# Synthesizing value sensitive design, responsible research and innovation, and energy justice

A conceptual review

**Citation for published version:**
Jenkins, K, Spruit, S, Milchram, C, Höffken, J & Taebi, B 2020, 'Synthesizing value sensitive design, responsible research and innovation, and energy justice: A conceptual review', *Energy Research & Social Science*, vol. 69, 101727. https://doi.org/10.1016/j.erss.2020.101727

**Digital Object Identifier (DOI):**
10.1016/j.erss.2020.101727

**Link:**
Link to publication record in Edinburgh Research Explorer

**Document Version:**
Peer reviewed version

**Published In:**
Energy Research & Social Science

# Synthesizing value sensitive design, responsible research and innovation, and energy justice: A conceptual review

**Abstract**

Many academic approaches that claim to consider the broad set of social and ethical issues relevant to energy systems sit side-by-side without conversation. This paper considers three such literatures: Value Sensitive Design, Responsible Research and Innovation and the Energy Justice framework. We argue that whilst definitions of these concepts appear, on face value, to be united by a common normative goal – improving the social outcomes and mitigating sensitivities at the interface of technological energy systems and human livelihoods –, their existence in academic silos has obscured complementarities, which, once synthesized, might increase their overall academic and practical relevance. This paper fills the emergent gap of critically discussing the concepts and their strengths and challenges as well as how they could contribute to each other. It compares: (1) the things that they claim to tackle, (2) the solutions they claim to provide and (3) the points that clearly distinguish one approach from another (if any at all). Not only does this make this paper the first of its kind, but it also makes it an impactful one. With each concept gaining various degrees of support in academia and practice, our discussion reveals where tensions exist and where positive gains can be made. We identify five opportunities for collaboration and integration with implications for the achievement of energy systems that are acceptable from a societal and ethical perspective.

**Keywords:** value sensitive design; responsible research and innovation; energy justice; energy systems; conceptual review

## 1. Introduction

Academia is a profession in which we, as scholars, are encouraged to create scholarly niches; to find something new and novel that defines shifting paradigms, sets agendas and singles out field-leading scholars. It is also a profession that is geographically disparate, with national scholarly traditions and policy landscapes that shape varying academic priorities. As a result, many agendas sit side-by-side without conversation. This is increasingly true for approaches that claim to consider the broad set of social and ethical issues that are relevant in energy systems, and thus to play a role in predicting and preventing negative energy-related social outcomes. As the first of three core approaches explored throughout this paper, Value Sensitive

Design (VSD) exists as a theoretically grounded approach to the design of technology that accounts for human values throughout the design process [1], typically following a tripartite methodology focusing on conceptual, empirical and technical investigations. Second, Responsible Research and Innovation (RRI) has appeared as an approach that anticipates and assesses potential implications and societal expectations with regards to research and innovation, holding the aim of fostering inclusive and sustainable processes and outcomes [2]. Finally, the Energy Justice framework, which most commonly employs a three-tenet approach of distributional justice, justice as recognition and procedural justice, exists in order to evaluate (a) where injustices emerge, (b) which affected sections of society are ignored, and (c) which processes exist for their remediation in order to (i) reveal, and (ii) reduce such injustices [3].

Whilst definitions of these concepts[1] appear, on face value, to be united by a common normative goal – improving the social outcomes and mitigating sensitivities at the interface of technological energy systems and human livelihoods –, they have existed in academic silos and no academic work has systematically compared their common challenges, common solutions and clear contributions. Put another way, no one has yet compared: (1) the things that they claim to tackle, (2) the solutions they claim to provide and (3) the points that clearly distinguish one approach from another (if any at all). Thus, amidst what could be considered as an increasing trend in energy and social science scholarship towards "concept soup", this paper will fill the emergent gap of critically discussing the concepts in and of themselves, as well as a combination of them. Not only does this make this paper the first of its kind, but it also makes it an impactful one. With each concept gaining various degrees of support in academia and practice, our discussion will reveal where tensions exist and where positive gains can be made.

Our paper also responds to critical gaps in the literature. First, we reply to Sovacool et al.'s [4] call for not only more philosophical approaches to energy justice, but for more conceptual approaches. In particular, we argue that a key way to achieve this is to test and triangulate energy justice with other domains, something that has not been done in relation to the responsible research and innovation and value sensitive design literatures before. Second, we respond to Sovacool and Hess' [5] article which calls for theoretical triangulation across normative theories[2], particularly as these can emphasize structure, agency and meaning to different degrees. Indeed, as the authors state, 'we also need to incorporate theories, concepts, ideas, and data from other perspectives […], and we need not shy away from normative

[1] Which are inevitably contested in their own right.

[2] Which they define as theories attempting to answer whether a technology is a net positive or negative for society and individuals.

questions of efficacy, justice, and sustainability [5: 743]. As an outcome, our synthesis therefore starts a dialogue on the potential for new frameworks of analysis and new applications, in addition to exposing challenges and strengths found in each of the three literature sets.

Conceptually, our exploration is guided by the question, how can value sensitive design, responsible research and innovation and energy justice – in combination – contribute to designing energy systems that are acceptable from a societal and ethical perspective? All three approaches engage with the energy system as a *sociotechnical* construct; where alongside technological changes, innovation processes also involve changes in infrastructures, markets, regulations, user practices and so on [6]. However, they intervene in different ways and with attention to different aspects of the energy system (e.g. design processes, technological artefacts or externalities). Together, they may provide a way to address the full extent of the sociotechnical energy system (from here on 'energy system'), rather than parts of it. This leads us to our second gap in the literature to date: that the applications of each concept to case studies of energy systems are variously achieved, but very necessary. Alongside achieving rapid emissions reductions targets in response to national and international agendas, we simultaneously have to address other concerns, including questions of social justice [7], energy access [8], energy security [9], energy poverty [10] and social acceptance [11], as well as the ethical acceptability of technologies more broadly [12]. Moreover, as new or reformed energy systems emerge, it is necessary to embed societal concerns and the values they represent—privacy and trust in the context of smart grids, for example [13]—into technology design and implementation both in order to (a) secure their sensitive rollout and (b) ensure that technologies are accepted and used appropriately. Thus, considering the energy system and examples from it throughout this paper enables us to move beyond the theoretical "cliff hanger" – the use of the VSD, RRI and Energy Justice concepts as a conceptual or empirical lens –, to a consideration of how we may mobilize them or make them applicable. Methodologically, our paper shares its approach with that of Hess [14: 4], who presents a review essay drawing on "a relatively concentrated set of publications into a qualitative analysis of findings, gaps, and future possibilities". This is not a systematic process, but a sustained discussion bringing together key literature.

Our article proceeds as follows. With acknowledgment that the readers of this journal may not be experts in these approaches, sections 2, 3 and 4 first introduce VSD, RRI and Energy Justice in turn. Within each section, we provide a definition of the concept and outline contemporary debates, applications and methodological approaches before highlighting critical strengths and challenges. In all cases, we offer the caveat that these are not the *only* strengths and challenges of these approaches, only some of the most salient. Throughout, we also weave through discussions of their applications to the case study of energy systems, using this case study to draw together a series of conceptual comparisons that highlight both similarities and tensions across the frameworks. Our discussion then presents five opportunities for collaboration and integration between them: (1) de-silo-ing the academic debate, (2) expanding practical applicability, (3) appreciating longitudinal processes and the full life cycle of technology, (4) including a wide range of relevant voices and attributing responsibility and (5) getting to grips with normative theory. We close with a summary of our core findings as well as a guide for future research in this novel, necessary and truly interdisciplinary field.

# 2. Value Sensitive Design

## 2.1. Definition and brief description

Value Sensitive Design is a "theoretically grounded approach to the design of technology that accounts for human values in a principled and comprehensive manner throughout the design process" [15: 56]. VSD is often seen as one of the most extensive approaches to incorporating diverse human values into the design of technologies [16,17]. Here, a value is broadly defined as "what a person or group of people consider important in life" [15: 57]. VSD therefore builds on the core assumption that technological design *can* be improved by a systematic effort to explicitly address human values, and that technological products are not only a potential threat (e.g. artefacts producing 'externalities' such as coal-fired power stations) but can also create positive *added* value.

VSD and its related theoretical and methodological frameworks have been under development since the early 1990s, yet also draw on an older set of literatures, including contributions on values and technology by Norbert Wiener [18], Joseph Weizenbaum [19] and Langdon Winner [20]. Initially established in the fields of information technology and human computer interaction [21], example energy systems applications include the study of value conceptions and norms in public debates on controversial energy technologies [22,23], community acceptance for wind energy projects [24] and design for sustainability transitions including a case study of solar photovoltaics [25]. Some deliberately extend VSD from technological artefacts—material, man-made energy systems components—to systems themselves, analysing how values become embedded in institutions and in processes of stakeholder interaction [26,24].

It is worth stating at this stage that VSD shares its approach with similar literatures that also call for designing with and for values. This includes the approaches of 'Design for values' [see also 27] and value-specific conceptions such as 'Design for Privacy', 'Safe-by-Design' [28,29,30], 'Design for wellbeing' [31] or 'Design for Capabilities' [27]. To clarify then, whilst we acknowledge their different denominations, we focus on their basic tenets and do not semantically differentiate between them. Indeed, for simplicity of reading, we refer to this literature collectively as VSD.

### 2.2. Key features

VSD scholars commit to several key principles. Firstly, VSD aims to *proactively* account for values throughout the design process, requiring designers to make fundamental value-based decisions about the technology early on. Practically, this means identifying potential ethical concerns from the point of conception onwards [17]. It also implies understanding the values at stake and designing for these, while reflecting on the extent to which different values could be accommodated simultaneously and which trade-offs are needed. This may include the consideration of values beyond the initial scope of the technology's – or as is our concern here, energy system's – purpose. To be clear, energy systems are typically designed with the goals of environmental sustainability, affordability, and security of supply in mind, but the criteria of fairness and justice are gaining more attention as many controversies around renewable energy systems imply justice trade-offs. A vivid example, which also illustrates that values beyond the initial system scope need to be considered, is designing hydropower dams that reconcile the complex trade-offs between emission reduction and downstream impacts on water supply.

Yet this does not mean that values are solely endogenous to technology (that they have an internal cause or origin) and that design can fully determine the impact of a technology during its use. On the contrary, the second key feature of VSD is its *interactional perspective* on technological appropriation and on embedding values into design. VSD acknowledges that whilst values can be deliberately embedded in specific design features, they may also emerge as a result of implementation and use of the system [32]. Thus, they can form both an intended and an unintended impact.

Thirdly, VSD aims to identify and account for both *direct and indirect stakeholders*. While direct stakeholders refer to individuals and organizations that directly interact with a technology, indirect stakeholders are all other parties who are affected as a result of its use [17,15]. In energy systems, this principle would, for example, draw attention to future generations and how nuclear energy generation and waste might impact them [33].

### 2.3. Methodology

VSD scholars have developed a tripartite methodology to consider values during technology design. This consists of conceptual, empirical, and technical investigations which are used in an iterative and integrative way (for a detailed description, see [17] and Friedman *et al.* [21,15]). Conceptual investigations are analyses grounded in philosophy, which aim to identify the direct and indirect stakeholders affected by the technology and to identify and conceptualize the values that might be implicated [26]. The conceptualization of values here therefore includes decisions on how to deal with trade-offs among conflicting values, and whether moral values (e.g. social justice) should have a greater weight than non-moral values (e.g. aesthetics) [16].

Empirical investigations focus on the values, experiences, and understandings of stakeholders affected by the technology and utilize a wide range of social-scientific qualitative and quantitative methods such as interviews, observations, surveys, or experiments [15]. Finally, technical investigations aim to understand how existing properties of the technology itself support or harm values, and involves the actual design of the technology to support the values identified during the conceptual investigation. Thereby, relatively abstract values need to be translated into more concrete norms and detailed design requirements [34]. Several iterations of these three types of investigations could lead to a VSD.

### 2.4. Strengths

***Practical design guidelines and flexible methodologies***

One of the main strengths of VSD is that its tripartite methodology offers practical design guidelines and a step-by-step, hands-on process that allows flexible methods within each stage. Indeed, VSD methods have been growing in diversity and are continuously refined. For instance, the Envisioning Cards toolkit is used in empirical investigations to elicit values and the value dams and flows method provides a framework to translate values into more concrete design requirements that helps prioritize values based on the views of direct and indirect stakeholders [17]. The VSD literature also identifies a range of methods for designers to deal with value conflicts and find trade-offs between them. In essence, these are methods derived from multi-criteria decision making such as "even swap", "eliminating dominated alternative(s)", "efficiency/effectiveness assessment", "cost-benefit analysis", "multiple criteria design analysis", "the Best Worst Method" and "satisficing", amongst others [35,33,36]. Thus, VSD appears both adaptable and creative in its practice-oriented approach.

