Routledge
Taylor & Francis Group

Journal of Human Development and Capabilities
A Multi-Disciplinary Journal for People-Centered Development

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/cjhd20

Using the Capability Approach as a normative perspective on energy justice: Insights from two case studies on digitalisation in the energy sector

Rafaela Hillerbrand, Christine Milchram & Jens Schippl

To cite this article: Rafaela Hillerbrand, Christine Milchram & Jens Schippl (2021): Using the Capability Approach as a normative perspective on energy justice: Insights from two case studies on digitalisation in the energy sector, Journal of Human Development and Capabilities, DOI: 10.1080/19452829.2021.1901672

To link to this article: https://doi.org/10.1080/19452829.2021.1901672

JOURNAL OF HUMAN DEVELOPMENT AND CAPABILITIES
https://doi.org/10.1080/19452829.2021.1901672

Routledge
Taylor & Francis Group

OPEN ACCESS Check for updates

Using the Capability Approach as a normative perspective on energy justice: Insights from two case studies on digitalisation in the energy sector

Rafaela Hillerbrand, Christine Milchram and Jens Schippl

Institute for Technology Assessment and Systems Analysis (ITAS), Karlsruhe Institute of Technology, Karlsruhe, Germany

ABSTRACT
This paper explores how the Capability Approach (CA) can enrich the concept of energy justice by assessing the impact of two cases of digitalisation in the energy sector. Digitalisation promises technical solutions to pressing challenges in the energy sector such as climate change and fossil fuel scarcity. Current academic and popular discussions of these solutions are dominated by a techno-utopian ideal, which sometimes obscures complex ethical and social challenges. Furthermore, technology assessment in the energy sector often focuses on environmental and economic aspects of sustainability, while issues of energy justice or broader ethical concerns are often a low priority. In this paper, we explore whether Nussbaum's version of the CA can be used as a systematic approach to the assessment of technological options that helps bring energy justice into the spotlight. Drawing on examples from two different areas of the energy system, namely, smart grids for the electricity sector and autonomous vehicles for the mobility sector, we demonstrate that the CA provides a normative framework that allows for aspects of individual deliberation and as such is well suited as a normative metric for the conception of energy justice in social science.

KEYWORDS
Energy justice; normativity; Capability Approach; central capabilities; smart grids; automated driving

Introduction

Climate change and limited fossil fuel resources are driving multiple changes to the energy sector, from a transition towards more renewable energy sources to greener private transport options. Digitalisation is seen as a central technology enabling these transitions (e.g., Muench, Thuss, and Guenther 2014), but raises new ethical concerns related to, for example, data safety and security. These ethical challenges are all the more pressing as digitalisation occurs on much

Correspondence Address: Christine Milchram Institute for Technology Assessment and Systems Analysis (ITAS), Karlsruhe Institute of Technology, Postfach 3640, D-76021 Karlsruhe, Germany. Email: christine.milchram@kit.edu

faster timescales than the typical energy sector investment periods of several decades (Milchram et al. 2018a).

The digital revolution will be seen in all three segments of the energy sector, namely, power, heat, and transportation, as well as in the increasing connection and integration of these three segments. This paper focuses on power and transportation since these sectors currently have the greatest potential for digital transformation (Thomopoulos and Givoni 2015; Fleischer and Schippl 2018; International Energy Agency 2015, 2011). Digitalisation already plays an integral part in the power sector, primarily in the form of smart grids. In the mobility sector, digitalisation is often associated with automated or connected vehicles, which have become one of the most debated topics in the field within just a few years (Fleischer and Schippl 2018; Docherty, Marsden, and Anable 2018; Schippl and Arnold 2020).

To address the various ethical challenges associated with digitalisation in the energy sector, the emerging field of energy justice seems most suitable. Energy justice provides a general concept for applying justice principles to the different areas associated with human energy consumption (Jenkins et al. 2016; Miller, Iles, and Jones 2013; Sovacool and Dworkin 2015). This concept emerged within the social sciences with the aim of moving the energy discourse beyond economic considerations.

In this paper we aim to show that the Capability Approach (CA) can enrich the concept of energy justice by serving as a 'metric of justice', giving an indication of *what* one needs to include when judging whether a state of affairs is just (e.g., Hillerbrand 2015; Wood and Roelich 2020). The CA has gained prominence over the last few decades as a leading alternative for thinking about poverty but has only recently been applied to energy use (and all its preconditions, effects, and side-effects). Such applications often focus on energy poverty (e.g., Middlemiss et al. 2019; Day, Walker, and Simcock 2016; Pachauri and Spreng 2011; Pachauri et al. 2004) and also include considerations of justice (e.g., Bartiaux et al. 2018; Melin and Kronlid 2019; Wood and Roelich 2020). For example, in applying a capabilities perspective to energy poverty, Day, Walker, and Simcock (2016) relate energy services to the attainment of basic capabilities and propose a definition of energy poverty that focuses on the 'inabilities to realise essential capabilities' as a consequence of 'insufficient access to affordable, reliable, and safe energy services' (Day, Walker, and Simcock 2016, 260). Bartiaux et al. (2018) operationalise a range of Nussbaum's capabilities using secondary quantitative data from the 'Generation and Gender Programme' and show that energy poverty in Belgium is related to the deprivation of many capabilities, including not just those related more closely to energy but also capabilities connected with recreation, feeling of fulfilment, and security. In this paper, we do not intend to redefine energy justice, but rather to illustrate how Nussbaum's capabilities can provide normative guidance when assessing technological developments.

In the following section, we illustrate how the CA may enrich the concept of energy justice by two case studies elucidating different aspects of digitalisation in the energy sector: smart grids and autonomous vehicles (section 3). Sections 4 and 5 compare the two cases and discuss possibilities for future research.

Energy Capabilities as an Interpersonal Normative Foundation for Energy Justice

Energy justice addresses the 'equitable access to energy, the fair distribution of costs and benefits, and the right to participate in choosing whether and how energy systems will change' (Miller, Iles, and Jones 2013, 143). Justice here is constructed in three dimensions, namely, distributive justice (addressing the allocation of benefits and harms), justice as recognition (giving attention to inclusiveness and potential misrecognition of vulnerable stakeholder groups), and procedural justice (concerned with equitable decision-making processes) (McCauley et al. 2013). Although energy justice literature treats these three dimensions as parallel considerations, the dimension of recognition seems to operate on a different level. The question of whom to recognise as a moral object—e.g., all human stakeholders, other sentient beings, or nature for its own sake—arguably precedes considerations of distributional and procedural justice.

The concept of energy justice, though normative in itself, is rooted in practical concerns and as such may profit from a more profound normative foundation (c.f. Sovacool et al. 2017; Pellegrini-Masini, Pirni, and Maran 2020 for related criticism). A tighter connection to ethical theorising may help in deciding which of the many ethically relevant challenges in energy supply, demand, and various other aspects of the energy system are most pressing. Without such a theoretical commitment, the energy justice debate runs the risk of predominantly considering issues that are already addressed in the public discourse, rather than actively shaping the discourse on energy ethics. For example, Jenkins et al. (2016) discuss the distributional impacts of the German energy transition for the most economically vulnerable, while omitting losses faced by major energy suppliers that have to close down nuclear power plants. This is not to say that there are no good reasons to focus on those who are worst off economically, but such reasons need to be clarified. To be fair to the article, the discussion of the energy transition may be interpreted as an illustrative example, rather than a comprehensive evaluation of all issues of justice relating to the energy transition. Even so, there remains a drawback, namely, that without (even tentatively) spelling out a material normative foundation, the evaluation may become somewhat arbitrary. Such a foundation would, for example, specify how to balance different obligations towards various stakeholders.

