Consumer-Centric Electricity Markets: Six Design Principles

Anne Michaelis[a,b,*], Lisa Hanny[c,d], Marc-Fabian Körner[a,b], Jens Strüker[a,b], Martin Weibelzahl[a,b,e]

[a] University of Bayreuth, FIM Research Center for Information Management, Wittelsbacherring 10, 95444 Bayreuth, Germany

[b] Fraunhofer FIT, Branch Business & Information Systems Engineering, Wittelsbacherring 10, 95444 Bayreuth, Germany

[c] University of Applied Sciences Augsburg, FIM Research Center for Information Management, Alter Postweg 101, 86159 Augsburg, Germany

[d] Fraunhofer FIT, Alter Postweg 101, 86159 Augsburg, Germany

[e] SnT – Interdisciplinary Center for Security, Reliability and Trust, University of Luxembourg, 29, Avenue John F. Kennedy, 1885 Luxembourg

[*] Corresponding author
E-Mail address: anne.michaelis@fit.fraunhofer.de

Abstract: Key to the necessary decarbonization of energy systems is the large-scale expansion of renewable energy sources and their integration into the electricity system. This integration is challenging because the feed-in from renewable energy sources is highly intermittent and largely dependent on uncontrollable factors such as weather patterns. To maintain grid stability, which refers to the required balance between demand and supply in the electricity system, flexibility is key. Large flexibility potentials can be found on the electricity demand side. However, current electricity market design in Europe, while providing major flexibility incentives, often neglects small-scale electricity consumers and distributed energy resources. We contribute to shape future electricity markets with consumers at the heart by developing six design principles for a consumer-centric electricity market design. We proceed by conducting a systematic literature review and evaluate the findings by expert interviews. Based on the developed design principles, we define a consumer-centric electricity market design as a set of market rules that align with the rules of other relevant energy markets and allow for the efficient matching of electricity demand and supply, with consumers having nondiscriminatory market access, being exposed to fine-grained price signals, being able to express their preferences, and having sufficient possibilities to protect themselves against unexpected price spikes. By actively incorporating consumers into electricity markets, we contribute to the overarching goal of integrating renewable energy sources while promoting energy justice, i.e., supporting a balanced mix of economic, political, environmental, and social interests.

Keywords: Energy transition, electricity, flexibility, energy justice, consumer-centric electricity market, consumer-centric market design, consumer participation, demand side participation

1. Introduction

To meet the 1.5-degree goal outlined in the Paris Agreement, rapid decarbonization of the energy sector is essential [1]. Current decarbonization efforts, however, are insufficient, potentially leading to global temperature increases of up to 2.4 degrees [2]. As a result, global efforts to reduce greenhouse gas emissions need to be significantly enhanced to ensure that international climate goals remain attainable and to preserve a habitable planet for present and future generations. Intensifying decarbonization efforts in the energy sector is complex, necessitating far-reaching changes, encompassing the way that electricity is generated and consumed [3]. Such changes inevitably impact the economy and society at large, raising concerns about balancing the interests, needs, and new opportunities of stakeholders in the energy system. This ties directly to the concept of energy justice in a future decarbonized world [4] [5].

Regarding electricity generation, a crucial step toward decarbonization is the large-scale expansion of renewable energy sources (RES) and their integration into the electricity system. This integration is challenging due to the highly intermittent feed-in of RES, influenced by variable factors such as time of day or season. To maintain the stability of the underlying electricity grid, i.e., the balance of electricity demand and supply, flexibility is key. In this context, flexibility is defined as the ability to swiftly respond to fluctuations in renewable electricity production and potential forecast errors [6,7]. Sources of flexibility could come from the electricity demand side, such as industrial companies, household consumers, or distributed energy resources (DER) like electric vehicles. Demand-side flexibility, in this context, refers to the flexible adaption of demand patterns, such as shifts in industrial production processes or household consumption in response to electricity system needs [8]. Despite the pressing need for DER integration and consumer integration for a successful energy transition, outdated regulations often prevent small-scale electricity consumers in particular from actively participating in many electricity systems.[1]

The described global challenges related to RES (and complementary demand flexibility from consumers / DERs), are also present in the European Union (EU). The unveiled “Fit for 55” package sets forth ambitious climate objectives, such as becoming the world’s first climate-neutral continent by 2050 [12]. To achieve this goal, the EU underscores the urgency for the rapid and large-scale expansion of RES across all member states. The European Commission also highlights the vast potential of demand-side flexibility and expressly emphasizes the challenge and necessity of placing “consumers at the heart of the energy transition” [13]. In its latest consultation document, the European Commission indicates that European electricity markets currently fall short in meeting new requirements and effectively incorporating new energy technologies such as demand-side flexibility [14]. Consequently, the European Commission proposes a fundamental overhaul of electricity wholesale markets to better integrate consumers [14].

Despite initial measures such as the Block Exchange Notification of Demand Response in France [15], many EU electricity consumers have limited avenues to offer their flexibility as a grid- or system-stabilizing service [16]. This is because European electricity spot markets, designed in the 1990s, were initially predicated on the idea that controllable electricity supply

[1] Notwithstanding the general problem of outdated regulation, first examples to leverage demand-side flexibility on various electricity and flexibility markets can be found [9] for instance in Australia in the form of a Wholesale Demand Response Mechanism [10] or in Great Britain in the form of a Demand Flexibility Service [11].

would align with electricity demand (not vice versa) [17]. However, modern electricity markets are pivotal for flexibility provision and investments, providing key economic incentives for consumers to actively monetize their flexibility, i.e., achieve cost savings by adjusting their electricity consumption. Ideally, market prices should echo the economic value of flexibility at specific times and locations, promoting flexibility precisely when and where it is essential to address grid congestion or system imbalances. Thus, opening up electricity spot markets to all consumers and making market design more "consumer-centric" is crucial to fully leverage demand-side flexibility. Participating in electricity spot markets offers consumers greater autonomy in their electricity purchases, direct access to electricity, and control over their temporal consumption behavior, impacting their electricity bills and their CO_2 footprint.

Involving consumers into electricity markets is highly nontrivial, as it drastically increases the number of players, which complicates the process of market clearing or matching demand with supply. New challenges also emerge for consumers, as active market participation demands consumers to have at least a basic understanding of market rules together with a constant monitoring of market dynamics, such as electricity prices or the behavior of other market participants.

Recent deployments of digital technology solutions like smart meters or real-time mobile applications, can help in managing the growing number of (decentralized) market participants and flexibility assets, thus supporting the tangible implementation of consumer-centric electricity markets. These digital technology solutions enable greater automation of electricity purchases and flexibility marketing, acting as a crucial "decision support" for electricity consumers, e.g., by making flexibility provision revenues more transparent and understandable [18].

Ultimately, successfully opening up electricity markets to all consumers and making market design consumer-centric is important, allowing electricity consumers to actively contribute to the energy transition, e.g., by capitalizing their flexibility and investing in new climate-friendly technologies such as heat pumps or electric vehicles [19]. This not only promotes the integration of RES (and, thus, the energy transition), but also advances energy justice, i.e., a just and equitable balance of economic, political, environmental, and social interests [5]. This is the case, as the energy transition requires a huge societal effort, necessitating the engagement of every stakeholder in the electricity system as described before, i.e., every individual electricity consumer [20]. However, the concrete rules for a consumer-centric market design (CCMD) need to be chosen judiciously to properly incentivize consumers to actively engage in market interactions and respond to market signals in both the short and medium terms [21]. Thus, a CCMD needs to adhere to certain design principles, outlining the overarching goals of consumer-centric electricity markets, from which specific rules can be derived. Against this backdrop, we pose the following research question: What are design principles for a consumer-centric market design in European electricity spot markets? In addressing this research question, we contribute to the fields of electricity market design [22–24] and energy justice [25–27], fields in which consumer centricity is emerging as an essential part of future electricity markets (see also Section 2 for more details).

Our article is structured as follows: Section 2 delves into relevant background and related literature regarding challenges of the energy transition, the need for consumer engagement, and the different forms of energy justice. In Section 3, we present our methodology: We develop design principles by conducting a systematic literature review and interviewing electricity market-design experts to derive a clear vision of future consumer-centric electricity spot markets in Europe. Subsequently, in Section 4, we present the developed design principles for a CCMD and the resultant definition of a CCMD, discussing how these derived design principles contribute to energy justice. Lastly, Section 5 draws main conclusions and summarizes the article.

