the same time dealing with rising energy costs [6]. Although the concept of smart grid technologies comprises many technological applications and lacks a single definition, widely accepted definitions include efficient management of intermittent supply, two-way communication between producers and consumers, and the use of innovative ICT solutions [7,8].

In spite of their promising benefits for low-carbon energy systems, several challenges are associated with smart grid technologies. Next to concerns about high costs as well as uncertain investment and regulatory environments, moral values underlie many societal concerns [9]. Concerns about data privacy and security have already delayed smart meter introductions in Europe and the US [10,11]. The possibility to share end-users' energy consumption data automatically and in (near) real time with grid operators and store these data in central databases raises concerns that energy companies could use this data to get insight into activities in a household that are considered as private [12]. Related to storing sensitive data in central databases are fears that these data could be threatened by cyberattacks and used in a harmful way. Additionally, consumer fears of reduced autonomy are reflected in concerns that smart meters or smart household appliances might give energy companies more control over a household's electricity use [13]. Further concerns that energy suppliers will not be transparent about benefits and pass financial savings on to their customers relate to the values of trust and a fair distribution of costs and benefits [14].

Challenges in the smart grid development which are related to moral values need to be addressed to achieve sustainable energy systems and might hinder the wider acceptance and adoption of smart grid technologies. There is an extensive literature on factors influencing technology acceptance and adoption in the field of technology and innovation management [15,16], and social psychology [17,18]. Innovation management scholars emphasize market acceptance, which is determined largely by environmental and market-specific factors, the characteristics of the technology itself, and firm-level characteristics [19–21]. Theories in social psychology, on the other hand, concentrate on individual user acceptance, with models stressing the importance of technology specific beliefs, social influences, and personality beliefs as factors for acceptance [17,18,22]. Although these bodies of literature focus on a wide range of potential factors for acceptance, moral values—characteristics of a technology with ethical importance [23]—are typically not included in these factors. Given that moral values underlie societal concerns uttered in public debates, there is a need for research that addresses how moral values impact the acceptance of smart grid technologies. This paper therefore aims at exploring this relationship. It addresses the questions which moral values are relevant for the acceptance of smart grid technologies and how these values influence smart grid acceptance. The paper contributes to the development of sustainable smart grid technologies. To achieve sustainability, it is important not only to consider environmental impacts such as carbon emissions but also social and ethical impacts such as privacy and justice. We stress the importance of social and ethical aspects for sustainability by emphasizing the role of moral values for smart grid technologies.

The paper is structured as follows: The next section provides a theoretical background on moral values drawing from the field of ethics of technology, as well as factors for technology acceptance and adoption drawing from technology and innovation management, and social psychology. Sections 3 and 4 contain the methodology and results of a systematic literature review on values associated with the acceptance of smart grid technologies. The two final sections are devoted to discussions and conclusions.

2. Theoretical Perspectives

2.1. Ethics of Technology

Moral values are evident in societal concerns about smart grid technologies. Ethics of technology is the major field concerned with moral values and technologies. Moral values are used to make statements about ethical and social consequences of technologies. Although an unanimously agreed upon definition of the term 'moral values' is lacking, they often refer to abstract principles and "general convictions and beliefs that people should hold paramount if society is to be good" [24] (p. 1343). They are considered to be intersubjectively shared, which means they are principles that different individuals can relate to and generally hold important [24,25]. As such, moral values relate to convictions of what is perceived as good and bad that are shared by members of a society [26]. Typical examples of importance for technologies are health, well-being, safety, or justice [23,27].

Evaluations of technologies with respect to ethical and social consequences are grounded in the understanding that technologies are not neutral objects, but value-laden [28,29]. That means that they are capable of endorsing or harming values [30]. Winner [30] gives the much-cited example of very low overpasses over the only highway connecting New York with Long Island Beach, thereby hindering public busses (the main method of transportation for less well-off societal groups including racial minorities) to access the beach. The example is often used to illustrate the moral importance of technological design [29,31]. Moral considerations of technological design are especially relevant as technologies do usually not only fulfill the specific function they are designed for, but also have positive and negative side effects [32].

For the design of technologies, moral values are (perceived) technology characteristics that go beyond functional requirements and address requirements of ethical importance such as justice, trust, privacy and more [28,33]. They are seen as identifiable entities that should be considered in design or be embedded in technologies. To embed value in technologies through design choices, Value Sensitive Design (VSD) scholars follow a tripartite approach [28,33]. The approach consists of iterative conceptual, empirical, and technical investigations (for a detailed description of the approach, see for example [27,34,35]). Conceptual investigations are applied to find out what values are relevant, and to identify indirect and direct stakeholders as well as reflections on how to deal with value conflicts. Empirical investigations focus on the stakeholders as unit of analysis in order to get insights into their interpretation and prioritization of different values. Technical investigations focus on the technology itself to identify which technological features support or harm which values. They refer to the "translation" of abstract values into concrete design requirements of the technology.

VSD scholars strive for an in-depth understanding of moral values and the design of technologies that are "better" from an ethical standpoint. Their research aim is focused on integrating convictions "that people should hold paramount if society is to be good" [24] (p. 1343) into the design of technologies. Hence, their research aim does typically not include testing effects of their design on social acceptance of technologies.

2.2. Technology Acceptance and Adoption

Acceptance of novel energy technologies is typically defined in terms of perceptions of stakeholders involved in energy projects [36]. Acceptance can range from passive consent with novel technologies to more active approval such as taking action to promote a technology [37]. Adoption of technologies is defined as the behavior to purchase and use a technology [38]. Adoption can therefore be measured through e.g., market share. Some scholars include behavior towards energy technologies in their definition of "acceptance." When acceptance is defined as purchase/use, "acceptability" is sometimes used to refer to positive attitudes towards technologies (e.g., [39–41]). For the purpose of this research, the definition of acceptance includes the purchase or use of a technology.

Various scholars have focused on factors that affect acceptance of technologies, particularly in the fields of technology and innovation management, and social psychology (Table 1).

2.2.1. Technology and Innovation Management

Scholars in the area of technology and innovation management take a market and firm perspective towards factors for technology acceptance and adoption [15,16,19–21,42,43]: Factors pertain to environmental and market-specific factors, the characteristics of the technology itself, and firm-level characteristics [16,44].

Within environmental and market-specific factors, a strong emphasis is put on network effects. Network effects are positive consumption externalities that occur when the utility of a technology for one consumer increases with the number of other consumers that have adopted the technology [15,19,20,44]. In addition, a high diversity in the inter-organizational network, which is the extent to which stakeholders from different industries are involved in developing and marketing a technology, is beneficial for technology adoption [16,45,46].

Table 1. Overview of factors for technology acceptance/adoption.

Type of Factors	Factors (Examples)	Technology & Innovation Management	Social Psychology
Environmental and market characteristics	Network effects, switching costs, installed base, regulators, suppliers	√	
Technology-specific characteristics	Technological superiority, complementary goods, compatibility	√	
Firm-level characteristics	Financial strength, brand reputation, pricing strategy, time of market entry	√	
Perceived technology-specific characteristics	Performance and effort expectancy, cost-benefit perceptions, hedonic motivations		√
Perceived social influences	Subjective norm, image		√
Perceived personality characteristics	Personal norms, ecological worldviews, innovativeness		√
Others	Experience, habit		√

Related to characteristics of the technology, the extent to which a given technology performs superior to competing technologies (i.e., its technological superiority) is generally regarded as beneficial for its adoption [20]. In addition, a greater availability and variety of complementary goods has a positive effect on adoption [15,19,47].

In addition, firm-level characteristics are found to impact technology adoption. The financial strength of the firm in terms of the availability of appropriate financial resources to develop and market the technology [48], the brand reputation and credibility [16], and a strong learning orientation from past experiences [15] are beneficial for the firm's specific technology to become adopted. Several factors are related to the firms' strategic choices connected to the introduction of the technology, such as the pricing strategy and timing of market entry [15,16].

2.2.2. Social Psychology

Whereas technology management scholars focus on a firm or market perspective, social psychologists concentrate on individual user acceptance. Among the most prominent theories are the Theory of Planned Behavior (TPB) [22], the Technology Acceptance Model (TAM) [49], and its advancements to the Unified Theory of Acceptance and Use of Technology (UTAUT) [17,50], the Norm Activation Model (NAM) [51,52], or the Value-Belief-Norm theory (VBN) [18]. (Note that the term "values" in this context needs differentiation from moral values in an ethics of technology context. Value orientations or values are referred to in social psychology as individuals' personality characteristics [53]. Moral values in an ethics of technology context are perceived characteristics of the technology [33].)

Factors for technology acceptance can be categorized as technology-specific beliefs, social influences, and personality beliefs. Technology-specific beliefs include beliefs that a technology will be useful and enhance the achievement of a consumer's goal (performance expectancy) and perceptions of the ease of use associated with a technology (effort expectancy) [17,49]. Consumers are also more likely to adopt a technology if they perceive facilitating conditions, including the support available to use a technology [17,22]. Monetary aspects are considered in terms of the perceived trade-off between costs and gains. Finally, hedonic motivations (expected fun, enjoyment) are also found to positively impact acceptance [17,54].

Social influences—interchangeably used with subjective norm [22], and image [50]—cover perceptions that important others such as family and friends believe they should use a technology and the belief that the use will enhance their social status [17].