The CA can offer such a normative foundation that can be usefully applied to energy justice (Schlosberg 2007). It can serve as a 'metric of justice' (cf. Hillerbrand 2015; Wood and Roelich 2020), providing normative guidance on what needs to be distributed among human beings, namely, the capabilities. While other normative theories such as utilitarian accounts may also provide this kind of guidance, for reasons that will become clear below, we focus on the contribution the CA can make.

In general, the CA offers a broad normative framework for assessing individual human wellbeing and social arrangements. The CA defines a well-lived human life as one in which central decisions are made by the person herself. The freedom to choose and to actively realise what one has reason to value is seen as intrinsically valuable (Sen 1992). Assessing the quality of life in terms of freedom and action, the CA takes into account the fact that human beings differ in their capacities to make use of goods and resources, while at the same time assuming that 'reasonably valuable activities' can be defined in a generalised and objective way, at least in principle. Note that while Nussbaum offers an account of these central capabilities (see below), for Sen the important capabilities are decided collectively. Thus the CA goes beyond subjective accounts that build on stated preferences, as is the case in utilitarian or primarily participatory approaches that focus on stakeholder involvement.

Let us briefly consider some central characteristics of the CA that may be helpful in enriching energy justice. Firstly, the individual is the central unit of evaluation in CA. This approach may thus provide an individualistic foundation for the concept of sustainability, which is commonly perceived as an aggregated concept (cf. Hillerbrand 2018). This enables us to compare ethical issues that prima facie arise at the level of the individual with aggregate concerns like ecological issues. Thus we can address conflicts between, for example, issues of privacy raised by introducing smart grids and sustainability considerations that stress the need to integrate more intermittent renewable energies such as wind or solar. Secondly, assuming that the CA can meaningfully include people living not only in the present but also in the future,[1] this approach responds to the challenge inherent in sustainability considerations, namely, the empirical inaccessibility of the interests of future generations (Hillerbrand 2015).

Thirdly, with its central focus on capabilities, the CA not only takes into account the impacts that a certain arrangement of energy sources may have on various aspects of human wellbeing, it also allows us to consider alternative courses of action. As the central unit of evaluation are capabilities and not actual functionings, the CA puts emphasis on alternative, but possible realizations of the world; for assessing technological systems this puts particular focus on alternative technological development paths as they are often addressed in technology assessment under the header of scenarios. As the future may reveal unforeseeable risks with new technologies, this puts emphasis on the reversibility of technological developments or human actions more broadly (or, rather, the closest possible approximation of their reversibility, cf. Hillerbrand 2015).

The freedom to choose one's own concept of wellbeing as highlighted in Sen's version of the CA provides some normative guidance, but orientational knowledge for energy justice considerations requires further elaboration. What are the relevant capabilities? Here, Nussbaum's account of 'central human capabilities' offers a starting point (Nussbaum 2007, 76–78). Influenced by Aristotelian thinking, Nussbaum puts human dignity at the centre of her account of the CA. Although the suggestion of a 'list' of relevant capabilities is contested among CA scholars (cf., e.g., Day, Walker, and Simcock 2016; Robeyns 2005), the foundational idea that the list is open for interpretation and adaptation makes it a good starting point for this paper. The abstract nature of the central capabilities demands contextualisation, and Hillerbrand and Goldammer (2018) have recently conceptualised the central human capabilities in the context of energy systems. These 'energy capabilities' are not additional or new capabilities, but an adaption of Nussbaum's lists as found in Nussbaum (2006, 76) and Nussbaum (1999, 49–59), tailored to energy ethics, in order to, for example, better enable engagement with various stakeholders.

The central human capability of **life** refers to the ability to live and not to die prematurely. **Bodily health** or **bodily integrity** refers to the ability to enjoy good health and to eat adequately, to have shelter and to be safe from violence, as well as to move freely from one place to another. For the energy capabilities, 'life' is associated with major life-threatening accidents in the energy sector, while 'bodily integrity' encompasses all other impacts of energy systems on human health.

For Nussbaum, **emotions** refer broadly speaking to the capability to avoid trauma and to feel joy. In the energy system, this might be negatively impacted by fear of accidents, be they realistic or not, or trauma from losing habitat (e.g., due to climate change or lignite production). Energy technologies may also have a positive impact here, in the certainty of a stable power supply, for example, or the feelings of safety in a warm house.

In addition to emotion, Nussbaum lists further cognitive aspects in her catalog of central capabilities. For a dignified human life, one needs to be able to **use one's senses, imagination, and intellectual abilities**. One (negative) connection of this capability with energy arises when certain aspects of an energy system are placed under a taboo. Climate engineering—the conscious manipulation of the earth's climate—may be a case in point. On the positive side, we can classify various energy systems by the extent to which they constructively influence the central capabilities of 'senses, imagination and thought.'

Trust refers to the capability to engage in relationships with people and things outside of ourselves. When thinking about energy, changes in the environment due to energy infrastructures or other large-scale impacts are detrimental to our ability to trust the stability of our environment.

Ecological connectivity describes the ability to empathise or sympathise with non-human animals, plants, and nature in general. While trust is related to large-scale ecological changes that are partly perceived as abstract, smaller and more direct environmental impacts of the energy system fall under ecological connectivity.

Nussbaum's central capability of **practical reason** refers to the ability to develop a conception of 'the good' and of 'the good life.' It also entails the capability to plan and critically reflect on one's own life. Given the central importance that the energy supply holds for the individual and the enormous impacts of energy systems on humans and their environment, this central capability includes critical reflection on personal energy use and thus a reflection on the preferred energy system. This presupposes the ability to develop a concept of a good energy system and to critically question existing systems or political proposals. It further requires that decisions in the energy sector be sufficiently transparent and citizens sufficiently knowledgeable in the field.

Affiliation refers to the capabilities of social interaction and identifying with others, the ability to 'live with others and live for others', the 'ability to practice justice, and make friendships'. Amongst other aspects of justice, this capability is concerned in part with distributive justice, i.e., questions regarding the costs and benefits of energy policy regulations (understood broadly, not just in economic terms) and their impact on distribution.

The capability of **play** is all about the ability to laugh, play, and enjoy relaxing activities. When comparing different energy systems, this category raises the question of how the energy quantities or services being provided influence the capability of play.

Control of one's environment is the capability to live one's own life rather than a life chosen by someone else, and thus relates to personal autonomy. In the form of electricity, energy can promote an autonomous life in a fundamental way. Here it is important to distinguish energy systems from one another in terms of the degree of participation (financial or otherwise) they allow for various components of the energy system.

Evaluating Technological Developments with a Capability-theoretic Approach

Approach

In the following, we present our evaluation of two technological developments: smart grids in the power sector and autonomous driving in the mobility sector.

We focus here on potential impacts for stakeholders that are directly and indirectly influenced by the use of electricity and mobility systems (cf. Davis and Nathan 2015). Rather than providing a comprehensive analysis of all consequences of these technologies, we illustrate potential impacts for their end-users. Thus, we do not discuss, for example, impacts along the supply chain such as human rights violations in the extraction of raw materials needed for batteries and solar panels. This capabilities-based assessment is the authors' analysis, based on a consideration of the systems' characteristics vis-à-vis Hillerbrand and Goldammer's (2018)energy capabilities presented in Section 2. Table 1 provides an overview of our capabilities-based assessment.

In the field of smart grids (SG), the case studies are two pilot projects implemented in the Netherlands, in which nearly 50 households in two neighbourhoods are interconnected with specific smart grid approaches. Such pilot projects are currently the dominant form of smart grid implementation for residential households (Evers and Chappin 2020; Grimm, Kretschmer, and Mehl 2020). Data on the aims, technological set-up, and actors involved in these pilot projects was collected using semi-structured interviews and a document analysis in the context of the study in Milchram et al. (2020). The interviewees were members of distribution system operators, energy suppliers, aggregators, hardware and software providers, consultancies, as well as the households that participated in the projects, and thus were all directly involved in the design, implementation, and use of the system.