***Clear allocation of responsibility***

A second key strength of the VSD methodology is that most of the work is intended to be led in the design phase by the design team or designer itself. VSD ascribes to the idea that technological design process itself can embed values, and that protecting or realizing values is not only a matter of regulation and the management of externalities. This means that designers and design teams bear a large responsibility for translating knowledge about behaviour and values into technological artefacts. This is different to ethical approaches that are more reactive, where it is often unclear who has the responsibility to respond to ethical harms or concerns. Furthermore, it gives a positive twist to ethics that is often (at least perceived to be) negative and forbidding, 'preventing disvalue' instead of giving room for more creative normative work and 'creating value'.

### 2.5. Challenges

***Missing ethical theory***

Despite the aspiration to integrate philosophical and pragmatic design considerations, VSD has been criticized for focusing primarily on design guidelines at the expense of explicit underlying ethical theory [37]. As an illustration, for the elicitation of important stakeholder values in particular, VSD relies on bottom-up descriptive approaches such as surveys of stakeholders and future users [38].

In addition, a clear ranking of values or valuation of what is at stake is underexplored. Whenever guidelines are presented for ranking values, they often conclude by saying that the provided guidelines remain in need of an underlying ethical theory for a normative reflection (e.g. [36]). In general, then, it is safe to assume that VSD has an insufficient grounding for the determination of moral values [39]. As a provocative example, Albrechtslund [16] raises the thought that VSD *could* be used to operationalize the values of Nazi Germany by defending values that are regarded as important by key stakeholders, but that would not be regarded as aspirational from the point of moral goodness. Hence, since ethical theory is not inscribed in VSD itself, scholars who wish to apply VSD need to choose a value theory to build on as normative foundation. As Friedman *et al.* [15] suggest, this could stem from integrating the ample work being undertaken on deontology, consequentialism, or virtue ethics. For energy systems in particular, some scholars have drawn upon the capabilities approach [40,27].

***Focus on artefacts rather than systems***

Another critique of VSD pertains to its focus on technological artefacts rather than on socio-technical systems as a whole [26]. Particularly in energy systems, design guidelines that 'only' focus on technological artefacts might not be sufficient to grasp the complex interactions between technologies, institutions, and stakeholders that socio-technical systems entail. Based on this critique, there have been some recent applications of VSD to energy systems. Dignum *et al.* [22] explore arguments and norms in public debates on potential shale gas extractions to infer a set of relevant, underlying values and Mouter *et al.* [23] extend this work to explore values, norms, and design requirements in a controversy around pre-existing gas extraction. Thus, whilst this is a cited limitation in the literature to date [26], this goes to show that there is no principled reason why VSD may *not* be increasingly applied to systems in the future.

***Values arising during use underrepresented***

Whereas the interactional perspective on values outlined above acknowledges that values can be embedded in design features *and* arise from implementation and use, VSD scholars are critiqued for having insufficiently theorized about the interaction between designing and using a technology [16]. Technologies will in some cases be used in ways unforeseen by their designers, and value interpretations change through stakeholder interaction with the technology. Hence, VSD scholars engaged in value discovery need to carefully and explicitly distinguish between what can be determined during the design, what might be predicted with a certain probability, and what is principally unpredictable and beyond the knowledge of designers [16]. Yetim [41] suggests that designing for flexibility coupled with continuous user participation and discourse is needed to deal with changing salience and interpretation of values. One may also suggest that VSD requires something akin to Phase 4 trials in medicine, where monitoring of use after the approval to market a drug may lead to adjustments in drug content, administration methods, and recognition of (beneficial) 'off-label' use.

# 3. Responsible Research and Innovation

## 3.1. Definition and brief description

RRI is underpinned and co-defined by ongoing academic debates in the fields of Science and Technology Studies, Philosophy of Technology, Applied Ethics, and Governance and Regulation Studies [42]. Here, it represents longstanding concerns about the societal role science and technology should have, including how to govern science and technology while acknowledging their unpredictability; and questions about the consideration and importance of (certain) values in scientific and technological developments. As an evolving concept with various definitions [43,44,45,46], RRI is often referred to as an umbrella term drawing on insights rooted in a variety of debates and approaches, all of which are synthesized through the "explicit link between innovation and responsibility" [47: 2]. Collingridge's [48] work on "The Social Control of Technology" is often cited as a milestone in the formative debates of RRI, though work on the relationship between science, technology and society significantly pre-date this [49]. RRI also draws on recent perspectives relating to the various forms of constructive [50], participatory [51] or real-time technology assessment [52], as well as Value Sensitive Design [53], upstream public engagement [54], and anticipatory governance [55], for instance.

Although it has been discussed for around half a century, the intellectual discourse on RRI started to expand rapidly in the mid-2000s [56,57] with the development of several dedicated books (including [44,42,58]), multiple RRI projects, and the launch of *The Journal of Responsible Innovation*. Moreover, while the application areas of RRI research have initially focused on nanotechnologies, synthetic biology and geoengineering [44], over time the focus of research has broadened in analytical scope, as well as in terms of its empirical and geographical application: RRI is not only used to analyse "single" or "stand-alone" technological innovations, but also systems, of which work on health-related AI and ICT systems are recent examples [59,60]. Empirically, RRI scholarship has investigated the practices that are embedded in contexts of academia and the private sector [61] and has been discussed in connection with sustainable development, for example [62]. Geographically, scholars have also extended their attention to increasingly diverse locations, including Asia and Latin America, though we must note that RRI work still remains a largely "Western affair" or "European agenda" [57,58].

Outside of academia, RRI has gained particular traction in the European policy context [43]. Faced with the questions of how to deal with the potentially contested impacts of scientific and technological developments, RRI emerged as a new governance and policy approach to steer the direction of science and technology in ethically acceptable, sustainable and societally desirable ways. Stressing the role of science and technology (and their governance) in tackling grand societal challenges (which we return to later), the European Commission embraced RRI as an approach "to achieve better alignment of research and innovation with societal needs" [63: 5] and to align research policy with societal values [64]. The early engagement of a range of stakeholders and their enablement to evaluate and steer the direction of research and innovation processes is seen as an important aspect to realize this. In 2014, RRI was inscribed in the EU's main research and innovation funding program, Horizon 2020 [63].

### 3.2 Key features

Since the early 2000s, the framing of "Grand Challenges" has gained increasing prominence in EU policy circles, reflecting discussions about the public value of science and technology in and for society, what type of societal impacts techno-science should have and how to foster this [56]. RRI is posted as a solution to such questions and remains part of a broader trend towards challenge-led science and innovation in which framings to justify (investments in) science and technology go beyond purely economic terms [43].

RRI aims to address societal challenges by engaging the public in research and innovation processes, and by doing that at an early stage of development. Analytically, three rationales for this public participation underpinning are distinguishable: (1) the normative rationale, emphasizing that public participation is considered to be good and sometimes necessary for an ethically legitimate innovation; (2) the substantive rationale, underpinning that participation is necessary as it helps to improve the outcomes (and certainly when done early in the process); and (3) the instrumental rationale that considers public participation as a means to smooth implementation and decision processes [65]. Critical scholars of participation find that the instrumental rationale is often the main driver for supporting greater participation [56], which can be problematic in those instances in which participation is instrumentalized to advance certain preconceived outcomes.

Regardless of the underlying motives, two key aspects are important in public engagement efforts of RRI: first, the consideration of a variety of (often marginalized) stakeholders and perspectives to steer the direction of science and innovation, and second, engaging these stakeholders throughout the innovation process. While the emphasis often lies on engaging stakeholders early on, some scholars identify the "mid-stream" as a temporal moment in which RRI also needs to operate [66].

The aim to enable inclusive and early engagement of stakeholders is also related to another key feature of RRI, i.e. the notion of *anticipation*. It is widely accepted that scientific and technological developments can have unintended consequences. When dealing with the unpredictability and uncontrollability of the results from techno-science, calls for improved anticipation emerge, stressing to systematically think about "what if …" questions [67,68]. By example, in the production of renewable energy electrification, rare earth minerals are required for the batteries bringing in often overlooked, or psychologically distant considerations around socially and environmentally unsustainable practices. Thus, ideas of anticipation aim to encourage diverse stakeholders to articulate "a future-oriented disposition that can provide appropriate guidance" [56: 856]. In this regard, anticipation in RRI is not only grounded in the insight that science and technology can cause risks, uncertainties and unintended consequences. Though discussed to a lesser extent, it can also create added value and thus resonate with more "constructive overtones" [68: 1570], thereby acknowledging the power of science and technology to shape futures.

There are three further questions that shape the academic and public discourse of RRI. We now discuss each in turn. First, RRI asks what is innovation, and does the notion only have bearing on new and emerging technologies or also on those experiencing ongoing innovation? Relatedly, when does an "emerging" technology become "established", and is it then out of scope, e.g. innovations in nuclear energy technologies or wind power? [69, 70]. Technologies keep progressing and whilst nuclear energy production is at least 6 decades olds, nuclear reactor technology has evolved substantially, engendering new societal benefits but also risks. In this regard, the scale of applicability of a system and how and when it should be *innovated* technologically and institutionally are of central concern [71].

Second, RRI's emphasises *responsibility*, but what does responsibility entail and does engaging with RRI incur an implicit ethical acceptability of the discussed innovation? While the notion of responsibility is conventionally understood within a consequentialist framing, RRI moves away from this. Responsibility, therefore, is not something that is assumed after the consequences of one's actions have occurred. Instead, responsibility in RRI is conceptualized within a future-oriented framing, in which innovation is seen "as a collective, uncertain and unpredictable activity" [43: 756]. With this, two main dimensions of responsibility in RRI emerge. First, several authors have suggested rethinking the notion of responsibility in RRI as a form of care [72;73,74,75,76,77], where the notion of care or future care encases an attitude towards technological futures [72]. Second, caring is complemented by another dimension of responsibility; responsiveness. Being responsible means to be responsive to changing circumstances and to be able to respond to changing values by changing the shape or the direction of the innovation efforts [78]. Cumulatively then, RRI is based on the premise that scientific and technological uncertainty requires a forward-looking understanding of responsibility based on care and responsiveness, which is inclusive and deliberative and thus more adaptive to societal needs.

In the RRI literature there is a tendency to correlate any innovation that is the subject of inquiry with 'morally acceptable' technologies, since the 'responsible' in RRI supposedly warrants that. This is, of course, a false assumption as it has been emphasized by Blok and Lemmens [79] and later by Bergen [80]. Indeed, not every innovation is worth undertaking. RRI therefore needs to be considered as a framework to consider not only *how* to innovate responsibly but also *whether* a technology (as an outcome of an innovation process) can be responsible at all. Engaging with RRI is thus not the end but the beginning of a discussions about ethical acceptability and its possible criteria for a specific technology. Certain nuclear power plant technologies may not be developed if they waste they produce is more susceptible for misuse, for example.

Third, RRI poses the need to anticipate future outcomes; what does that say about how to deal with uncertainties, especially regarding the normative acceptability of outcomes that are substantially different from the anticipated ones, for example? The central discussion of "uncertainty" in RRI draws on the work of Collingridge [48] and Wynne [81], who worked on the social construction of uncertainty from a critical theory background. Here, notions of uncertainty are central to understanding why an anticipatory orientation of the RRI literature and approach has become so important and why non-consequentialist approaches to RRI have become increasingly central. They also require consideration of the ethical implications of uncertainty. The first response to this was the introduction of the Precautionary Principle (PP) that warns that if we do not have full scientific knowledge of an innovations consequences it must be stopped. The PP has often been criticized as being a too restrictive for innovations, however especially in the realm of policy, thus preventing important technological and economic developments on the grounds of *potential consequences*. Instead, the EU policy is strongly presupposing adherence to Innovation Principles. The RRI discussions has been, in a sense, a compromise between the PP and the Innovation Principle. Yet, the question of how to deal with uncertainties, especially when the actual consequences are drastically different (less favourable) than the anticipated ones remains the subject of intellectual and policy inquiry. One line of thought follows Jonas [82] in suggesting that technological innovation needs to become more 'humble' or, as Jasanoff [83: 240] writes, focused on 'technologies of humility', "to make apparent the possibility of unforeseen consequences; to make explicit the normative that lurks within the technical; and to acknowledge from the start the need for plural viewpoints and collective learning".