Personality-specific beliefs mostly refer to the role of personal norms as factors for pro-environmental behavior. They play a prominent role in the Norm Activation Model (NAM) [51,52] and the Value-Belief-Norm theory (VBN) [18]. Personal norms are perceptions about one's moral obligation to take pro-environmental actions [18,40]. They are shaped by ecological worldviews, which are general beliefs about the relationship between humans and the environment [40].

Scholars also combine models focusing on technology-specific beliefs such as TPB and TAM with models focusing on personality-beliefs such as NAM. Broman Toft et al. [38] for example combine TAM with NAM and show that if smart grid technologies are perceived as useful and easy to use, consumers are likely to show stronger personal norms to use the technology. Huijts et al. [41] posit that perceived costs and benefits—elements from TBP—impact personal norms, which is a concept from NAM.

3. Method

To understand the role of moral values for the acceptance of smart grid technologies in greater details, we conducted a systematic literature review. We analyzed journal articles reporting the results of empirical studies to ensure capturing original research results. Articles were retrieved from the databases Scopus and Web of Science (see Table 2 for the full search queries). To capture a diverse range of smart grid technologies, search terms included smart grid, smart energy, smart metering, smart home, home energy management, energy and digitalization, and smart technology. Acceptance, acceptability, and adoption were used as search terms, because, as outlined in Section 2.2, these are common concepts which are often used interchangeably to study social acceptance of emerging technologies (e.g., [36–41]). An initial screening of relevant publications revealed that the term "values" is often not mentioned explicitly, even when moral values were included as factors for smart grid acceptance [2,55–58]. To ensure capturing all relevant publications, the term "values" was therefore not included in our search terms.

Table 2. Search queries used in the systematic literature review.

Database	Search Query	# of Results	Date
Scopus	((TITLE-ABS-KEY (smart AND grid) OR TITLE-ABS-KEY (smart AND meter*) OR TITLE-ABS-KEY (smart AND energy) OR TITLE-ABS-KEY (smart AND home*) OR TITLE-ABS-KEY (home AND energy AND management) OR TITLE-ABS-KEY (smart AND technology) OR TITLE-ABS-KEY (energy AND digital*)) AND (TITLE-ABS-KEY (acceptance) OR TITLE-ABS-KEY (acceptability) OR TITLE-ABS-KEY (adoption))) AND (LIMIT-TO (DOCTYPE, "ar ") OR LIMIT-TO (DOCTYPE, "ip")) AND (LIMIT-TO (SUBJAREA, "ENER ") OR LIMIT-TO (SUBJAREA, "ENVI") OR LIMIT-TO (SUBJAREA, "OCI") OR LIMIT-TO (SUBJAREA, "BUSI")) AND (LIMIT-TO (LANGUAGE, "English"))	444	5 January 2018
Web of Science	(TS = (smart grid OR smart energy OR smart meter* OR smart home* OR home energy management OR smart technology OR energy digital*) AND TS = (acceptance OR acceptability OR adoption)) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article) Refined by: WEB OF SCIENCE CATEGORIES: (ENVIRONMENTAL SCIENCES OR ECONOMICS OR ENVIRONMENTAL STUDIES OR PSYCHOLOGY APPLIED OR BUSINESS OR SOCIOLOGY OR GREEN SUSTAINABLE SCIENCE TECHNOLOGY OR URBAN STUDIES OR PSYCHOLOGY MULTIDISCIPLINARY OR PSYCHOLOGY EXPERIMENTAL OR SOCIAL SCIENCES INTERDISCIPLINARY)	262	5 January 2018

The database search resulted in 706 articles, which were screened for inclusion in the detailed review (see Figure 1 for flow diagram of systematic literature review). After removing duplicates, the 532 unique search results were screened based on their abstracts. Articles that solely focused on technical issues or did not report results of empirical studies were excluded. As a result, for example, a study by Park et al. [59] was eligible for further analysis because it investigated consumer acceptance of a home energy management system. In contrast, a study by Vagropoulos et al. [60] was excluded because it presented an optimization model and did not empirically assess the acceptance of smart grid technologies. This abstract screening resulted in a total of 103 relevant articles, which were subsequently analyzed with respect to moral values as factors for smart grid acceptance. In the analysis, we searched for values of ethical importance often mentioned in the VSD literature. In addition, we aimed to find additional values that were reported in empirical smart grid studies but not included in prior literature. Apart from identifying values, we analyzed their conceptualizations, the relevant stakeholder group, the technical context, and applied methodologies. The analysis resulted in a group of 49 papers that reported moral values as factors for smart grid acceptance (see Appendix A) and a group of 54 studies that did not include moral values as factors for smart grid acceptance (for example a study by Kobus et al. [61] focusing on the role of smart appliances to bring about electricity demand shift by residential households).

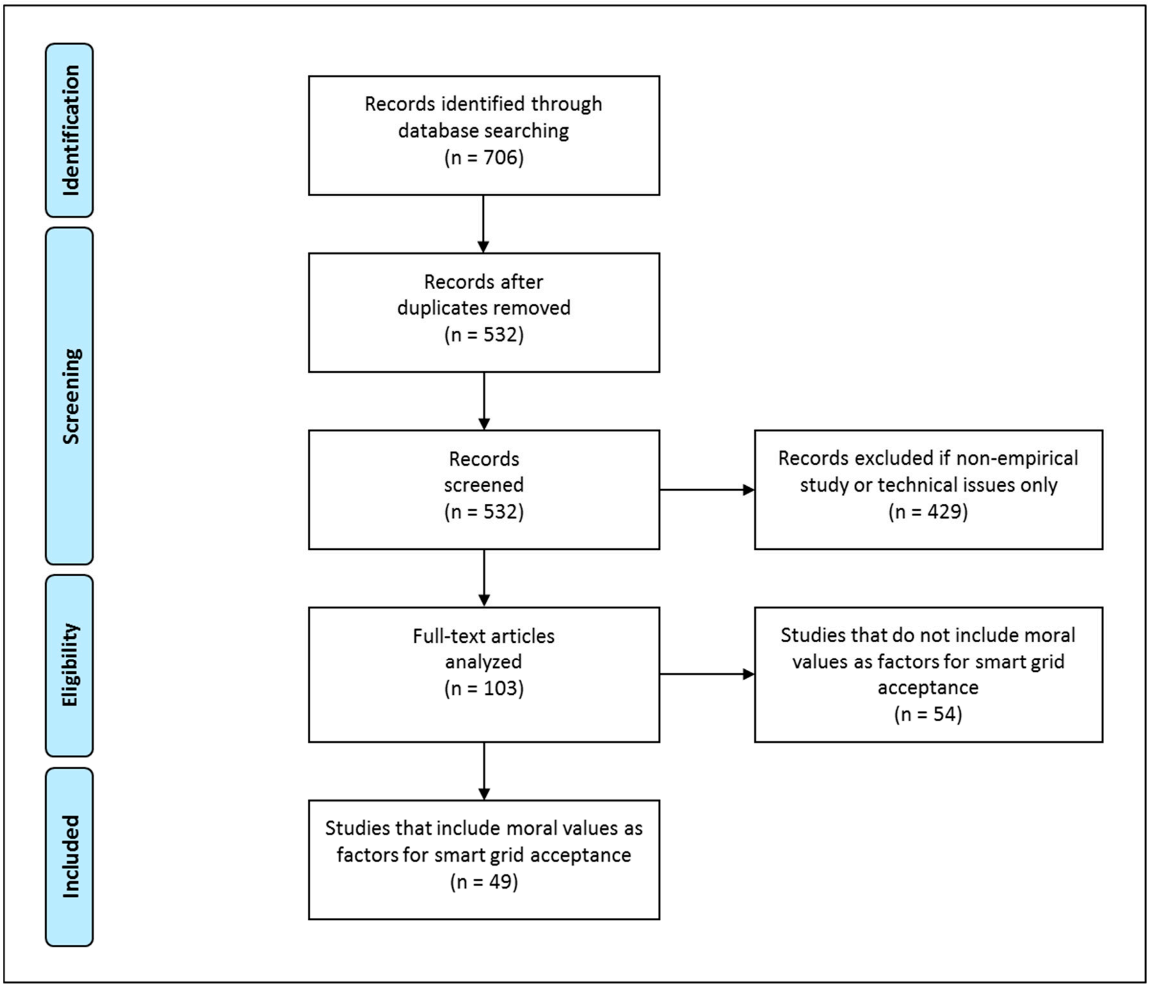

Figure 1. Flow diagram for systematic literature review (Based on [62]).

4. Results

Our literature review reveals that moral values can act as factors for smart grid acceptance; moral values were found in 49 articles on smart grid acceptance (see Appendix A). These articles were published in 23 different journals. However, more than 50% are concentrated in four journals: *Energy Research & Social Science* and *Energy Policy* were the most frequent journals, with 10 and nine publications respectively, followed by four publications in *Energy Efficiency* and three publications in *Renewable and Sustainable Energy Reviews*. The journals cover a large diversity of subject areas, including energy research, environmental science, engineering, business and management research, computer science, psychology, and philosophy. (Journals have been mapped to subject areas based on their categorizations in Scopus and Web of Science.)