For automated driving, we chose to evaluate two scenarios that reflect widely shared assessments of possible trajectories for future development, since broad-

Table 1. Assessment of the impacts of digitalisation on the capabilities in the different cases. Positive impacts: moderate (+), strong (++), very strong (+++); negative impacts: moderate (–); strong (–), very strong (—); No impact (0)

	SG1 (VPP)	SG2 (GF)	AV1	AV2
Life	++ –	++ –	+++ –	++ –
Bodily health / bodily integrity	++ –	++ –	+++ –	+ –
Emotions	+	++	++ –	+ –
Trust	+ –	++ –	++ –	+ 0
Senses, imagination, and thought	+ 0	+++ 0	++ 0	+ 0
Practical reason	+ 0	+++ 0	+++ –	0 –
Affiliation	0	0	++ 0	+ 0
Ecological Connectivity	+	+	++ 0	0 –
Play	0	++	++ –	+ 0
Control	++ –	+++ –	++ –	0 0

scale commercialisation of automated driving is a more distant prospect than that of smart grids. Most experts expect that automated vehicles (AVs) will be commercialised sooner or later (Deloitte 2019; Fleischer and Schippl 2018; Skinner and Bidwell 2016) and that they will have substantial impacts on the design and sustainability of the mobility sector. However, whether AVs will increase or reduce the overall sustainability of the mobility sector is still contested (Canzler and Knie 2016; Noy and Givoni 2018; Givoni, Fleischer, and Schippl 2018; Thomopoulos and Givoni 2015; UITP 2017; Schikofsky, Dannewald, and Kowald 2020; Fagnant and Kockelman 2015). Our scenarios are primarily based on recent work by Truffer, Schippl, and Fleischer (2017) and Schippl, Truffer, and Fleischer (2017) as well as other work in the field (in particular Fraedrich, Beiker, and Lenz 2015; Fraedrich et al. 2017). It is important to note that we are not concerned with the likelihood of these different trajectories; rather, we have selected plausible scenarios that combine a very high degree of digitalisation with enormous transformative potential for the mobility sector. We intend to demonstrate that the CA can help with early identification of challenges related to energy justice, which may arise in the rapidly progressing field of digitalisation.

Digitalising Electricity Networks

Digitalisation of electricity networks – commonly denominated by the umbrella term 'smart grids' – is considered as an important enabler to transition to a more sustainable electricity system, as it allows dealing more effectively and efficiently with intermittent supply from wind and solar energy (Muench, Thuss, and Guenther 2014). The functioning of smart grids depends to a large extent on collection, sharing, and processing of real-time data on electricity use, which raises serious concerns regarding, for example, consumer data privacy and security (Milchram et al. 2018b).

In the following, we briefly introduce our cases, which represent typical smart grid implementations: Approximately 50 households with solar panels were equipped with home batteries and home energy management systems to maximise the local use of solar energy and test the effects of these novel technologies on the distribution networks.

Case I: Virtual Power Plant in Amsterdam (VPP)

In this project, the combined flexible capacity of 48 photovoltaic systems and home (lithium-ion) batteries are used for trading on the electricity market. A virtual power plant is a centralised online platform that aggregates a number of smaller devices into a larger capacity, which then resembles a traditional power plant (Gerritse et al. 2019). From 2016 to 2019, the project aimed to test storage systems and the smart use of flexibility in order to understand their impact on low-voltage electricity grids. Additionally, the project sought to develop a business case for trading local flexibility on the wholesale market and thereby give residential households access to energy markets. The project was a collaboration between the largest Dutch distribution system operator, which led the project and operates the local distribution grid; a small energy supplier and aggregator, which operated the virtual power plant; a software provider, which supplied the platforms to schedule batteries and trade on the wholesale market; and 48 households with photovoltaic systems in Amsterdam Nieuw-West (Gerritse et al. 2019). Most of the participating households owned and lived in their houses, and on average showed a relatively high interest in the energy transition and in new technologies (Gerritse et al. 2019).

Case II: GridFlex in Heeten (GF)

This pilot project aims to maximise the self-consumption of solar energy within a community. The system is a combination of storage in sea-salt batteries, an energy management system, and variable electricity tariffs to close the gap between the supply of renewable energy and electricity use in the neighbourhood. The project, which started in 2017, focuses on creating a community identity around supporting a sustainable energy system (GridFlex 2019) and developing a replicable model of a local energy system through variable pricing and storage (Enexis 2017). GF is a collaboration of a local energy cooperative, which led the project; the local distribution system operator, which developed and enabled charging of variable network tariffs; a hardware provider, which developed and implemented the sea-salt batteries; a software provider for the energy management system; university researchers who developed the algorithm for battery (dis)charging; several consultancies specialising in battery systems and citizen energy initiatives; and 47 households in a neighbourhood supplied with electricity through a single transformer. They are owners and occupiers of their houses, 50% own photovoltaic systems, and 20 are equipped with batteries.

Potential Positive Impacts

A Larger Share of Renewable Energy. Smart grids promise to enable higher rates of renewable energy generation, which can be seen in both pilot projects' aim of enabling the increasing implementation of photovoltaic systems by residential households. This can have positive impacts on the capabilities 'life' and 'bodily health', as reduced air pollution benefits the health and quality of life of present generations, while that of future generations is improved by the reduction of greenhouse gas emissions. Although these effects will materialise only if such systems are applied on a large scale, they demonstrate the obvious positive capability impacts of smart grids.

Control, Autonomy, and Increased Household Participation. Both pilot projects enable households to play a more active role in the electricity system.

This has implications for the capability 'control over one's environment'. In the case of the VPP, residential households gained access to the wholesale electricity market, which is usually reserved for energy suppliers, energy service providers, and large industrial consumers. In the case of GF, the system enables households to maximise the use of locally generated solar energy, thus becoming more independent from the main electricity network while reducing network load and potentially the need for network expansion. Whereas the VPP was offered as an aggregator service, GF offered more direct household participation through its governance as an energy cooperative.

Reflection, Control, Playfulness, and Emotions Through Visualized Electricity. One of the core benefits or value propositions of smart grids is that electricity flows can be visualised in real time. In the projects discussed here, a web portal (VPP) and an app (GF) functioned as user interfaces to the energy management systems. These user interfaces can depict electricity flows among solar panels, batteries, household appliances, and the electricity grid, and thus enable consumers to gain a greater insight into their electricity generation and use.

The possibility of making electricity usage visible enables consumers to reflect on how their behaviour impacts energy use, which contributes to the capabilities 'senses, imagination, and thought' and 'practical reason'. This impact is stronger in GF than VPP due to a more detailed app that clearly visualises electricity flows among solar panels, batteries, and the network, and also uses a simple and transparent traffic-light system to highlight energy costs as high (red), medium (orange), or low (green).

In addition, consumers gain a greater degree of control over their electricity use, costs, and ultimately the associated carbon emissions, which once again positively impacts the capability 'control over one's environment'. Users might for example switch on appliances when solar generation is high, or adjust battery settings so that midday solar peaks are stored in the battery. The traffic light system in GF enables users to make more informed decisions about their energy use, and offers more control over their energy expenses and carbon footprint. This control is not enabled in the case of VPP, where, as mentioned, the battery is controlled by an aggregator.

Making electricity visible also allows consumers to engage more playfully with electricity than in the status quo, and thus relates to 'play'. Apps can be used for gamification such as creating playful competition among neighbours to lower energy-related emissions. In GF, the app-enabled coordination among the community and encouraged talking about electricity use and generation, creating a general feeling of 'playing around with new gadgets', as interviews revealed.

