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Conflicting values in the smart electricity grid a comprehensive overview

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ABSTRACT

This paper aims to anticipate social acceptance issues related to the deployment of the smart electricity grid by identifying underlying value conflicts. The smart electricity grid is a key enabler of the energy transition. Its successful deployment is however jeopardized by social acceptance issues, such as concerns related to privacy and fairness. Social acceptance issues may be explained by value conflicts, i.e. the impossibility for a technological or regulatory design to simultaneously satisfy multiple societal expectations. Due to unsatisfied expectations concerning values, social discontent may arise. This paper identifies five groups of value conflicts in the smart electricity grid: consumer values versus competitiveness, IT enabled systems versus data protection, fair spatial distributions of energy systems versus system performance, market performance versus local trading, and individual access versus economies of scale. This is important for policy-makers and industry to increase the chances that the technology gains acceptance. As resolving value conflicts requires resources, this paper suggests three factors to prioritize their resolution: severity of resulting acceptance issues, resolvability of conflicts, and the level of resources required. The analysis shows that particularly the socio-economic disparities caused by the deployment of the smart electricity grid are alarming. Affordable policies are currently limited, but the impact in terms of social acceptance may be large.

1. Introduction

The introduction of the smart electricity grid raises concerns in terms of social acceptance, which might hamper the energy transition. The smart electricity grid is defined as "electricity networks that can 'intelligently' integrate the behavior and actions of all users connected to it (…) in order to efficiently deliver sustainable, economic and secure electricity supplies" [1]. To do so, it incorporates a range of technologies including smart meters, communication technologies, smart home appliances, and distributed energy systems [2]. By efficiently integrating the behavior of all actors, appliances, and facilities at the supply and demand side of the electricity grid, the smart electricity grid supports the deployment of intermittent power sources such as wind and solar power [3]. The social acceptance [4] of the smart electricity grid is however uncertain, despite favorable policies [5] and numerous R&D and demonstration projects [6]. Issues of socio-political acceptance with regard to privacy have arisen during the deployment of smart meters in the Netherlands [7]. The installation of distributed energy systems affects communities in terms of space and fairness [8]. Market acceptance of smart electricity grid technologies is also uncertain [9]. Issues of social acceptance are challenging for policy-makers and the industry as they hamper the deployment of technologies that may have large societal benefits.

This paper studies the occurrence of social acceptance issues using a value perspective. A value is defined as "what a person or group of people consider important in life" [10]. Values relate to societal expectations of technologies, both in terms of design objectives and compliance requirements [11]. Examples of values are sustainability, privacy, efficiency, and security of supply. These values can be social, economic, or technical (see section 2.1). Unsatisfied expectations concerning values may eventually result in social acceptance issues [12], although the underlying causality is often complex. From a value perspective, the difficulty to resolve acceptance issues can be explained by the fact that values are in conflict [13]. In that case, a value can only be practically realized in a specific context at the expense of another value. For example, in the smart electricity grid, consumption data can be used to increase security of supply, but can also reveal the load consumption pattern of consumers, thereby raising privacy concerns. Hence, inevitably, the deployment and use of a technology favors some values over others. Value conflicts embedded in technologies are therefore potential sources of social acceptance issues that might emerge during the deployment and operation phases.

The goal of this paper is to anticipate social acceptance issues that might occur during the deployment and operation phase of the smart

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List of abbreviations:

AMI	Advanced Metering Infrastructure
HAN	Home Area Network
IT	Information Technology
PV	Photo-Voltaic
R&D	Research and Development
WAN	Wide-Area Network

electricity grid by identifying underlying value conflicts. For policy-makers and the industry, an overview of underlying value conflicts is important to identify potential technological or regulatory adjustments required to increase the chances that the technology gains acceptance. Systematic overviews of conflicting values for a technology are rare in the scientific literature, and none could be found about the smart electricity grid. Particularly the diversity of the (type of) sources of information required to build such a list, and the fact that values are often discussed in a latent manner (i.e. not named explicitly in texts or discussions but implied) are problematic. To address these challenges, this paper uses the approach proposed by de Wildt et al. [14]. This computer-aided approach can extract value conflicts addressed by the literature by passing through a very large set of scientific articles originating from multiple scientific communities. This is done using probabilistic topic models (a suite of algorithms used to systematically discover themes addressed within a range of documents) and semantic fields (sets of words referring to a common idea). As scientific articles may propose solutions to value conflicts, the approach captures both value conflicts addressed by a body of literature as well as solutions for their resolution.

This paper is structured as follows. Section 2 discusses the literature on values and social acceptance and on value conflicts. Section 3 describes the method and approach used for this research. Section 4 presents the identified value conflicts and innovations proposed by the scientific literature for their resolution. Finally, Section 5 discusses the prioritization of conflicts and offers a critical perspective on how they are currently addressed.

2. Theory

2.1. Values and social acceptance

The concept of values is frequently used in the context of social protests emerging from the deployment of technologies. Here, values are frequently discussed in terms of 'human', 'personal', 'moral' or 'social' values. Examples of values include *power*, *hedonism* and *tradition* [15], or *privacy* and *trust* [16]. In this context, values are frequently named to understand the nature of citizens or technology users' behavior and are assumed to drive social response to the introduction of technologies [17]. By more carefully considering these values during the design of technologies, the social acceptance of technologies can be increased and potential social opposition can be prevented [18].

However, there is a wider notion to values, in the sense of 'public values' or 'societal values', which serve the public good (for example [19–21]). This notion is not limited to citizens and (potential) users of technologies. Here, the term value is used more broadly and refers to what can be considered as societally valuable or to "statements about whether certain things or state of affairs are good, i.e. valuable, or bad in a certain respect" [13]. Generally, the intersubjective and societal notion of values holds, and thus values are not to be mistaken with individual desires or interests [13]. Within this notion, values are not solely indicators of human or moral concerns of citizens or users that need to be considered during the technology design phase. Rather, values may be technical and economic as well. They can be explicit goals for design or for driving the design and deployment of technologies rather than solely being considered as social requirements [11]. For example, the value *environmental sustainability* drives the deployment of renewables. *Profitability* is a requirement to ensure that renewable energy technologies are deployed on a larger scale.