The most prevalent subject area was energy research: 32 out of 49 articles were published in this field. A smaller number of articles were published in the three subject areas that can provide the theoretical background to understand the role of values for social acceptance and were reviewed earlier. First, this concerns ethics of technology: two articles were published in journals within the subject area of philosophy (*Journal of Information*, *Communication and Ethics in Society*, and *Public Understanding of Science*). Second, three articles were published in journals that contribute to the field of technology and innovation management, such as *Technological Forecasting and Social Change*. Third, a total of 18 publications are from journals where theories on technology acceptance from social psychology are widely used, for example the *Journal of Consumer Policy* and *Psychology & Marketing*, but also *Energy Research & Social Science*.

Twenty-five studies with qualitative approaches exploring smart grid acceptance used predominantly expert interviews, focus groups, public workshops, and in-depth interviews, while 27 studies used quantitative methodologies to test the impact of various values on acceptance or adoption (three publications rely both on qualitative and quantitative methodologies). Twelve publications tested consumer acceptance of smart grid technologies based on technology acceptance models used in social psychology. The other 14 articles using quantitative methods derived their own antecedents of smart grid acceptance.

In the 49 publications, a range of moral values have emerged as factors for acceptance or adoption of various smart grid technologies (Table 3). These values were reported either as drivers or barriers of smart grid acceptance/adoption. A value is classified as a "driver" if it provides impulse, motivation, or reason for smart grid introduction or if smart grid technologies are perceived to have a positive influence on these values. A value is identified as a "barrier" if it is expressed as concerns or if there is a perceived fear that the technology might have adverse consequences for this specific value.

The drivers of smart grid acceptance were environmental sustainability, security of supply, and transparency. Data privacy, data security, (mis)trust, health, justice, and reliability were found as barriers to smart grid acceptance. Control, inclusiveness, quality of life, and affordability were partly identified as driver and partly as barrier. All of these values emerged in studies using inductive qualitative approaches. Most of them were also included in quantitative studies, with the exception of distributive justice, inclusiveness, quality of life, and transparency.

The majority of these values are relevant for citizen or consumer acceptance. Only seven articles report values relevant for office workers, manufacturing companies, energy companies, or the society at large. While values for office workers are similar to consumers' concerns (trust and quality of life or comfort), the values reported for companies and the societies in general are the main drivers for smart grid development: environmental sustainability and security of supply.

Table 3. Values relevant for the acceptance of smart grid technologies.

Values	# of Articles (N = 49)	Technological Context						Sources
		Smart Grid	Smart Metering	Smart Home	DSM	Household Storage	Smart EV Charging	
Environmental Sustainability	22	+	+	+	+		+	[11,56–59,63–79]
Security of Supply	7		+	+	+	+	+	[3,67–69,72,78,79]
Transparency and Accuracy	6		+	+	+			[56,58,67,76,77,80]
Privacy	24	−	−	−	−			[2,11,14,55,56,58,63,74–77,79,81–92]
Security	15	−	−	−				[2,11,55,68,74–77,79,81,85,86,89,92,93]
(Mis)Trust	14	−	−	−	−			[14,63,75,76,81,83,90–92,94–98]
Health	5		−					[11,56,68,86,91]
Distributive and Procedural Justice	5		−	−	−			[14,56,57,75,96]
Control and Autonomy	14	−	−	+/−	+/−			[14,55,56,66,67,73,79,81,88,93,94,99–101]
Inclusiveness	7		−	+/−				[14,75–77,79,81,93]
Quality of Life	7			+	−			[58,66,73,75–77]
Reliability	5			+/−				[75,77,79–81]
Affordability of energy	4		+/−	+/−	−			[11,71,76,99]

+: Driver; −: Barrier; +/−: mentioned both as driver and barrier depending on study; refer to text for details; DSM: Demand-side management; EV: Electric vehicle.

4.1. Moral Values That Act as Drivers of Smart Grid Acceptance

The most often cited positive driving force (22 publications, [11,56–59,63–79]) for the acceptance of various smart grid technologies was their contribution to the environmental sustainability of energy systems. Environmental sustainability refers to the reduction of emissions from the electricity sector, thereby contributing to climate change goals [75,78]. Smart grid technologies contribute to environmental sustainability by facilitating the integration of renewable energy sources and electric vehicles [63,69,72]. In addition, smart metering and smart home networks are perceived by consumers to enable them to save energy through better visualization of the energy consumption of various household appliances, thereby lowering not only energy costs but also emissions [56,57,75].

Another key factor positively related to the acceptance of smart grid technologies was the security of electricity supply (seven publications, [3,67–69,72,78,79]). "Security of supply" in the context of electricity systems is defined as a low risk of interruptions in the supply [3]. Given that the electricity system is vital for the functioning of modern societies, a high security of supply is one of the central values in any debate on changing energy systems. Smart meters were perceived to enhance the security of supply, because they allow detection and reduction of power outages faster than conventional meters [68]. Household electricity storage systems allow to reduce the risk of supply interruptions because they can serve as a buffer for excess energy and allow to decouple electricity generation from consumption [3]. Smart charging systems allow to shift the charging time of electric vehicles and thereby can help to avoid grid overload problems [69,72].

In the context of smart metering, smart home, and demand-side management, transparency and accuracy were found to be further values motivating the acceptance of such technologies (six publications, [56,58,67,76,77,80]). Greater accuracy and a better overview of energy consumption data as well as transparency in the impact of consumption patterns on cost and the environment, which are enabled through smart meters and in-home displays, contributed positively to the acceptance these technologies [56,58].

4.2. Moral Values That Form Barriers for Smart Grid Acceptance

Privacy was by far the most prevalent moral value reported as a perceived barrier, mentioned in 24 publications [2,11,14,55,56,58,63,74–77,79,81–92]. Concerns about privacy are related to the increased collection and transmission of information on energy consumption compared to traditional meters [2]. Triggered by the possibility to share end-users' energy consumption data automatically and in real time with grid operators and store these data in central databases, consumers are concerned that energy companies could use these data to get insight into activities in a household that are considered as private [55,56]. Explicitly mentioned was the fear that smart grid technologies could allow identification of the type and time of use of household appliances [86]. In addition, consumers were concerned that their personal data could be sold commercially [91]. One study also reported the perceived danger in the effect of combining different pieces of data to reveal more information or patterns about consumer behavior that could be extracted from single pieces [75].

Concerns about data and cyber security were the second most often reported barrier to smart grid, smart metering, and smart home acceptance (15 publications, [2,11,55,68,74–77,79,81,85,86,89,92,93]). Security refers to the existence of mechanisms that ensure that personal data is protected from outside, malicious attacks [2,68]. The increased collection and transmission of more energy consumption data than with "dumb" systems are at the core of security concerns. Consumers are concerned that their consumption data, which is transmitted to e.g., grid operators, might fall into the wrong hands due to cyberattacks. They stress the importance of ensuring that personal data is adequately protected and encrypted [81,85,89]. In addition, and specifically connected to smart home platforms, consumers uttered the fear that outsiders could get more easy access to their private spaces/homes [55].

Trust, or rather the lack of trust by consumers in organizations charged with the implementation and management of smart grid technologies (e.g., electric utilities, governmental authorities), was reported as one of the key barrier values for smart grid acceptance (14 publications, [14,63,75,76,81,83,90–92,94–98]).

While trust was mainly relevant in consumer acceptance studies, one study from the perspective of US utilities revealed that utilities were aware of the problematic (mis)trust by consumers towards their companies [63]. Consumers' lack of trust is reflected in concerns that the utilities industry and the government (a) are not open about their benefits and (b) will not pass any financial savings on to customers. Consumers also found it difficult to understand why utilities would promote energy-saving messages while they are perceived to increase profits with an increased energy consumption [76,91,94]. Additionally, concerns were related to the degree of trust that the personal data shared through smart meters with energy companies is protected [90,98].

In the context of smart metering, consumers perceived health risks were found to be negatively connected to the acceptance and use of smart meters (five publications, [11,56,68,86,91]). Perceived health risks refer to the subjective evaluation of potential health threats resulting from an event or an activity [56]. Health risks were connected with exposure to electromagnetic radiation from smart meters [68,86,91]. Whether or not radiation poses objective threats to consumers' health, the fact that smart meters are perceived as health risks in studies on consumer acceptance indicates that such concerns should be taken seriously by utilities and governmental authorities when introducing smart metering.

Concerns about the fairness of smart metering and demand-side management reflected the values of distributive and procedural justice as a barrier for smart grid acceptance from the perspective of energy consumers (five publications, [14,56,57,75,96]). Distributive justice refers to a fair distribution of costs and benefits among the key stakeholders involved in these technologies [14,56,57]. Consumers feared that they will have to bear the costs for the introduction of smart metering without receiving apparent benefits while energy providers would profit from financial savings [57]. In addition, there was a perception that the responsibility for saving energy would be pushed on consumers while supplier obligations to ensure low consumer prices would be neglected [14]. Procedural justice refers to fairness in decision making processes, often based on the fact that all relevant stakeholders are able to participate in the process. Although this concern was less prevalent than distributive justice, it yielded interesting results in a study by Guerreiro et al. [56]. The authors were interested in the use of smart meters combined with an in-home display and found that increased perceptions of procedural justice let to decreased use in the devices. It might be that respondents who perceived the process of introduction as being fair felt a lower need to control the equipment.