Finally, one might argue that an increased awareness of energy-related behaviour, the necessity to use renewable energy or save energy, and how this is connected to mitigating climate change also impacts the capability of 'ecological connectedness'. Strictly speaking, however, the technology might only change how humans relate to human use of resources, not how humans relate to other species.

Trust, Affiliation, and Solidarity in the Community as co-benefits. Beyond energy-related benefits, GF also had co-benefits due to the community-oriented project development and the leading role of a cooperative. Interviews revealed that the community-centric approach fostered solidarity among participants through working towards a common purpose of taking action against climate change and creating a better community, with positive impacts on the capabilities 'affiliation' and 'trust'. The 100% participation rate in the project also increased inclusion, communication, and familiarisation with less well-known community members.

Potential Negative Impacts

Data Privacy, Security, and the Need to Uphold Trust in the System. The most salient challenge that accompanies the introduction of smart grids is the reliance on real-time collection and sharing of household energy data (Milchram et al. 2018b). Data on household electricity use and generation is collected and used by project partners to optimally (dis)charge the batteries, trade on the wholesale market (in the case of VPP), and set price signals in the app (in the case of GF), as well as for visualising electricity flows for households. This reliance on detailed energy use data threatens household privacy and presents security challenges. The risk of personal data being used in ways that are not fully under one's own control can challenge the capability 'control over one's environment'. Data can be abused, for example, to reveal the presence, absence, and activities of people in a household. In extreme cases, when this leads to physical and psychological harm, even 'life', 'bodily health', and 'emotions' might be threatened. The risk of data abuse was slightly lower in GF than in VPP, as the former had a more stringent approach to anonymizing all household data at the point of transmission from the household to the external database and IT system used for controlling the local smart grid.

Data sharing also presents challenges for household trust in the system. If data is abused, users lose trust and may react by using fewer smart grid technologies and refusing to participate in demand response activities, potentially endangering the stability of the entire electricity network. Experiences from the VPP project already indicate the importance of upholding household trust in the system. Some households started to mistrust the battery scheduling, primarily because they had no insight into its (dis)charging processes, and unplugged the battery as a consequence. In a more realistic (future) scenario of a service where users can utilise one part of the battery for self-consumption while another part is made available for grid-stabilizing purposes, loss of trust might result in users switching batteries to full self-consumption mode, and thus nullify the positive effects of batteries on greater flexibility in the electricity network.

Control, Senses, and Reasoning – but for Whom?. Whereas smart grids *claim* potential positive impacts related to increased citizen participation and the possibility of visualising electricity flows in real time, a closer look at the pilot projects reveals that many of these positive impacts are uncertain and precariously dependent on the design of specific system components. Firstly, the increase in control that comes with a more influential and active role for citizens in the electricity system is only accessible to societal groups with the financial means and whose houses fulfil the physical requirements for installing photovoltaic systems and batteries. This poses structural entry barriers for households that are already considered more vulnerable and at greater risk of suffering from energy poverty: lower-income households, social housing tenants, and elderly and disabled people. The effect is stronger in VPP than in GF, in which participation is possible for households who do not own photovoltaic systems and batteries.

Secondly, visualisation of electricity flows is intended to enable reflection and reasoning about how behaviour impacts energy use (i.e., the capabilities 'senses, imagination, and thought' and 'practical reason') as well as household control over electricity use, costs, and related carbon emissions (i.e., the capability 'control'). These impacts, however, are mediated by the design of the user interface. For example, in VPP, electricity flows to and from the battery are not visualised and the (dis)charging behaviour of the battery remains opaque to users, thus neither reflection nor control is enabled. Another example is the app in GF, which showed 'expensive' times to use electricity, but gave no specific advice about which appliances might be switched off to save energy. Furthermore, the need for novel user interfaces raises concerns about a loss of control and shift of power in the energy system towards software providers.

Automated Vehicles

As we turn to automated vehicles (AVs), it is important to note the different levels of automation, ranging from no automation (level 0), to driver assistance systems (levels 1–4), and finally to fully automated cars (level 5). The last is able to handle all driving situations that a human driver can (SAE International 2018), and this is the technology on which our first scenario is based. Our second scenario involves level 4 automation: Here, without a driver the car can only manage certain situations that are possible in limited, special areas; otherwise, the driver must take over control of the car.

While there is no clear agreement on what automated mobility systems will look like, the following two trajectories for development are envisioned frequently and form the basis of the two scenarios sketched below (Deloitte

2019; Fraedrich et al. 2017; Fraedrich, Beiker, and Lenz 2015; Givoni, Fleischer, and Schippl 2018; Thomopoulos and Givoni 2015; UITP 2017). Note that we set the focus on urban mobility; a spatially more differentiated analysis would go beyond the scope of this paper:

- The first trajectory assumes a mobility system based on collective mobility; automated vehicles supplement and improve public transport, which becomes increasingly attractive (a virtuous cycle), while the private car increasingly loses its competitive edge; mobility systems become far more sustainable, and fewer cars in cities open new possibilities for urban development and improved quality of life.
- By contrast, in a second trajectory automated driving strengthens mobility based on individual cars; automated cars allow users to do things like working, sleeping, relaxing, etc., instead of driving; the car becomes a highly convenient 'third place' (Dobrindt 2016) between home and workplace; public transport usage declines, and investments in public transport decline as well (a vicious cycle); people are willing to commute over longer distances, leading to urban sprawl.

Scenario I: Shared Automated Vehicles

In this scenario, society in general and mobility, in particular, are influenced by the deeply institutionalised paradigm of the sharing economy (cf. Truffer, Schippl, and Fleischer 2017). Mobility is characterised by highly flexible, driverless on-demand services. People living in urban areas usually do not own private cars. Various players provide a huge variety of multimodal options that enable 'seamless mobility' without personal cars. All motorised transport runs on electricity from renewable sources. Automated cars are primarily used as robo-taxis or small buses that supplement conventional public transport. Citizens show a high level of willingness to provide personal data for high-quality services in all spheres of daily life, including the mobility sector. Users decide only where to go, not how to get there. Sophisticated apps or mobility platforms navigate them to their destinations. The system is highly efficient and affordable, in part because a wide range of personal user data is accessible to mobility providers. Self-driving vehicles are perceived as very useful and safe. People want to live in livable cities that do not allocate too much space for parking cars.

Scenario II: Cocooning in Private Cars

In this scenario, individualisation and cocooning are dominant societal trends (cf. Truffer, Schippl, and Fleischer 2017). The ideal of a self-controlled way of life coincides with the tendency to avoid the public sphere wherever possible. Some reasons for this are security concerns triggered by terror attacks, riots, and contagious diseases. Secure privacy is highly valued, in the real and virtual worlds. Brands carry significant weight and cars serve as a means to express one's personal 'way of life'. People want to have and use highly individualised private cars. Public transport systems erode in a kind of vicious circle. The quality of bus and tram services decreases, which in turn increases the usage of private cars. Based on negative experiences, society regards privacy issues and hacking as severe risks. There is a high level of distrust in big data. The benefits of driverless cars cannot outweigh security concerns. Therefore, for the majority, level 4 automation is a good compromise between convenience and security: the driver always has the ability to control the car. There is a strong societal commitment to car-based mobility, which leads to cities flooded with cars and further urban sprawl. In consequence, public spaces become less attractive. At the same time, however, alarming impacts of climate change lead to a general acceptance of policies reducing greenhouse gas emissions. Planning policies are car-friendly but they are pushing towards small and 'clean' electric cars. Society tries to combine individualisation and cocooning with sustainability.

Potential Positive Impacts

Safety and Environmental Benefits. Some of the connections between the opportunities linked to AVs and certain capabilities are obvious. Among the most important promises of AVs is a reduction in accidents, which clearly relates to the CCs 'life' and 'bodily health'. If one assumes that a small number of accidents remains per vehicle kilometre travelled, safety gains are found in both scenarios, but are clearly higher in the first, where less vehicles kilometres are driven because collective transport is predominant.