Scholarship on risk governance focusses on normative implications of future uncertainties [84], for instance, by making innovations (or the laws that regulate those innovations) more adaptive to future developments [85]. Others propose that important innovations are considered as social experiments that require continuous reflection and review [86,87]. Focussing on the role of the innovator, work on virtue ethics stresses the importance of certain virtues underpinning the activities of the innovation actors [88], with recent suggestions pointing towards more action-oriented understandings of innovation ethics [89].

### 3.3 Methodology

Strictly speaking, RRI does not have one clearly demarcated methodology, though two broad traditions can be distinguished: a normative substantial approach and a process approach. The normative approach "starts with norms and values as predetermined (substantial) inputs in the innovation process in order to generate responsible outputs" [90: 6]. We could, for instance, consider RRI as an endorsement of public values [91]. In contrast, the process approach has quickly gained dominance in both the European policy context and in the scholarly debate aiming, for instance, to achieve sustainable development [92]. The process approach is mainly underpinned by a framework developed by Stilgoe *et al.* [68] and Owen *et al.* [44]. In their work, the authors propose that responsible innovation is underpinned by four dimensions; anticipation, reflexivity, inclusion, responsiveness. These dimensions can function as guiding principles to reorient science and innovation practices towards the social shaping of innovation as a shared responsibility for the future [43,68] by proposing tailor-made principles and ways to responsibly manage and govern the process of scientific and technological development. This might partially explain the concept's widespread uptake, as it provided an explicit RRI framework, which aligned with institutionalization efforts of RRI at EU policy level.

### 3.4 Strengths

***Uptake in policy practice***

While RRI's use in industry is still in its infancy [93], RRI is a vividly discussed notion in both policy and academic circles. This points to its pertinence for theoretical reflection and practical use for policy. RRI addresses many of the lingering issues that emerge in the governance of science and technology under one banner by being concrete enough to remain actionable but open enough to accommodate differences. This usefulness is reflected in its institutionalization at EU but also national policy level. The integration of RRI in the EU's funding instrument further help to advance RRI, not only through enabling practice application but also regarding its theoretical development.

***Normative qualification of innovation***

By essentially stressing the normativity of innovations, RRI introduces a normative qualifier in a domain that has traditionally been dominated by rationalist-maximizing economic-thinking. The normative qualification extends to both the process and outcome dimension: "responsible" qualifies the contexts in which innovations are being developed, but also introduces normativity into the "outcome" of research and innovations, so that they end up more socially desirable [94]. By qualifying innovation processes and outcomes, it sets a benchmark and guidepost.

***Disciplinary diversity***

RRI's theoretical and conceptual openness or flexibility also makes it possible for a range of academic disciplines to relate, reflect and further develop it [95]. Its roots in different discussions and disciplines contribute to its diverse theoretical foundations. Methodologically, too, RRI has been explored by employing a range of research methods, though mainly within a qualitative research framing [47,96,97,58,98].

### 3.5 Challenges

***Conceptual naivety***

RRI's inclusivity may also foster conceptual naivety. Several authors have stressed how accounts of RRI are often based on an uncritical view of "innovation". For example, Blok and Lemmens [99] show the rather unnuanced way how "innovation" is understood. Bergen [100] calls for reconsidering the relation between responsible innovation. Genus and Stirling [49: 62] argue that RRI practices often simply follow the generally projected innovation pathways and do not question this "incumbent innovation trajectory". In a similar vein, Pfotenhauer *et al.* [101] warn against an "innovation imperative" privileging technocratic overtones at the expense of discursive and political deliberations.

Focusing on the science-policy nexus, Oudheusden has also identified power and politics as further dimensions in need of conceptual attention, proposing the reframing of RRI "along more politically sensitive criteria" [102: 81]. Others stress the need for institutional paradigm shifts in thinking about science-society relations, "to ensure RRI's capacity to innovate innovation policy" [103: 163] and more broadly, authors have called to rethink "the dominant economic imperative of science", proposing a cultural political economy of research and innovation [104: 151]. This includes the explicit recognition of the role of power in shaping (the governance of) science, technology, and innovation.

***Inability to handle normative complexity***

Its practical and theoretical openness and flexibility also points to RRI's potential challenge. As an umbrella notion RRI draws its strength from its encompassing characteristics and not from its definitional unambiguity or its theoretical-methodological preciseness. RRI's emphasis on including the views of a variety of stakeholders is an example for this. While stressing public engagement, RRI does not – and perhaps cannot – decide which opinions to include (e.g. [26]), how to deal with the diversity of morally laden opinions and values [105], and more specifically, what to do when two diverging values (or otherwise morally relevant opinions) cannot be accommodated simultaneously and choices need to be made [91].

***Enabling participation***

Calls for inclusive deliberation in RRI (and elsewhere) are not straightforward as they raise issues of representation, scale and scope. A central question, though not new, is how to elicit participation by truly diverse publics and stakeholders without stifling their proactivity [106,107]. This is especially challenging as inclusivity in RRI tends to be "undercut by an orientation towards 'inviting' participation of publics" which might hamper pro-active and self-initiated participation [61: 7]. For example, Ruiten [108] notes that in the development of High-Voltage Powerlines in the Netherlands, the drive to be inclusive by opening up processes and commitments to diverse viewpoints may, counterintuitively, stand in the way of decision-making.

# 4 Energy Justice

## 4.4 Definition and brief description

Energy justice promises itself as a means of overcoming the neglect of moral issues in energy systems design, use and decommissioning. Energy Justice - a framework that according to one definition, seeks to 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" ([109: 143) - evolved from the environmental and climate justice literatures [110]. The concept's energy-only focus (which Jenkins [111] argues distinguished from complementary climate and environmental justice literatures) serves as an early point of distinction from the VSD and RRI approaches.

Although it has been claimed that "Energy Justice" first emerged as a policy term in the early 2000s [112], notions of equality, fairness, and justice in energy systems pre-date these scholarly contributions. Energy Justice can be linked to race-based social movements around the siting of toxic facilities and key climate negotiations, for example. Nonetheless, it is since this explicit, policy-based emergence that an extensive Energy Justice literature has developed, including applications at the household and community level (e.g. [113,114], national (e.g. [115]) and international scales (e.g. [116]). Other studies have applied Energy Justice to particular contemporary issues, including nuclear energy (e.g. [117]), energy regulation (e.g. [118]) and the spatiality of Energy Justice vulnerabilities (e.g. [119]).

As with VSD, we acknowledge that "Energy Justice" isn't the only framework or concept that seeks to engage with justice, equity and rights in energy systems. Szulecki [120] positions *energy democracy* as either the normative goal of decarbonisation and energy transformation or a descriptive term for pre-existing examples of decentralized and (typically) bottom-up civic energy initiatives, for instance, and Smith and High's [121: 7] work considers *energy equity* as "a call for us to be cognisant of the moral aspects of social life as it pertains to matters of energy". Other terms may include, 'fuel poverty', 'energy vulnerability' and 'energy poverty' [119] alongside 'energy precarity', for example [122]. Amongst this often-competing terminology, we position Energy Justice as an overarching, aspirational goal that encompasses numerous problem-focused approaches [123].

## 4.5 Key Features

In order to conceptualize the goal of Energy Justice and the means of achieving it, a range of tenet frameworks have been developed. The most widely used of these is the approach outlined by McCauley *et al.* [124], which focuses on 'distributional justice', 'procedural justice' and 'justice as recognition'. These are drawn from the environmental justice literatures as outlined in detail by Schlosberg [125], who bases his conceptualization largely on justice theorists such as Rawls [126], Young [127], and Fraser [128], as well on his empirical work with environmentalist movements in the US.

Through these tenets, Energy Justice takes on both empirical and normative roles questioning what *is* happening and what *ought to be* [3]. As one example, Forman [129: 650] explores the community ownership of renewables, using the tenet framework to examine "how Energy Justice is negotiated and contested at community-scale through a focus on issues of distributive and procedural justice". Forman emphasises the ways in which community energy is often involved in a wide range of local objectives and directs attention to how best to support such initiatives to further stimulate local action and deliver more widespread equity gains. For Sovacool and Dworkin [130], this means that Energy Justice can act as (1) a *conceptual tool* that integrates different justice concerns, (2) an *analytical tool* for researchers to understand how values are integrated into energy systems or to solve energy problems, and (3) a *decision-making tool* for energy planners and consumers looking to make more informed energy choices. It should be noted too that Energy Justice theoretically concerns itself with the allocation of energy systems burdens *and* benefits, though mention of the latter is often less substantive.

## 4.6 Methodology

If following the tenet model for Energy Justice, there is a logic that if an injustice is to be tackled, you must (a) identify the concern – distribution, (b) identify who it affects – recognition, and only then (c) identify strategies for remediation – procedure [3]. Within this approach, distributional justice is concerned with the division of energy services, benefits, and harms among present and future generations. Justice as recognition represents a concern for who is, or who is not, affected by and included in energy decisions, arguing for a fair representation and respect for the opinions of all individuals and groups affected by changes in energy systems. Procedural justice then investigates the mechanisms through which those decisions occur, and stresses the need of equitable access to information, access to decision-making processes, and access to legal processes for achieving redress [130]. Although apparently step-wise, this approach does not mean to imply that justice as recognition is subservient to distributional justice or that the tenets are clearly separable. Instead, in line with Honneth [131] and Fraser [128], justice as recognition (and as Pesch et al. [147] argue, procedural justice too) forms a pre-requisite of distributional justice. Said another way, one needs to consider what matters to whom before injustices in the distribution of elements of concern can be addressed. In contrast, competing conceptual approaches embed insights from actor network theory, assemblages, and capabilities approaches, amongst others (see [132,133,134]).

Beyond the dominance of the three-tenet stepwise, conceptual framework the methodological approaches to Energy Justice are currently diverse and include a large prevalence of conceptual contributions, qualitative studies, and analyses of secondary data sources such as policy documents. As a specific example, Castán Broto *et al.* [135] present the amalgamated findings of semi-structured interviews, site visits to off-grid energy service projects, a systematic review of particular projects, ethnographic field visits, workshops and a household survey. In the same paper, they also go on to advocate for stronger consideration of the methods for understanding Energy Justice dilemmas.

## 4.7 Strengths

***Temporal flexibility***

Energy Justice can play a role in the consideration of longitudinal processes with social justice outcomes, permitting investigations into past, present *and* future energy systems impacts that raise normative questions around intergenerational equity, for example [136]. As an illustration, McCauley and Heffron [137] consider restorative notions of justice which may encompass past damages that have already occurred, existing crimes perpetrated against individuals, the environment and the climate, as well as unforeseen harms that will come throughout the post-carbon transition. In contrast, Heffron *et al.* [138: 171] introduce the concept of thinking in the "future tense", whereby specific attention is given to future generations, and to ensuring that they are treated as equally significant to the present populations. Alongside evaluations of current practices, this allows us to consider evolving Energy Justice issues acknowledging that what may seem like a social justice gain today (e.g. strong support for wind farms or large-scale solar energy) can become a social injustice tomorrow when implemented poorly or unfairly (e.g. wind farms in Mexico that forcibly displace indigenous people from their lands [139] or solar energy parks in India leading to exclusion and land grabbing [140]).

***Transitions thinking***

The rapid growth in popularity of Energy Justice includes strong intersectionality with just transitions thinking (e.g. [137]), transitions frameworks such as the multi-level perspective on socio-technical systems (e.g. [116]), sustainability transitions goal setting (e.g. [141]) and whole systems applications in this setting [142]). As an example, Energy Justice research has been positioned as a method to explore how inclusive forms of transitions can be conceptualized or operationalized, engaging with the social justice issues that are otherwise below-the-radar outcomes of transition processes [141]. Indeed, leading scholars highlight that Energy Justice research could explore transition dynamics that induce, reinforce, exacerbate or mitigate poverty, inequality and exclusion within and across past, current and future timeframes. With these bodies of scholarship finding prominence outside of academia and being reflected in national policies, this suggests the potential of the concept to inform practical outcomes.