4.3. Moral Values with Ambiguous Effects on Smart Grid Acceptance

Control or autonomy—defined in this context as the perception that one can direct events in life free of outside influence [100]—was related to consumers concerns about loss of control and autonomy with the introduction of smart metering and the installation of smart home platforms. They feared losing control to ICT systems and perceived the monitoring of daily behavior as too intrusive and restrictive [55,81]. Concerns were also directed to a fear of loss of control towards energy suppliers, who might manage their energy consumption for them [14,56]. While control was mostly perceived as a barrier (12 publications, [14,55,56,67,73,79,81,88,93,94,99,101]), a later study reported a positive effect of control on the acceptance of an automated demand-side response tariff [100]. This suggests that concerns about the loss of control play a more ambivalent role than previously assumed. The authors explain the effect with two reasons. Firstly, the tariff's impact was clearly defined (e.g., the room temperature was only allowed to shift by 1 °C). Secondly, the option of overriding the automation was presented, which might have restored perceptions of self-control [14,100].

Inclusiveness was both seen as a barrier and a driver for smart grid acceptance. Inclusiveness refers to giving all different societal groups the possibility to be included in the technological development. On the one hand, six studies revealed that consumers were concerned that elderly people, disabled people, and people with less affinity to computers and IT systems would be systematically excluded from the smart grid development [14,75,77,79,81,93]. In another study, however, consumers expressed positive views about the benefits, the support, and the additional services that smart homes could offer in assisted living for the elderly and people with disabilities [76].

Increased quality of life was seen as a driver for smart home technologies in six publications [58,66,73,75–77]. Smart home services such as health monitoring or a remote control of security are perceived as practical and automation is seen as enhancing convenience and comfort [73,76]. However, it was reported as a barrier in one study, in which building occupants were concerned with reductions in their living quality as a consequence of demand-side management [102]. When building equipment such as ventilation fans or cooling systems have communication and control capabilities to steer the energy demand of the building automatically, the effects on the perceived thermal comfort of building occupants was reported as a major concern and barrier for the implementation of such a DSM measure [102].

The reliability of novel smart home technologies was questioned and reported as barrier by consumers in four publications [75,77,79,81]. The adoption of non-mainstream technology was seen as risky with respect to the malfunctioning of the system, such as a break-down of communication systems or room sensors being triggered unintentionally [75,77]. Consumers felt unease at becoming reliant on computer systems they might not fully understand. In addition, concerns were reported that innovations, once adopted, would not widely spread or become rapidly obsolete due to fast technological progress. This was especially seen problematic when smart home technologies were seen as a costly and long-term investment [79]. However, one publication found that in-home displays have the ability to enhance the reliability of an entire home energy management system because such displays support in discovering system failures or underperformance [80].

Future affordability of energy was found to be both a driver and a barrier for the acceptance of smart metering, smart home platforms, and demand-side management. Affordability is the availability of financial means to be able to pay for energy. In two studies [11,99], the potential of smart meters and smart home platforms to save energy and prevent energy poverty were seen as reasons to accept these technologies. In two different studies [71,76], however, consumers were concerned about hidden costs and were generally skeptical whether smart grid technologies will indeed reduce their energy bills.

5. Discussion

Our literature review on the role of moral values for the acceptance of smart grid technologies showed that values are indeed discussed in the literature on smart grid acceptance and adoption. However, their relationship with acceptance is not always clear. Whereas certain values are always seen as either drivers or barriers, others could be seen as having an ambiguous effect on acceptance. We turn to a more detailed discussion of our findings.

5.1. Values as Factors for Consumer and Citizen Acceptance

In general, our results show that moral values can act as important factors for consumer and citizen acceptance of smart grid technologies. The fact that all the values we found have emerged from inductive, qualitative studies indicates that consumers expressed values in an unprompted way as both drivers for smart grid development and concerns around these technologies. Thus, values were not a priori introduced into these studies by researchers but were expressed by consumers independently. In addition, quantitative studies confirmed for almost all reported values that they influence consumer or citizen acceptance. Distributive justice, inclusiveness, quality of life, and transparency were the exceptions which were only reported in qualitative studies.

However, our results also show that there are two aspects of values which pose additional complexities to their investigation as factors for acceptance. First, some values were found to have an ambiguous effect on acceptance. More specifically, whereas some values were clearly positive forces driving smart grid development (e.g., environmental sustainability) and some were clearly consumer concerns around the technology (e.g., privacy, justice), some were mentioned both as drivers and barriers. For example, studies mentioned the potential of smart grid technologies to save energy and thus save costs as perceived benefits with regards to energy affordability [11,99]. However, consumers were also concerned that they will have to bear the costs for the introduction of smart grid technologies through higher electricity bills. Another example is inclusiveness; whereas there are concerns that several societal groups (e.g., the elderly, disabled) would be systematically excluded because of the focus on novel ICT [14], benefits that smart homes in particular could offer in assisted living for the elderly and disabled are expressed [76]. Additionally, the value of control was mostly perceived as a barrier due to a perceived loss of consumers' control to electronic devices or energy suppliers. Automated demand-response tariffs were particularly in focus of this concern. However, once the impact of such a tariff was clearly defined, the degree of external control through the tariff was very small, and consumers had the option to override the automation, the perceived loss of control was no longer a problem [100].

These examples illustrate the importance of the detailed technological and regulatory context for the effect direction on acceptance. In the example of control, the way an automated demand-response tariff was structured with respect to definition of boundaries of the automation or overriding possibilities was decisive whether control was seen as a barrier or not. The debate to what extent smart metering impacts energy affordability depends on the regulation of electricity prices: if smart meters enable consumers to save costs by using less energy, these savings might be offset because costs for the smart metering infrastructure are socialized, i.e., paid by consumers through the network tariffs on electricity bills.

The examples also illustrate that whether certain values have a positive or negative impact on smart grid acceptance depends on their interpretation by consumers. Values can therefore be characterized as "contestable concepts," having two levels of meaning [103]. The first level is expressed in a short definition; for example, energy affordability is generally defined as having the financial means to be able to pay for energy. The second level of meaning refers to the value's conception. Here, contestation occurs over how the concept should be interpreted and whether a technology contributes to the value or endangers it [103]. It is thus important to understand values at the level of conception, since this is the level where controversies arise and the way values impact technology acceptance might depend on their conception [104]. In the example of affordability, the debate is not about the definition or importance of affordability, the debate is whether certain features of smart grid technologies are perceived to contribute to energy affordability while others do not. As a consequence, future research should carefully consider different potential conceptions of values when testing their effect on acceptance.

Second, certain values are closely interrelated, increasing the complexity in deriving their separate effects on smart grid acceptance. Probably the most prevalent relationship could be observed between data privacy and security. Both concerns are related to the increased transmission and storing of personal data. They are frequently mentioned in context with each other [2,55,56,76] or even measured as one construct (e.g., [84,85]). However, they are different concepts. Privacy refers to the concern that individuals' personal data can be used externally to infer information about activities that are considered as private [12]. Security concerns on the other hand are defined in terms of the risk that personal data is subject to malicious external attacks, e.g., through hacking [2]. Their conceptual differentiation means on the one hand that different measures need to be taken by policy makers and industry actors responsible for smart grid introduction to protect consumers' privacy and data security. On the other hand, their conceptual differentiation could imply different effects on consumer acceptance. They should therefore be treated as separate concepts in academic studies on smart grid acceptance.

Distributive justice is connected to affordability concerns. Consumers were concerned that they will have to bear the costs for e.g., the smart meter introduction, whereas energy providers would profit from financial savings [57]. Consumers perceived an unfairness that smart grid technologies might lead to higher energy costs and a lower affordability of energy [56]. As a consequence, concerns about fairness and affordability might reinforce each other in their negative effect on smart grid acceptance.

In addition, several values were connected with the perceived trust of consumers in energy companies and government authorities. Concerns about distributive justice were connected with the lack of trust that energy companies are not open about their benefits and would not pass on financial savings to consumers [57,76]. Also, trust was related to privacy and security concerns: Perceived consumer trust about the protection of personal data [98]. This points to the central importance of trust between consumers and authorities or organizations charged with the implementation and management of smart grid technologies as potential antecedent for several other values; a relationship that is worth considering in smart grid acceptance studies. Trust is also suggested as antecedent for consumer beliefs by Huijts et al. [41] in their conceptual development of a framework for acceptance of energy technologies. Trust is suggested as influencing positive and negative affect, perceived costs, risks and benefits, and also procedural justice.

5.2. Combining Insights from Ethics with Technology Acceptance Literature

In contrast to our results, current theoretical frameworks for technology acceptance and adoption do not seem to pay attention to moral values as factors for acceptance (see Section 2.2). Frameworks for technology acceptance and adoption in technology and innovation management fields focus on market-, firm-, and technology-specific characteristics [16,21,44]. In social psychology, technology acceptance models focus on factors pertaining to technology beliefs, social influences, and personality beliefs [17,18].

Therefore, we propose that moral values should be included more systematically in studies on the acceptance or adoption of smart grid technologies, and potentially technology acceptance in general. Scientific understanding of the role of values for technology acceptance can be gained by combining insights from ethics of technology with literature on technology acceptance.