2. Background and related research

This section establishes the theoretical foundation for the following sections, especially for Section 4, which presents the design principles of a CCMD and discusses the contributions of a CCMD to the evolution of energy justice. Therefore, in Section 2.1, we illustrate general challenges of the energy transition and the importance of CCMD. In Section 2.2, we then provide a definition of energy justice and elaborate on its varied forms.

2.1 Challenges of the energy transition

The energy transition presents challenges to electricity systems worldwide. It necessitates the large-scale integration of DER like renewable energies in the near future. However, integrating high volumes of DER requires appropriate flexibility resources that can accommodate the intermittency of RES, given their dependency on unpredictable factors such as the time of day or season. Flexibility resources are instrumental in addressing the unique attributes of renewable-based electricity systems, as they assist in balancing intermittent electricity supply and demand at all times in the network [8,28]. A broad range of these flexibility resources already exists today, including controllable electricity generators, storage technologies, sector coupling, grid upgrades, and controllable loads such as consumer devices or industrial processes [17]. Demand-side flexibility is especially gaining traction due to its relatively low cost compared to large-scale storage technologies or grid expansions [28]. Moreover, demand flexibility does not face public acceptance challenges or protracted administrative approval processes. The flexibility potential of households and consumer devices, including electric vehicles and heat pumps, is projected to reach up to 162.4 TWh by 2050 in Germany [29]. Harnessing this vast flexibility potential will require the inclusion of small-scale electricity consumers in electricity systems, empowering these customers to optimize their flexibility in line with electricity system requirements.

Despite the need for leveraging demand-side flexibility, many small-scale electricity consumers in Europe, especially households or individual devices, remain sidelined from market interactions due to outdated regulations or market designs [30]. While the role of electricity consumers has strengthened over the years, exemplified by increased freedom in choosing electricity suppliers, electricity consumers "behind the meter" remain largely outside the competitive space in electricity markets in Europe [3]. This exclusion is problematic, as it prevents consumers from reacting to market signals or profiting from their flexibility, leading to untapped flexibility potentials.

2.2 The need for a consumer-oriented market design

Electricity market design is critical to overcoming current barriers to consumer participation, as it can potentially open the market to small-scale electricity consumers and lower entry barriers, especially regarding offering flexibility on electricity markets. A future-oriented market design might recognize flexibility "as a service", generating monetary incentives for electricity consumers.

However, market design is not only about granting market access to electricity consumers, but also about creating the right incentives for active engagement and a far-reaching flexibility provision. By using the term market design, we primarily focus on the design of European electricity spot markets, but also consider possible ramifications for other markets, such as balancing markets or futures. Notably, spot markets set central price signals for futures markets [31]. In general, market design is a set of rules that structures interaction and information exchange to facilitate transactions [31]. While some electricity consumers, such as energy-intensive industries, can already participate in most of today's markets, their participation underscores the need to expand the scope of market design beyond mere market access: Despite potential access, many electricity-intensive companies in Germany largely avoid active flexibility provision. This is because market signals are heavily skewed by levies, taxes, and outdated regulations, which sometimes even penalize flexibility provision by these companies [32]. Simply opening electricity markets to small-scale consumers such as households or DER will not fully realize their flexibility potential unless the market design encourages active flexibility provision and simultaneous deployment of/investment in facilitating technologies. Hence, market design should be "consumer-centric", focusing not only on market access, but also on setting targeted incentives for active consumer engagement in the short and medium terms.

2.3 Forms of energy justice

Transitioning to a decarbonized electricity system with net-zero emissions is a multifaceted endeavor, affecting various electricity system stakeholders including policymakers, investors, and consumers. Addressing and balancing the diverse economic, environmental, and political interests of these stakeholders emerges as a crucial challenge in electricity market design, termed the "energy trilemma" [5,33]. The energy trilemma is often visualized as a triangle, with economic (e.g., amortization of investments and affordability of electricity), environmental (e.g., decarbonization and climate change mitigation), and political (e.g., security and affordability of supply) dimensions at the vertices. Energy justice is located in the center of this triangle, striving for a just and equitable balance between the three dimensions of the energy trilemma [5] (see Figure 1). By targeting a just and equitable balance, energy justice extends beyond economic efficiency or the optimization of the interplay of the different interests [5]. Instead, energy justice aims to cater to society's members, including small-scale electricity consumers and DER, ensuring a habitable environment for present and future generations. Consequently, energy justice leans on related areas such as environmental and climate justice, but with a clear directive to derive actionable policy implications for solving the energy trilemma [34–36].

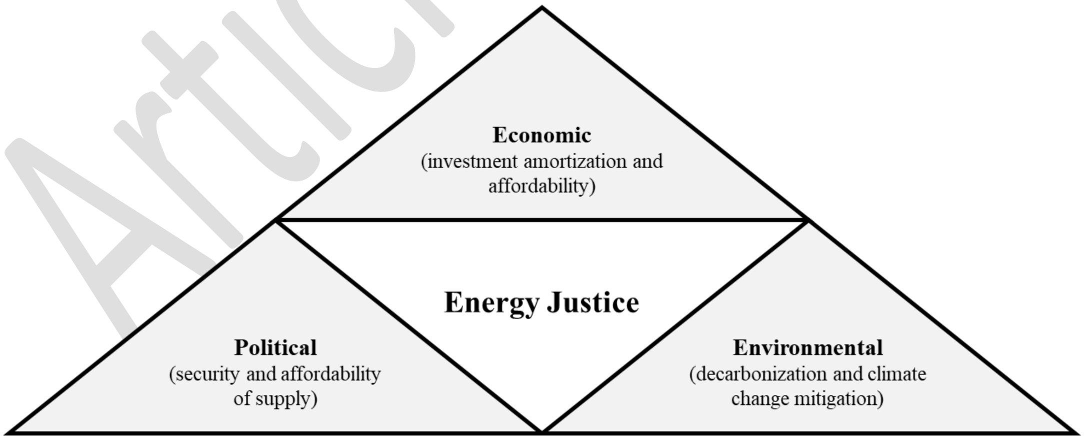

Figure 1: Energy justice aims at balancing the energy trilemma according to Heffron et al. (2015)

Given its focus on policy implications and practical implementation, energy justice serves as a pivotal driver in shaping upcoming electricity markets and rectifying past "policy failures" [32,37]. In this context, energy justice seeks to derive policy implications that address collapsed incentives, abandoned projects, missteps, and misguided decisions [37]. One such corrective measure might involve enhancing consumer integration in electricity markets, a facet that was not central to political discourse when the current market design was established. Energy justice is now pushing for greater fairness, equality, equity, and inclusivity for electricity consumers in political decision-making, ensuring that justice becomes the cornerstone of future electricity markets [37]. Conversely, upcoming electricity market designs need to explicitly encompass energy justice in its five distinct forms, as follows [5,34]:

- **Distributive justice** focuses on the fair distribution of environmental benefits and ills from a physical perspective, but also on their associated responsibilities, as well as economic returns.
- **Procedural justice** aims at establishing processes that are open for all stakeholders in a non-discriminatory way.
- **Recognition justice** refers to equal rights of all stakeholders and the absence of physical threats or any other undue influence in decision-making.
- **Restorative justice** stipulates the rectification of any injustice caused in energy systems, e.g., by the means of legal arbitration procedures.
- **Cosmopolitan justice** states that every member of society must contribute a "fair share" in reaching common goals like the energy transition – also beyond national borders.

3. Method

To address our identified research gap, we employ the design science research (DSR) approach outlined by [38] and adopt the design science research methodology (DSRM) by [39], which comprises six iterative phases: problem identification, objectives of a solution, design and development, demonstration, evaluation, and communication (see Figure 2) [39].