***Exposing marginalization***

Through the prominence of justice as recognition as a core tenet, Energy Justice gives particular weight to groups and individuals that are marginalised in energy decision-making and outcomes. This practice has its roots in the focus on 'justice as recognition' as an analytically separable dimension of justice. It stresses that an understanding of *who* wins, *who* loses, *how* and *why* is the first and foremost precondition to establish more just distributions of benefits and harms [125,143]. Studies often highlight, for instance, the marginalization of the poor and their livelihoods in developing countries as large companies seize common land for commercial production, or food-versus-bio-fuel conflicts [144] and the unequal distribution of biofuel benefits in Less-Developed Countries [145]. Energy Justice also highlights that due consideration should be given to marginalized groups such as non-users, non-dominant and non-state-based actors in shaping transition processes [146]. As one example, Pesch et al. [147] discuss how controversies around the Barendrecht gas field in the Netherlands are at least partly the outcome of formal institutions' limited focus on procedural justice and not being able to respond to justice as recognition-based considerations or protestors.

***Systems-wide potential***

Finally, Energy Justice also encompasses an explicit call for systems-wide applications of Energy Justice thinking (see [148,149]). For Jenkins *et al.* [3] whole systems applications of Energy Justice evaluations – those that focus from resource mining through to waste, whilst also considering the lifecycles of particular facilities - demonstrate the potential for a global account for energy's social, economic, and environmental impacts. For example, Sovacool *et al.* [142] conduct a whole systems analysis of four European low-carbon transitions, including nuclear power in France, smart meters in Great Britain, electric vehicles in Norway, and solar photovoltaic panels in Germany, considering how each of these transitions may impact wider communities and countries. Beyond natural science definitions of energy systems, Energy Justice may thus also apply to *social* systems. Energy Justice has also been positioned as a mechanism that can: (1) expose exclusionary and/or inclusionary technological and social niches before they develop, leading to potentially new and socially just innovation; (2) provide a way for these actors to normatively judge them, potentially destabilizing existing regimes using moral criteria; and (3) if framed as a matter of priority at the landscape level could exert pressure on the regime below, leading to the widespread reappraisal of our energy choices and integration of moral criteria, for example [116].

## 4.8 Challenges

***Academia and beyond?***

One of the primary critiques of Energy Justice so far is its limited application outside of academia. The use of Energy Justice in practice has rarely been analysed, and there is little reflection on how Energy Justice becomes a deliverable policy outcome (though with some notable exceptions, including the work on the ENGAGER network on how energy access is legally protected in different global jurisdictions [150]) [151]. This challenge is particularly notable as the use of Energy Justice in practice has a longer history than in academia, and yet this is rarely reflected in conceptual or analytical investigations. As examples, Heffron and McCauley [151] mention the neglected work of the NGOs 'The Energy Justice Network' (since 1999) in the US and the 'Centre for Sustainable Energy' in the UK (at least since 2009). In order to create a stronger link between Energy Justice research and practical energy policy, Heffron and McCauley [151] suggest a stronger realization of the dominant influence of economists and industry on energy policy, relying on cost-benefit models as the major tool for decision-making. Whether this is the best pathway or not, more work is required on how Energy Justice insights could complement and expand existing Energy Justice practice in both bottom-up and top-down domains.

***Limited philosophical exposure***

Apart from limited interaction with practice, we also observe that the Energy Justice literature has largely developed without interdisciplinary insights from established philosophical approaches to justice in the energy domain. Indeed, at present, the predominant underpinning of Energy Justice research is Western philosophy and human-centred approaches only [152,141,4] and in many cases, most Energy Justice studies have focused only on a descriptive account of the triumvirate of tenets. Sovacool *et al.* [4] *have* explored several alternative non-western philosophies and their potential to strengthen Energy Justice theory, yet this field is embryonic. Moreover, there is a burgeoning call to explore more-than-human justice considerations including animal-centrism, biocentrism, and ecocentrism approaches [4]. As a consequence, there is currently still a lack of normative principles of just distribution, for instance, and despite the aspiration to take on a normative perspective questioning what *ought* to be, Energy Justice research has focused more on establishing *what* the benefits and harms are that need to be distributed rather than *how* to distribute them in situations of scarcity.

We present a summary of all approaches in Table 1 below.

**Table 1**: Summary of the three approaches

| Dimension for Comparison | Value Sensitive Design | Responsible Research and Innovation | Energy Justice |
|---|---|---|---|
| **General** | | | |
| Aim | To incorporate diverse human values into the design of technologies | More responsive and inclusive innovation, solve societies' Grand Challenges. | To reduce instances of injustice related to energy systems. |
| Community | Academic: Computer science, Ethics of Technology/Engineering Ethics | Academic: Science and Technology Studies, Philosophy of Technology, Applied Ethics, and Governance and Regulation Studies<br>Policy: European Commission, EU and National Research Funders. | Academic: Mainly social sciences and scholarship around Environmental and Climate justice. |
| **Key Features** | | | |
| Key actors | Designers, in collaboration with social scientist and philosophers. | Researchers, developers, regulators, society (framing RRI as collective responsibility) | From grassroots to policy, though with a general emphasis on the latter |
| Research mode | Design research: Embedding values and overcoming value conflicts is a design challenge. | Anticipatory governance: Focus on uncertainty and anticipation of the future, through participatory methodology. | Systems analysis: Justice issues are externalities, focus on identifying energy system burdens. |
| **Methodology** | | | |
| Dominant Framework | Tripartite methodology to design for values:<br>- Conceptual investigations<br>- Empirical investigations<br>- Technical investigations | Four guiding principles:<br>- Anticipation<br>- Reflexivity<br>- Inclusion<br>- Responsiveness | Three tenets of Energy Justice:<br>- Distributional justice<br>- Procedural justice<br>- Justice as recognition |
| Normativity | Both descriptive and normative, technologies are seen as a way to solve normative issues. | Normative, substantive and instrumental rationales are all used to justify participatory RRI approach. | Both descriptive and normative role for Energy Justice concept and research. |
| **Strengths and challenges** | | | |
| Strengths | - Practical design guidelines<br>- Clear allocation of responsibility | - Uptake in policy practice<br>- Normative qualification of innovation<br>- Disciplinary diversity | - Temporal flexibility<br>- Transitions thinking<br>- Exposing marginalization<br>- Systems-wide potential |
| Challenges | - Missing ethical theory<br>- Focus on artefacts rather than systems<br>- Values arising during use underrepresented | - Conceptual naivety<br>- Inability to handle normative complexity<br>- Enabling participation | - Academia and beyond?<br>- Limited philosophical exposure |

# 5 Five opportunities for collaboration and integration across energy scholarship

In the introduction, we stated that the VSD, RRI and Energy Justice literatures appear to have a common objective: the aspiration to grasp the social and ethical impacts that come with energy technologies and energy systems change. Yet as has been shown in sections 2-4, they go about this in different ways, each representing different approaches, conceptual baggage, communities and normative commitments. Nonetheless, several areas of overlap and potential synthesis do emerge. Perhaps ambitiously, it might be possible to conceive that each approach may present a different step in the process of whole energy systems change; RRI might apply to scientific development, VSD to the design of products and services, and energy justice to the delivery and the operation of resultant systems, for instance. On a conceptual level, RRI, relates to debates discussed within VSD and to the inclusion of values in design [153]. Energy Justice *could* also be conceived of as a value informing VSD and RRI, and Energy Justice and RRI also resonate strongly when it comes to the inclusion of marginalized voices. In this section, we will further focus on the similarities and differences between the three approaches with a focus on integration and collaboration across energy scholarship to improve the social outcomes of technological energy systems. The result is an overview of five opportunities for further scholarship in this area. This synthesis should be seen as the start of dialogue on the potential for new frameworks of analysis and new applications, in addition to directly answering the challenges found in each of the three literature sets.

### *1) De-silo-ing the academic debate*

One of the main objectives of this paper is to de-silo the academic debate around social and ethical issues in energy systems, and each of the concepts described above can play a role in doing so. Despite interdisciplinary claims, Energy Justice is arguably the most homogenous of the three concepts in terms of its conceptual and disciplinary foundation as well as the origins of its methodological toolkits. In essence, it consists largely of geographical, sociological or broader social scientist perspectives, although we do acknowledge increasing contributions from law [154,118], public health [155], and business and innovation studies, amongst others [156]. RRI, in comparison, has brought together scholars from a broad range of fields, as outlined above. This trend has been partially supported by the way RRI funding schemes were initiated, which required collaborations between social science and humanities on the one hand, and between these newly paired collaborators with engineering sciences on the other. Mainly developing in the context of ICT, VSD has been able to bring scholars from the humanities, social sciences, sciences and engineering to the table. Through such multidisciplinary collaborations, VSD has also integrated philosophy and ethics perspectives within varying engineering fields[3]. In contrast to Energy Justice, RRI and VSD may also achieve broader interdisciplinary reach given that the technologies they are applied to are not just energy systems related, but build on traditions of research into nanotechnologies, artificial intelligence and robotics, amongst others).

With this interdisciplinary orientation in focus – and calls for Energy Justice in particular to increase its interdisciplinary reach [149] –, we argue for a more active interlinking of these three conceptual, methodological and social worlds as a tool for uniting not only disparate scholarly contributions, but also the truly interdisciplinary groups behind them. In this way, the concepts become a tool for coordination through which we can map and respect the complexities of socio-technical energy systems. Such an approach has the potential to substantially enhance the visibility and contribution of the social science and humanities to energy research, which is still largely dominated by techno-economic approaches [157]. It will also help transfer methodological skills and knowledge from VSD and RRI with a view to expanding the methodological repertoire of Energy Justice which, to date, has comparatively limited methodological reach; particularly with respect to experimental, modelling and quantitative insights.

Instrumentally, this could be achieved by creating joint academic outputs through journals related to these concepts (e.g. the *Journal of Responsible Innovation*, *Energy Research & Social Science*, *Science and Public Policy* or *Technological Forecasting and Social Change*). Moreover, it could be achieved by physically bringing these communities together, as was the case during the 2019 Lorentz workshop in Leiden that inspired this publication [158][4]. This, in effect, is our first "call to arms" and exists as an example of where the interdisciplinary success of one contribution can contribute to the comparatively neglected interdisciplinary reach of another.

### *2) Expanding practical applicability*

[3] For an overview of applications of VSD with engineering fields, see the following handbook: Van den Hoven et al. (2015).
[4] https://www.lorentzcenter.nl/lc/web/2019/1071/info.php3?wsid=1071&venue=Oort

Both RRI and VSD have strong traction outside of academia whereas for Energy Justice, this practical-reach is currently more limited[5]. For RRI this may not be a surprise; from the start, RRI was a policy-oriented concept that spoke to both academic and policy practice (often with a technology/innovation focus) [43], and it was partially involved in EU policy parlance [159]. Moreover, the Netherlands and the United Kingdom are prime indicators of RRI increasingly being funded and implemented within a national innovation policy frame [46], creating the driving force for the EU focus on RRI. In these and other contexts, RRI has been developed into an operational approach that integrates certain process dimensions and thematic elements that have proven to usefully signpost and guide the implementing RRI in practice [45,160]. Indeed, it is this integrative characteristic that so contributes to both the notion's continuous practical and theoretical use(fulness). VSD, in comparison, takes existing design methodology and engineering practices as its starting point and builds from that. In theory, this makes the concept easy to handle for practitioners. Thus, both these concepts thus seem to 'make sense' outside of academia in that they fit the discourse and way of working in policy and engineering practices.

Whilst Energy Justice is still largely academically embedded, it could benefit from both the technical and policy contexts of VSD and RRI. For instance, Stirling [161] argues there is an urgent need to open up energy policy, which can be done, in part, through strengthening ties between policy and research (as is the case with RRI scholars). To 'design for justice' could also be a new opportunity for designers and engineers who seek to integrate a wider range of (well-defined) values. Energy Justice scholars could also benefit from insights into how the RRI concept made policy traction and where appropriate, try to mirror them given that justice considerations should an explicit role in energy policy formation, even where justice is largely being overlooked in innovation policy. Conversely, when VSD include justice as a value to design artefact or systems, or when RRI discusses considerations of justice as an important indicator for innovating *responsibly*, they often relate to justice in a specific meaning. This includes, for instance designing future energy systems such that they could take intergenerational justice into account, often discussing temporal distributive issues of justice to the effect of what burdens can we justifiably impose on future generations (e.g. [162,163]).