Unsatisfied expectations concerning values may eventually lead to social acceptance issues. Wüstenhagen et al. [4] identify three dimensions of social acceptance: socio-political, community, and market acceptance. Socio-political acceptance relates to the national, political, and policy level. At this level, a technology is typically considered as accepted when it is encouraged by policies, enabled by law, and supported within political debates. Community acceptance refers to the response at local level, by residents and local authorities. The acceptance can be considered as wider when it is at least tolerated by these stakeholders rather than leading to street protests. Market acceptance is an indicator of the adoption of technologies (i.e. whether they are commercially successful) and of the willingness for investors to invest. Values may relate to each of these dimensions. A better consideration of values may lead to a more successful deployment of technologies with respect to these three dimensions [20].

The relationship between value (un)fulfillment and social acceptance is complex. To get a better grasp of the complexity between values and technological use, van de Poel [22] and Taebi [23] advocate sharpening the distinction between moral acceptability and social acceptance. Moral acceptability refers to an ethical judgement of a technology, recognizing the "moral issues that emerge from its introduction" [23]. Social acceptance refers to whether a technology is accepted or at least tolerated by individuals and organizations. Both notions are complementary. Merely considering the reaction of (groups of) individuals may lead to overlooking underlying moral issues. Similarly, prevailing stakeholders' opinions might be informative for a complete ethical evaluation, or in case moral choices are inescapable.

2.2. Value conflicts

While a range of values that may potentially influence the acceptance of a technology, it may be difficult to satisfy all values at the same time. This can be due to physical, economic, or regulatory constraints. In some cases, the fulfillment of two values may even be in opposition to each other [24], i.e. conflicting values. According to Van de Poel [13], "two or more values conflict in a specific situation if, when considered in isolation, they evaluate different options as best".

Conflicting values are widespread in the design of technologies and infrastructures. In information technologies, common conflicts occur between *accountability* and *privacy*, between infrastructure *control* and *democratization*, and between *security* and *privacy* [24]. This last conflict also applies for security technologies of buildings [25]. In the energy sector, tensions between *safety*, *economic viability*, and *environmental sustainability* play a central role in prioritizing different types of power production technologies, for example, in nuclear energy [26]. In wind power deployment, there is a strong tension between *environmental sustainability* and the use of space (i.e. *landscape authenticity*) [27].

The difficulty in coping with value conflicts is explained by the frequent absence of a common measure to compare two alternatives fulfilling two values differently, as well as the seriousness of the choice in terms of societal impact. A common scale for comparison often exists for trade-offs between commodities (products that can be traded) and/or currencies (valuations of commodities) [28]. This is where cost-benefit analyses tend to be highly instrumental [29]. For choices between non-commodities (non-tradable objects such as emotions or values), alternatives tend to be incommensurable [28,29]. For example, in the case of smart meter deployment, how can personal privacy be valued compared to the benefits of smart meters in terms of security of supply? If these non-commodities are values, making a choice means favoring one legitimate and morally defensible vision of the good over another [30]. The literature refers to these as 'tragic choices' [31] or choices under 'social incommensurability' [29]. A parallel can also be made with moral dilemmas [32]. Hence, when choosing a value over another, a morally valuable societal aspect is diminished. Any resulting form of stakeholders' protests that might potentially emerge is both morally legitimate and hardly escapable unless another morally valuable societal aspect is disfavored in return.

Value conflicts may be resolved through innovation. Van de Poel [32] identifies three main ways to cope with conflicting values: value re-specification, trade-offs, and innovation. Re-specification focuses on clarifying how a design embeds or undermines different values [32], for example, through participatory processes and stakeholder dialog [33]. Trade-offs can be made, for example, by using social multi-criteria evaluations [29]. Finally, Van de Poel [32] underlines that, while some values are conceptually in conflict (for example, *confidentiality* and *transparency*), other values conflict only in specific situations. These conflicts may be resolved through innovation. The innovation process broadens the technological and regulatory feasibility set, thereby offering opportunities to resolve conflicting values [34]. An example is the design and deployment of storm surge barriers in the Netherlands, which resolved the conflict between flood risk prevention (*safety*) and ecological repercussions (*environment*) [35].

3. Methods and approach

3.1. Methods

A difficulty when creating a comprehensive list of value conflicts relates to the interpretation of values. Values tend to be discussed in a latent manner, whether orally or in the literature. This means that often the value in question is not explicitly named, but a broad set of words is used that, to some extent, refers to this value. For example, articles addressing privacy issues may not use this word specifically, but use terms such as ‘data protection’, ‘theft’, and ‘cybersecurity’. In some cases, articles may also directly refer to technical solutions such as ‘encryption’ or ‘data aggregation’, or to the sources of privacy concerns (i.e. ‘hackers’). Typically, these sets of words tend to differ depending on the scientific fields from which the article originates. These same words may in some cases have totally different meanings when they are used in a different context. For example, the word ‘private’ may also be used to express the idea of ownership.

The difficulty to interpret values means that one cannot conclude that a certain value is discussed solely because a certain word has been used. Rather, there is a dependency towards the human mind that is able to capture such complexity. Consequently, existing reviews of value conflicts for a technology are rare and tend to rely on qualitative content analyses (e.g., Milchram et al. [36] and Dignum et al. [37]). However, if a comprehensive list of value conflicts needs to be built, it involves exploring a greater number of documents, preferably originating from multiple types of sources. Christen et al. [38] use bibliometric analysis and outline a map of conflicting values in cybersecurity. However, the authors encountered problems such as the size of the literature and the difficulty to visualize “contextual aspects of possible conflicts” [38].

de Wildt et al. [14] proposed a computer-aided approach. This approach can be used to make a comprehensive overview of value conflicts. The advantage of such an approach is the number of documents that can be processed, and therefore the diversity of value conflicts that can be found. This approach relies on probabilistic topic models [39] and semantic fields (set of words referring to a common idea) to conclude whether a certain value is discussed within a document. The principle of probabilistic topic models is the following. A topic model algorithm can autonomously identify topics addressed by a set of documents. This is done by passing through the text of multiple articles and observing words that are frequently named together within one article. The algorithm returns a set of topics, each being reported as a distribution over a fixed set of words. The interpretation of topic returned is to be done by the researcher. For example, a topic with high probabilities on words such as ‘solar’, ‘energy’ and ‘photovoltaics’ points to a topic about solar energy. The algorithm also returns how much of each topic a document addresses. Articles referring to a topic of interest can be captured by indicating a minimum percentage of words that have been attributed by the algorithm to this topic.