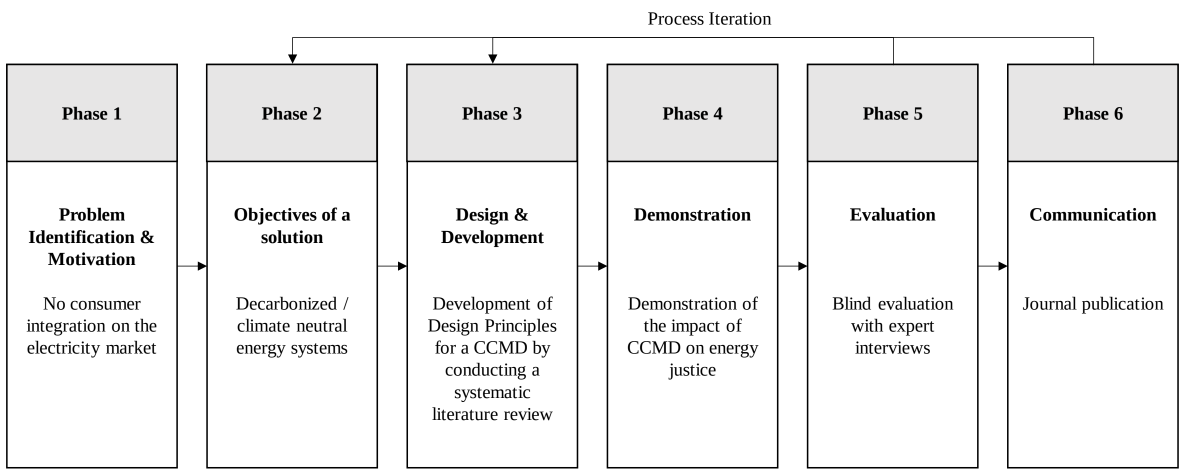

Figure 2: Components of the DSRM process according to Peffers et al. (2007)

3.1 Problem identification and motivation

In line with the chosen research method, we begin by *identifying a problem* of practical relevance. As highlighted in the previous sections, especially small-scale electricity consumers and DERs are not actively integrated into current electricity markets. Our motivation is to open electricity markets for all consumers and to make the market design more "consumer-centric".

3.2 Objectives of a solution

Next, we define the *objectives of a potential solution* to the identified problem. The potential solution should support the integration of consumers and in this way foster energy justice. It should also contribute to the energy transition and a future decarbonized energy system.

3.3 Design and development

As part of the *design and development* phase of design principles for a CCMD, we conduct a systematic literature review in line with [40–42] (see Figure 3). We employ the methodology of a systematic literature review, as this allows us to reflect upon the body of published research. Following the guidelines by [40–42], we (1) define the search term, (2) search in data base, (3) select relevant articles, (4) analyze articles, and (5) present results.

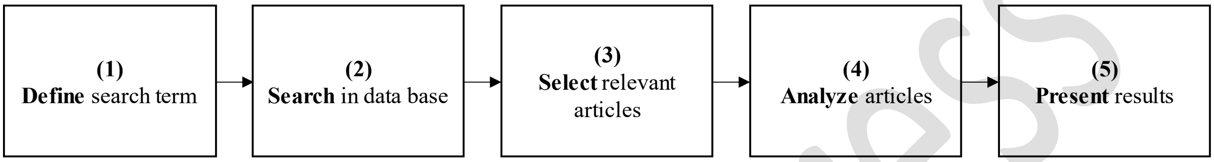

Figure 3: Systematic literature review process according to Wolfswinkel et al. (2013)

In defining the search term (1), we consider three components, resulting in the following search string:

(“DER” OR “distributed energy resources” OR “consumer” OR “consumer-centric” OR “consumer centric” OR “behind the meter”) AND (“electric*” OR “power”) AND (“market design” OR “market engineering”)

For our database (2), we select Scopus because it is one of the largest abstract and citation databases for peer-reviewed literature. The initial search in June 2022 returned 303 articles. We then conduct title, abstract, and full-text screening (3). We exclude articles that do not concern day-ahead, intraday, or balancing markets, i.e., local electricity- or flexibility markets, or peer-to-peer trading. However, we include papers on retail markets, because they are closest to consumers and we also include papers addressing prosumers, because they will continue to play an important and active role in the future electricity market [43]. After the title and abstract screening, 39 articles remain for detailed full-text reading (see Figure 4). A forward-backward reference search yielded eight additional relevant articles. We then analyze the chosen articles (4) and develop the initial design principles for a CCMD (5).

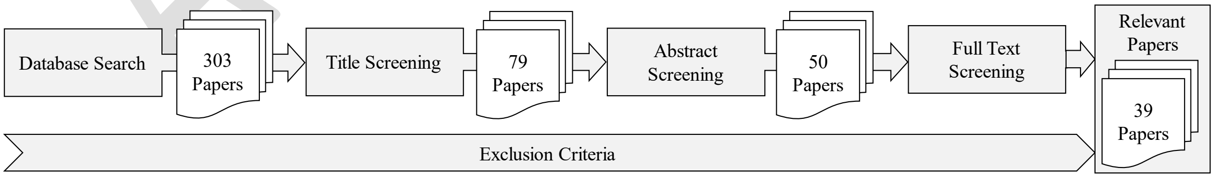

Figure 4: Paper screening process

To formulate the design principles for a CCMD, we adapt the scheme of [44] for developing design principles. We express the design principles in words as follows:

Design Principle Name: For an *Implementer* to achieve or allow for an *Aim* for a *User* in a *Context*, employ *Mechanisms* M_1, M_2, … M_n involving *Enactors* E_1, E_2, … E_n [44].

3.4 Demonstration

As part of the *demonstration*, we illustrate the impact of CCMD on energy justice in Section 4.

3.5 Evaluation

To enhance the projectability of the design principles, we evaluate and refine the design principles through iterative *evaluation* cycles. For this, we conduct qualitative, semi-structured expert interviews, adhering to the recommendations of [45] and [46]. We use these expert interviews as a blind evaluation to mitigate bias [47]. Our interviews are guided by a questionnaire featuring open questions, such as "What do you understand by CCMD?", "How should a CCMD be designed?", and "What measures are needed to implement a CCMD in practice?". We pre-tested the guiding questionnaire before conducting the expert interviews. Regarding our interview partners, we target experts in European electricity market design. In addition to researchers that work in this very innovative and emerging field, we also interviewed experts from market and system operation sectors. We observed that no additional insights regarding our design principles for a CCMD were provided in the last three interviews. Hence, we conclude the interview process. Of the 15 interviewed experts in European electricity market design, we interviewed five experts in person and ten experts via video call. The interviews lasted from approximately half an hour to one hour. Table 1 presents an overview of the interviewed experts, their business domain, their job title, and the interview style.

Table 1: Overview of the interview partners

ID	Business Domain	Job title	Interview style
# 1	Research Institute	Senior Researcher	In person
# 2	Market and System Operation	Senior Professional	Via video call
# 3	Research Institute	Researcher	In person
# 4	Research Institute	Senior Researcher	In person
# 5	Market and System Operation	Senior Professional	Via video call
# 6	Research Institute	Senior Researcher	In person
# 7	Market and System Operation	Consultant	Via video call
# 8	Research Institute	Researcher	In person
# 9	Market and System Operation	Team Lead	Via video call
# 10	Research Institute	Researcher	Via video call
# 11	Market and System Operation	Professional	Via video call
# 12	Research Institute	Researcher	Via video call
# 13	Market and System Operation	Professional	Via video call
# 14	Research Institute	Researcher	Via video call
# 15	Research Institute	Researcher	Via video call

[48] suggest that between 11 to 20 interviews, a saturation is typically reached. After this number, the value of additional interviews decreases [48]. We achieved this recommended interview count. All interviews were audio-recorded and transcribed, allowing us to align the responses with our literature-based design principles. In an iterative process, we re-evaluate the design principles for a CCMD and their implications for energy justice. Section 4 presents the final design principles, and discusses their implications for energy justice.

3.6 Communication

In Phase 6, we share our findings through this article, thereby disseminating our research findings, especially our design principles for a CCMD and their implications for energy justice.

4. Toward a consumer-centric market design

Based on our systematic literature review and further validated through expert interviews, we present our developed six design principles for a CCMD in Section 4.1. Following this, Section 4.2 provides a definition of a CCMD.

4.1 Design principles for consumer-centric market design

For an enhanced utilization of RES, it is essential that electricity markets are open to all consumers and ensure consumer-centricity. Such openness and centricity would enable consumers to sell their self-generated electricity and/or offer flexibility in their electricity consumption. In this regard, the specific design choices for a CCMD must be carefully selected to ensure the right incentives are in place. Here, we present our design principles for a CCMD.

Figure 5 illustrates the six derived design principles for a CCMD with the overall aim to integrate DER and RES into the system.