---

[5] Although we acknowledge that Energy Justice concerns *are* echoed through grassroots movements (in the United States in particular) and through some political action, yet such cases rarely use the same framework or approach as scholarly Energy Justice contributions. Moreover, industry and policy uptake is very limited.

Here, the three-tenet account of Energy Justice could be very helpful in designing for justice in a conceptually richer fashion that also accounts for non-distributive account of justice.

Appreciating that they are not without their own challenges, RRI and VSD can also learn from each other. In particular, we caution that the attractiveness of the open, flexible and integrative character of RRI notion (especially when used in contexts of policy and implementation), can also be seen as a pitfall. It is difficult to disagree with a drive towards “responsible innovations” – who would want irresponsible ones? Yet, there is a potential that this becomes a reductionary view akin to “common-sense morality” and that a dichotomy between “good” and “bad” innovation loses its thrust as a sophisticated approach that could steer policy. This critique can be drawn in parallel with the notion of sustainability. With sustainability (or RRI, respectively) becoming mainstreamed it has faced critiques of being very generic. To that end, Cuppen *et al.* [164] show concern that it has partly lost its power in public and political debates. Alternatively, some hold the view that as sustainability becomes more mainstream, it is replaced by more concrete, refined concepts, with the outcome that it is increasingly implemented. Thus, the aim of people working in sustainability is to make sustainability the “new normal” i.e. something that needs no more explicit definition or reference. Here, then, whilst we push towards opportunities for expanding the practical applicability of all concepts, we must also consider a tension between their “reach” or uptake in the most simplistic terms, and the need for reflexivity on and attention to their core principles and definitions.

### 3) Appreciating longitudinal processes and the full life cycle of technology

Both VSD and RRI have strong temporal limits given their almost exclusive focus on research and technological development processes as opposed to the technology’s implementation and use. Of the two, VSD is most strict in this sense and has been critiqued for its particularly limited engagement with the implementation and use of technology and the values that arise during this phase, including the limited consideration of the values or ethical problems that arise from unintended side effects [16]; values that could emerge as a result of such unintended impacts [165], and values that might change during the life-time of the designed artefact or system [166]. For RRI, despite emphasizing innovation as both a *product* and a *process,* and reflecting on use and the horizon of technological futures, it does not tend to embrace a focus on long-term systems dynamics.

In contrast, one of the strengths of Energy Justice is its consideration of longitudinal processes of transition and systems change, including investigations into past, present *and* future energy systems impacts, raising normative questions around intergenerational equity, for example [136]. Thus, there is potential to integrate Energy Justice and VSD perspectives in particular – given that VSD is the weakest of the three approaches in this regard –, enabling researchers to look beyond research and innovation processes and engage with the embedding and operation of energy technologies in society. This includes interventions for new technologies entering development *and* for new innovations within pre-existing energy systems. We say this conscious that the design-orientation of VSD and RRI approaches are typically perceived to be a barrier for their integration into already entrenched systems; a barrier we would argue is easy to overcome. Further, Energy Justice's systems focus may open the door to critiquing innovation and technological progress itself and the implicit assumption within VSD and RRI that some form of innovation is desirable without necessarily questioning the goal behind it. For RRI and VSD the energy system is the 'context' in which technology is developed, but it is not the focal point of analyses. In this regard, Energy Justice provides a wider lens of analysis and invites RRI and VSD scholars to think outside the box.

#### *4) Including a wide range of relevant voices and attributing responsibility*

All three approaches open up actor-based concerns by emphasizing the need for including a wider range of voices in energy systems considerations. In VSD, the actors affected by technologies are seen as 'indirect stakeholders', whose values need to be investigated and recognized in the design process. Yet this does not necessarily result in participatory methods to include those stakeholders actively in the design process. RRI is more participatory in this respect. With its strong focus on embedding stakeholders' opinions, relevant actors can be explicitly invited to the table to ensure hegemonic and technocratic values do not dominate the innovation process. In Energy Justice, through the principle of justice as recognition, the strategic integration of marginalized groups gains particular weight, contributing to a deeper understanding of what those marginalized voices may say.

Of particular interest for VSD and RRI is Energy Justice's consideration of *non-users,* individuals who may not interact with the object of innovation but instead, will be increasingly marginalised by their lack of access to it or by the effects of its production. In an increasingly digital world, this may include elderly members of society who are not Internet savvy or Internet connected and therefore, cannot benefit from smart metering or smart home technologies [167]. Alternatively, it may concern the artisanal miners in the Democratic Republic of Congo who mine the cobalt mineral that goes into electric vehicle batteries [168]. In RRI, VSD and Energy Justice then, there is potential to broaden the range of stakeholders engaged with innovation outcomes (as long as the processes are coordinated mindfully and with attention to principles of due process). Yet we cannot pretend the picture is entirely rosy or clean cut; all frameworks, whether conceived of individually or in combination, must consider which groups to include or exclude (including where to draw boundaries), how to deal with conflict or contrast in priorities, and how to deal with inevitable trade-offs (especially if looking across timescales and systems spaces). Of special importance for all approaches is the consideration of future generations for the sake of the normative aim to achieve sustainable energy systems and the descriptive characteristics of energy systems, in which decisions taken today have implications for future generations on various timescales (whether this is e.g. nuclear waste, electricity networks, or power plant construction). We position this as an increasingly imperative area of empirical and conceptual investigation, particularly if we are to move towards the social acceptance necessary for radical energy systems transformations.

Once actors (and their social values) are identified, we must next consider who is responsible for engaging with them. VSD presupposes a clear allocation or responsibility; designers (and those involved with design processes) are responsible for making the design process value inclusive and for ensuring feedback is acted upon before implementation and use of the product. Within this structure, VSD designers can act as intermediaries/translators of relevant social values, channelling them into the design. RRI expands the circle of potential responsible agencies with policy makers, research managers and even end users by making them all part of the innovation process. For Energy Justice, the division of responsibility is currently the least clear as most work is focused on identifying problems and injustices, but not on identifying who should respond to them and create a more just energy system. This despite calls to consider not only questions of "justice *for whom?",* but "justice *by whom?"*, opening up explicit debates about responsibility for ensuring socially just outcomes across a range of actor groups, including local communities, non-governmental actors, industry bodies and policy decision-makers [169]. Nonetheless, combining all three concepts invites us to think about responsibility as a more complex and divided concept where responsibility is multifaceted and changes longitudinally based on the actor in question. Furthermore, a systemic focus on responsibility would also invite us to see responsibility not as something that is fixed, but that is formed through power relations and social processes, and as something that might be challenged itself.[6]

[6] For example, through VSD, does it make sense that designers might be responsible for determining appropriate societal impacts that are sometimes driven by commercial decisions?

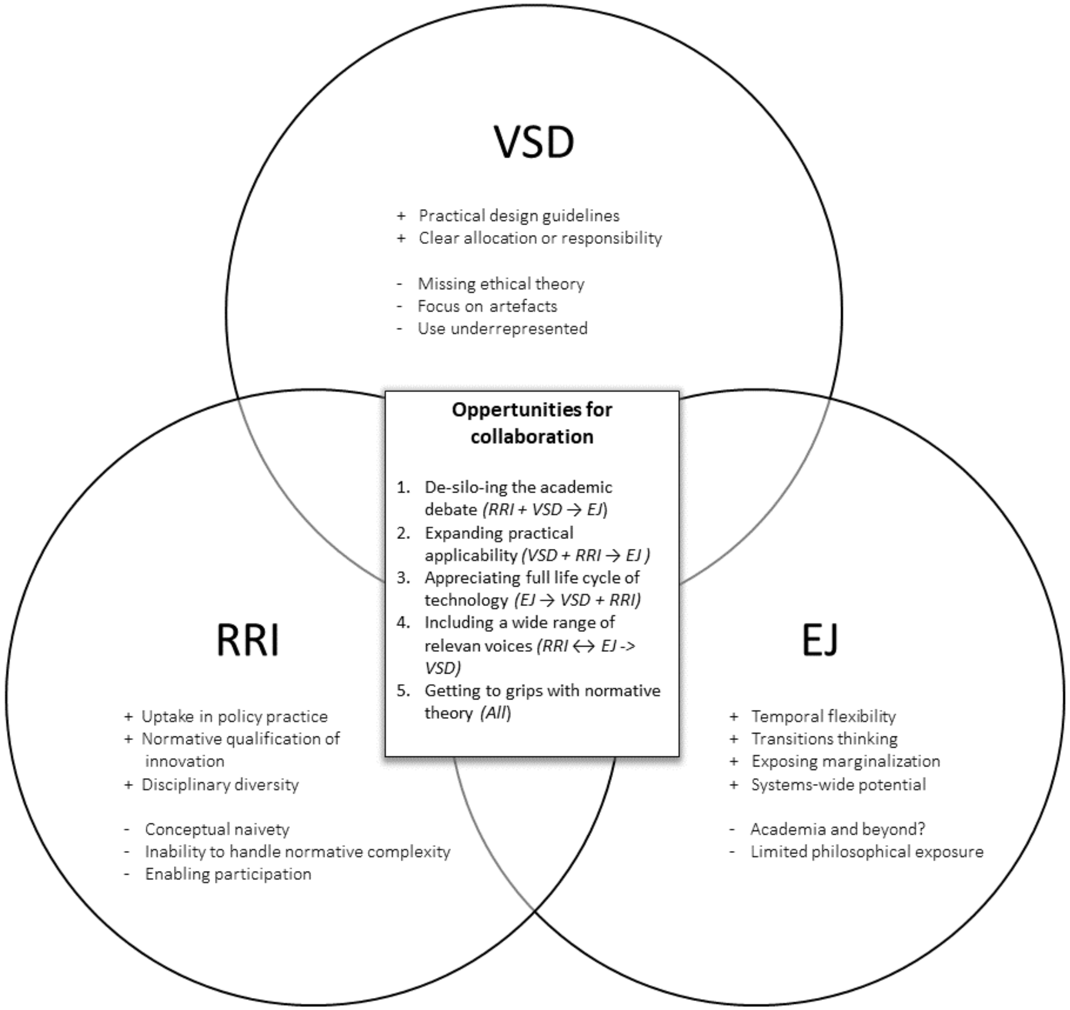
### 5) *Getting to grips with normative theory*

As one of our bolder claims for opportunities, all three approaches must engage more explicitly with the role of normative theory. One of the main critiques of VSD is that it does not have a foundation in ethical theory that provides a guide for value prioritization. This is important in practice because not all values can be captured and achieved within technology design, and designers will decide on value conflicts. Furthermore, within RRI discourse, it is invariably emphasized that stakeholders' opinions need to be included, yet precisely how to weigh conflicting and diverse views and engage more explicitly with underlying power and politics (the challenges of which are noted above) are less clear. In essence, RRI is capturing the normativity of innovation and stating it should be "responsible" but it does not necessarily help to address *normative uncertainties* and in instances where there is no one unequivocal answer to the normative inquiry [170], for instance when considering how to deal with stakeholders with varying (normative) opinions. Indeed, RRI work seems to have been most about 'opening up' innovation processes, but does not often provide a way to 'close down' and make decisions [171]. Energy Justice provides more normative guidance in this respect, although there are emerging debates over whether it truly gets to grips with the "justice" it is inferring exists.

Although it is not openly declared, most accounts of Energy Justice (including that of Jenkins *et al.* [3]) do not advocate for deterministic approaches to "just" outcomes, but instead, allow for a plurality of definitions that emphasise the contextualised voices of affected populations including "cries for justice" through grassroots social movements. Yet, it must also be acknowledged that some writers do take stances on "moral goods". Reflecting on core Energy Justice contributions in the literature, this might include the view that energy systems should not produce injustices such as exploitation of people, structural marginalization, energy poverty, or domination of decision making by business and political elites. In this way, Energy Justice *could* provide some normative guidance for RRI and VSD, but only if this were explicitly grounded in normative theory and/or the accounts of communities that verify the moral righteousness of such stances. Such accounts could also include increased attention to non-Western philosophical approaches or more-than-human stances, including animal-centrism, biocentrism and ecocentrism [4]. Said another way, this normative guidance would even be stronger with an increased philosophical exposure of current Energy Justice approaches, particularly through theories providing principles of just distribution. In this respect Energy Justice may also help counter the challenge of RRI as being too open and flexible (an "anything goes" approach) by setting some normative ground rules that determines the design space in which innovations can be developed.

We summarise these opportunities for collaboration and integration within Figure 1.