3.2. Approach

The approach aims to extract value conflicts in the smart electricity grid by observing a very large body of literature related to this topic. The logic used to identify value conflicts is the following. A large share of the scientific literature proposes solutions or approaches (in some form) to address a technological or regulatory challenge (i.e. a trade-off). For example, solutions could be proposed to produce reliable products at lower costs, or to support the diffusion of technologies with the lowest amount of subsidies. In some cases, the trade-off is between two values (i.e. a value conflict). Indeed, as explained by Van de Poel [32], innovation plays a key role in solving value conflicts (see section 2.2). Hence, if two values are observed within an article, and provided the fact that they are in conflict, this article both indicates a value conflict addressed in the literature and an approach to resolve this conflict. Using the approach proposed by de Wildt et al. [14], this can be done systematically for a large body of literature.

A large set of possible values that may be in some way connected or affected by the deployment of the smart electricity grid with possible conflicts between them may initially be established. Our choice is to concentrate on conflict between a reduced number of seven key values. The first three selected values are the three pillars of the European Union energy policy: *reliability*, *environmental sustainability*, and *competitiveness* [40]. Next, *efficiency* is a key value in engineering design, strongly determining the economic success of a technology. Finally, as the expectation is that conflicting values may relate to technology users and citizens as well, three ‘more human’ values are chosen: *safety & health*, *justice*, and *privacy*, the latter related to societal discussions about the increased use of information technologies.

In line with the approach proposed by de Wildt et al. [14], a set of 380,760 articles retrieved from Scopus in March 2018 using the query AUTHKEY (energy) was used. This also holds for the topic model of 100 main topics in the energy literature created and presented by the authors. Since this paper addresses the smart electricity grid, topics having high probabilities on words referring to this concept were selected. These topics were then verified by manually exploring the content of highly cited articles that were assigned to these topics by the algorithm and evaluating whether they were indeed related to the smart electricity grid. Four topics were finally identified, containing 24,799 articles. Table 1 presents the ten most probable words which describe the topics.

To identify articles addressing values, semantic fields (i.e. a set of words referring to a common idea) need to be created in multidisciplinary teams [14]. Five researchers who were all acquainted with the concept of values and all had a strong background in the energy

Table 1
Smart electricity grid topics.

Topic 1	Topic 2	Topic 3	Topic 4
electric	algorithm	connected	microgrid
vehicles	optimization	generator	distributed
vehicle	scheduling	inverter	microgrids
charging	optimal	synchronous	resources
hybrid	programming	generators	generation
battery	objective	grid	distribution
forecasting	genetic	tracking	power
management	stochastic	wind	grid
plug	multi	control	storage
strategy	proposed	point	coordination

domain together created the semantic fields of values. They originate from various scientific fields such as system engineering, ethics, standardization, and economics, concerned about the deployment of the smart electricity grid. The creation of semantic fields was done by progressively excluding words from a very large initial set of potentially relevant words. Table 6 in the Appendix shows the semantic fields and the definition of values provided to the researchers during the workshop.

To extract value conflicts from the body of literature, articles in these four topics mentioning at least one word of each of the semantic fields of two values were isolated. The set of related articles was then sorted on number of citations for each combination of two values. For each combination of values, the research concentrated on the 20 articles with the highest number of citations published from 2016 and after. The focus of the search is on recent articles because our interest lies primarily in conflicting values that have not yet been (satisfactorily) resolved and that may require policies or design adjustments to support smart electricity grid acceptance. Value conflicts that are discussed in older literature should still appear in recent articles if they have not been resolved. Section 4 presents the results of our analysis.

4. Results

The section presents the conflicting values identified in the literature, as well as solutions proposed by this literature to address them. Table 2 shows the total number of articles found for each combination of two values. The results show that the smart electricity grid is most frequently addressed from a technical angle. Technical values (e.g. *efficiency* and *reliability*) are dominant in the literature, followed by *safety & health*, and *environmental sustainability*. Other social values such as *justice* and *privacy* are not frequently addressed.

Based on the analysis, value conflicts can be divided in two categories: those resolved by the smart electricity grid and new conflicts caused by its deployment and use. Indeed, before introducing new conflicts, the smart grid is a solution to a value conflict in itself. In our analysis, multiple conflicting values are combined if they relate to a similar fundamental design challenge. For example, both environmental sustainability versus efficiency and environmental sustainability versus reliability relate to the incapacity of the electricity grid to efficiently and reliably cope with high voltage fluctuations caused by increasing the share of renewable energy supply. Table 3 presents a summary of existing conflicts resolved by the smart electricity grid (category A). These are in blue and are discussed in Section 4.1. New conflicts (category B) are in orange and are discussed in Section 4.2.

4.1. Conflicts resolved by the smart electricity grid

4.1.1. Conflict A1 - security of supply versus renewables

Numerous articles address the value conflict between *reliability* and energy *efficiency* on the one hand, and *environmental sustainability* on the other. This value conflict is one motivation for deploying the smart electricity grid. The literature attributes the emergence of this conflict to changing energy policy goals. While, traditionally, reliability and efficiency have always been key values in the energy sector mainly to guarantee economic development and security of supply, environmental sustainability has gained importance lately due to arising environmental concerns and the depletion of coal, gas and oil resources [41].