Ethics of technology and particularly VSD approaches can be beneficial for the identification and conceptualizations of relevant values for a particular technological context. In their tripartite approach, VSD scholars place great emphasis on identifying relevant values. They do this both from an ethical normative perspective and a descriptive perspective relying on the opinions of key stakeholders involved with a technology [27,33]. In addition, they acknowledge that values can be interpreted and prioritized differently by different stakeholder groups and therefore integrate considerations around conceptions of values explicitly in their empirical approaches [35,104]. Their in-depth understanding of different conceptualization of values can contribute to the two complexities about the relationships between values and social acceptance we encountered in our results, namely that these relationships hinge on detailed interpretations of values and that there are mutual interdependencies between different values. Methods of elicitation of technology specific values from VSD can be used by researchers studying smart grid acceptance. This includes what VSD researchers call conceptual investigations, philosophically informed considerations of how stakeholders might be affected by the technology. It also includes empirical investigations, in which VSD scholars use the entire range of qualitative and quantitative empirical methods to answer questions such as how stakeholders interpret different values for the given technological context or which values are prioritized by different stakeholder groups affected by the technology [34].

Ethicists and VSD scholars focus on the understanding of values and possibilities to integrate them into technological design. However, their research aims do not include testing whether a design for values increases the acceptance and adoption of technologies. Their approach seems to underlie the implicit proposition that a proper integration of values that are judged as important for the context of a specific technology will contribute to enhancing acceptance in society [28].

The literature on technology acceptance is complementary to that because it does study the impact of a diverse range of factors on technology acceptance and adoption. Thus, it provides not only rigorous quantitative methods to test relationships but also measurement scales for values and acceptance in surveys or experiments [17,40,41].

More specifically, our results indicate that adaptations of technology acceptance models from social psychology might be suitable to include moral values (see Section 2.2.2 for a review). Half of the publications in our systematic literature review including values as factors and using deductive theory testing approaches investigate smart grid acceptance based on models used in social psychology (e.g., [3,56,85,98,100]). Although they only include a sub-set of relevant values in their models, these studies provide first indications how to integrate values in acceptance models and which other model variables values might be related to.

Most of these scholars study values as direct antecedents of intentions to use or use of smart grid technologies. For example, Fell et al. [100] find that control over comfort and timing of activities are related to intentions to adopt a demand-side management scheme and Römer et al. [3] relate security of supply concerns to purchase intentions of household storage systems.

A number of studies show effects of values on several different variables in technology acceptance models, particularly perceived risk and perceived usefulness or ease of use, concepts that are used in both UTAUT and TAM. Chou et al. [85] find that concerns on data privacy and security impact perceived risk. In a similar vein, Guerreiro et al. [56] stress the connection between health concerns and perceived risk. Park et al. [68] find that perceived security of supply and environmental sustainability impact perceived usefulness, and perceived security and health concerns affect perceived risk. Perceived usefulness and risk impact in turn impacts intentions to use smart grid technologies.

The indication from our results that technology acceptance models from social psychology might be suitable to include moral values is in line with a proposed framework for public acceptance of sustainable energy technologies such as wind mills or hydrogen vehicles by Huijts et al. [41]. The authors stress the importance of procedural and distributive justice measured as perceived fairness of the decision process leading up to the technology's introduction as well as the perceived fair distribution of costs and benefits, affecting attitudes toward the technologies. Additionally, they hypothesize that the degree of trust in actors that are responsible for the technology is seen as influencing positive and negative affect, perceived costs, risks and benefits, which in turn affect attitudes toward the technologies. Positive attitudes toward technologies are then related to intentions to accept and technology acceptance.

6. Conclusions

Smart grid technologies are seen as an important enabler in the transition to more sustainable energy systems, but the development has been challenged among others by societal concerns [2,11]. In this paper, we showed that societal concerns about smart grid technologies reflect moral values, which are (perceived) technology characteristics about ethical and social consequences of technologies such as justice, trust, or privacy. We proposed that concerns related to moral values might hinder the wider acceptance and adoption of smart grid technologies. The paper set out to address the questions which moral values are relevant for smart grid technologies and how they influence smart grid acceptance.

Our results show that moral values can act as drivers and barriers for consumer and citizen acceptance of smart grid technologies. On the one hand, values such as environmental sustainability and security of supply positively influence smart grid acceptance. On the other hand, concerns about privacy, security, or health negatively impact their acceptance. In addition, several values were mentioned both as driving factors for smart grid acceptance and as concerns (e.g., affordability, inclusiveness). Studying the impact of values on acceptance is not only made complex by these ambiguous interpretations, but also by instrumental relationships between certain values such as affordability and distributive justice. It is thus important to consider the detailed technological and regulatory context, the nature of values as contestable concepts, and interdependencies between them.

Based on our results, we propose that future research should strive for a better understanding of the role of moral values as factors for smart grid acceptance in order to contribute to embedding values in smart grid design. This can be done by bridging literature from ethics of technology with technology acceptance. Ethicists study in depth which values are implied in certain technologies. In their focus on a normative perspective, however, they do not relate values to the empirical acceptance of technologies [28]. Technology acceptance studies provide a complementary perspective because they test the impact of a wide range of factors on acceptance, yet typically without considering values as factors [15–18]. The results of our systematic literature review show that especially acceptance models widely used in social psychology such as TAM, TPB, or UTAUT offer a good foundation to study the effect of values as perceived technology characteristics on smart grid acceptance.

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Appendix A

Table A1. Overview of articles considering values for smart grid acceptance.

Authors	Year	Journal	Citations *	Main Contribution	Methodology	Technology
Aduda et al.	2016	Sustainable Cities and Society	18	Investigate effect of demand-side management on building performance indicators	Field study with follow-up survey	DSM
Balta-Ozkan et al.	2013	Energy Policy	88	Explore key barriers to smart home adoption in the UK	Expert interviews, deliberative public workshops	Smart Home
Balta-Ozkan et al.	2013	Energy	28	Explore key barriers to smart home adoption in the UK	Expert interviews, deliberative public workshops	Smart Home
Balta-Ozkan et al.	2014	Technology Analysis and Strategic Management	11	Explore technical and economic drivers and barriers to smart home market development in three European countries (UK, DE, IT)	Deliberative public workshops	Smart Home
Balta-Ozkan et al.	2014	Energy Research & Social Science	22	Explore drivers and barriers to smart home market development in three European countries (UK, DE, IT)	Deliberative public workshops	Smart Home
Barnicoat & Danson	2015	Energy Research & Social Science	17	Explore how older tenants in rural Scotland interact with technology	In-depth interviews	Smart Home
Begier	2014	Journal of Information, Communication and Ethics in Society	0	Explore strategies to build relationships with energy consumers during exchange of energy meters	Focus groups, survey	Smart Metering
Berry et al.	2017	Energy Efficiency	0	Explore residential consumers' attitudes towards and experiences with an in-home display and energy management system	In-depth interviews	Smart Home
Buchanan et al.	2016	Energy Policy	6	Explore opportunities and threats of smart metering initiatives	Focus groups	Smart Metering/Smart Services
Buryk et al.	2015	Energy Policy	11	Investigate impact of disclosing environmental benefits on DSM adoption	Choice experiment	DSM
Chen et al.	2017	Energy Research & Social Science	8	Investigate social-psychological factors affecting smart meter support and adoption intention	Survey	Smart Metering
Cherry et al.	2017	Energy Research & Social Science	6	Explore experts' and public's visions of smart homes	Semi-structured interviews	Smart Home
Chou & Yutami	2014	Applied Energy	16	Investigate antecedents of willingness to adopt smart meter	Survey	Smart Metering
Chou et al.	2015	Renewable and Sustainable Energy Reviews	6	Investigate antecedents of willingness to adopt smart meter	Survey	Smart Metering

Table A1. *Cont.*

Authors	Year	Journal	Citations *	Main Contribution	Methodology	Technology
Dedrick et al.	2015	Electronic Markets	3	Examine factors influencing smart grid adoption among US utilities	Semi-structured interviews	Smart Grid
Ehrenhard et al.	2014	Technological Forecasting and Social Change	19	Explore acceptance of smart home among the elderly	In-depth interviews	Smart Home
Fell et al.	2015	Energy Research & Social Science	18	Investigate factors for acceptance of different demand-side response tariffs	Experiment	DSM
Gerpott & Paukert	2013	Energy Policy	27	Investigate factors for willingness-to-pay for smart meters	Survey	Smart Metering
Ghazal et al.	2015	Renewable and Sustainable Energy Reviews	3	Investigate factors for consumer acceptance of a smart plug system	Survey	Smart Home
Goulden et al.	2014	Energy Research & Social Science	90	Explore perceptions of centralized and decentralized smart grid platforms	Focus groups	Smart Grid
Guerreiro et al.	2015	Energy Efficiency	3	Understand socio-psychological and technological aspects that influence use of smart meters	Survey, discourse analysis	Smart Metering
Hall et al.	2016	Energy Policy	6	Explore consumer interest and responses to the concept of cost-reflective pricing	Focus groups	DSM
Hammer et al.	2015	User Modelling and User-Adapted Interaction	5	Build user-trust model for decision making on energy management systems in office buildings	Survey experiment, (Living Lab) model	Energy management systems
Hess & Coley	2014	Public Understanding of Science	16	Explore complaints in the public debate on wireless smart meters in California	Discourse analysis	Smart Metering
Kahma & Matschoss	2017	Energy Research & Social Science	4	Investigate the non-adoption of smart energy services through focus on non-users	Survey	Smart Home
King & Jessen	2014	International Journal of Law and Information Technology	5	Explores the key privacy and data protection concerns for both the EU and USA consumers related to data sharing in smart metering systems	Secondary data analysis (of legal regimes)	Smart Metering
Krishnamurti et al.	2012	Energy Policy	93	Explore consumer beliefs about smart meters in the US	In-depth interviews, survey	Smart Metering
Li et al.	2017	Applied Energy	1	Investigate user perception of smart grids and energy flexible buildings to identify suitable user groups	Survey	Smart Grid
Luthra et al.	2014	Renewable and Sustainable Energy Reviews	61	Explore barriers to smart grid adoption	Expert interviews	Smart Grid
Matschoss et al.	2015	Energy Efficiency	4	Identify pioneering customers for novel energy efficiency services enabled by smart grid technologies	Survey	DSM
Mesarić et al.	2017	Sustainability	2	Explore the influence of users' energy-related behavior on smart grid processes	Focus groups	DSM