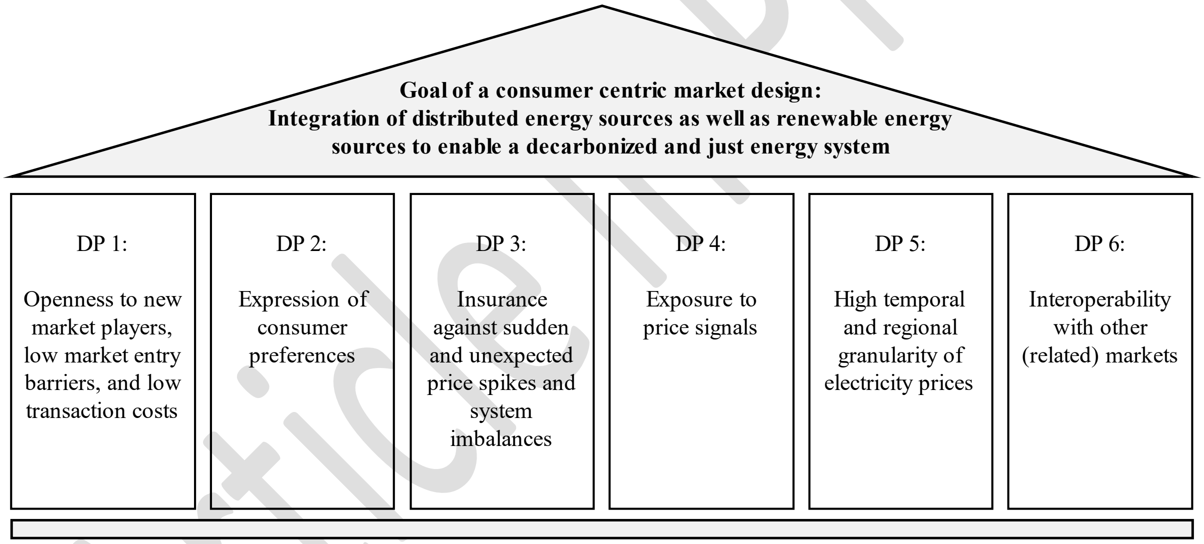

Figure 5: Key design principles of a future-proof CCMD

In Table 2, we provide a more detailed overview of the developed design principles for a CCMD. In the sections that follow, we present the design principles, as stated in Section 3, in the following scheme adopted from [44]: *Design Principle Name:* For an *Implementer* to achieve or allow for an *Aim* for a *User* in a *Context*, employ *Mechanisms* M_1, M_2, ... M_n involving *Enactors* E_1, E_2, ... E_n.

Design Principle 1: Openness to new market players, low market entry barriers, and low transaction costs

The first design principle we developed for a CCMD states that a CCMD should be open to new market players and that market entry barriers and transaction costs for participation must be low. It is for instance crucial that there is a low entry threshold (e.g., small minimum trading volumes) and as little complexity as possible in order for the CCMD to gain acceptance and, consequently, generate active participation from consumers. Transaction costs are relevant at various levels. For example, the knowledge requirements should not be excessive, participation should be possible with minimal time and effort, and the monetary costs of participation should be kept to a minimum.

Granting access to wholesale electricity markets for small electricity consumers and automated consumer devices such as DER (M1) is an example to achieve this design principle. The integration and encouragement of aggregators (M2) and prosumers (M3) to participate in electricity markets further ensures that the CCMD remains open to new market players. Market transparency (M4) is essential for low-complexity participation, implying that market players should have access to pertinent market-related information to actively engage in the electricity market.

To implement a CCMD, adjustments at the regulatory level are necessary. For example, consumers have to be legally empowered to participate in the wholesale electricity market (E1). Additionally, another enactor that makes market participation easier are digital applications and smart devices, like smart meters, with which it is possible to use newly generated and necessary data (E2). To gain insights into the expected behavior of other, new market players, approaches from behavioral economics may be employed (E3).

Exemplary Potentials of Design Principle 1 to Foster Energy Justice

Currently, regulatory measures and market design often hinder the integration of consumers into the system, e.g., consumers cannot sell electricity from their photovoltaic (PV) system on the roofs of their respective household on markets. Thus, the CCMD addresses the question of how these currently excluded consumers can also become an active part of the market. Against this backdrop, the first design principle for the CCMD, "**Openness to new market players, low market entry barriers, and low transaction costs**", carries direct implications for energy justice. Returning to the different forms of energy justice, it is evident that by opening the market to new players, all consumers could potentially participate in the market. This would advance **recognition justice**, because the CCMD can establish equal rights for all consumers, including, e.g., those in structurally weak regions. At the same time, the design principle would also contribute to **procedural justice,** as the CCMD builds on processes that are open to all consumers in a non-discriminatory manner. In addition to that, the CCMD enables every individual to contribute to the energy transition and, thus, **cosmopolitan justice** also plays a significant role. **Distributive justice** also holds significance, as low market entry barriers and transaction costs can generally permit every individual to participate and share benefits, e.g., from flexibility marketing. It is worth noting that while the installation of a PV system on the roof or the purchase of an electric vehicle for the storage of electricity is typically feasible for affluent individuals, especially in the Western world also poor households have in many cases at least some flexibility potentials, e.g., a dishwasher, cooling system, or balcony power plant. Moreover, we emphasize that exploiting the flexibility of some consumer groups (which may, e.g., be "wealthier" households) can already yield monetary benefits for less flexible consumers (possibly poorer households) in the form of overall reduced price burden. This dynamic is depicted in Figure 6, which highlights the price-reducing effect for all consumers using a simplified two-period market. Notwithstanding these effects, it is highly important to identify further opportunities for financially vulnerable consumers to actively participate on future markets without fearing to be harmed by, e.g., unexpected price spikes. In this context, **restorative justice** and potential CCMD-driven legislation can serve as initial steps to further involve these financially vulnerable consumers as directly addressed by design principle 3.

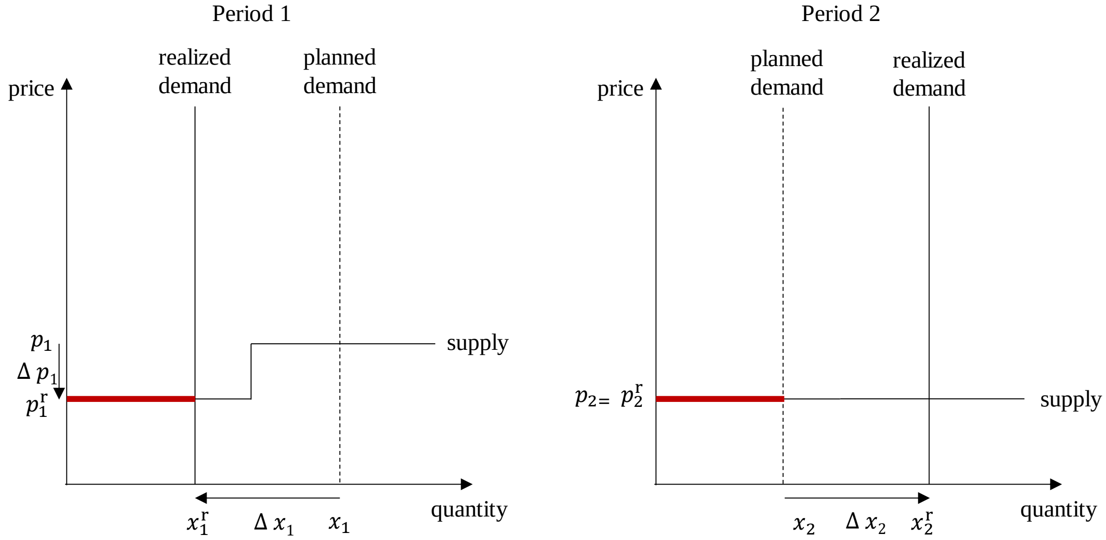

Figure 6: How the flexibility of certain consumer groups can reduce overall price levels with benefits for all. The two figures display electricity supply and demand curves across two time periods. Their intersection determines the electricity prices p and traded quantities x. As illustrated, a reduction in electricity demand, i.e., flexibility supply, diminishes prices in Period 1 for all consumers without increasing prices in Period 2 and harming other consumers. The red line indicates inflexible demand in the two periods, respectively.

Design Principle 2: Expression of consumer preferences

The second design principle concerns the ability to express preferences (and constraints) of consumers. Recognizing that consumers might not have singular preference, it becomes in consequence essential to offer a range of resulting trading alternatives.