These values are conflicting due to the physical limitations of the infrastructure chosen to transport energy (i.e. the electricity grid). Pearson [42] summarizes the three physical realities that largely impact the management of electricity supply: extreme speed of electricity movement, impossibility to delay electricity storage, and high difficulty to direct electricity flows. As a result, grid management needs to be extremely precise and responsive to ensure that supply and demand continuously match. Electricity produced by wind and solar photovoltaics (PV) is however largely unpredictable, thereby threatening this balance [43]. This may lead to an increased number of electricity outages, technical damages, and hence high financial costs. The seriousness of this problem is increased by the fact that power grids are aging in many (developed) countries [44] and are heavily centralized [45]; the power outage of only a few transmission nodes may switch off electricity in a large share of the country.

The solutions proposed in the literature to address the tension between grid reliability and environmental sustainability relate to the main attributes of the smart electricity grid. As the power produced by wind and solar energy is intermittent, more precise grid data is needed to ensure that supply and demand match. The effect of intermittent power can be reduced by asking consumers to shift electricity demand over time. They can also be resolved at the local level (micro-grids). First, more detailed grid information can be captured by means of "advanced monitoring, control, and communication technologies" [41]. The two-way communication facilitated by smart meters allows a flow of consumption information from seconds to 15-min intervals [46]. System operators can use this information to anticipate consumption and production fluctuation. Additionally, the generation of large amounts of data has led to the use of big data approaches to gain a better understanding of voltage changes in power networks [47]. Second, more detailed consumption information can be used to encourage consumers to provide demand response. This can be done through a range of programs proposed by utility companies [48]. Households but also commercial and industrial facilities can provide demand response [49], which can be triggered by the fluctuation of prices depending on electricity scarcity or excess [50]. Third, the tension between grid reliability and environmental sustainability can also be resolved at the local level through the creation of micro-grids. Three types of solutions are proposed by the literature: combination of complementary generation sources, (e.g. wind turbine, PV, and diesel generator) [51], installation of energy storage systems [52] and scheduling strategies [53–58].

By coping with the tension between grid reliability and environmental sustainability, the smart electricity grid also has benefits in terms of cost-efficiency of electricity supply. Fewer investments in capacity, transmission, and distribution limit the increase in electricity prices [59]. Smart meters avoid meter reading costs and reduce electricity theft [44]. Oliver and Sovacool [44] summarize the contribution of the smart electricity grids by showing that they can help to solve the Energy Trilemma: energy security, energy equity, and environmental

Table 2
Article counts mentioning two or more values found in smart electricity grid topics.

	Efficiency	Reliability	Safety &health	Env. sustainability	Justice	Privacy	Competitiveness
Efficiency							
Reliability	8763						
Safety & health	2643	1048					
Env. sustainability	12,860	2573	1296				
Justice	695	126	36	219			
Privacy	390	187	59	152	11		
Competitiveness	859	250	101	840	34	21	

Table 3
Value conflicts in the smart electricity grid (A: resolves, B: causes).

	Efficiency	Reliability	Safety and Health	Environmental sustainability	Justice	Privacy	Competitiveness
Efficiency							
Reliability	*B5 - Cons. values vs. competitiveness*						
Safety and Health	*B5 - Cons. values vs. competitiveness*	*B5 - Cons. values vs. competitiveness*					
Environmental sustainability	*A1 - Security of supply vs. renewables*	*A1 - Security of supply vs. renewables*					
Justice	*B3 - Market performance vs. local trading*	*B2 - Ind. access vs. eco. of scale* *B4 - Spatial distr. vs. system perf.*		*B2 - Ind. access vs. eco. of scale* *B4 - Spatial distr. vs. system perf.*			
Privacy	*B1 - IT vs. data protection*	*B1 - IT vs. data protection*	*B1 - IT vs. data protection*				
Competitiveness	*B5 - Cons. values vs. competitiveness*	*B5 - Cons. values vs. competitiveness*	*B5 - Cons. values vs. competitiveness*		*B2 - Ind. access vs. eco. of scale* *B4 - Spatial distr. vs. system perf.*		

sustainability.

4.2. Conflicts caused by the smart electricity grid

4.2.1. Conflict B1 - IT enabled systems versus data protection

First, the smart electricity grid has caused a value conflict between *privacy* on one hand and *reliability*, *environmental sustainability*, and *efficiency* on the other. Information technologies allow the grid to be more responsive to changes in power production and consumption. Privacy concerns may arise when information is collected and distributed across a network. This is especially a problem when these data are actually meaningful for other parties (whether a Distribution System Operator, a marketing firm, or a hacker).

According to the National Institute of Standards and Technology's 2010 cybersecurity report [60], Oliver and Sovacool [44] explain two categories of privacy concerns: concerns about consumption data that reveal personal information about lives of customers and concerns about cybersecurity attacks which may hamper the correct functioning of electricity supply. By accessing the smart meter, other appliances in homes can also be accessed [61]. Consumption data may include information about socio-economic status, usage of various appliances, and food consumption patterns [62]. A plug-in electric car, when connected to a home area network (HAN), may reveal its location as well as power injection and life patterns of owners [63]. These data may not only be used by potential criminals, for example, to verify the absence of home owners [62], but also by marketing firms interested in using or trading data [62], or employers wishing to monitor the productivity of employees [64].

In the smart electricity grid, privacy concerns center around information transfer in private and public networks. In household residences, the smart meter acts as a gateway between the wide-area network (WAN), i.e. the network between the system operator and consumers, and the HAN [46]. The HAN may connect appliances such as home energy management systems, smart kitchen and cleaning appliances, and plug-in electric cars. As wireless communication is typically used in both WAN and HAN networks, consumption data are more difficult to protect [62]. In a WAN network, a range of appliances tend to be placed in public spaces, thereby making them easily accessible to attackers [65]. Other services that are derived from the smart electricity grid, such as cloud services, raise security and privacy issues as well [41].

The literature proposes four types of solutions to address this conflict: technological innovations, design approaches, organizational approaches, and stakeholder communication. Technical innovations include intrusion detection systems, encryptions, access control systems, *anti*-malware software or firewalls, and aggregation of data [65]. Multiple authors propose packages which combine two or more of these solutions (for example [66–68]). To prove the efficacy of their solutions, these authors demonstrate how their solutions succeed at guaranteeing both privacy and efficiency at the same time. Brown [69] discusses the concept of ‘privacy by design’, which aims at taking privacy into account more systematically throughout the entire engineering process of products. Leszczyna [65] emphasizes the importance of using privacy standards in the design of products, as they lead to more reliable solutions and increase the confidence of potential adopters. Organizational approaches include naming an authority within a company or market in charge of safeguarding privacy [44]. Finally, stakeholder communication approaches include improved communication with consumers about the installation process of smart grid appliances, such as the smart meters, as well as about their effects [44], and a better promotion of other benefits that these appliances may have for consumers [48].