**Figure 1:** The intersectionality of Responsible Research and Innovation, Value Sensitive Design and Energy Justice



## 6 Conclusion

The very beginning of our paper introduced our guiding question how can value sensitive design, responsible research and innovation and energy justice – in combination – contribute to designing energy systems that are acceptable from a societal and ethical perspective? The conclusion here, is that our success depends on not only critically reflecting upon the strengths and weaknesses of single approaches such as VSD, RRI or Energy Justice, but on further exploring combinations and cross-pollination. Our paper represents a very first step towards this goal, and yet it is also the beginning of an embryonic field of scholarship that needs to develop rapidly. We've shown where scholarship can contribute and strengthen each other, and in writing this paper show that scholars from these different fields can learn to speak each other's language and form a new community. Whether the approaches discussed in this paper are taken individually or in combination, they face a daunting challenge. Global political landscapes are rapidly evolving and the climate change agenda is ever more pressing. Simultaneously, rapid energy systems change is occurring with only minimal attention to issues of social justice. Put another way, as energy systems constantly evolve, the race is on to make sure that the most positive social outcomes and acceptance are achieved. To guide our response to this challenge, we briefly present four extra challenges that build on and extend the discussion above and that, we hope, will guide future research in this field.

First, the urgency to change our current energy systems to make them considerably less carbon-intensive is on the policy agenda of most of the industrialized highly emitting countries. Too often, however, the perception of energy system change remains geographically confined, disregarding global flows of raw materials and resources that materially underpin these systemic changes. When designing and innovating energy systems this understanding of the global connectedness of the socio-techno-eco-systems is crucial. Thus, it follows that our scholarship needs to not only examine individual sites and locations, but whole energy systems from source-to-sink.

Second, VSD, RRI and Energy Justice provide valuable approaches for shaping the needed energy transitions in practice. Yet while the uptake of these approaches beyond academia seems to be more easily achieved in policy contexts, their application and translation into industry circles is still only rudimentary. This challenge and opportunity should be seized, as industry plays a central role in the material creation of our (future) energy systems.

Third, Energy Justice, VSD and RRI have developed within academic traditions and thinking in the Global North. Though their empirical application area is spreading, - especially

RRI is being applied and theorized in different geographical contexts of the South and East, including India (e.g. [172,173]), Southern Africa (e.g. [174]) and China (e.g. [175]) - authorship remains mainly based in countries of the North [57] – the scope of their application could profitably be expanded in order to reveal both new communities of concern and new perspectives on modes of recompense or resolution.

Finally, we find opportunity in what have become limitations of our own work. In particular, our discussion of the three approaches is not a full representation of their potential contributions to or applications beyond energy systems. Our empirical examples also do not do justice to the scope of concerns they present given the scale and intricacies of global energy systems. Last but not least, we chose to represent the dominant approaches to VSD, RRI and Energy Justice, and yet there are undoubtedly more that carry different emphases. We look forward to contributions that overcome these challenges and ultimately, to the appropriate recognition of all aspects of sociotechnical energy systems from conception through design and operation or refinement, and across all responsible groups.

[1] Friedman, P.H. Kahn Jr, A. Borning, A. Huldtgren, Value sensitive design and information systems, in: N. Doorn, D. Schuurbiers, I. Van de Poel, M. Gorman (Eds.), Early Engagem. New Technol. Open. up Lab., Springer Netherlands, Dordrecht, 2013: pp. 55–95.

[2] European Commission (2020) 'Responsible research and innovation', *European Commission.* Available online at: https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation. Accessed on: 4.5.20.

[3] Jenkins, K., McCauley, D., Heffron, R., Stephan, H. and Rehner, R. (2016) 'Energy justice: A conceptual review', *Energy Research and Social Science* 11: 174-182.

[4] Sovacool, B.K., Burke, M., Baker, L., Kotikalapudi, C.K. and Wlokas, H. (2017) 'New frontiers and conceptual frameworks for energy justice'. *Energy Policy* 105: 677-691.

[5] Sovacool, B.K. and Hess, D.J. (2017) 'Ordering theories: Typologies and conceptual frameworks for sociotechnical change', *Social Studies of Science* 47(5): 703-750.

[6] Geels, F.W., Schwanen, T., Sorrell, S., Jenkins, K. and Sovacool, B.K. (2018) 'Reducing energy demand through low carbon innovation: A sociotechnical transitions perspective and thirteen research debates', *Energy Research 7 Social Science* 40: 23-35.

[7] Levy, B.S. and Patz, J.A. (2015) 'Climate change, human rights, and social justice', *Annals of Global Health* 81(3): 310-322.

[8] Alstone, P., Gershenson, D. and Kammen, D.M. (2015) 'Decentralized energy systems for clean electricity access', *Nature Climate Change* 5: 305-314.

[9] Brown, M.A. and Sovacool, B.K. (2011) 'Climate change and global energy security: Technology and policy options', *MIT Press*

[10] Casillas, C.E. and Kammen, D.M. (2010) 'The energy-poverty-climate nexus', *Science* 330(6009): 1181-1182.

[11] Devine-Wright, P. and Batel, S. (2017) 'My neighbour, my country or my planet? The influence of multiple place attachments and climate change concern on social acceptance of energy infrastructure', *Global Environmental Change* 47: 110-120.

[12] Taebi, B. (2016) 'Bridging the gap between social acceptance and ethical acceptability', *Risk Analysis* 37(1): 1817-1827.

[13] Milchram, C., Hillerbrand, R., van de Kaa, G., Doorn, N. and Kunneke, R. (2018) 'Energy

justice and smart grid systems: Evidence from the Netherlands and the United Kingdom', *Applied Energy* 229: 124-1259.

[14] Hess, D.J. (2019) 'Cooler coalitions for a warmer planet: A review of political strategies for accelerating energy transitions', *Energy Research & Social Science* 57: 101246.

[15] Friedman, B., Kahn Jr, P.H., Borning, A., Huldtgren, A. (2013) 'Value sensitive design and information systems', in: Doorn, N., Schuurbiers, D., Van de Poel, I., Gorman, M. (Eds.), Early Engagement and New Technologies: Opening up the Laboratory. Springer Netherlands, Dordrecht, pp. 55–95.

[16] Albrechtslund, A. (2007) 'Ethics and technology design', *Ethics and Information Technology* 9(1): 63–72.

[17] Davis, J. and Nathan, L.P. (2015) 'Value Sensitive Design: Applications, Adaptations, and Critiques', in: van den Hoven, J., Vermaas, P.E., van de Poel, I. (Eds.), Handbook of Ethics, Values, and Technological Design: Sources, Theory, Values and Application Domains. Springer Netherlands, Dordrecht, pp. 11–40.

[18] Wiener, N. (1988) The human use of human beings: Cybernetics and society. Perseus Books Group.

[19] Weizenbaum, J. (1976) Computer power and human reason: From judgment to calculation., Computer power and human reason: From judgment to calculation. W. H. Freeman & Co, Oxford, England.

[20] Winner, L. (1980) Do Artifacts Have Politics? *Daedalus* 109: 121–136.

[21] Friedman, B., Kahn, P., Borning, A. (2002) 'Value sensitive design: Theory and methods', in: University of Washington Technical Report. University of Washington, Washington, D.C., pp. 2–12.

[22] Dignum, M., Correljé, A., Cuppen, E., Pesch, U., & Taebi, B. (2016). 'Contested Technologies and Design for Values: The Case of Shale Gas', *Science and Engineering Ethics* 22(4): 1171–1191

[23] Mouter, N., de Geest, A., Doorn, N. (2018) 'A values-based approach to energy controversies: Value-sensitive design applied to the Groningen gas controversy in the Netherlands', *Energy Policy* 122: 639–648.

[24] Oosterlaken, I. (2014) 'Applying value sensitive design (VSD) to wind turbines and wind parks: An exploration', *Science and Engineering Ethics* 21(2): 359-379.

[25] Mok, L. and Hyysalo, S. (2018) 'Designing for energy transition through Value Sensitive Design', *Design Studies* 54: 162-183.

[26] Correljé, A., Cuppen, E., Dignum, M., Pesch, U., & Taebi, B. (2015). Responsible

Innovation in Energy Projects: Values in the Design of Technologies, Institutions and Stakeholder Interactions. In E. J. Koops, I. Oosterlaken, H. A. Romijn, T. E. Swierstra, & J. Van den Hoven (Eds.), *Responsible Innovation 2: Concepts, Approaches* and Applications (pp. 183–200). Berlin: Springer International Publishing.

[27] Oosterlaken, I. (2015) 'Human Capabilities in Design for Values: A Capability Approach of "Design for Values", in can den Hoven, J., Vermaas, P. and van de Peol, I. (Eds.) Handbook of Ethics, Values, and Technological Design. Springer, Dordrecht.

[28] Van de Poel, I., Spruit, S. and Robaey, Z. (2018) 'The food warden: An exploration of issues in distributing responsibilities for safe-by-design synthetic biology applications', *Science and Engineering Ethics* 24(6): 1673-1696.

[29] Van de Poel, I, and Z Robaey. (2017) "Safe-by-Design: From Safety to Responsibility." *NanoEthics* 11 (3): 297–306.

[30] Van den Hoven, J, P Vermaas, and I Van de Poel (Eds.) (2015) *Handbook of Ethics and Values in Technological Design: Sources, Theory, Values and Application Domains*. Dordrecht: Springer.

[31] Van de Poel, I (2015). Can we design for well-being, In 'The Good Life in a Technological Age', Chapter: 21, Publisher: Springer, Editors: Brey, P., Briggle, A. and Spence, E. pp.295-306.

[32] Flanagan, M., Howe, D.C., Nissenbaum, H. (2008) 'Embodying values in technology: Theory and practice', in: Van Den Hoven, J., Weckert, J. (Eds.), Information Technology and Moral Philosophy. Cambridge University Press, New York, pp. 322–353.

[33] Taebi, B. and Kadak, A.C. (2010) 'Intergenerational considerations affecting the future of nuclear power: equity as a framework for assessing fuel cycles', *Risk Analysis* 30: 1341–1362.

[34] Van de Poel, I. (2013) Translating Values into Design Requirements, in: Michelfelder, D.P., McCarthy, N., Goldberg, D.E. (Eds.), Philosophy and Engineering: Reflections on Practice, Principles and Process. Springer Netherlands, pp. 253–266.

[35] I. Van de Poel, Values in engineering design, in: A.W.M. Meijers (Ed.), Handb. Philos. Sci., 2009: pp. 973–1006.

[36] Kaa, G van de, J Rezaei, B Taebi, I van de Poel, and A Kizhakenath (2019) "How to Weigh Values in Value Sensitive Design: A Best Worst Method Approach for the Case of Smart Metering." *Science and Engineering Ethics*.

[37] Manders-Huits, N. (2011). 'What values in design? The challenge of incorporating moral values into design', *Science and Engineering Ethics*, *17*(2), 271–287.

[38] Van Wynsberghe, A. and Robbins, S. (2014) 'Ethicist as Designer: A Pragmatic Approach to Ethics in the Lab', Science and Engineering Ethics 20: 947–961.

[39] Umbrello, S. (2019) 'Imaginative Value Sensitive Design: Using Moral Imagination Theory to Inform Responsible Technology Design', *Science and Engineering Ethics*: 1-21.

[40] Hillerbrand, R., Milchram, C. and Schippl, J. (2019) 'The capability approach as a normative framework for technology assessment: Capabilities and digitization in the energy system', *Normativity in Technology Assessment* 28(1): 52-57.

[41] Yetim, F. (2011) 'Bringing Discourse Ethics to Value Sensitive Design: Pathways toward a Deliberative Future'. AIS Trans. Human-Computer Interact. 3: 133–155.

[42] Koops, B.J. (2015) 'The concepts, approaches, and applications of responsible innovation', In Responsible Innovation 2 (pp. 1-15). Springer, Cham.

[43] Owen, R., Macnaghten, P. and Stilgoe, J. (2012) 'Responsible research and innovation: From science in society to science for society, with society', *Science and public policy*, 39(6): 751-760.

[44] Owen, R., Bessant, J.R. and Heintz, M. eds. (2013) 'Responsible innovation: managing the responsible emergence of science and innovation in society'. John Wiley & Sons.

[45] RRI tools, n.d. 'RRI in a nutshell', Available at: https://www.rri-tools.eu/about-rri. Accessed 2.1.2020.

[46] Sutcliffe, H. (2011) A report on responsible research and innovation. *MATTER and the European Commission*.