Table A1. *Cont.*

Authors	Year	Journal	Citations *	Main Contribution	Methodology	Technology
Michaels & Parag	2016	Energy Research & Social Science	7	Investigated perceptions of demand reduction, load shifting, and energy storage as prosumer activities in Israel	Survey	DSM
Moser	2017	Energy Efficiency	1	Investigate factors for social acceptance of load-shifting programs for smart appliances	Experiment	DSM
Muench et al.	2014	Energy Policy	21	Explore barriers to smart grid implementation	Expert interviews	Smart Grid
Ornetzeder et al.	2009	WIT Transactions on Ecology and the Environment	1	Explore public's opinion on future sustainable energy technology research	Participatory technology assessment workshop	Smart Metering Smart Home
Paetz et al.	2012	Journal of Consumer Policy	85	Explore behavioral aspects, motives, and barriers for smart home acceptance	Focus groups	Smart Home
Park et al.	2014	Energy Policy	19	Tested factors for consumer acceptance of smart meters	Survey	Smart Metering
Park et al.	2017	Sustainability	0	Investigate consumer acceptance of a home energy management system	Survey	Smart Home
Raimi & Carrico	2016	Energy Research & Social Science	4	Examine the American lay public's level of knowledge about smart meters	Survey	Smart Metering
Römer et al.	2015	Electronic Markets	4	Investigate factors for household acceptance of electricity storage systems	Survey	Household Storage
Sandström & Keijer	2010	OPEN HOUSE INTERNATIONAL	0	Explore attitudes and acceptance of residents towards smart homes	Survey	Smart Home
Schmalfuß et al.	2015	Energy Research & Social Science	3	Investigate user experience with smart charging system	Field study with follow-up interviews	Smart Charging
Schweitzer et al.	2016	Psychology & Marketing	2	Investigate impact of perceived disempowerment on adoption intention of smart home applications	Experiment	Smart Home
Shrouf & Miragliotta	2015	Journal of Cleaner Production	54	Explore experts view on energy-efficient production management practices supported by the Internet of Things	Expert interviews	Smart Metering and appliances in factory production processes
Spence et al.	2015	Nature Climate Change	14	Investigate public perceptions of different demand-side management possibilities in the UK	Survey	DSM
Will & Schuller	2016	Transportation Research Part C: Emerging Technologies	8	Investigate factors for the acceptance of smart charging	Survey	Smart Charging
Wilson et al.	2017	Energy Policy	12	Identify perceived benefits and risks of smart home technologies	Survey	Smart Home
Yang et al.	2017	Industrial Management and Data Systems	4	Investigate customers' adoption intentions of smart home services	Survey	Smart Home
Zhou & Brown	2017	Journal of Cleaner Production	10	Compare factors for smart metering penetration rates across five European countries	Case study research (secondary data)	Smart Metering

* Number of citations according to Scopus/Web of Science.

References

1. European Commission 2030 Energy Strategy. Available online: https://ec.europa.eu/energy/en/topics/energy-strategy/2030-energy-strategy (accessed on 16 December 2016).
2. Muench, S.; Thuss, S.; Guenther, E. What hampers energy system transformations? The case of smart grids. *Energy Policy* **2014**, *73*, 80–92. [CrossRef]
3. Römer, B.; Reichhart, P.; Picot, A. Smart energy for Robinson Crusoe: An empirical analysis of the adoption of IS-enhanced electricity storage systems. *Electron. Mark.* **2015**, *25*, 47–60. [CrossRef]
4. Lund, H.; Hvelplund, F.; Østergaard, P.; Möller, B.; Mathiesen, B.V.; Connolly, D.; Andersen, A.N. Analysis: Smart Energy Systems and Infrastructures. In *Renewable Energy Systems*; Lund, H., Ed.; Elsevier Inc.: Oxford, UK; Waltham, MA, USA, 2014; pp. 131–184, ISBN 9780124104235.
5. Fallah, S.; Deo, R.; Shojafar, M.; Conti, M.; Shamshirband, S. Computational Intelligence Approaches for Energy Load Forecasting in Smart Energy Management Grids: State of the Art, Future Challenges, and Research Directions. *Energies* **2018**, *11*, 596. [CrossRef]
6. Pooranian, Z.; Abawajy, J.; P, V.; Conti, M. Scheduling Distributed Energy Resource Operation and Daily Power Consumption for a Smart Building to Optimize Economic and Environmental Parameters. *Energies* **2018**, *11*, 1348. [CrossRef]
7. Xenias, D.; Axon, C.J.; Whitmarsh, L.; Connor, P.M.; Balta-Ozkan, N.; Spence, A. UK smart grid development: An expert assessment of the benefits, pitfalls and functions. *Renew. Energy* **2015**, *81*, 89–102. [CrossRef]
8. Pooranian, Z.; Nikmehr, N.; Najafi-Ravadanegh, S.; Mahdin, H.; Abawajy, J. Economical and environmental operation of smart networked microgrids under uncertainties using NSGA-II. In Proceedings of the 2016 24th International Conference on Software, Telecommunications and Computer Networks (SoftCOM), Split, Croatia, 22–24 September 2016.
9. Sintov, N.D.; Schultz, P.W. Adjustable green defaults can help make smart homes more sustainable. *Sustainability* **2017**, *9*, 1–12. [CrossRef]
10. Cuijpers, C.; Koops, B.-J. Smart Metering and Privacy in Europe: Lessons from the Dutch Case. In *European Data Protection: Coming of Age*; Gutwirth, S., Leenes, R., de Hert, P., Poullet, Y., Eds.; Springer: Dordrecht, The Netherlands, 2013; pp. 269–293, ISBN 978-94-007-5170-5.
11. Raimi, K.T.; Carrico, A.R. Understanding and beliefs about smart energy technology. *Energy Res. Soc. Sci.* **2016**, *12*, 68–74. [CrossRef]
12. McKenna, E.; Richardson, I.; Thomson, M. Smart meter data: Balancing consumer privacy concerns with legitimate applications. *Energy Policy* **2012**, *41*, 807–814. [CrossRef]
13. Ligtvoet, A.; Van de Kaa, G.; Fens, T.; Van Beers, C.; Herder, P.; Van den Hoven, J. Value Sensitive Design of Complex Product Systems. In *Policy Practice and Digital Science: Integrating Complex Systems, Social Simulation and Public Administration in Policy Research*; Janssen, M., Wimmer, A.M., Deljoo, A., Eds.; Springer International Publishing: Cham, Switzerland, 2015; pp. 157–176, ISBN 978-3-319-12784-2.
14. Buchanan, K.; Banks, N.; Preston, I.; Russo, R. The British public's perception of the UK smart metering initiative: Threats and opportunities. *Energy Policy* **2016**, *91*, 87–97. [CrossRef]
15. Schilling, M.A. Technology Success and Failure in Winner-Take-All Markets: The Impact of Learning Orientation, Timing, and Network Externalities. *Acad. Manag. J.* **2002**, *45*, 387–398.
16. Suarez, F.F. Battles for technological dominance: An integrative framework. *Res. Policy* **2004**, *33*, 271–286. [CrossRef]
17. Venkatesh, V.; Thong, J.; Xu, X. Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology. *MIS Q.* **2012**, *36*, 157–178. [CrossRef]
18. Stern, P.C. Toward a Coherent Theory of Environmentally Significant Behavior. *J. Soc. Issues* **2000**, *56*, 407–424. [CrossRef]
19. Cusumano, M.A.; Mylonadis, Y.; Rosenbloom, R.S. Strategic Maneuvering and Mass-Market Dynamics: The Triumph of VHS over Beta. *Bus. Hist. Rev.* **1992**, *66*, 51–94. [CrossRef]
20. Katz, M.L.; Shapiro, C. Network externalities, competition, and compatibility. *Am. Econ. Rev.* **1985**, *75*, 424–440.
21. Schilling, M.A. Technological Lockout: An Integrative Model of the Economic and Strategic Factors Driving Technology Success and Failure. *Acad. Manag. Rev.* **1998**, *23*, 267–284. [CrossRef]
22. Ajzen, I. The Theory of Planned Behavior. *Organ. Behav. Hum. Decis. Process.* **1991**, *50*, 179–211. [CrossRef]