4.2.2. Conflict B2 - individual access versus economies of scale

Second, the smart electricity grid has caused a value conflict between *justice* on the one hand and *reliability*, *competitiveness* and *environmental sustainability* on the other. This conflict relates to inequalities in how individuals or groups are affected, but also whether they may use smart grid developments to their benefit. It is explained by the fact that populations are heterogeneous in terms of income, education, and type of housing. In early phases of deployment, technologies tend to be more expensive and their usage more complex. This raises concerns in terms of accessibility.

The following socio-economic injustices are discussed in the literature. Chatterton et al. [70] observe that high income population have more ability to adopt clean and energy efficient technologies, not only due to their stronger financial positions, but also due to housing ownership and the type of residence in which they live. Hence, these populations are more capable of making financial savings. Additionally, the deployment of these distributed technologies is supported through subsidies. Hence, they are paid by all, including poorer consumers [71]. Obtaining subsidies for these small-scale technologies is furthermore a privilege, as utility-scale projects may offer similar environmental benefits at far lower costs [72]. Oppenheim [73] explains that utility regulation has historically been designed based on a compromise between guaranteeing an acceptable return on investments and reasonable electricity costs for all consumers. Distributed generation decreases utility sales but not the costs of maintaining the production and distribution infrastructure. This burden is put on all households, including those without the financial means to participate in smart grid developments.

To address this conflict, approaches proposed by the literature focus on recognizing the diversity of individuals and communities. Bednar et al. [74] explore the relationship between cultural/racial differences in neighborhoods and consumption diversity and show that this can identify efficiency potential and threats of fuel poverty. Botelho et al. [75] demonstrate the use of the contingent valuation method to estimate local welfare costs of renewable energy development and underline the effectiveness of community-based approaches to support the deployment of energy efficiency measures.

4.2.3. Conflict B3 - market performance versus local trading

Third, the smart electricity grid has caused a value conflict between *efficiency* and *justice*. The smart electricity grid supports new organizational models in terms of energy production and storage. For example, these activities may be performed individually or through energy communities, allowing electricity to be traded directly between households. The drawback is that injustices may result from these new organizational models in terms of electricity trading and inequalities in personal involvement and financial investments of individuals within communities. In energy communities, there is a mismatch between overall economic performance of the community and the fair distribution of costs and benefits between individual members. For both shared production units and storage systems, energy costs are reduced when exchanges with the distribution grid are minimized [76]. Typically, however, the load profile of each participant is different, meaning that the benefits of using locally produced or stored electricity may not be the equal for all users and may not match how much participants have invested in these (shared) infrastructures [77].

Another issue is typical of markets. As in any markets, issues for market power may arise in energy communities or other forms of organization models, allowing electricity trading between households. In some cases, entities within the network may react inappropriately to market rules (whether intentionally or not), thereby negatively impacting the reward of others [78]. Also, consumption information of participants may be unintentionally shared asymmetrically or used illegally, thereby allowing some participants to exercise market power or obtain unfair financial gains [79]. Leaked information about how much electricity is injected into the grid by a household can be used as bargaining power for the utility company as it knows that a householder may not be home and has to sell his electricity in any case [63].

Solutions proposed by the literature mostly include improved market and distribution allocation schemes that take fairness between participants into account (for example [76,77,80,81]. This is done using game-theory (for example [82,83]), based on Nash bargaining [84], by comparing different types of allocation schemes (Shapely, the Nucleolus, DP equivalent method, Nash-Harsanyi) [85]. Akula et al. [63] propose a privacy preserving scheme based on an aggregator that groups a set of bids of different storage units proposing to sell electricity, masks these individuals' bids and shares them with the utility. This way, the consumption of information of each community member is masked.

4.2.4. Conflict B4 - fair spatial distributions of energy systems versus system performance

Fourth, the smart electricity grid has caused a value conflict between *justice* on one hand, and *reliability*, *competitiveness* and *environmental sustainability* on the other. This conflict relates to inequalities in how different individuals or groups are positively or negatively affected by technologies supported by the smart grid. While these clean technologies have benefits for all, their installation at local level has consequences. Botelho et al. [75] identify the effects in terms of landscape change, land costs, countryside accessibility, and social consequences as they may change the habits and interactions between individuals in communities. These consequences are not limited to smart electricity grid developments but are of importance for a wide range of energy transition developments in general [86]. As individuals live in different geographical regions, some of them being more appropriate for the installation of e.g. production infrastructures, inequalities in terms of space are created. To address this conflict, Schweizer et al. [87] propose a "forward-looking model" which assesses the opportunities and risks associated with the deployment of infrastructures and identifies alternative options and how they relate to "plural values, interests, and preferences of those affected by each option". Simpson and Clifton [71] underline the role of procedural justice in addressing fairness issues.

4.2.5. Conflict B5 - consumer values versus competitiveness

Fifth, the smart electricity grid has caused a value conflict between *safety & health*, *efficiency*, *competitiveness* and *reliability*. This conflict results from the novelty of the technologies on which the smart electricity grid relies. To be marketable, technologies need to fulfil a range of requirements. However, time is needed before all requirements can be matched satisfactorily. For example, Posada et al. [88] explain that "for large scale electrochemical storage to be viable, the materials used need to be low cost, devices should be long lasting and operational safety is of utmost importance".