[47] Genus, A. and Iskandarova, M. (2017) 'Responsible innovation: its institutionalization and a critique', *Technological Forecasting and Social Change* 128: 1-9.

[48] Collingridge, D. (1980) 'The Social Control of Technology'. London, UK: Frances Pinter.

[49] Genus, A. and Stirling, A. (2018) 'Collingridge and the dilemma of control: Towards responsible and accountable innovation', *Research policy* 47(1): 61-69.

[50] Schot, J. and Rip, A. (1997) 'The past and future of constructive technology assessment', *Technological forecasting and social change* 54(2-3): 251-268.

[51] Joss, S. and Belluci, S. (2002). Participatory Technology Assessment: European Perspectives. Gateshead.

[52] Guston, D.H. and Sarewitz, D. (2002) 'Real-time technology assessment', *Technology in society* 24(1-2): 93-109.

[53] Friedman, B. ed. (1997) Human values and the design of computer technology (No. 72). Cambridge University Press.

[54] Wilsdon, J. (2005) 'Paddling upstream: New currents in European technology assessment',

*The future of technology assessment* :22-29.

[55] Barben, D., Fisher, E., Selin, C. and Guston, D.H. (2008) '38 Anticipatory Governance of Nanotechnology: Foresight, Engagement, and Integration' in The handbook of science and technology studies, p.979.

[56] Stilgoe, J. and Guston, D.H. (2017) Responsible research and innovation. Handbook of science and technology studies, pp.853-880

[57] Timmermans, J. (2017) 'Mapping the RRI landscape: An overview of organisations, projects, persons, areas and topics'. In Responsible Innovation 3 (pp. 21-47). Springer, Cham.

[58] Asveld, L., van Dam-Mieras, R., Swierstra, T., Lavrijssen, S., Linse, K., & Van den Hoven, J. (Eds.) (2017) Responsible Innovation 3. A European Agenda? Cham: Springer.

[59] Smallman, M. (2019). Policies designed for drugs won't work for AI. *Nature*, *567*.

[60] Stahl, B.C. and Coeckelbergh, M. (2016) Ethics of healthcare robotics: Towards responsible research and innovation, *Robotics and Autonomous Systems* 86: 152-161.

[61] Genus, A. and Iskandarova, M. (2018) 'Responsible innovation: Its institutionalisation and a critique', *Technological Forecasting and Social Change* 128: 1-9.

[62] Voegtlin, C. and Scherer, A.G. (2017) 'Responsible innovation and the innovation of responsibility: Governing sustainable development in a globalized world', *Journal of Business Ethics* 143(2): 227-243.

[63] European Commission (2013) 'Fact sheet: Science with and for Society in Horizon 2020'. European Commission.

[64] Novitzky, P., Bernstein, M.J., Blok, V., Braun, R., Chan, T.T., Lamers, W., Loeber, A., Meijer, I., Lindner, R. and Griessler, E. (2020) 'Improve alignment of research policy and societal values', *Science* 369: 39–41.

[65] Fiorino, D.J. (1990) "Citizen participation and environmental risk: a survey of institutional mechanisms" in Science, Technology and Human Values, vol. 15/2, pp. 226-243

[66] Richter, J. A., Tidwell, A. S., Fisher, E., and Miller, T. R. (2017) 'STIRring the grid: engaging energy systems design and planning in the context of urban sociotechnical imaginaries', *Innovation: The European Journal of Social Science Research* 30(3): 365-384.

[67] Ravetz, J.R. (1997) The science of 'what-if?', *Futures* 29(6): 533-539.

[68] Stilgoe, J., Owen, R. and Macnaghten, P. (2013) 'Developing a framework for responsible innovation', *Research Policy* 42(9): 1568-1580.

[69] Ortt, J.R., Kamp, L.M., Künneke, R., 2020. How responsible was innovation in subsequent wind power episodes?, in: Ortt, J.R., van Putten, D., Kamp, L.M., van de Poel, I. (Eds.), Responsible Innovation in Large Technological Systems. Routledge, London & New York, pp. 96–114.

[70] Taebi, B., Roeser, S., Van de Poel, I., 2020. Responsible innovation of nuclear energy technologies. Social experiments, intergenerational justice and emotions, in: Ortt, J.R., Van Putten, D., Kamp, L.M., van de Poel, I. (Eds.), Responsible Innovation in Large Technological Systems. Routledge, London & New York, pp. 64–79.

[71] Ortt, J.R., van Putten, D., Kamp, L.M., van de Poel, I. (Eds.), 2020. Responsible Innovation in Large Technological Systems. Routledge, London & New York.

[72] Adam, B. and Groves, C. (2011) 'Futures tended: care and future-oriented responsibility', *Bulletin of Science, Technology & Society*, *31*(1), pp.17-27.

[73] Grinbaum, A. and Groves, C. (2013) What is "responsible" about responsible innovation? Understanding the ethical issues. *Responsible innovation: Managing the responsible emergence of science and innovation in society*, pp.119-142.

[74] Pavie, X. (2014) 'The importance of responsible innovation and the necessity of 'Innovation-Care', *Philosophy of Management* 13(1): 21-42.

[75] Pellé, S. and Reber, B. (2015) 'Responsible innovation in the light of moral responsibility', *Journal on Chain and Network Science* 15(2); 107-117.

[76] Groves, C. (2015) 'Logic of choice or logic of care? uncertainty, technological mediation and responsible innovation', *NanoEthics* 9(3): 321-333.

[77] Preston, C.J. and Wickson, F. (2016) 'Broadening the lens for the governance of emerging technologies: Care ethics and agricultural biotechnology'. *Technology in Society 45*: 48-57.

[78] Pellizzoni, L. (2004) 'Responsibility and environmental governance', *Environmental politics* 13(3): 541-565.

[79] Blok, V., Lemmons, P., 2015. Three Reasons Why It Is Questionable and Calls for a Radical Transformation of the Concept of Innovation, in: Koops, E.J., Oosterlaken, I., Romijn, H.A., Swierstra, T.E., Van den Hoven, J. (Eds.), Responsible Innovation 2: Concepts and Approaches. Springer International Publishing, Berlin, pp. 19–35.

[80] Bergen, J.P., 2017. Responsible Innovation in light of Levinas: rethinking the relation between responsibility and innovation. Journal of Responsible Innovation 4, 354–370. https://doi.org/10.1080/23299460.2017.1387510

[81] Wynne, B., 1987. Uncertainty—technical and social. *Science for public policy*, pp.95-115.

[82] Jonas, H. (1973) "Technology and Responsibility: Reflections on the New Tasks of Ethics," *Social Research: An International Quarterly* 40(1): 31–54.

[83] Jasanoff, S. (2003) 'Technologies of humility: citizen participation in governing science', *Minerva* 41: 223-244

[84] Taebi, B., Kwakkel, J.H. and Kermisch, C. 'Governing climate risks in the face of normative uncertainties'. *WIREs Climate Change n/a*, e666.

[85] IRGC, 2016. Planning Adaptive Risk Regulation. International Risk Governance Council, Lausanne.

[86] Van de Poel, I., 2016. An Ethical Framework for Evaluating Experimental Technology. Sci Eng Ethics 22, 667–686. https://doi.org/10.1007/s11948-015-9724-3

[87] Taebi, B., Roeser, S., Van de Poel, I., 2020. Responsible innovation of nuclear energy technologies. Social experiments, intergenerational justice and emotions, in: Ortt, J.R., Van Putten, D., Kamp, L.M., van de Poel, I. (Eds.), Responsible Innovation in Large Technological Systems. Routledge, London & New York, pp. 64–79.

[88] Grinbaum, A. and Groves, C. (2013) 'What is "responsible" about responsible innovation? Understanding the ethical issues', *Responsible innovation: Managing the responsible emergence of science and innovation in society*: 119-142.

[89] Blok, V. (2018). Innovation as ethos: Moving beyond csr and practical wisdom in innovation ethics. In *Handbook of Philosophy of Management.* Handbooks in Philosophy. Springer, Cham. (pp. 1-14).

[90] Blok, V. (2019) "Innovation as Ethos". In: Neesham C., Segal S. (Eds.) Handbook of Philosophy of Management. Handbooks in Philosophy. Springer, Cham.

[91] Taebi, B., Correljé, A., Cuppen, E., Dignum, M., & Pesch, U. (2014). 'Responsible innovation and an endorsement of public values: the need for interdisciplinary research', *Journal of Responsible Innovation* 1(1): 118–124.

[92] Cuppen, E., Grift, E. van de, & Pesch, U. (2019). Reviewing responsible research and innovation: lessons for a sustainable innovation research agenda? In F. Boons & A. McMeekin (Eds.), *Handbook of Sustainable Innovation* (pp. 142–164). Edgar Online.

[93] Lubberink, R., Blok, V., Van Ophem, J. and Omta, O. (2017) 'Lessons for responsible innovation in the business context: A systematic literature review of responsible, social and sustainable innovation practices', *Sustainability* 9(5): 721.

[94] von Schomberg, R. (2019) "Why responsible innovation?." In the International Handbook on Responsible Innovation. Edward Elgar Publishing.

[95] Gianni, R. (2014) Governance of Responsible Innovation. Framework for the comparison of theories of responsible innovation in research. Available online at: https://www.great-project.eu/D5.1. Accessed on 4.5.20.

[96] Iatridis, K. and Schroeder, D. (2016) 'Responsible Research and Innovation in Industry: The Case for Corporate Responsibility Tools', *SpringerBriefs in Research and Innovation Governance.*

[97] Van den Hoven, J., Doorn, N., Swierstra, T., Koops, B. and Romijn, H. (Eds.) (2014) 'Responsible Innovation 1: Innovative Solutions for Global Issues', Springer Netherlands

[98] Koops, B., Oosterlaken, I., Romijn, H., Swierstra, T. and van den Hoven, J. (Eds) (2015) 'Responsible Innovation 2: Concepts, Approaches, and Applications', *Springer International Publishing*.

[99] Blok, V. and Lemmens, P. (2015) 'The emerging concept of responsible innovation. Three reasons why it is questionable and calls for a radical transformation of the concept of innovation'. In *Responsible Innovation 2* (pp. 19-35). Springer, Cham.

[100] Bergen, J.P. (2017). 'Responsible Innovation in light of Levinas: rethinking the relation between responsibility and innovation', *Journal of Responsible Innovation* 4(3): 354–370.

[101] Pfotenhauer, S.M., Juhl, J. and Aarden, E. (2019) 'Challenging the "deficit model" of innovation: Framing policy issues under the innovation imperative', *Research Policy* 48(4): 895-904.

[102] Michiel van Oudheusden (2014) Where are the politics in responsible innovation? European governance, technology assessments, and beyond, Journal of Responsible Innovation, 1:1, 67-86, DOI: 10.1080/23299460.2014.882097

[103] De Saille, S., 2015. Innovating innovation policy: the emergence of 'Responsible Research and Innovation'. *Journal of Responsible Innovation*, *2*(2), pp.152-168.

[104] Tyfield, D., 2012. A cultural political economy of research and innovation in an age of crisis. *Minerva*, *50*(2), pp.149-167.

[105] Cuppen *et al.* (2015) 'How stakeholder interactions can reduce space for moral considerations in decision making: a contested CCS project in the Netherlands', *Environment and Planning A* 47: 1963-1978.

[106] Chilvers, J. (2010) 'Sustainable participation? Mapping out and reflecting on the field of public dialogue on science and technology', *Summary Report.* Working Paper. Sciencewise Expert Resource Centre, Harwell.

[107] de Saille, S. (2015) 'Dis-inviting the unruly public', *Science as Culture 24*(1): 99-107.

[108] Ruiten, K. (2019) Understanding Social Acceptance. A case study of a siting process of hign-voltage transmission lines in the Southwest of the Netherlands. *TU Delft Repository*

[109] C. Miller, A. Iles, C. Jones, The Social Dimensions of Energy Transitions, Sci. Cult. (Lond). 22 (2013) 135–148.

[110] S.M. Hall, Energy justice and ethical consumption: comparison, synthesis and lesson drawing, Local Environ. 18 (2013) 422–437.

[111] Jenkins, K. (2018) 'Setting energy justice apart from the crowd: Conceptual insights from the environmental and climate justice movements', *Energy Research & Social Science* 39: 117-121.

[112] Jenkins, K., McCauley, D. and Forman, A. (2017) Editorial, 'Energy justice: A policy approach', *Energy Policy* 105: 631-634.