The first mechanism for manifesting these consumer preferences is the provision of adequate bidding languages suitable for all participating market players and assets (M1). The second mechanism involves offering different trading products tailored to the preferences of market participants (M2). Drawing an analogy from the telephone industry, there are now flat rates that grant users unlimited calls at any time. In the past, contracts charged users more for calls between 8 a.m. and 8 p.m. compared to after 8 p.m. In the context of a CCMD, this could translate to some products with no temporal or spatial constraints, while other products offer broader flexibility in electricity consumption over time. In addition, there could be, for example, tariffs replicating green electricity surplus in the grid.

To achieve the expression of consumer preferences, digital technologies are required, especially to assist in the bidding and selection of trading products with high temporal resolution (E1). Moreover, as new bidding languages and trading products are introduced, the market clearing processes have to adapt, necessitating modifications to the market-clearing algorithm (E2).

Exemplary Potentials of Design Principle 2 to Foster Energy Justice

In the following we examine the implications for energy justice of the design principle "**Expression of consumer preferences**". Specifically, articulating preferences through comprehensive bidding languages and aligned trading products that reflect individual needs and preferences allows to supply services like flexibility in a best-possible way. This enhances the active participation of consumers, thereby advancing to **distribute justice**. Expounding further, this principle offers parity to all electricity consumers, e.g., industry, household, DER, etc. This ensures no prejudicial treatment toward, for example, small-scale electricity consumers. Consequently, **recognition justice** is strongly supported by this design principle. Ultimately, consumers can contribute even more strongly to the energy transition according to their own wishes, and, thus, the expression of consumer preferences also provides a contribution to **cosmopolitan justice**.

Design Principle 3: Insurance against sudden and unexpected price spikes and system imbalances

The third design principle for a CCMD emphasizes protection against unforeseen price spikes and system imbalances. The goal of this design principle is to shield consumers from excessive volatility, monetary burden, and damage – notwithstanding the fact that DERs may take on some level of price risk that is manageable for them in future. We note that this design principle is key to successfully allow a broad range of (small) consumers to actively participate at markets.

Given this context, the CCMD should incorporate insurance mechanisms to safeguard vulnerable electricity consumers (M1). This entails ensuring that financially vulnerable consumers consistently have access to a basic electricity supply at affordable rates, fostering societal acceptance and support for the transformation. In addition, security of supply must be ensured for every citizen at all times, including emergency measures in the case of extreme situations and imbalances (M2).

To identify a suitable insurance, it is essential to examine consumers' risk preferences and the extent of risk manageability (E1). Another enactor is the enhancement of price development forecasting (E2). Further, to ensure preparedness for emergencies, another measure for insurance is corresponding scenario modeling for emergency cases (E3). Finally, we note that historically, classical electricity suppliers acted as intermediaries, absorbing the risk with tariffs that did not directly transfer price peaks or fluctuations to end consumers on a 1:1 basis, incurring an extra charge for this service. In the case of future end consumers who actively feed in electricity or offer flexibility, the risk of price peaks may be assumed by an aggregator for consumer groups that cannot manage their own risks. This implies that traditional electricity suppliers could transition into aggregators, or new aggregators might arise to serve these specific consumer groups (E4).

Exemplary Potentials of Design Principle 3 to Foster Energy Justice
For our third example, we explore the design principle titled "**Insurance against sudden and unexpected price spikes and system imbalances**". The insurance against sudden and extreme price spikes supports **recognition justice**, as all players have the same rights, and nobody needs to be exposed to a greater risk involuntarily. Regarding consumers who feed in electricity or offer flexibility, the risk of price peaks could be assumed by either an aggregator (compensated with an appropriate fee) for consumer groups unable to navigate risks independently or directly by consumers equipped with adequate risk management

capabilities. This encourages broader consumer participation, thus bolstering **distributive justice**.

Design Principle 4: Exposure to price signals

CCMD should also enable consumers to respond to wholesale price signals, a benefit they cannot currently derive in many real-world markets.

One mechanism to enable the exposure of consumers to price signals (in "normal" market situations) relates to new business models suitable for exploiting growing price fluctuations. Examples include new business models of power exchange operators or electricity suppliers as highlighted in Section 4.1.3 (M1). Along with this, it is also necessary to create incentives for corresponding investments "behind the meter", including PV systems, electric vehicles, home storage, and heat pumps (M2).

In this context, digitization plays a vital role. Measures that may result in and enable increased exposure to price signals include, for example, smart metering systems and automated energy management systems for demand response (E1). Furthermore, to avoid price distortions and increase price transparency, tariff structures may have to be amended, e.g., tariffs and network charges may have to be reduced or made more dynamic (E2). In particular, dynamic price signals or peak-time pricing can offer market players an excellent opportunity to respond to price signals (E3).

Exemplary Potentials of Design Principle 4 to Foster Energy Justice
The design principle **"Exposure to price signals"** has implications for energy justice.
First, this design principle contributes to **procedural justice** by granting all consumers the possibility of being exposed to price signals in a transparent and non-discriminatory manner. Second, the design principle further supports **recognition justice**, as it provides equal rights to all market actors. For example, industrial consumers who are already active on wholesale markets and household consumers who are currently excluded, obtain equal rights for market participation. Third, **cosmopolitan justice** is influenced by this design principle. Through voluntary exposure to price signals, consumers contribute to the energy transition in the sense of cosmopolitan justice as they adjust their consumption patterns based on renewable feed-in. Flexibility is one method of alignment with the feed-in, where consumers may shift their consumption from high price periods to more affordable ones.

Design Principle 5: High temporal and regional granularity of electricity prices

Another design principle for a CCMD concerns the high temporal and regional granularity of electricity prices. This principle is of particular importance due to the variability and decentralization of intermittent electricity generation.

One mechanism to address this involves representing transmission and distribution constraints within electricity prices (M1). In addition, prices must be calculated based on at a fine-grained temporal basis (M2).

To realize this, various strategies can be employed, such as shorter trading products close to real-time (E1) or the introduction of nodal prices (E2), or more frequent intraday auctions (E3). Such strategies are essential to ensure the proper integration of DERs and to mitigate the forecast uncertainty risk.

Exemplary Potentials of Design Principle 5 to Foster Energy Justice

The design principle **"High temporal and regional granularity of electricity prices"** fosters **cosmopolitan justice** by enabling market participants to contribute their "fair share" to the energy transition. Specifically, temporally and regionally fine-grained market prices guide the behavior of market participants in alignment with regional and temporal availability of renewable energies. High temporal and regional granularity in electricity prices may also incentivize future investments in renewable energies in regions where such investments have been neglected in the past.

Electricity prices characterized by high temporal and regional granularity enhance transparency regarding current system needs, thus, promoting **procedural justice**. For instance, high temporal granularity facilitates close to real-time market participation for all electricity consumers. Consequently, these electricity consumers can promptly respond to price signals, leveraging temporal price variations with high accuracy and thereby maximizing returns on flexibility measures. This approach ultimately advances **distributive justice**.

Design Principle 6: Interoperability with other (related) markets

The final design principle we derive for a CCMD pertains to interoperability with other markets. It is pertinent to emphasize that the first design principle - the ease of consumer participation in the market - has to be considered in this design principle.

Possible mechanisms encompass interoperability with balancing markets (M1), (local) flexibility markets (M2), (local) energy markets or peer-to-peer platforms (M3), or other European spot markets (M4).

To investigate the interplay between different markets, agent-based or other simulation types may be valuable in assessing such interoperability (E1). However, it is important that the interaction among various markets does not add unmanageable complexity for market players.

Exemplary Potentials of Design Principle 6 to Foster Energy Justice

The design principle **"Interoperability with other (related) markets"** contributes to various forms of energy justice. Regarding **procedural justice**, the design principle facilitates the active participation of consumers in several, well-integrated electricity markets, such as day-ahead or redispatch markets. Consumers are free to choose on which market they want to purchase electricity and can easily transition between markets. By integrating various markets, the design principle "Interoperability with other (related) markets" creates transparency and allows electricity consumers to simultaneously participate in different markets in a non-discriminatory manner. Furthermore, this design principle enhances **distributive justice**, as it allows for a more balanced distribution of economic benefits across the various markets. For instance, the close integration of various electricity markets may reduce the evolution of market power in one specific market, preventing the exploitation of consumers in that market, a phenomenon known as inc-dec gaming.

Finally, this design principle fosters **recognition justice** by granting equal rights to all electricity consumers across markets. The design principle harmonizes market rules in a way that does not provide consumers with more or less rights depending on the market they participate in. As a result, the rights for different groups in society are equally recognized in all markets, including the right of all consumers to participate in all electricity markets.