The literature mostly frequently addresses energy storage systems when it comes is technology development issues. Liu et al. [89] explain that one of the challenges to achieve optimal battery charging includes "various constraints for safe, efficient and reliable operation". Incidents with lithium-ion cells and sodium–sulfur batteries include release of toxic materials [88], and the consequences of excessive operational temperatures [89]. Kyriakopoulos and Arabatzis [52] compare energy storage systems in terms of reliability. The types of materials used largely influence the reliability of batteries; strategies suggested by these authors include alternative materials [88], improved battery charging strategies [89], and additional research [90]. More generally, the literature addresses the competitiveness of technologies. Jung et al. [91] perform a survey of social acceptance of renewable energy technologies for buildings. Cost effectiveness is one barrier for the development of these technologies and "could significantly affect the selection of the renovation option by the home owner". This holds for smart electricity grid appliances as well [92].

This value conflict does not only exist for physical appliances, but also for software. Jokar et al. [93] propose an electricity theft detection system in Advanced Metering Infrastructure (AMI) that is both "robust against non-malicious changes in usage pattern, and provide a high and adjustable performance with a low-sampling rate". Ahmad et al. [62]

discuss robustness in relation to metering equipment. For example, reliability is required to “transfer a high volume of data” and guarantee its accuracy.

To address this conflict, solutions proposed by the literature include both a better understanding of the core mechanism and properties of technologies (or its technological components), improvement of its operation and control rules, and comparison to other such technologies [94,95]. The literature also suggests new materials, such as the use of organic materials in energy storage systems [96], together with new combinations of technologies, e.g. hybrid energy storage systems (for example [97–99]). Several studies propose operation and control rules of batteries and charging systems to address the tensions between safety, reliability, and efficiency. This ranges from optimization methods and programs [100], operation rules [101] to full control schemes and management systems [102]. Generally, these studies emphasize the importance of financial incentives, including tax deductions and investment grants [91,103]. Finally, the literature underlines the importance of trained staff and community education [104].

5. Discussions

5.1. Prioritization of value conflicts

In this research, a comprehensive overview of value conflicts in the smart electricity grid was created. Six groups of value conflicts were identified. The smart electricity grid is seeking to resolve the conflict between grid reliability and environmental sustainability. It has however created five new conflicts: IT enabled systems versus data protection, individual access versus economies of scale, market performance versus local trading, fair spatial distributions of energy systems versus system performance, and consumer values versus competitiveness. This research also identified a range of solutions proposed by the literature to address these conflicts.

An overview of value conflicts is important for policy-makers and the industry as it gives an indication of future social acceptance issues that might hamper the successful deployment of the smart electricity grid. An illustration of possible social acceptance issues is proposed in Table 4. They have been categorized using the triangle of social acceptance proposed by Wüstenhagen et al. [4]. Possible socio-political acceptance issues include inadequate technology standards, citizen mistrust for governmental institutions and the rejection of legislation by legislative bodies. Community acceptance issues may be perceivable in the form of tensions between citizens, opposition against building permits and resistance from local authorities against national policies. Market acceptance issues encompass limited technology adoption, limited investments by the industry and the lobbying against new legislation.

Resolving value conflicts through technological design or policy arrangements may require resources. From a policy perspective, the question is which value conflict to prioritize. We suggest three factors for the prioritization of conflicts: severity of resulting acceptance issues, resolvability of conflicts, and resources required for conflict resolution.

5.2. Severity of resulting acceptance issues

A first factor for the prioritization of conflicts is the severity of resulting acceptance issues. Factors determining the severity of acceptance issues may include the direct impact on human wellbeing, the importance of the societal goals they are hampering (e.g. the energy transition), the size of the movement (number of individuals or firms involved) and their frequency (e.g. recurrent local protests against the installation of wind turbines). An additional factor is time. While Wolsink [105] shows that protests against the installation of wind farms often occur during the proposal phase, they could also only appear long after an infrastructure has been installed, for example in the case of natural gas extraction [106].

Fig. 1 proposes a classification of value conflicts based on the severity of resulting acceptance. The conflict between market performance and local trading has low severity since it is expected to be limited to frustrations between market participants and low production adoption. The conflicts between IT enabled systems and data protection may lead to political discussions in the national level, and therefore has medium severity. The conflict between fair spatial distribution of energy systems and system performance is frequent but tends to remain a local issue with limited severe impact on well-being. The effect of the conflict between consumer values and competitiveness is limited in

Table 4
Illustration of resulting acceptance issues.

	Socio-political acceptance issues	Community acceptance issues	Market acceptance issues
B1 - IT enabled systems versus data protection	- Inadequate privacy standards - Rejection of legislation by legislative bodies	- Tensions between individuals - Resistance from local authorities	- Limited consumer adoption - Limited investments by industry
B2 – Individual access versus economies of scale	- Protest movements on national level - Mistrust for governmental institutions - Rivalry between governmental institutions - Inadequate policies for technological development - Lack of political commitment	- Tensions between individuals and communities - Resistance from local authorities	- Limited consumer adoption - Limited investments by industry - Path dependencies leading to socially undesirable technologies
B3 - Market performance versus local trading	- Inadequate technology standards - Mistrust for governmental institutions	- Tensions between individuals	- Limited consumer adoption - Limited investments by industry
B4 - Fair spatial distributions of energy systems versus system performance	- Inadequate special planning - Mistrust for governmental institutions	- Opposition against building permits - Tensions between individuals and communities - Protest movements on local level	- Limited investments by industry - Non-involvement of consumers
B5 - Consumer values versus competitiveness	- Inadequate technology standards - Mistrust for governmental institutions - Inadequate policies for technological development - Rejection of legislation by legislative bodies	- Tensions between individuals and communities	- Limited consumer adoption - Limited investments by industry - Lobbying against new legislation

Table 5
Types of resources required to resolve conflicts.

	Resources
B1 - IT enabled systems versus data protection	- Organizations supervising the adequacy of technology standards - Governmental support schemes for technology and regulatory development addressing privacy issues - Communication strategy with involved stakeholders (producers and consumers)
B2 – Individual access versus economies of scale	- Financial support schemes to support technology access
B3 - Market performance versus local trading	- Organizations supervising the adequacy of technology standards - Governmental support schemes for regulatory development improving market design and rules
B4 - Fair spatial distributions of energy systems versus system performance	- Improved spatial planning regulation - Compensation mechanisms between negatively and positively affected areas - Communication strategy with involved stakeholders (producers and consumers)
B5 - Consumer values versus competitiveness	- Organizations supervising the adequacy of technology standards - Governmental support schemes for technology development

terms of direct impact on well-being. However, a fast diffusion of green technologies is needed to support the energy transition (e.g. energy storage systems). Finally, the conflict between individual access and economies of scale has high severity. Raising socio-economic inequalities may have a profound effect on societal cohesion and lead to social unrest on the national level. An example is the so-called 'gilets jaunes' movement in France which reveals a tension between socio-economic equality and the energy transition [107].