The same applies to a potential reduction in emissions of pollutants and noise, which can especially be expected from the first scenario. Fewer emissions are an advantage for all humans but may be a particular benefit for those who live in less-privileged areas along roads with dense traffic.

In addition, the CC 'ecological connectivity' may be affected when the environment suffers less from the negative consequences of mobility. In scenario 1, the significant reduction in the number of cars could help to bring more natural or semi-natural habitats close to citizens, for example, if a parking lot is converted into green space. Again, bringing more nature into cities could be of particular value for those living in less privileged, high-density areas.

Improved Control, Flexibility and Freedom of Choice. This dimension in particular addresses some capabilities that point to aspects not usually emphasised in assessing the impacts of digitalisation and automation in the mobility sector. These aspects draw on the core idea of the CA, that the individual herself should be able to decide what is important in her life. Working while travelling may not only be perceived as an increase in convenience, it may also help to increase the number and the range of possible activities and, thus, the degree of freedom in organising one's life. This relates primarily to the CC 'practical reason' and 'affiliation'. Mobility options that increase personal agency can improve the ability to realise one's conception of a good life. Improved access to mobility can also increase the range of options for social engagement and social interactions; both points impact the CC 'affiliation'. For example, it may become easier to visit one's mother living some hundred kilometres away. It can help to build meaningful bonds with others, which is the essence of the CC 'trust'. The CC 'emotion' also comes into play, when more freedom for action supports the ability to form attachments with things and people outside oneself. In principle, all this applies to both scenarios. The first scenario may again be the one that offers more freedom of choice, since the 'driver' should be able to use the entire journey for things other than driving. The complete relief from driving in this first scenario and the ability to do anything that can be done in a car, such as working, sleeping, or private communication, also impacts, among other things, the capability 'senses, imagination, and thought'. This applies within certain limits to the second scenario, e.g. for longer motorway trips. However, it is important to keep in mind that the positive effects outlined will only be fully effective if the mobility system is affordable and usable for all citizens.

Free Space and Participation in Urban Development. A significant difference between the two scenarios emerges when the reduction in the number of cars in scenario 1 is considered. This opens up considerable free space for urban development with positive effects, especially in densely built-up, less-privileged areas. Conversion of parking space can be used to develop new areas for recreation, sports, socialising, or for commercial development. Again, the capabilities mentioned above are positively affected, mainly because the range of available options for activities (shopping, recreation, etc.) can be expanded on a local basis; the new forms of mobility sketched in scenario 1 may render some motorised trips obsolete as new options emerge near one's home, which can easily be reached by foot or bicycle. If new potentials for urban development are exploited in a participatory manner, the CC 'control over one's environment' is affected as well. For example, in the conversion of space that has been used for parking for several decades, citizens could bring their ideas and expectations into planning processes.

Potential Negative Impacts

Environment and Health. When dealing with the potential positive impacts, it was argued that affordable and convenient mobility may allow for access to more options and, thus, to an increase in agency. The flipside of such a development could be an increase in vehicles kilometres travelled. If costs of transportation are low/marginal, an 'all you can drive' mentality may make people travel much more than today, with negative environmental impacts and, thus, with negative impacts on 'life' and 'bodily health'. Again, the negative impacts will clearly be larger in the second scenario, in which more resources are needed for the car-based mobility system (e.g., raw materials, emissions, space). This is also relevant since the production of batteries still involves considerable consumption of resources, and in the second scenario clearly more batteries will be needed than in the first one.

Vulnerability and Risks of Lock-ins. Another aspect to be considered here is the dependency on software. Especially in scenario 1, we see a mobility system that is in wide parts organised by software. Vulnerabilities arising from this can threaten several capabilities. This is obvious for 'life' and 'bodily health'. As real-world examples show, hacking of cars may lead to serious accidents (Miller and Valasek 2015). For scenario 1 in particular, the seamless web of mobility options may be impeded or even stalled by intentional manipulation. Furthermore, with its extremely data-intensive system, it might be impossible to return to a less data-intensive state, even if future generations should prefer to do so, due to missing infrastructures and competencies (lock-in). Since most people would not have a driving license, severe system failures could leave walking and cycling as the only options for mobility. This dependency is not so strong in the second scenario. In this case, there is no reason to assume that the number of driving licenses would be lower than today. It is conceivable that a less data-intensive system would still work when problems arise. There may even be a plan to revert to a sort of 'analog state' as a backup in case of severe software problems or a blackout.

Privacy, Control, and Freedom of Choice. The first scenario, which promises to deliver a good performance in terms of efficiency, affordability and environmental impacts, is highly dependent on users' willingness to provide personal data. People trust the overall organisation and are willing to give their personal data as long as they get affordable and convenient services. This creates opportunities for the misuse of data. Such misuse can have negative impacts on the personal and systemic levels. If trust is destroyed by malfunction, data misuse or cyber-attacks, a central pillar of the data-intensive system is endangered. On the individual level, one negative impact of scenario 1 is the near impossibility of opting out of the data-intensive system without significant disadvantages. Access to mobility is 'bought' with personal data. The freedom to choose a higher level of privacy or greater control over one's own data may come at the expense of the freedom to move or it may be linked with higher costs which may not be affordable for all citizens In particular, the capabilities 'trust', 'practical reason' and 'affiliation' can be violated by such developments. Further, in a system based on public transport, the public sphere is difficult to avoid for those who may wish to do so. Additionally, some people may perceive being navigated by 'the system' as a loss of autonomy.

Another negative aspect of scenario 1 may emerge if a kind of artificial intelligence both optimises and controls the mobility system. The system might then evolve autonomously and non-transparently, leaving society unable to exert democratic control. Furthermore, a mobility system dominated and controlled by one strong private player (i.e., an 'Amazon of mobility') may hamper the options for public participation and control if there are hardly any effective possibilities for political influence.

Discussion

When comparing these examples of digitalisation in the energy sector, we can state that it is possible to conduct a future-oriented assessment for both the power and transportation sectors through the lens of the CA. Developments in these two areas can lead to both positive and negative capability impacts. There is of course some uncertainty when it comes to assessing whether and to what extent these impacts will actually occur. It is unclear how the technologies will unfold in the future and there is some room for interpretation in terms of the capabilities. However, our analysis illustrates that it is entirely possible to point toward potentially critical developments in both areas. The CA reveals some pressing challenges even in mobility scenarios, which lie much further in the future than smart grids. This is an important point since the design of infrastructures is a decades-long process. Decisions taken today will affect future generations. It is therefore essential to assess future impacts even if certain knowledge on how these impacts will unfold is unavailable. This is also one of the motivations for working with scenarios in general (Grunwald 2018), and in thinking about automated vehicles in particular.

The case of smart grids allows for more detailed analysis, partly because concrete examples are already running as pilot projects. In the smart grid case studies selected for this paper, transparency of electricity flows and control over one's own power consumption are of particular relevance for some capabilities. Specific aspects of the design of these systems can make a difference in terms of the CA, as exemplified by the traffic light system in the GF case study. The analysis also points to entry barriers for lower-income households, which is an important issue if the smart grid approaches are to be rolled out in an entire region or country.

Transparency of personal mobility flows is not so much an issue in the case of AVs. The two AV scenarios clearly differ from one another more than the two smart grid cases do. The first scenario is much closer to common understandings of a sustainable mobility future, particularly if conventional sustainability indicators are applied, such as emissions, number of cars, or a waste of space. However, the CA highlights some serious risks, especially in the first scenario and to a lesser extent in the second: democratic control, privacy issues, and lock-ins or path dependencies. Since all these aspects are also relevant for the SG case, we discuss them together in the following.