The above examples clearly illustrate that a CCMD has major beneficial implications for energy justice, and, thus, the implementation of a CCMD would be a major step toward a just electricity system.

Table 2: Design Principles for a CCMD

Design Principle	Formulation of the Design Principle
Openness to new market players, low market entry barriers, and low transaction costs	For market designers to achieve or allow for openness to new market actors in future consumer-centric electricity spot markets, employ Mechanisms • M1: Grant access to small-scale electricity consumers and automated consumer devices like DER on wholesale electricity markets [21,24–27,30–34,37–44] • M2: Foster the emergence and participation of aggregators in electricity markets [49–57] • M3: Foster the emergence and participation of prosumers in electricity markets [58,59] • M4: Market transparency: Access to market information and the behavior of other market players involving Enactors • E1: Grant consumers the legal right to participate in electricity wholesale markets [57,60,61] • E2: Make use of newly generated data by smart devices such as smart meters to facilitate market participation, i.e., make it user friendly [57,60,62,63] • E3: Behavioral economics research allows to obtain insight into the anticipated behavior of new market actors on electricity wholesale markets [60]
Expression of consumer preferences	For market designers to achieve or allow for the expression of consumer preferences in future consumer-centric electricity spot markets, employ Mechanisms • M1: Adequate bidding languages for all participating market actors and assets • M2: Trading products that reflect the needs and preferences of market players, e.g., small-scale trading products, green electricity products [20] involving Enactors • E1: Digital technology solutions to support the submission of bids and selection of trading products with high temporal resolution • E2: Adaption of market clearing processes to account for new bidding languages and trading products, i.e., adaption of market clearing algorithm
Insurance against sudden and unexpected price spikes and system imbalances	For market designers to achieve or allow for an insurance against sudden and unexpected price spikes or system imbalances in future consumer-centric electricity spot markets, employ Mechanisms • M1: Insurance mechanism for vulnerable electricity consumers (“primary care”) [64,65] • M2: Emergency measures in case of system imbalances to grant security of supply at all times

	involving Enactors • E1: Investigate consumer risk preferences [64] • E2: Enhanced forecasting for price developments • E3: Risk analysis and scenario-modeling for emergency cases • E4: Aggregator for consumer groups that cannot manage the risks themselves
Exposure to price signals	For market designers to achieve or allow for an increased exposure of electricity consumers to wholesale price signals in future consumer-centric electricity spot markets, employ Mechanisms • M1: Allow for new business models to exploit price fluctuations [53,54,57,58,66–75] • M2: Incentivize “behind-the-meter” investments [75,76] involving Enactors • E1: Digitization of assets, smart metering and automated energy management systems to guide demand response [58,71,77] • E2: Amendment of tariff structure to avoid price distortions and increase price transparency [57] • E3: Dynamic price signals and peak-time pricing [57,73,78]
High temporal and regional granularity of electricity prices	For market designers to achieve or allow for high temporal and regional granularity for price signals in future consumer-centric electricity spot markets, employ Mechanisms • M1: Representation of transmission and distribution constraints in electricity prices [31,66,76,79–83] • M2: Calculation of prices at a temporally fine-grained basis involving Enactors • E1: Shorter trading periods close to real-time [81,83,84] • E2: Introduction of nodal prices • E3: More frequent intraday auctions [82]
Interoperability with other (related) markets	For market designers to achieve or allow for interoperability with other (related) markets in future consumer-centric electricity spot markets, employ Mechanisms • M1: Interoperability with balancing markets [23,34,35,38,42,56] • M2: Interoperability with (local) flexibility markets [62,69] • M3: Interoperability with (local) energy markets and peer-to-peer platforms [42,44,57,58] • M4: Interoperability with other European spot markets [60,65] involving Enactors

	• E1: Agent-based simulations or other types of simulations to investigate the interactions of different markets [61]

4.2 Deriving a definition of consumer-centric market design

Building on the six design principles we developed for a CCMD, we arrive at the following definition for a CCMD that incorporates the characteristics of a future-proof CCMD as a key building block for a deep decarbonization:

Consumer-centric electricity market design is a set of market rules that are consistent with the rules of other relevant energy markets and allow efficiently matching electricity demand and supply, with consumers having nondiscriminatory market access, being exposed to fine-grained price signals, being able to express their preferences, and having sufficient possibilities to protect themselves against unexpected price spikes.

5. Conclusion

To achieve global climate objectives and the specific targets established by national governments, such as net-zero and deep decarbonization, the proportion of RES must escalate rapidly. This will inevitably make electricity generation highly decentralized and intermittent. Simultaneously, there is a surge in the number of especially small-scale flexibilities, such as electric vehicles and heat pumps, which are currently unable to actively engage in electricity markets. A consumer-centric market design (CCMD) integrates consumers and contributes to a decarbonized and just energy system. A CCMD not only empowers consumers with especially small-scale assets to sell their self-generated electricity on the market, but also amplifies the system's flexibility by influencing electricity consumption patterns. Over the medium term, this leads to incentives for additional flexibility investments.

The precise design options for a CCMD need to be chosen carefully. These design options have to appropriately incentivize consumers to actively engage in market interactions. To this end, we have outlined six design principles for a CCMD: (1) openness to new market players, low market entry barriers, and low transaction costs; (2) expression of consumer preferences; (3) insurance against sudden and unexpected price spikes and system imbalances; (4) exposure to price signals; (5) high temporal and regional granularity of electricity prices; and (6) interoperability with other (related) markets.

Shifting the focus of future market design to the consumer side inherently brings forth questions of energy justice. In this article, we discuss the implications of a CCMD for energy justice. The energy transition intersects with the various interests of stakeholders in the electricity system, e.g., economic, environmental, and political interests. A CCMD is one important means to create a balance between these interests by fostering energy justice. For example, the first design principle concerning "openness to new market players, low market entry barriers, and low transaction costs" highlights the significant positive effect of a CCMD on energy justice. This design principle affects recognition justice, procedural justice, cosmopolitan justice, distributive justice, and restorative justice. Notably, the opening of CCMD to all market players is a major step towards a just and decarbonized energy system as described in this article. Overall, CCMD can foster different forms of energy justice with its design principles. At the same time, energy justice can be a booster for a successful CCMD and correct for past policy injustice and corresponding failures. Therefore, it is important not to focus on one CCMD design principle or on one energy justice form, but to consider and investigate all of them together and from an integrated perspective.

To put it in a nutshell, this article provides a comprehensive examination of the CCMD concept including the development of design principles for a CCMD, the presentation of a definition of a CCMD, and the discussion of implications of a CCMD for energy justice. Further research could explore how small-scale electricity consumers in particular make their buy or sell decisions, how their preferences are formed, or how electricity consumers should be protected against sudden price spikes under different circumstances using concrete policy instruments. Moreover, future research could focus on developing specific incentives and designing corresponding measures for financially vulnerable individuals that help realize design principle 3 "Insurance against sudden and unexpected price spikes and system imbalances". In addition, further research could also explore how digital technologies might enhance and enable a CCMD. A concrete case study could be used to derive an agenda for necessary policy changes in various countries that will help these countries advance a CCMD. In this way, a CCMD can serve as an important backbone for a future low-carbon and equitable society.

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References

[1] Rogelj J, Elzen M den, Höhne N, Fransen T, Fekete H, Winkler H et al. Paris Agreement climate proposals need a boost to keep warming well below 2 °C. Nature 2016;534(7609):631–9. https://doi.org/10.1038/nature18307.

[2] European Commission. COP26: EU helps deliver outcome to keep the Paris Agreement targets alive; Available from: https://ec.europa.eu/commission/presscorner/detail/en/IP_21_6021.

[3] Strüker J, Weibelzahl M, Körner M-F, Kießling A, Franke-Sluijk A, Hermann M. Decarbonisation through digitalisation Proposals for Transforming the Energy Sector. University of Bayreuth; 2021.

[4] Tomain JP. Energy justice in a net-zero world. The Journal of World Energy Law & Business 2022;15(3):173–82. https://doi.org/10.1093/jwelb/jwac002.

[5] Heffron RJ, McCauley D, Sovacool BK. Resolving society's energy trilemma through the Energy Justice Metric. Energy Policy 2015;87:168–76. https://doi.org/10.1016/j.enpol.2015.08.033.