5.3. Resolvability of the conflict

A second factor for the prioritization of conflicts is their degree of resolvability, hence the extent to which they are expected to be resolved in the future. Factors influencing the resolvability of a conflict may include the inherency of the conflict, the availability of measures needed to resolve the conflict, and the degree to which resolution depends on other factors, for example, technological development.

Fig. 2 shows a classification of value conflicts based on their degree of resolvability. The conflicts related to IT, market performance, and spatial distribution of energy systems are all inherent conflicts. Information technologies require (consumption) data. Any form of trading may create issues of fairness between those who have better access, attributes, or skills to get the best of an existing market. Infrastructures require space. Solutions found in the literature are limited to mitigation efforts. The conflict between individual access and economies of scale has medium resolvability. It can be addressed through financial support schemes (although at high costs), but its resolution depends on the speed of technological development impacting the accessibility of the technology. Finally, the conflict between consumer values versus competiveness has high resolvability. This conflict is typically solved as a result of market competition and various forms of governmental support schemes.

5.4. Required resources for conflict resolution

A third factor for the prioritization of conflicts is the level of resources required to resolve a conflict. Besides actual costs, other factors may include the distribution of costs over time (one-time only or continuous), the uncertainty associated with future costs and economic spin-offs generated by the resource. Table 5 provides an illustration of types of resources required to (partially) solve value conflicts.

Fig. 3 classifies value conflicts based on the level of resources required. The conflicts between IT enabled systems and data protection, market performance and local trading and consumer values and competitiveness require relatively limited resources. Typical measures are in the form of support schemes for technological development. These measures tend to generate economic spin-offs. The conflicts between fair spatial distribution of energy systems and system performance, and individual access and economies of scale require higher resources. They involve forms of compensation for which positive economic repercussions are more uncertain. They differ by the number of individuals requiring compensation.

5.5. Reflecting on the current prioritization of value conflicts

Looking at the classifications of value conflicts made in section 5.1, some appear more concerning than other. The conflict between consumer values and competitiveness is generally well-covered through technology standards and various support schemes. Still, the smart electricity grid faces big technological challenges, for example in the case of energy storage systems. The conflict between market performance and local trading cannot be solved structurally, but the impact on human well-being is limited. More concerning conflicts are the ones between the fair spatial distribution of energy systems versus system performance, IT enabled systems versus data protection and individual access versus economies of scale.

The conflict between the fair spatial distribution of energy systems and system performance has largely been addressed by the literature (e.g Wolsink [108], Haggett [109], Devine-Wright and Howes [110], Bidwell [111]. Nevertheless, oppositions against the installation of renewable power plants are recurrent [112]. The inherency of underlying value conflict (*justice* vs. *efficiency*) may explain the persistence of resistances (see section 4.2). To address injustices, approaches that give individuals more power in decision-making might be effective. This includes participatory decision-making [105] and citizen ownership of energy systems [113].

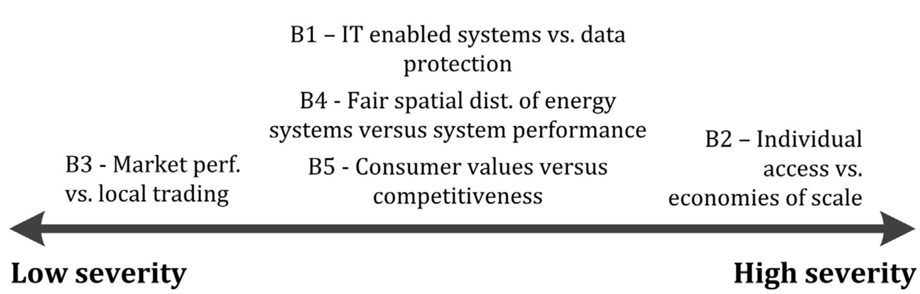

Fig. 1. Classification of value conflicts by degree of severity of resulting acceptance issues.

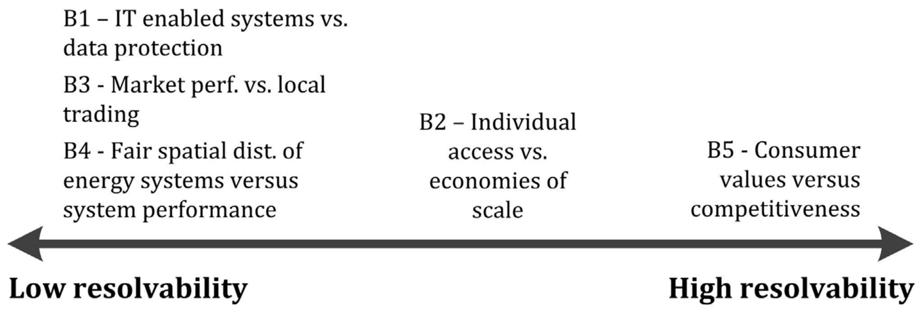

Fig. 2. Classification of value conflicts by degree of resolvability.

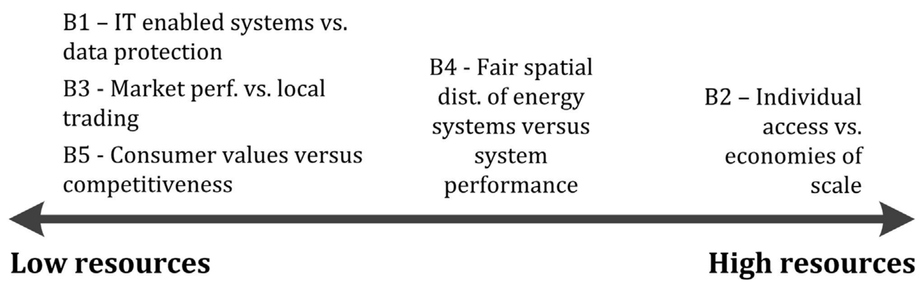

Fig. 3. Classification of value conflicts by required resources for their resolution.