[113] Sovacool, B.K., Lipson, M.M. and Chard, R. (2019) 'Temporality, vulnerability, and energy justice in household low carbon innovations', *Energy Policy* 128: 495-504.

[114] Mundaca, L., Busch, H. and Schwer, S. (2018) '"Successful" low-carbon energy transitions at the community level? An energy justice perspective', *Applied Energy* 218: 292-303.

[115] Malakar, Y., Herington, M.J. and Sharma, V. (2019) 'The temporalities of energy justice: Examining India's energy policy paradox using non-western philosophy', *Energy Research & Social Science* 49: 16-25.

[116] Jenkins, K., Sovacool, B.K. and McCauley, D. (2018) 'Humanizing sociotechnical transitions through energy justice: An ethical framework for global transformative change', *Energy Policy* 117: 66-74.

[117] McCauley, D., Brown, A., Rehner, R., Heffron, R. and van de Graaff, S. (2018) 'Energy justice and policy change: An historical political analysis of the German nuclear phase-out', *Applied Energy* 228: 317-232.

[118] Maher, I. and Stefan, O. (2019) 'Delegation of powers and the rule of law: Energy justice in EU energy regulation', *Energy Policy* 128: 84-93.

[119] Bouzarovski, S. and Simcock, N. (2017) 'Spatializing energy justice', *Energy Policy* 10: 640-648.

[120] Szulecki, K. (2017) 'Conceptualizing energy democracy', *Environmental Politics* 27(1): 21-41.

[121] Smith, J. and High, M.M. (2018) 'Exploring the anthropology of energy: Ethnography, energy and ethics', *Energy Research and Social Science* 30: 1-6.

[122] Petrova, S. (2018) 'Encountering energy precarity: Geographies of fuel poverty among young adults in the UK', *Transactions of the Institute of British Geographers* 43: 17-30.

[123] Jenkins, K.E.H., Stephens, J., Reames, T. and Hernandez, D. (2020) 'Towards impactful energy justice research: Transforming the power of academic engagement', *Energy Research and Social Science*. In press.

[124] McCauley, D., Heffron, R., Stephan, H. and Jenkins, K. (2013) 'Advancing energy justice: The triumvirate of tenets', *International Energy Law Review* 32(3): 107-110.

[125] Schlosberg, D. (2007) 'Defining Environmental Justice: Theories, Movements, and Nature', Oxford University Press, New York.

[126] Rawls, J. (1999) 'A theory of justice', Belknap Press of Harvard University Press, Cambridge, Mass.

[127] I.M. Young, Justice and the Politics of Difference, Princeton University Press, Princeton, New Jersey, 1990.

[128] Fraser, N. (1996) 'Justice interruptus: Critical reflections on the "postsocialist" condition', New York: *Routledge.*

[129] Forman, A. (2017) 'Energy justice at the end of the wire: enacting community energy and equity in Wales', *Energy Policy* 107: 649-657.

[130] Sovacool, B.K. and Dworkin, M.H. (2015) 'Energy justice: Conceptual insights and practical applications', *Applied Energy* 142(C): 435-444.

[131] Honneth, A. (2004) 'Recognition and justice: Outline of a plural theory of justice', *Acta Sociologica* 47(4): 351-364.

[132] Wong, C.M.L. (2016) 'Assembling interdisciplinary energy research through an Actor Network Theory (ANT) frame, *Energy Research & Social Science* 12: 106-110.

[133] Day, R. and Walker, G. (2013) 'Household energy vulnerability as "assemblage". In Bickerstaff, K., Waler, G. and Bulkeley, H. (Eds.) 'Energy justice in a changing climate', Zed Books. London pp. 14-30.

[134] R. Day, G. Walker, N. Simcock, Conceptualising energy use and energy poverty using a capabilities framework, Energy Policy. 93 (2016) 255–264.

[135] Castán Broto, V., Baptista, I., Kirshner, J., Smith, S. and Alves, S.N. (2018) 'Energy justice and sustainability transitions in Mozambique', *Applied Energy* 228: 645-655.

[136] Jenkins, K. and Taebi, B. (2019) 'Multinational energy justice for managing multinational risks: A case study of nuclear waste repositories', *Risk, Hazards and Crisis in Public Policy* 10(2):176-196.

[137] McCauley, D. and Heffron, R. (2018) 'Just transition: Integrating climate, energy and environmental justice', *Energy Policy* 199: 1-7.

[138] Heffron R.J., McCauley, D. and Sovacool, B.K. (2015) 'Resolving Society's Energy Trilemma through the Energy Justice Metric', *Energy Policy*, 87: 168-176.

[139] Oceransky, S. (2010) 'Fighting the enclosure of wind: Indigenous resistance to the privitization of wind resources in Southern Mexico. In Abramsky, K. (ed.) 'Spartking a worldwide energy revolution. Social struggles in the transition to a post-petrol world. California: AK Press.

[140] Yenneti, K., Day, R. and Golubchikov, O. (2016) 'Spatial justice and the land politics of renewables: dispossessing vulnerable communities through solar energy mega-projects', Geoforum, vol. 76, pp. 90-99.

[141] Köhler, J., Geels, F. Kern, F., Markard, J. Wieczorek, A.J., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fuenfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Muehlemeier, S., Nykvist, B., Onsongo, E., Pel, B., Raven, R., Rohracher, H., Sanden, B., Schot, J., Sovacool, B.K., Turnheim, B., Welch, D., and Wells, P. (2019) 'An agenda for sustainability transitions research: State of the art and future directions', *Environmental Innovation and Societal Transitions* 31: 1-32.

[142] Sovacool, B.K., Hook, A., Martiskainen, M., and Baker, M. (2019) 'The whole system energy injustice of four European low-carbon transitions', *Global Environmental Change* 58: 101958.

[143] Newell, P. and Mulvaney, D. (2013) 'The political economy of the 'just transition', *The Geographical Journal* 179(2): 132-140.

[144] Raman, S. and Mohr, A. (2014) 'Biofuels and the role of space in sustainable innovation journeys', *Journal of Cleaner Production* 65: 224-233.

[145] Romijn, H.A. and Caniëls, M. (2011) 'The Jatropha biofuels sector in Tanzania 2005-2009: Evolution towards sustainability?' *Research Policy* 40(4): 618-636.

[146]Seyfang, G. and Smith, A. (2007) 'Grassroots innovations for sustainable development: Towards a new research and policy agenda', *Environmental Politics* 16(4): 584-603.

[147] Pesch, Y., Correljé, A., Cuppen, E. and Taebi, B. (2017) 'Energy justice and controversies: Formal and informal assessment in energy projects', *Energy Policy* 109: 825-834.

[148] Jenkins, K., McCauley, D., Heffron, R. and Stephan, H. (2014) 'Energy justice, a whole systems approach'. *Queen's Political Review* 2(2): 74-87.

[149] McCauley, D., Ramasar, V., Heffron, R.J., Sovacool, B.K., Mebratu, D. and Mundaca, L.

(2019) ‘Energy justice in the transition to low carbon energy systems: Exploring key themes in interdisciplinary research’, *Applied Energy* 109: 916-921.

[150] ENGAGER (2020) ‘Aims and objectives’, *Energy Poverty Action.* Available at: http://www.engager-energy.net/aims-and-objectives/. Accessed 9.3.30

[151] Heffron, R.J. and McCauley, D. (2017) ‘The concept of energy justice across the disciplines’, *Energy Policy* 105: 658-667.

[152] Bombaerts, G., Jenkins, K.E.H., Sanusi, Y. and Wang, G. (2019) ‘Energy justice across borders’, Springer International Publishing.

[153] Carbajo, R. and Cabeza, L.F. (2018) ‘Renewable energy research and technologies through responsible research and innovation looking glass: Reflections, theoretical approaches and contemporary discourses’, *Applied Energy* 211: 792-808.

[154] Baker, S.H. (2019) ‘Anti-Resilience: A Roadmap for Transformational Justice within the Energy System’, *Harvard Civil Rights- Civil Liberties Law Review (CR-CL)*, 54: 1-48.

[155] Hernández, D. and Siegel, E. (2019) ‘Energy insecurity and its ill health effects: A community perspective on the energy-health nexus in New York City’, *Energy Research & Social* Science 47: 78-83.

[156] Hiteva, R. and Sovacool, B.K. (2017) ‘Harnessing social innovation for energy justice: A business model perspective’, *Energy Policy* 107: 631-639.

[157] Sovacool, B.K. (2014) What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda’, *Energy Research & Social Science* 1: 1-29.

[158] Lorentz Centre (2019) ‘Exploring the role of values in RRI for energy systems’, *Lorentz Center@Oort.*

[159] Van den Hoven, J., Jacob, K., Nielsen, L., Roure, F., Rudze, L., & Stilgoe, J. (2013). Options for Strengthening Responsible Research and Innovation. Report of the Expert Group on the State of Art in Europe on Responsible Research and Innovation. Brussels: European Commission.

[160] RRI-EU (2020) ‘Responsible research & innovation’, Available at: https://ec.europa.eu/programmes/horizon2020/en/h2020-section/responsible-research-innovation Accessed 10.03.2020

[161] Stirling, A. (2014) ‘Transforming power: Social science and the politics of energy choices’, *Energy Research & Social Science* 1: 83-95.

[162] Pols, A. and Spahn, A. (2015) ‘Design for the Value of Democracy and Justice.’ In Handbook of Ethics, Values, and Technological Design: Sources, Theory, Values and

Application Domains, edited by J Van den Hoven, P Vermaas, and I Van de Poel, 335–63. Dordrecht: Springer.

[163] Taebi, B. and Kloosterman, J.L. (2015) "Design for Values in Nuclear Technology." In *Handbook of Ethics, Values, and Technological Design: Sources, Theory, Values and Application Domains*, edited by J Van den Hoven, P Vermaas, and I Van de Poel, 805–29. Dordrecht: Springer.

[164] Cuppen, E., Pesch, U., Remmerswaal, S., & Taanman, M. (2019). 'Normative diversity, conflict and transition: shale gas in the Netherlands', *Technological Forecasting and Social Change.*

[165] Pesch, U, Correljé, A., Cuppen, E., Taebi, B. and van de Grift, E. (2017) "Formal and Informal Assessment of Energy Technologies." In *Responsible Innovation 3. A European Agenda?*, edited by L Asveld, R van Dam-Mieras, T Swierstra, S Lavrijssen, K Linse, and J Van den Hoven, 131–48. Cham: Springer.

[166] Van de Poel, I. (2018). 'Design for value change', *Ethics and Information Technology*, 1–5.

[167] Balta-Ozkan, N., Davidson, R., Bicket, M., Whitmarsh, L. (2013) 'Social barriers to the adoption of smart homes', *Energy Policy* 63, 363–374.

[168] Sovacool, B.K. (2019) 'The precarious political economy of cobalt: Balancing prosperity, poverty, and brutality in artisanal and industrial mining in the Democratic Republic of Congo', *The Extractive Industries and Society* 6(3): 915-939.

[169] Jenkins, K., McCauley, D. and Warren, C. (2017) 'Attributing responsibility for energy justice: A case study of the Hinkley Point Nuclear Complex', *Energy Policy* 108: 836-843.

[170] Taebi, B., Kwakkel, J.H. and Kermisch, C. 'Governing climate risks in the face of normative uncertainties'. *WIREs Climate Change n/a*, e666.

[171] Stirling, A. (2008) "Opening up" and "closing down" power, participation, and pluralism in the social appraisal of technology. *Science, Technology, & Human Values* 33(2): 262-294.

[172] De Hoop, E., Pols, A. and Romijn, H. (2016) 'Limits to responsible innovation', *Journal of Responsible Innovation* 3(2): 110-134.

[173] Srinivas, K.R. and Pandey, P. (2019) 'Chapter 30: Indian perspectives on responsible innovation and frugal innovation', in the International Handbook on Responsible Innovation. Edward Elgar Publishing.

[174] Hartley, S., McLeod, C., Clifford, M., Jewitt, S. and Ray, C. (2019) 'A retrospective analysis

of responsible innovation for low-technology innovation in the Global South', *Journal of Responsible Innovation* 6(2): 143-162.

[175] Gao, L., Liao, M. and Zhao, Y. (2019) 'Exploring complexity, variety and the necessity of RRI in a developing country: the case of China', *Journal of Responsible Innovation* 6(3): 368-374.