23. Shrader-Frechette, K.S.; Westra, L. Overview: Ethical Studies about Technology. In *Technology and Values*; Shrader-Frechette, K.S., Westra, L., Eds.; Rowman & Littlefield Publishers: Lanham, MD, USA, 1997; pp. 3–10.
24. Taebi, B.; Kadak, A.C. Intergenerational considerations affecting the future of nuclear power: Equity as a framework for assessing fuel cycles. *Risk Anal.* **2010**, *30*, 1341–1362. [CrossRef] [PubMed]
25. Van de Poel, I. Values in engineering design. In *Handbook of the Philosophy of Science*; Meijers, A.W.M., Ed.; Oxford University Press: New York, NY, USA, 2009; Volume 9, pp. 973–1006.
26. Künneke, R.W.; Mehos, D.C.; Hillerbrand, R.; Hemmes, K. Understanding values embedded in offshore wind energy systems: Toward a purposeful institutional and technological design. *Environ. Sci. Policy* **2015**, *53*, 118–129. [CrossRef]
27. Friedman, B.; Kahn, P.H., Jr.; Borning, A.; Huldtgren, A. Value sensitive design and information systems. In *Early Engagement and New Technologies: Opening Up the Laboratory*; Doorn, N., Schuurbiers, D., Van de Poel, I., Gorman, M., Eds.; Springer: Dordrecht, The Netherlands, 2013; pp. 55–95, ISBN 9400778430.
28. Manders-Huits, N. What values in design? The challenge of incorporating moral values into design. *Sci. Eng. Ethics* **2011**, *17*, 271–287. [CrossRef] [PubMed]
29. Albrechtslund, A. Ethics and technology design. *Ethics Inf. Technol.* **2007**, *9*, 63–72. [CrossRef]
30. Winner, L. Do Artifacts Have Politics? *Daedalus* **1980**, *109*, 121–136.
31. Shilton, K.; Koepfler, J.A.; Fleischmann, K.R. Charting Sociotechnical Dimensions of Values for Design Research. *Inf. Soc.* **2013**, *29*, 259–271. [CrossRef]
32. Barry, C. The Ethical Assessment of Technological Change: An overview of the issues. *J. Hum. Dev.* **2001**, *2*, 167–189. [CrossRef]
33. Flanagan, M.; Howe, D.C.; Nissenbaum, H. Embodying values in technology: Theory and practice. In *Information Technology and Moral Philosophy*; Van Den Hoven, J., Weckert, J., Eds.; Cambridge University Press: New York, NY, USA, 2008; pp. 322–353.
34. Friedman, B.; Kahn, P.; Borning, A. Value sensitive design: Theory and methods. In *University of Washington Technical Report*; University of Washington: Washington, DC, USA, 2002; pp. 2–12.
35. Davis, J.; Nathan, L.P. Value Sensitive Design: Applications, Adaptations, and Critiques. In *Handbook of Ethics, Values, and Technological Design: Sources, Theory, Values and Application Domains*; van den Hoven, J., Vermaas, P.E., van de Poel, I., Eds.; Springer: Dordrecht, The Netherlands, 2015; pp. 11–40.
36. Wüstenhagen, R.; Wolsink, M.; Bürer, M.J. Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy* **2007**, *35*, 2683–2691. [CrossRef]
37. Sauter, R.; Watson, J. Strategies for the deployment of micro-generation: Implications for social acceptance. *Energy Policy* **2007**, *35*, 2770–2779. [CrossRef]
38. Broman Toft, M.; Schuitema, G.; Thøgersen, J. Responsible technology acceptance: Model development and application to consumer acceptance of Smart Grid technology. *Appl. Energy* **2014**, *134*, 392–400. [CrossRef]
39. Schuitema, G.; Steg, L.; Forward, S. Explaining differences in acceptability before and acceptance after the implementation of a congestion charge in Stockholm. *Transp. Res. Part A Policy Pract.* **2010**, *44*, 99–109. [CrossRef]
40. Steg, L.; Dreijerink, L.; Abrahamse, W. Factors influencing the acceptability of energy policies: A test of VBN theory. *J. Environ. Psychol.* **2005**, *25*, 415–425. [CrossRef]
41. Huijts, N.M.A.; Molin, E.J.E.; Steg, L. Psychological factors influencing sustainable energy technology acceptance: A review-based comprehensive framework. *Renew. Sustain. Energy Rev.* **2012**, *16*, 525–531. [CrossRef]
42. Suarez, F.F.; Utterback, J.M. Dominant designs and the survival of firms. *Strateg. Manag. J.* **1995**, *16*, 415–430. [CrossRef]
43. Gallagher, S.; Park, S.H. Innovation and competition in standard-based industries: A historical analysis of the US home video game market. *Eng. Manag. IEEE Trans.* **2002**, *49*, 67–82. [CrossRef]
44. Van de Kaa, G.; Van den Ende, J.; de Vries, H.J.; Van Heck, E. Factors for winning interface format battles: A review and synthesis of the literature. *Technol. Forecast. Soc. Chang.* **2011**, *78*, 1397–1411. [CrossRef]
45. Van de Kaa, G.; De Vries, H.J.; Rezaei, J. Platform selection for complex systems: Building automation systems. *J. Syst. Sci. Syst. Eng.* **2014**, *23*, 415–438. [CrossRef]
46. Van de Kaa, G.; De Vries, H.J. Factors for winning format battles: A comparative case study. *Technol. Forecast. Soc. Chang.* **2015**, *91*, 222–235. [CrossRef]

47. Van de Kaa, G.; De Vries, H.J.; Van den Ende, J. Strategies in network industries: The importance of inter-organisational networks, complementary goods, and commitment. *Technol. Anal. Strateg. Manag.* **2015**, *27*, 73–86. [CrossRef]
48. Teece, D.J. Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Res. Policy* **1986**, *15*, 285–305. [CrossRef]
49. Davis, F.D.; Bagozzi, R.P.; Warshaw, P.R. User Acceptance of Computer Technology: A Comparison of Two Theoretical Models. *Manag. Sci.* **1989**, *35*, 982–1003. [CrossRef]
50. Venkatesh, V.; Davis, F.D. A theoretical extension of the technology acceptance model: Four longitudinal Studies. *Manag. Sci.* **2000**, *46*, 186–205. [CrossRef]
51. Schwartz, S.H. Normative Influences on Altruism. In *Advances in Experimental Social Psychology*; Berkowitz, L., Ed.; Advances in Experimental Social Psychology; Academic Press: New York, NY, USA, 1977; Volume 10, pp. 221–279.
52. Schwartz, S.H.; Howard, J.A. A normative decision-making model of altruism. In *Altruism and Helping Behavior: Social, Personality and Developmental Perspective*; Rushton, J.P., Sorrentino, R.M., Eds.; Lawrence Erlbaum: Hillsdale, NJ, USA, 1981; pp. 198–211.
53. Schwartz, S.H. Are There Universal Aspects in the Structure and Contents of Human Values? *J. Soc. Issues* **1994**, *50*, 19–45. [CrossRef]
54. Ahn, M.; Kang, J.; Hustvedt, G. A model of sustainable household technology acceptance. *Int. J. Consum. Stud.* **2016**, *40*, 83–91. [CrossRef]
55. Ehrenhard, M.; Kijl, B.; Nieuwenhuis, L. Market adoption barriers of multi-stakeholder technology: Smart homes for the aging population. *Technol. Forecast. Soc. Chang.* **2014**, *89*, 306–315. [CrossRef]
56. Guerreiro, S.; Batel, S.; Lima, M.L.; Moreira, S. Making energy visible: Sociopsychological aspects associated with the use of smart meters. *Energy Effic.* **2015**, *8*, 1149–1167. [CrossRef]
57. Hall, N.L.; Jeanneret, T.D.; Rai, A. Cost-reflective electricity pricing: Consumer preferences and perceptions. *Energy Policy* **2016**, *95*, 62–72. [CrossRef]
58. Paetz, A.-G.; Dütschke, E.; Fichtner, W. Smart Homes as a Means to Sustainable Energy Consumption: A Study of Consumer Perceptions. *J. Consum. Policy* **2012**, *35*, 23–41. [CrossRef]
59. Park, E.-S.; Hwang, B.; Ko, K.; Kim, D. Consumer Acceptance Analysis of the Home Energy Management System. *Sustainability* **2017**, *9*, 2351. [CrossRef]
60. Vagropoulos, S.I.; Balaskas, G.A.; Bakirtzis, A.G. An Investigation of Plug-In Electric Vehicle Charging Impact on Power Systems Scheduling and Energy Costs. *IEEE Trans. Power Syst.* **2017**, *32*, 1902–1912. [CrossRef]
61. Kobus, C.B.A.; Klaassen, E.A.M.; Mugge, R.; Schoormans, J.P.L. A real-life assessment on the effect of smart appliances for shifting households' electricity demand. *Appl. Energy* **2015**, *147*, 335–343. [CrossRef]
62. Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G.; Altman, D.; Antes, G.; Atkins, D.; Barbour, V.; Barrowman, N.; Berlin, J.A.; et al. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Med.* **2009**, *6*. [CrossRef] [PubMed]
63. Dedrick, J.; Venkatesh, M.; Stanton, J.M.; Zheng, Y.; Ramnarine-Rieks, A. Adoption of smart grid technologies by electric utilities: Factors influencing organizational innovation in a regulated environment. *Electron. Mark.* **2015**, *25*, 17–29. [CrossRef]
64. Ghazal, M.; Akmal, M.; Iyanna, S.; Ghoudi, K. Smart plugs: Perceived usefulness and satisfaction: Evidence from United Arab Emirates. *Renew. Sustain. Energy Rev.* **2015**, *55*, 1248–1259. [CrossRef]
65. Li, R.; Dane, G.; Finck, C.; Zeiler, W. Are building users prepared for energy flexible buildings?—A large-scale survey in the Netherlands. *Appl. Energy* **2017**, *203*, 623–634. [CrossRef]
66. Mesarić, P.; Đukec, D.; Krajcar, S. Exploring the Potential of Energy Consumers in Smart Grid Using Focus Group Methodology. *Sustainability* **2017**, *9*, 1463. [CrossRef]
67. Moser, C. The role of perceived control over appliances in the acceptance of electricity load-shifting programmes. *Energy Effic.* **2017**, 1–13. [CrossRef]
68. Park, C.K.; Kim, H.-J.; Kim, Y.-S. A study of factors enhancing smart grid consumer engagement. *Energy Policy* **2014**, *72*, 211–218. [CrossRef]
69. Schmalfuß, F.; Mair, C.; Döbelt, S.; Kämpfe, B.; Wüstemann, R.; Krems, J.F.; Keinath, A. User responses to a smart charging system in Germany: Battery electric vehicle driver motivation, attitudes and acceptance. *Energy Res. Soc. Sci.* **2015**, *9*, 60–71. [CrossRef]