The conflict between IT enabled systems and data protection in the smart electricity grid has largely been addressed by legislation. At European level, for example, regulation EU-2016/679 and Directive 95/46/EC apply. Different tasks force are involved in this topic such as Expert Group 2 of the European Commission Smart Grids Task Force on privacy, data protection and cyber-security and the Energy Expert Cyber Security Platform. Critics against privacy issues in smart meters are however recurrent and have an impact on the success of their deployment (for example Cuijpers and Koops [7], Faure and Schleich [114]). The fact that underlying values are inherently in conflict means that these critics cannot be completely discredited. One approach may be to increase trust between energy utilities and consumers, for example by making the design of platforms more transparent (e.g. Ref. [115]).

The most concerning conflict is probably the one between individual access and economies of scale. Several authors have already described possible negative impacts of the energy transition in terms of socio-economic inequalities (e.g. Mullen and Marsden [116], Sonnberger and Ruddat [117], Healy and Barry [118]). This is not different for the smart electricity grid. While early adopters have a critical role in the diffusion of technologies, these typically more privileged populations are also the ones receiving public money through financial incentives and other support schemes. Technologies in the smart electricity grid also allow these populations to make financial savings. Finding the right balance between sustainability and socio-economic equality is difficult (e.g. Mehling [107]) and the impact of not succeeding may be large for future generations.

5.6. Contributions and future work

This work offers four main contributions.

1. This work anticipates potential acceptance issues that might emerge during the deployment and operation phase of the smart electricity grid. This is done by identifying underlying value conflicts. This work is particularly important for policy-makers and the industry to identify potential actions required to increase the chances that the technology gains acceptance.
2. This work provides an overview of the state of research in addressing value conflicts. Using the approach proposed by de Wildt et al. [14], this work identifies both latent value conflicts and solutions proposed across multiple scientific communities.
3. This work contributes to conceptualizing the notion of value conflicts by suggesting three factors for their prioritization: severity of resulting acceptance issues, resolvability, and required resources for the resolution of conflicts. This contributes to making the notion of value conflicts more tangible and hence more useful for policy-making.
4. This work reflects on current approaches in addressing value conflicts. The conflict between individual access and economies of scale is probably the most concerning as it directly affects the success of crucial sustainability efforts as well as societal cohesion on a national level.

Future work includes the analysis of a wider range of values, possibly related to other infrastructures. In this paper, seven values and potential conflicts between them were included. Other relevant values for the smart electricity grid may include autonomy, which is strongly supported by the deployment of the smart electricity grid, and trust, which is often discussed in the deployment of energy infrastructures. Further research using the same approach could explore how these values conflict with others, and examine solutions proposed by the literature to address them. The same approach could also be used to study other infrastructures, the deployment and use of which are expected to raise acceptance issues too.

The need to further clarify the relationship between value fulfillment and social acceptance is essential. As explained in Section 2.1, this relationship is complex. The fact that an innovation (partially) resolves a value conflict and hence supports a better fulfillment of values is meaningful with regard to its ‘acceptability’, i.e. the extent to which it is considered morally just. Additional factors however come into play which determine its ‘acceptance’, i.e. whether it is actually accepted within society [22]. This includes norms, beliefs, and history between stakeholders. Insights from additional fields e.g. innovation management, adoption of innovation literature, and social psychology are needed to determine the acceptance of technologies. The Technology Acceptance Model [119] and the Value-Belief-Norms model [120] are considered evident next steps. These models may be combined with simulation methods that are able to represent to complexity of individual decision-making in social environments, such as agent-based modeling [121].

Finally, a more dynamic approach to ethics of technology is advocated. Within this field, analyses of the morality of technologies tend to be conducted in a static manner. However, the fact that innovations can resolve but also create new conflicts shows that a more dynamic approach to ethics of technology is required. As values change over time and are an integral part of the design and deployment of technologies, the morality of these artefacts may change over time as well. Hence, different trade-offs may be preferred at different moments in time. An increased consideration of the notion of 'Evolutionary Account of Morality' [122] as well as of 'complex adaptive systems' [123] in ethics of technology is essential. Doing so may lead to better design and policy recommendations to support the morality of technologies facing a wide range of uncertain future scenarios.

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Appendix

Table 6
Definitions of values and semantic fields

Values	Definitions	Semantic fields
Efficiency	The system has high effective operation as measured by a comparison of production and cost (as in energy, time, and money).	effectiveness, efficacy, ineffectiveness, inefficiency, productivity, performance, efficiency, efficient
Reliability	The system is capable of performing without failure under a wide range of conditions.	fitness, resilience, strength, unbreakable, adaptability, integrity, breakable, collapse, failure, reliability, maintainability, resiliency
Safety and Health	The system does not harm people.	safeness, danger, distress, endangerment, imperilment, jeopardy, peril, healthiness, illness, sickness, unhealthiness, dreadful, hazard, wellbeing, safe, harmful, health
Environmental sustainability	The system does not burden ecosystems, so that the needs of current generations do not hinder future generations.	unsustainable, sustainability, sustainable, natural, ecological, eco-friendly, nature-friendly, environmentally-friendly, intergenerational, renewable, environmental, climate, sustainability, sustainability
Justice	The system is just, impartial, or fair.	equity, fair, inequity, injustice, just, impartial, unfair, unbiased, justice, objectivity, equality, lawful, egalitarian, distributive
Privacy	The system allows people to determine which information about the need to control is used and communicated.	hack, hacker, cybersecurity, cyber, internet of things, data protection, privacy
Competitiveness	The system offers an economic advantage.	competitor, contestant, rival, noncompetitor, market structure, barriers to entry, monopoly, oligopoly, competition, contestability, strategic behavior, competition, complementary assets, competitive, advantage, stakeholders, competitiveness, stakeholders, competitiveness

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