[6] Kondziella H, Bruckner T. Flexibility requirements of renewable energy based electricity systems – a review of research results and methodologies. Renewable and Sustainable Energy Reviews 2016;53:10–22. https://doi.org/10.1016/j.rser.2015.07.199.

[7] Bertsch J, Growitsch C, Lorenczik S, Nagl S. Flexibility in Europe's power sector — An additional requirement or an automatic complement? Energy Economics 2016;53:118–31. https://doi.org/10.1016/j.eneco.2014.10.022.

[8] Heffron R, Körner M-F, Wagner J, Weibelzahl M, Fridgen G. Industrial demand-side flexibility: A key element of a just energy transition and industrial development. Applied Energy 2020;269:115026. https://doi.org/10.1016/j.apenergy.2020.115026.

[9] International Energy Agency. Demand Response. [August 06, 2023]; Available from: https://www.iea.org/energy-system/energy-efficiency-and-demand/demand-response.

[10] Australian Energy Market Operator. Wholesale demand response mechanism. [August 05, 2023]; Available from: https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/market-operations/wdrm.

[11] Office of Gas and Electricity Markets. Decision on the Demand Flexibility Service in relation to an update to the Terms and Conditions related to Balancing. [August 05, 2023]; Available from: https://www.ofgem.gov.uk/publications/decision-demand-flexibility-service-relation-update-terms-and-conditions-related-balancing.

[12] European Commission. European Green Deal; Available from: https://ec.europa.eu/clima/eu-action/european-green-deal_en#modal.

[13] Directorate-General for Energy. Clean Energy for all Europeans 2019. https://doi.org/10.2833/9937.

[14] European Commission. Reform of Electricity Market Design: Commission Staff Working Document. [August 05, 2023]; Available from: https://energy.ec.europa.eu/system/files/2023-03/SWD_2023_58_1_EN_autre_document_travail_service_part1_v6.pdf.

[15] Réseau de Transport d'Electricité. Participate in the Block Exchange Notification of Demand Response (NEBEF) mechanism. [August 05, 2023]; Available from: https://www.services-rte.com/en/learn-more-about-our-services/participate-nebef-mechanism.

[16] Ibn Saif, A. U. N., Khadem SK (eds.). Consumer-centric Electricity Market: Review of key European projects. IEEE; 2020.

[17] Fridgen G, Keller R, Körner M-F, Schöpf M. A holistic view on sector coupling. Energy Policy 2020;147:111913. https://doi.org/10.1016/j.enpol.2020.111913.
[18] Körner M-F, Bauer D, Keller R, Rösch M, Schlereth A, Simon P et al. Extending the Automation Pyramid for Industrial Demand Response. Procedia CIRP 2019;81:998–1003. https://doi.org/10.1016/j.procir.2019.03.241.
[19] Patnam BSK, Pindoriya NM. Demand response in consumer-Centric electricity market: Mathematical models and optimization problems. Electric Power Systems Research 2021;193:106923. https://doi.org/10.1016/j.epsr.2020.106923.
[20] Oliveira C, Botelho DF, Soares T, Faria AS, Dias BH, Matos MA et al. Consumer-centric electricity markets: A comprehensive review on user preferences and key performance indicators. Electric Power Systems Research 2022;210:108088. https://doi.org/10.1016/j.epsr.2022.108088.
[21] Pinson P, Baroche T, Moret F, Sousa T, Sorin E, You S. The emergence of consumer-centric electricity markets. Distribution & Utilization;34(12):27–31.
[22] Cramton P. Electricity market design. Oxford Review of Economic Policy 2017;33(4):589–612. https://doi.org/10.1093/oxrep/grx041.
[23] Hu J, Harmsen R, Crijns-Graus W, Worrell E, van den Broek M. Identifying barriers to large-scale integration of variable renewable electricity into the electricity market: A literature review of market design. Renewable and Sustainable Energy Reviews 2018;81:2181–95. https://doi.org/10.1016/j.rser.2017.06.028.
[24] Parag Y, Sovacool BK. Electricity market design for the prosumer era. Nat Energy 2016;1(4):1–6. https://doi.org/10.1038/nenergy.2016.32.
[25] Domegni K, Azouma YO. Productive uses of energy: A solution for promoting energy justice in rural areas in West Africa. Renewable and Sustainable Energy Reviews 2022;160:112298. https://doi.org/10.1016/j.rser.2022.112298.
[26] Upham P, Sovacool B, Ghosh B. Just transitions for industrial decarbonisation: A framework for innovation, participation, and justice. Renewable and Sustainable Energy Reviews 2022;167:112699. https://doi.org/10.1016/j.rser.2022.112699.
[27] Heffron RJ. Applying energy justice into the energy transition. Renewable and Sustainable Energy Reviews 2022;156:111936. https://doi.org/10.1016/j.rser.2021.111936.
[28] Heffron RJ, Körner M-F, Schöpf M, Wagner J, Weibelzahl M. The role of flexibility in the light of the COVID-19 pandemic and beyond: Contributing to a sustainable and resilient energy future in Europe. Renew Sustain Energy Rev 2021;140:110743. https://doi.org/10.1016/j.rser.2021.110743.
[29] Öko-Institut e.V. Das technische Flexibilitätspotenzial im Stromsystem bis zum Jahr 2050; Available from: https://www.flickr.com/photos/oekoinstitut/51971887527/in/photostream/.
[30] Mahmud K, Khan B, Ravishankar J, Ahmadi A, Siano P. An internet of energy framework with distributed energy resources, prosumers and small-scale virtual power plants: An overview. Renewable and Sustainable Energy Reviews 2020;127:109840. https://doi.org/10.1016/j.rser.2020.109840.
[31] Bichler M, Buhl HU, Knörr J, Maldonado F, Schott P, Waldherr S et al. Electricity Markets in a Time of Change: A Call to Arms for Business Research. Schmalenbach Journal of Business Research 2022;74(1):77–102. https://doi.org/10.1007/s41471-021-00126-4.

[32] Hanny L, Wagner J, Buhl HU, Heffron R, Körner M-F, Schöpf M et al. On the progress in flexibility and grid charges in light of the energy transition: The case of Germany. Energy Policy 2022;165:112882. https://doi.org/10.1016/j.enpol.2022.112882.
[33] Heffron RJ, Körner M-F, Sumarno T, Wagner J, Weibelzahl M, Fridgen G. How different electricity pricing systems affect the energy trilemma: Assessing Indonesia's electricity market transition. Energy Economics 2022;107:105663. https://doi.org/10.1016/j.eneco.2021.105663.
[34] McCauley D, Heffron R. Just transition: Integrating climate, energy and environmental justice. Energy Policy 2018;119:1–7. https://doi.org/10.1016/j.enpol.2018.04.014.
[35] Evans G, Phelan L. Transition to a post-carbon society: Linking environmental justice and just transition discourses. Energy Policy 2016;99:329–39. https://doi.org/10.1016/j.enpol.2016.05.003.
[36] Kortetmäki T. Reframing Climate Justice: A Three-dimensional View on Just Climate Negotiations. Ethics, Policy & Environment 2016;19(3):320–34. https://doi.org/10.1080/21550085.2016.1226238.
[37] Sokołowski MM, Heffron RJ. Defining and conceptualising energy policy failure: The when, where, why, and how. Energy Policy 2022;161:112745. https://doi.org/10.1016/j.enpol.2021.112745.
[38] Gregor S, Hevner AR. Positioning and Presenting Design Science Research for Maximum Impact. MISQ 2013;37(2):337–55. https://doi.org/10.25300/misq/2013/37.2.01.
[39] Peffers K, Tuunanen T, Rothenberger MA, Chatterjee S. A Design Science Research Methodology for Information Systems Research. Journal of Management Information Systems 2007;24(3):45–77. https://doi.org/10.2753/MIS0742-1222240302.
[40] Webster J, Watson RT. Analyzing the Past to Prepare for the Future: Writing a Literature Review. MIS Quarterly 2002;26(2):xiii–xxiii.
[41] vom Brocke J, Simons A, Riemer K, Niehaves B, Plattfaut R, Cleven A. Standing on the Shoulders of Giants: Challenges and Recommendations of Literature Search in Information Systems Research. Communications of the Association for Information Systems 2015;37. https://doi.org/10.17705/1CAIS.03709.
[42] Wolfswinkel JF, Furtmueller E, Wilderom CPM. Using grounded theory as a method for rigorously reviewing literature. European Journal of Information Systems 2013;22(1):45–55. https://doi.org/10.1057/ejis.2011.51.
[43] Orlandini T, Soares T, Sousa T, Pinson P (eds.). Coordinating Consumer-Centric Market and Grid Operation on Distribution Grid; 2019.
[44] Gregor S, Kruse LC, Seidel S. Research Perspectives: The Anatomy of a Design Principle. JAIS 2020;21:1622–52. https://doi.org/10.17705/1jais.00649.
[45] Myers MD, Newman M. The qualitative interview in IS research: Examining the craft. Information and Organization 2007;17(1):2–26. https://doi.org/10.1016/j.infoandorg.2006.11.001.
[46] Schultze U, Avital M. Designing interviews to generate rich data for information systems research. Information and Organization 2011;21(1):1–16. https://doi.org/10.1016/j.infoandorg.2010.11.001.
[47] MacCoun R, Perlmutter S. Blind analysis: Hide results to seek the truth. Nature 2015;526(7572):187–9. https://doi.org/10.1038/526187a.
[48] Marshall B, Cardon P, Poddar A, Fontenot R. Does Sample Size Matter in Qualitative Research?: A Review of Qualitative Interviews in is Research. Journal of Computer