70. Shrouf, F.; Miragliotta, G. Energy management based on Internet of Things: Practices and framework for adoption in production management. *J. Clean. Prod.* **2015**, *100*, 235–246. [CrossRef]
71. Spence, A.; Demski, C.; Butler, C.; Parkhill, K.; Pidgeon, N. Public perceptions of demand-side management and a smarter energy future. *Nat. Clim. Chang.* **2015**, *5*, 550–554. [CrossRef]
72. Will, C.; Schuller, A. Understanding user acceptance factors of electric vehicle smart charging. *Transp. Res. Part C Emerg. Technol.* **2016**, *71*, 198–214. [CrossRef]
73. Wilson, C.; Hargreaves, T.; Hauxwell-Baldwin, R. Benefits and risks of smart home technologies. *Energy Policy* **2017**, *103*, 72–83. [CrossRef]
74. Zhou, S.; Brown, M.A. Smart meter deployment in Europe: A comparative case study on the impacts of national policy schemes. *J. Clean. Prod.* **2017**, *144*, 22–32. [CrossRef]
75. Balta-Ozkan, N.; Davidson, R.; Bicket, M.; Whitmarsh, L. The development of smart homes market in the UK. *Energy* **2013**, *60*, 361–372. [CrossRef]
76. Balta-Ozkan, N.; Amerighi, O.; Boteler, B. A comparison of consumer perceptions towards smart homes in the UK, Germany and Italy: Reflections for policy and future research. *Technol. Anal. Strateg. Manag.* **2014**, *26*, 1176–1195. [CrossRef]
77. Balta-Ozkan, N.; Boteler, B.; Amerighi, O. European smart home market development: Public views on technical and economic aspects across the United Kingdom, Germany and Italy. *Energy Res. Soc. Sci.* **2014**, *3*, 65–77. [CrossRef]
78. Buryk, S.; Mead, D.; Mourato, S.; Torriti, J. Investigating preferences for dynamic electricity tariffs: The effect of environmental and system benefit disclosure. *Energy Policy* **2015**, *80*, 190–195. [CrossRef]
79. Cherry, C.; Hopfe, C.; MacGillivray, B.; Pidgeon, N. Homes as machines: Exploring expert and public imaginaries of low carbon housing futures in the United Kingdom. *Energy Res. Soc. Sci.* **2017**, *23*, 36–45. [CrossRef]
80. Berry, S.; Whaley, D.; Saman, W.; Davidson, K. Finding faults and influencing consumption: The role of in-home energy feedback displays in managing high-tech homes. *Energy Effic.* **2017**, *10*, 787–807. [CrossRef]
81. Balta-Ozkan, N.; Davidson, R.; Bicket, M.; Whitmarsh, L. Social barriers to the adoption of smart homes. *Energy Policy* **2013**, *63*, 363–374. [CrossRef]
82. Begier, B. Effective cooperation with energy consumers: An example of an ethical approach to introduce an innovative solution. *J. Inf. Commun. Ethics Soc.* **2014**, *12*, 107–121. [CrossRef]
83. Chen, C.; Xu, X.; Arpan, L. Between the technology acceptance model and sustainable energy technology acceptance model: Investigating smart meter acceptance in the United States. *Energy Res. Soc. Sci.* **2017**, *25*, 93–104. [CrossRef]
84. Chou, J.-S.; Yutami, G.A.N. Smart meter adoption and deployment strategy for residential buildings in Indonesia. *Appl. Energy* **2014**, *128*, 336–349. [CrossRef]
85. Chou, J.-S.; Kim, C.; Ung, T.-K.; Yutami, G.A.N.; Lin, G.-T.; Son, H. Cross-country review of smart grid adoption in residential buildings. *Renew. Sustain. Energy Rev.* **2015**, *48*, 192–213. [CrossRef]
86. Hess, D.J.; Coley, J.S. Wireless smart meters and public acceptance: The environment, limited choices, and precautionary politics. *Public Underst. Sci.* **2014**, *23*, 688–702. [CrossRef] [PubMed]
87. King, N.J.; Jessen, P.W. Smart metering systems and data sharing: Why getting a smart meter should also mean getting strong information privacy controls to manage data sharing. *Int. J. Law Inf. Technol.* **2014**, *22*, 215–253. [CrossRef]
88. Krishnamurti, T.; Schwartz, D.; Davis, A.; Fischhoff, B.; de Bruin, W.B.; Lave, L.; Wang, J. Preparing for smart grid technologies: A behavioral decision research approach to understanding consumer expectations about smart meters. *Energy Policy* **2012**, *41*, 790–797. [CrossRef]
89. Luthra, S.; Kumar, S.; Kharb, R.; Ansari, M.F.; Shimmi, S.L. Adoption of smart grid technologies: An analysis of interactions among barriers. *Renew. Sustain. Energy Rev.* **2014**, *33*, 554–565. [CrossRef]
90. Matschoss, K.; Kahma, N.; Heiskanen, E. Pioneering customers as change agents for new energy efficiency services???an empirical study in the Finnish electricity markets. *Energy Effic.* **2015**, *8*, 827–843. [CrossRef]
91. Michaels, L.; Parag, Y. Motivations and barriers to integrating 'prosuming' services into the future decentralized electricity grid: Findings from Israel. *Energy Res. Soc. Sci.* **2016**, *21*, 70–83. [CrossRef]
92. Yang, H.; Lee, H.; Zo, H. User acceptance of smart home services: An extension of the theory of planned behavior. *Ind. Manag. Data Syst.* **2017**, *117*, 68–89. [CrossRef]

93. Ornetzeder, M.; Bechtold, U.; Nentwich, M. Participatory assessment of sustainable end-user technology in Austria. *WIT Trans. Ecol. Environ.* **2009**, *121*, 269–278. [CrossRef]
94. Goulden, M.; Bedwell, B.; Rennick-Egglestone, S.; Rodden, T.; Spence, A. Smart grids, smart users? the role of the user in demand side management. *Energy Res. Soc. Sci.* **2014**, *2*, 21–29. [CrossRef]
95. Hammer, S.; Wißner, M.; André, E. Trust-based decision-making for smart and adaptive environments. *User Model. User-Adapt. Interact.* **2015**, *25*, 267–293. [CrossRef]
96. Kahma, N.; Matschoss, K. The rejection of innovations? Rethinking technology diffusion and the non-use of smart energy services in Finland. *Energy Res. Soc. Sci.* **2017**, *34*, 27–36. [CrossRef]
97. Sandström, G.; Keijer, U. Smart home systems—Accessibility and trust. *Open House Int.* **2010**, *35*, 6–14.
98. Gerpott, T.J.; Paukert, M. Determinants of willingness to pay for smart meters: An empirical analysis of household customers in Germany. *Energy Policy* **2013**, *61*, 483–495. [CrossRef]
99. Barnicoat, G.; Danson, M. The ageing population and smart metering: A field study of householders' attitudes and behaviours towards energy use in Scotland. *Energy Res. Soc. Sci.* **2015**, *9*, 107–115. [CrossRef]
100. Fell, M.J.; Shipworth, D.; Huebner, G.M.; Elwell, C.A. Public acceptability of domestic demand-side response in Great Britain: The role of automation and direct load control. *Energy Res. Soc. Sci.* **2015**, *9*, 72–84. [CrossRef]
101. Schweitzer, F.; Van den Ende, E. To Be or Not to Be in Thrall to the March of Smart Products. *Psychol. Mark.* **2016**, *33*, 830–842. [CrossRef] [PubMed]
102. Aduda, K.O.; Labeodan, T.; Zeiler, W.; Boxem, G.; Zhao, Y. Demand side flexibility: Potentials and building performance implications. *Sustain. Cities Soc.* **2016**, *22*, 146–163. [CrossRef]
103. Jacobs, M. Sustainable Development as a Contested Concept. In *Fairness and Futurity: Essays on Environmental Sustainability and Social Justice*; Dobson, A., Ed.; Oxford University Press: Oxford, UK, 1999; pp. 21–45.
104. Dignum, M.; Correljé, A.; Cuppen, E.; Pesch, U.; Taebi, B. Contested Technologies and Design for Values: The Case of Shale Gas. *Sci. Eng. Ethics* **2016**, *22*, 1171–1191. [CrossRef] [PubMed]