Control of the system is a highly relevant issue in both areas. In the SG case, transparency and control over one's own electricity flows are important prerequisites for the participatory design of the energy system. Participation may be impeded in both cases if the system is controlled and optimised by artificial intelligence or if the overall system is driven by one dominant private player, as in the 'Amazon of mobility'. If all the system is controlled by a single private actor, society has no real room to maneuver and participation can become useless. This conception of user control as a prerequisite for and aspect of participation also expands on the predominant notion of participation in decision-making processes, for example, in deciding a location for a wind park, which is the main focus of procedural justice in the energy justice literature (Boudet 2019; McCauley et al. 2013).

As can be expected when dealing with digitalisation, privacy is a relevant issue in all cases, affecting a number of capabilities such as 'trust', 'control over one's environment', or even 'bodily health' and 'life'. Problems arise if users are more or less forced to provide personal data in order to access a certain infrastructural service. There is a tension between the provision of personal data on the individual level and, on the systemic level, the requirement to optimise the system in terms of efficiency and sustainability. The CA is able to illuminate this potential trade-off. It highlights the fact that the most sustainable solution in terms of environmental performance may come with significant drawbacks for some of the capabilities. As stated above, balancing considerations of sustainability with impacts on individuals is beyond the scope of this paper, as such a comparison would require much more detail on the specific technologies than is given in the broad scenarios we considered. However, it can be noted that in our assessment the capability-perspective brings commonly aggregated considerations of sustainability into relation with impacts on individuals.

Further, it becomes obvious that the vulnerability of data-intensive systems is a drawback, especially if options for opting out no longer exist. Such lock-ins or path dependencies are an important point for the assessment of potential future development trajectories. Insights from research in the social sciences on innovations as well as transition studies highlight that path dependencies may impede alternative courses of action – but they can also help to stabilise sustainable pathways (Elzen et al. 2004). Such path dependencies, or lock-ins, are widely discussed in the literature on energy and mobility transitions (Geels et al. 2012; Truffer, Schippl, and Fleischer 2017). One key conclusion is that early action is needed to ensure that complex sociotechnical dynamics take the desired direction. A precondition for early action is raising awareness of potential challenges (and benefits). The CA can surely make a contribution here. In both the SG and the AV examples, some critical aspects related to lock-ins emerged. Particularly in the first AV scenario, but also in both SG cases, future generations may not have the capability to return to less data-intensive systems even if they should wish to do so, perhaps for reasons that we cannot anticipate from today's perspective.

Outlook

In sum, our analysis has revealed that the CA provides a normative framework suitable for assessing both existing cases (smart grids) as well as future scenarios (automated driving). Applying the categories of the central capabilities, we further found that some relevant aspects are emphasised and become palpable that are not necessarily highlighted in current discussions of energy justice. As such, the CA can help to inform and shape the scientific and public discourse on energy ethics.

However, in order for the CA to become a useful normative metric, further research on energy capabilities is needed, at a minimum, in the following areas. One question concerns whether energy capabilities need to be further adapted to the developments of digitalisation in large-scale infrastructures. Analyses such as the one carried out in this paper could help to reduce the 'interpretative leeway' and to apply the central capabilities more precisely. Additionally, Nussbaum's CA posits that the central capabilities need to be fulfilled for all members of a society in order for the society to be considered a just one. We think that the energy capabilities may be best understood as a checklist pointing to issues that are relevant in terms of energy justice. Here, capabilities need to be made tangible and specific to the fields of power and mobility. This may be best achieved in terms of thresholds (cf. the suggestions by Murphy und Gardoni 2012 or Frigo and Hillerbrand (n.d.)). Though concrete thresholds may be impossible to determine due to the complex nature of sociotechnical dynamics in the system (i.e., uncertainties, unknowns) and because the actual threshold also depends on technological developments, vague or even qualitative thresholds may be a useful way forward in moving towards a practical application of the normative metric depicted in this paper. Such specifications need to be a matter of deliberation among the various stakeholder groups affected by these technologies. Furthermore, in order to be effective as a systematic analysis of (in)justices, the CA thus needs to explicitly take a whole-systems approach, as is demanded by many energy justice researchers. This would allow us to account for effects along the entire value chain and the corresponding spatial impacts, which can extend from local to international scales (Sovacool et al. 2019; Jenkins et al. 2020).

In addition, more in-depth knowledge about the impacts of digitalisation is needed, particularly in the fields we highlighted in this paper. Field trials such as those carried out in the smart grid case are an appropriate method. Here, the

CA can highlight often overlooked areas and thus help to shape and guide the empirical research. It is important, however, that research on the CA already be given a central position in the design of such field experiments or living labs, and not remain simply a side issue, as rather marginal accompanying research.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by Nederlandse Organisatie voor Wetenschappelijk Onderzoek: [Grant Number 313-99-305].

About the Author(s)

Rafaela Hillerbrand holds two doctorate degrees, one in physics and one philosophy. Since 2015, she is professor for philosophy of engineering and technology at KIT. Her interdisciplinary research is located at the intersection between epistemology and ethics; one research focus is on how to act responsibly in the light of uncertainties and risks associated with technological progress.

Christine Milchram is a postdoctoral researcher at the Institute of Technology Assessment and Systems Analysis (ITAS) at Karlsruhe Institute of Technology (KIT). She has a PhD from Delft University of Technology (Netherlands) (2016–2020), where she has been working on values and acceptability of smart grid systems. Her research interests at the intersection of philosophy and social sciences lie in sustainable energy systems, energy justice, and design for values.

Jens Schippl studied geography, biology and of sociology at Heidelberg University. Since 2006 he works at the Institute of Technology Assessment and Systems Analysis (ITAS) at Karlsruhe Institute of Technology (KIT). His research interests encompass sociotechnical processes of change, foresight and technology assessment in the mobility sector.

Note

1. Although Nussbaum briefly mentions future generations in her writings (Nussbaum 2007), there remain many open questions regarding how the CA can be extended to include future generations. While most scholars seem to assume, as we do, that such an extension is possible (Gutwald et al. 2014; Melin and Kronlid 2019), there are some who argue that, for example, Nussbaum's central capabilities would have to be revised to be suited for a future ethics (Watene 2013, 2014).

ORCID

Rafaela Hillerbrand http://orcid.org/0000-0002-7890-3715
Christine Milchram http://orcid.org/0000-0002-6325-4329

References

Bartiaux, F., C. Vandeschrick, M. Moezzi, and N. Frogneux. 2018. "Energy Justice, Unequal Access to Affordable Warmth, and Capability Deprivation: A Quantitative Analysis for Belgium." *Applied Energy* 225 (September): 1219–1233. doi:10.1016/j.apenergy.2018.04.113.

Boudet, H. S. 2019. "Public Perceptions of and Responses to New Energy Technologies." *Nature Energy* 4 (6): 446–455. doi:10.1038/s41560-019-0399-x.

Canzler, W., and A. Knie. 2016. "Mobility in the Age of Digital Modernity: Why the Private Car Is Losing Its Significance, Intermodal Transport Is Winning and Why Digitalisation Is the Key." *Applied Mobilities* 1 (1): 56–67. doi:10.1080/23800127.2016.1147781.

Davis, J., and L. P. Nathan. 2015. "Value Sensitive Design: Applications, Adaptations, and Critiques." In *Handbook of Ethics, Values, and Technological Design: Sources, Theory, Values and Application Domains*, edited by Jeroen van den Hoven, Pieter E. Vermaas, and Ibo van de Poel, 11–40. Dordrecht: Springer Netherlands. doi:10.1007/978-94-007-6970-0_3.

Day, R., G. Walker, and N. Simcock. 2016. "Conceptualising Energy Use and Energy Poverty Using a Capabilities Framework." *Energy Policy* 93: 255–264. doi:10.1016/j.enpol.2016.03.019.