Information Systems 2013;54(1):11–22. https://doi.org/10.1080/08874417.2013.11645667.
[49] Borne O, Korte K, Perez Y, Petit M, Purkus A. Barriers to entry in frequency-regulation services markets: Review of the status quo and options for improvements. Renewable and Sustainable Energy Reviews 2018;81:605–14. https://doi.org/10.1016/j.rser.2017.08.052.
[50] Borne O, Petit M, Perez Y (eds.). Provision of frequency-regulation reserves by distributed energy resources: Best practices and barriers to entry; 2016.
[51] Burger S, Chaves-Ávila JP, Batlle C, Pérez-Arriaga IJ. A review of the value of aggregators in electricity systems. Renewable and Sustainable Energy Reviews 2017;77:395–405. https://doi.org/10.1016/j.rser.2017.04.014.
[52] Eid C, Codani P, Chen Y, Perez Y, Hakvoort R (eds.). Aggregation of demand side flexibility in a smart grid: A review for European market design; 2015.
[53] Farrokhseresht M, Paterakis NG, Gibescu M, Tohidi Y, Slootweg JG (eds.). A survey on the participation of distributed energy resources in balancing markets; 2018.
[54] Guédou B, Rigard-Cerison A (eds.). Comparison of market designs enabling DSR participation in the energy market; 2016.
[55] Haring T, Mathieu JL, Andersson G (eds.). Decentralized contract design for demand response; 2013.
[56] Koliou E, Eid C, Hakvoort RA (eds.). Development of Demand Side Response in liberalized electricity markets: Policies for effective market design in Europe; 2013.
[57] Crasta C, Agabus H, Palu I (eds.). EU electricity market design issues and solutions for increased RES penetration; 2020.
[58] Botelho DF, Dias BH, Oliveira LW de, Soares TA, Rezende I, Sousa T. Innovative business models as drivers for prosumers integration - Enablers and barriers. Renewable and Sustainable Energy Reviews 2021;144. https://doi.org/10.1016/j.rser.2021.111057.
[59] Ghorani R, Farzin H, Fotuhi-Firuzabad M, Wang F. Market design for integration of renewables into transactive energy systems. IET Renewable Power Generation 2019;13(14):2502–11. https://doi.org/10.1049/iet-rpg.2019.0551.
[60] Lavrijssen S. Power to the energy consumers. European Energy and Environmental Law Review 2017;26(6):172–87.
[61] Kühnlenz F, Nardelli P, Karhinen S, Svento R. Implementing flexible demand: Real-time price vs. market integration. Energy 2018;149:550–65. https://doi.org/10.1016/j.energy.2018.02.024.
[62] Staudt P, Weinhardt C. Market Engineering for the Smart Grid; 2022.
[63] Strielkowski W, Streimikiene D, Fomina A, Semenova E. Internet of energy (IoE) and high-renewables electricity system market design. Energies 2019;12(24). https://doi.org/10.3390/en12244790.
[64] Lynch M, Longoria G, Curtis J. Market design options for electricity markets with high variable renewable generation. Utilities Policy 2021;73. https://doi.org/10.1016/j.jup.2021.101312.
[65] Boltz W. The Challenges of Electricity Market Regulation in the European Union. In: Evolution of Global Electricity Markets: New Paradigms, New Challenges, New Approaches; 2013, p. 199–224.
[66] Conejo AJ, Sioshansi R. Rethinking restructured electricity market design: Lessons learned and future needs. International Journal of Electrical Power and Energy Systems 2018;98:520–30. https://doi.org/10.1016/j.ijepes.2017.12.014.

[67] Eid C, Bollinger LA, Koirala B, Scholten D, Facchinetti E, Lilliestam J et al. Market integration of local energy systems: Is local energy management compatible with European regulation for retail competition? Energy 2016;114:913–22. https://doi.org/10.1016/j.energy.2016.08.072.
[68] Hansen J, Somani A, Sun Y, Zhang Y (eds.). Auction design for power markets based on standardized contracts for energy and reserves; 2016.
[69] Ibn Saif A, Khadem SK (eds.). Consumer-centric Electricity Market: Review of key European projects; 2020.
[70] Keay M, Rhys J, Robinson D. Electricity Markets and Pricing for the Distributed Generation Era. In: Distributed Generation and its Implications for the Utility Industry; 2014, p. 165–187.
[71] Rious V, Perez Y, Roques F. Which electricity market design to encourage the development of demand response? Economic Analysis and Policy 2015;48:128–38. https://doi.org/10.1016/j.eap.2015.11.006.
[72] Robinson D. What market design, fiscal policy, and network regulations are compatible with efficient behind the meter investments? In: Behind and Beyond the Meter: Digitalization, Aggregation, Optimization, Monetization; 2020, p. 361–379.
[73] Weiller C, Shang AT, Mullen P. Market Design for Electric Vehicles. Current Sustainable/Renewable Energy Reports 2020;7(4):151–9. https://doi.org/10.1007/s40518-020-00163-3.
[74] Welsch M. Europe's Energy Transition. In: Europe's Energy Transition: Insights for Policy Making; 2017, p. 3–6.
[75] Yazdani H, Doostizadeh M, Aminifar F. Unlocking the value of flexibility of behind-the-meter prosumers: An overview of mechanisms to esteemed trends. Electricity Journal 2022;35(5). https://doi.org/10.1016/j.tej.2022.107126.
[76] Wang Q. Advances of wholesale and retail electricity market development in the context of distributed energy resources. In: New Technologies for Power System Operation and Analysis; 2020, p. 99–142.
[77] Eid C, Codani P, Perez Y, Reneses J, Hakvoort R. Managing electric flexibility from Distributed Energy Resources: A review of incentives for market design. Renewable and Sustainable Energy Reviews 2016;64:237–47. https://doi.org/10.1016/j.rser.2016.06.008.
[78] Astier N, Léautier T-O. Demand response: Smart market designs for smart consumers. Energy Journal 2021;42(3):153–75. https://doi.org/10.5547/01956574.42.3.mdow.
[79] Cramton P. Electricity market design. Oxford Review of Economic Policy 2017;33(4):589–612. https://doi.org/10.1093/oxrep/grx041.
[80] Löschel A, Flues F, Pothen F, Massier P. The German electricity market in Upheavel: On the necessity of a new market design. Wirtschaftsdienst 2013;93(11):778–84. https://doi.org/10.1007/s10273-013-1598-x.
[81] Muhanji SO, Muzhikyan A, Farid AM. Distributed Control for Distributed Energy Resources: Long-Term Challenges and Lessons Learned. IEEE Access 2018;6:32737–53. https://doi.org/10.1109/ACCESS.2018.2843720.
[82] Newman J, MacDougall P. Increasing DER integration through discrete intraday settlements. Electricity Journal 2021;34(4). https://doi.org/10.1016/j.tej.2021.106932.
[83] Poplavskaya K, Vries L de. Distributed energy resources and the organized balancing market: A symbiosis yet? Case of three European balancing markets. Energy Policy 2019;126:264–76. https://doi.org/10.1016/j.enpol.2018.11.009.

[84] Fridgen G, Michaelis A, Rinck M, Schöpf M, Weibelzahl M. The search for the perfect match: Aligning power-trading products to the energy transition. Energy Policy 2020;144:111523. https://doi.org/10.1016/j.enpol.2020.111523.