Deloitte. 2019. "Urban Mobility and Autonomous Driving in 2035. How Robotaxis Will Affect Cities and Automakers." https://www2.deloitte.com/content/dam/Deloitte/de/Documents/Innovation/Datenland%20Deutschland%20_Autonomes%20Fahren_EN_Safe.pdf.

Dobrindt, A. 2016. "Deutschland Setzt Maßstäbe Bei Der Mobilität 4.0." Handelsblatt Journal "Die Zukunft Der Automobilindustrie". https://www.euroforum.de/news/Deutschland-setzt-Massstaebe-bei-der-Mobilitaet-40_1000451189.

Docherty, I., G. Marsden, and J. Anable. 2018. "The Governance of Smart Mobility." *Transportation Research Part A: Policy and Practice, Smart Urban Mobility* 115 (September): 114–125. doi:10.1016/j.tra.2017.09.012.

Elzen, B., F. W. Geels, P. S. Hofman, and K. Green. 2004. "Sociotechnical Scenarios as a Tool for Transition Policy: An Example from the Traffic and Transport Domain." In *System Innovation and the Transition to Sustainability: Theory, Evidence and Policy*, 251–281. Cheltenham, UK: Edward Elgar. http://sro.sussex.ac.uk/27097/.

Enexis. 2017. *GridFlex Heeten Project Plan*. https://projecten.topsectorenergie.nl/storage/app/uploads/public/5a0/c1a/b96/5a0c1ab96bba0525772360.pdf.

Evers, G., and M. M. H. Chappin. 2020. "Knowledge Sharing in Smart Grid Pilot Projects." *Energy Policy* 143 (March): 111577. doi:10.1016/j.enpol.2020.111577.

Fagnant, D. J., and K. Kockelman. 2015. "Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations." *Transportation Research Part A: Policy and Practice* 77 (July): 167–181. doi:10.1016/j.tra.2015.04.003.

Fleischer, T., and J. Schippl. 2018. "Automatisiertes Fahren: Fluch Oder Segen für Nachhaltige Mobilität?" *TATuP Zeitschrift für Technikfolgenabschätzung in Theorie und Praxis* 27 (2): 11–15. doi:10.14512/tatup.27.2.11.

Fraedrich, E., S. Beiker, and B. Lenz. 2015. "Transition Pathways to Fully Automated Driving and Its Implications for the Sociotechnical System of Automobility." *European Journal of Futures Research* 3 (1): 11. doi:10.1007/s40309-015-0067-8.

Fraedrich, E., L. Kröger, F. Bahamonde-Birke, I. Frenzel, G. Liedtke, S. Trommer, B. Lenz, and D. Heinrichs. 2017. "Automatisiertes Fahren Im Personen- Und Güterverkehr. Auswirkungen Auf Den Modal-Split, Das Verkehrssystem Und Die Siedlungsstrukturen." *E-Mobil BW GmbH – Landesagentur Für Elektromobilität Und*

Brennstoffzellentechnologie Baden-Württemberg; Deutsches Zentrum Für Luft- Und Raumfahrt e.V. (DLR), Institut Für Verkehrsforschung; Ministerium Für Verkehr Baden-Württemberg, August.

Frigo, G., and R. Hillerbrand. n.d. "Energy and the Good Life: The Right to Energy Access and the Capabilities Approach." *Journal of Human Development and Capabilities* forthcoming.

Geels, F. W., R. Kemp, G. Dudley, and G. Lyons. 2012. *Automobility in Transition? A Socio-Technical Analysis of Sustainable Transport*. New York: Routledge. http://www.routledge.com/books/details/9780415885058/.

Gerritse, E., R. van Loon, M. van der Eerden, M. Zweistra, and J. W. Eising. 2019. "City-Zen: A Balanced Approach to the City of the Future (Final Project Report of Smart Grid Solutions in Amsterdam).".

Givoni, M., T. Fleischer, and J. Schippl. 2018. "Interview with Prof. Moshe Givoni." *TATuP Zeitschrift Für Technikfolgenabschätzung in Theorie Und Praxis* 27 (2): 68–71. doi:10.14512/tatup.27.2.68.

GridFlex. 2019. *GridFlex Heeten*. https://gridflex.nl/.

Grimm, V., S. Kretschmer, and S. Mehl. 2020. "Green Innovations: The Organizational Setup of Pilot Projects and Its Influence on Consumer Perceptions." *Energy Policy* 142 (April): 111474. doi:10.1016/j.enpol.2020.111474.

Grunwald, A. 2018. *Technology Assessment in Practice and Theory*. Routledge. https://www.routledge.com/Technology-Assessment-in-Practice-and-Theory-1st-Edition/Grunwald/p/book/9781138337084.

Gutwald, R., O. Leßmann, T. Masson, and F. Rauschmayer. 2014. "A Capability Approach to Intergenerational Justice? Examining the Potential of Amartya Sen's Ethics with Regard to Intergenerational Issues." *Journal of Human Development and Capabilities* 15 (4): 355–368. doi:10.1080/19452829.2014.899563.

Hillerbrand, R. 2015. "The Role of Nuclear Energy in the Future Energy Landscape: Energy Scenarios, Nuclear Energy, and Sustainability." In *The Ethics of Nuclear Energy*, edited by Behnam Taebi, and Sabine Roeser, 231–283. Cambridge: Cambridge University Press. https://www.cambridge.org/core/books/ethics-of-nuclear-energy/CA188D06289B34E424D627017007AC19.

Hillerbrand, R. 2018. "Why Affordable Clean Energy Is Not Enough. A Capability Perspective on the Sustainable Development Goals." *Sustainability* 10 (7): 2485–2485. doi:10.3390/su10072485.

Hillerbrand, R., and K. Goldammer. 2018. "Energy Technologies and Human Well-Being. Using Sustainable Design for the Energy Transition." In *The Future of Engineering: Philosophical Foundations, Ethical Problems and Application Cases*, edited by Albrecht Fritzsche, and Sascha Julian Oks, 151–175. Cham: Springer International Publishing. doi:10.1007/978-3-319-91029-1_11.

International Energy Agency. 2011. "Technology Roadmap - Smart Grids." International Energy Agency. doi:10.1007/SpringerReference_7300.

International Energy Agency. 2015. "Smart Grids in Distribution Networks: Roadmap Development and Implementation." International Energy Agency. https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapHow2GuideforSmartGridsinDistributionNetworks.pdf.

Jenkins, K., D. McCauley, R. Heffron, H. Stephan, and R. Rehner. 2016. "Energy Justice: A Conceptual Review." *Energy Research & Social Science* 11 (January): 174–182. doi:10.1016/j.erss.2015.10.004.

Jenkins, K., S. Spruit, C. Milchram, J. Höffken, and B. Taebi. 2020. "Synthesizing Value Sensitive Design, Responsible Research and Innovation, and Energy Justice: A

Conceptual Review." *Energy Research & Social Science* 69: 101727. doi:10.1016/j.erss.2020.101727.

McCauley, D., R. J. Heffron, H. Stephan, and K. Jenkins. 2013. "Advancing Energy Justice: The Triumvirate of Tenets." *International Energy Law Review* 32: 107–110.

Melin, A., and D. Kronlid. 2019. "Energy Scenarios and Justice Towards Future Humans." *Etikk i Praksis - Nordic Journal of Applied Ethics* (1 (March)): 39–54. doi:10.5324/eip.v13i1.2749.

Middlemiss, L., P. Ambrosio-Albalá, N. Emmel, R. Gillard, J. Gilbertson, T. Hargreaves, C. Mullen, T. Ryan, C. Snell, and A. Tod. 2019. "Energy Poverty and Social Relations: A Capabilities Approach." *Energy Research & Social Science* 55 (September): 227–235. doi:10.1016/j.erss.2019.05.002.

Milchram, C., R. Hillerbrand, G. van de Kaa, N. Doorn, and R. Künneke. 2018a. "Energy Justice and Smart Grid Systems: Evidence from the Netherlands and the United Kingdom." *Applied Energy* 229 (September 2017): 1244–1259. doi:10.1016/j.apenergy.2018.08.053.

Milchram, C., R. Künneke, N. Doorn, G. Van De Kaa, and R. Hillerbrand. 2020. "Designing for Justice in Electricity Systems : A Comparison of Smart Grid Experiments in the Netherlands." *Energy Policy* 147 (October): 111720. doi:10.1016/j.enpol.2020.111720.

Milchram, C., G. van de Kaa, N. Doorn, and R. Künneke. 2018b. "Moral Values as Factors for Social Acceptance of Smart Grid Technologies." *Sustainability* 10 (8): 2703. doi:10.3390/su10082703.

Miller, C., A. Iles, and C. Jones. 2013. "The Social Dimensions of Energy Transitions." *Science as Culture* 22 (2): 135–148. doi:10.1080/09505431.2013.786989.

Miller, C., and C. Valasek. 2015. "Remote Exploitation of an Unaltered Passenger Vehicle." http://illmatics.com/Remote%20Car%20Hacking.pdf.

Muench, S., S. Thuss, and E. Guenther. 2014. "What Hampers Energy System Transformations? The Case of Smart Grids." *Energy Policy* 73 (October): 80–92. doi:10.1016/j.enpol.2014.05.051.

Murphy, C., and P. Gardoni. 2012. "The Capability Approach in Risk Analysis." In *Handbook of Risk Theory*, edited by Sabine Roeser, Rafaela Hillerbrand, Per Sandin, and Martin Peterson, 1–28. Netherlands: Springer. doi:10.1007/978-94-007-1433-5.

Noy, K., and M. Givoni. 2018. "Is 'Smart Mobility' Sustainable? Examining the Views and Beliefs of Transport's Technological Entrepreneurs." *Sustainability* 10 (2): 19. doi:10.3390/su10020422.

Nussbaum, M. 1999. *Gerechtigkeit Oder Das Gute Leben*. Frankfurt/Main: Suhrkamp.

Nussbaum, M. C. 2006. *Frontiers of Justice: Disability, Nationality, Species Membership*. Annotated edition. Cambridge, Mass: The Belknap Press.

Nussbaum, M. C. 2007. *Frontiers of Justice: Disability, Nationality, Species Membership*. New Ed. Cambridge, Massachusetts, England: Harvard University Press.

Pachauri, S., A. Mueller, A. Kemmler, and D. Spreng. 2004. "On Measuring Energy Poverty in Indian Households." *World Development* 32 (12): 2083–2104. doi:10.1016/j.worlddev.2004.08.005.

Pachauri, S., and D. Spreng. 2011. "Measuring and Monitoring Energy Poverty." *Energy Policy* 39 (12): 7497–7504. doi:10.1016/j.enpol.2011.07.008.

Pellegrini-Masini, G., A. Pirni, and S. Maran. 2020. "Energy Justice Revisited: A Critical Review on the Philosophical and Political Origins of Equality." *Energy Research & Social Science Social Science* 59 (April 2018): 101310. doi:10.1016/j.erss.2019.101310.

Robeyns, I. 2005. "The Capability Approach: A Theoretical Survey." *Journal of Human Development* 6 (1): 93–117. doi:10.1080/146498805200034266.

SAE International. 2018. "Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. Ground Vehicle Standard:

J3016_201806." United States: SAE International. https://saemobilus.sae.org/content/J3016_201401/.

Schikofsky, J., T. Dannewald, and M. Kowald. 2020. "Exploring Motivational Mechanisms Behind the Intention to Adopt Mobility as a Service (MaaS): Insights from Germany." *Transportation Research Part A: Policy and Practice* 131 (January): 296–312. doi:10.1016/j.tra.2019.09.022.

Schippl, J., and A. Arnold. 2020. "Stakeholders' Views on Multimodal Urban Mobility Futures: A Matter of Policy Interventions or Just the Logical Result of Digitalization?" *Energies* 13 (7): 1–16.

Schippl, J., B. Truffer, and T. Fleischer. 2017. "Mapping Institutional Dynamics to Better Understand the Transformative Potential of Innovations : The Case of Automated Driving." In *8th International Sustainability Transitions Conference*, 1–16. Gothenburg.

Schlosberg, D. 2007. *Defining Environmental Justice: Theories, Movements, and Nature*. New York: Oxford University Press. https://books.google.nl/books?hl=de&lr=&id=SBkUDAAAQBAJ&oi=fnd&pg=PR13&dq=Schlosberg+Defining+Environmental+Justice:+Theories,Movements+and+Nature&ots=iBNLtkkz8T&sig=oNfBh91dc1tCGGK3aMCJ0nbS8Jk#v=onepage&q=Schlosberg%2520Defining%2520Environmental%2520Jus.

Sen, A. 1992. *Inequality Re-Examined*. Oxford: Clarendon Press. https://books.google.de/books/about/Inequality_Reexamined.html?id=HvMX68tJXqUC&source=kp_cover&redir_esc=y.

Skinner, R., and N. Bidwell. 2016. "Making Better Places. Autonomous Vehicles and Future Opportunities." WSP, Parsons Brinckerhoff in association with Farrells. http://www.wsp-pb.com/Globaln/UK/WSPPB-Farrells-AV-whitepaper.pdf.

Sovacool, B. K., and M. H. Dworkin. 2015. "Energy Justice: Conceptual Insights and Practical Applications." *Applied Energy* 142 (March): 435–444. doi:10.1016/j.apenergy.2015.01.002.

Sovacool, B. K., A. Hook, M. Martiskainen, and L. Baker. 2019. "The Whole Systems Energy Injustice of Four European Low-Carbon Transitions." *Global Environmental Change* 58 (August): 101958. doi:10.1016/j.gloenvcha.2019.101958.

Sovacool, B. K., P. Kivimaa, S. Hielscher, and K. Jenkins. 2017. "Vulnerability and Resistance in the United Kingdom's Smart Meter Transition." *Energy Policy* 109 (109): 767–781. doi:10.1016/j.enpol.2017.07.037.

Thomopoulos, N., and M. Givoni. 2015. "The Autonomous Car—a Blessing or a Curse for the Future of Low Carbon Mobility? An Exploration of Likely vs. Desirable Outcomes." *European Journal of Futures Research* 3 (1): 14. doi:10.1007/s40309-015-0071-z.

Truffer, B., J. Schippl, and T. Fleischer. 2017. "Decentering Technology in Technology Assessment: Prospects for Socio-Technical Transitions in Electric Mobility in Germany." *Technological Forecasting and Social Change* 122 (May): 34–48. doi:10.1016/j.techfore.2017.04.020.

UITP. 2017. "Autonomous Vehicles: A Potential Game Changer for Urban Mobility." Policy Brief. Brussels. https://www.uitp.org/sites/default/files/cck-focus-papers-files/PolicyBrief_Autonomous_Vehicles_LQ_20160116.pdf.

Watene, K. 2013. "Nussbaum's Capability Approach and Future Generations." *Journal of Human Development and Capabilities* 14 (1): 21–39. doi:10.1080/19452829.2012.747488.

Watene, K. 2014. "Beyond Nussbaum's Capability Approach: Future Generations and the Need for New Ways Forward." In *New Waves in Global Justice*, edited by Thom Brooks, 128–148. London: Palgrave Macmillan UK. doi:10.1057/9781137286406_7.

Wood, N., and K. Roelich. 2020. "Substantiating Energy Justice: Creating a Space to Understand Energy Dilemmas." *Sustainability* 12 (5): 1917. doi:10.3390/su12051917.