Simon Johanning, Nancy Retzlaff, Philipp Lämmel, Benjamin Dittwald, Thomas Bruckner

LabChain: an Interactive Prototype for Synthetic Peer-to-Peer Trade Research in Experimental Energy Economics

Identifier (Qucosa): urn:nbn:de:bsz:15-qucosa2-874949

Version: Akzeptiertes Manuskript / Post-Print / accepted Manuscript

Erstmalig hier erschienen/First published in:

IEEE Xplore, 2020 17th International Conference on the European Energy Market (EEM)

DOI: 10.1109/EEM49802.2020.9221919

Post-print, author version of article published on 13.10.2020 in
2020 17th International Conference on the European Energy Market (EEM), DOI: 10.1109/EEM49802.2020.9221919

LabChain: an Interactive Prototype for Synthetic Peer-to-Peer Trade Research in Experimental Energy Economics

Simon Johanning*†, Nancy Retzlaff†, Philipp Lämmel‡, Benjamin Dittwald‡, Thomas Bruckner†
* Corresponding author. Phone: +49 341 97 33554, e-mail: johanning@wifa.uni-leipzig.de
† Institute for Infrastructure and Resources Management (IIRM), Leipzig University
‡ Fraunhofer Institute for Open Communication Systems FOKUS

***Abstract*—Blockchain-based peer-to-peer (P2P) electricity markets received considerable attention in the past years, leading to a rich variety of proposed market designs. Yet, little comparability and consensus exists on optimal market design, also due to a lack of common evaluation and benchmarking infrastructure.**

This article describes LabChain, an interactive prototype as research infrastructure for conducting experiments in (simulated) P2P electricity markets involving real human actors. The software stack comprises: (i) an (open) data layer for experiment configuration, (ii) a blockchain layer to reliably document bids and transactions, (iii) an experiment coordination layer and (iv) a user interface layer for participant interactions.

As evaluation environment for human interactions within a laboratory setting, researchers can investigate patterns based on energy system and market setup and can compare and evaluate designs under real human behavior allowing alignment of intentions and outcomes. This contributes to the evaluation and benchmarking infrastructure discourse.

***Index Terms*—Peer-to-Peer Energy Trade, Blockchain, Experimental Energy Economics, Market Design, Research Infrastructure**

I. Introduction

The energy transition from large-scale, centrally managed electricity generation to a system of distributed generation constitutes a major motivation to investigate distributed control mechanisms, in particular for managing smart/micro grids and local electricity markets. Transaction-based energy systems, such as transactive energy and peer-to-peer (P2P) electricity trading [30] in particular have received considerable attention in recent years, both in the industry [2] and in academia [30, 51]. Yet, regulated, flexible and secure markets are lacking [67] and implementing these systems requires new trusted software platforms [70] and innovative information and communication technologies and trading platforms [29]. Blockchain technology is frequently seen as an answer to the need for local distributed control and management techniques of decentralized and digitalized energy systems [2] that addresses the requirement for secure, transparent and efficient decentralized technology to run these systems on [1]. While the majority of articles focus on security [15, 23, 24, 26, 32, 44, 50, 52, 53, 58, 59, 67], transparency [16, 40, 41, 62, 74], automation capabilities [23, 44, 59, 74] and trustability [12, 16, 23, 26, 32] of blockchain technology, many other properties around performance [5, 8, 11, 16, 23, 41, 53, 59, 67, 74], information quality [5, 8, 15, 16, 33, 44, 50, 52, 53, 58, 59, 67, 74], empowerment [11, 15, 16, 24, 26, 32, 33, 40, 41, 44] and a range of operational aspects [5, 11, 15, 18, 23, 29, 33, 37, 39, 41, 44, 53, 58, 59, 62, 67, 74] are seen to make blockchain technology an appropriate foundation for peer-to-peer electricity trade (see table I in the appendix for a more detailed overview).

As another driver for innovation of new business ideas that helps to reduce the creation of data silos [7], open data (OD) is another key development of digitalisation to deal with new data streams. The importance of OD is expressed in the European Data Strategy, particularly through the European Directive 2019/1024 on Open Data [13], which is aimed at making public sector information easier to access and re-use.

System descriptions and chosen approaches for P2P market design are highly heterogeneous (see e.g. III-A) and the discourse is characterized by active research and little consensus as to how to design these systems. Zhou et al. identify the need for a general and systematic simulation framework incorporating "[...] all fundamental elements of P2P energy sharing mechanisms" [78].

In many cases, the proposed trading mechanism(s) are furthermore not evaluated or compared to other cases [6, 9, 12, 23, 31, 39, 44–46, 48, 50, 53, 59, 60, 62, 64, 65, 67, 74], are only compared to a base case [4, 5, 10, 11, 15, 26, 27, 33, 34, 52, 58, 70–73, 76, 77] and are rarely compared to one another [8, 24, 29, 35, 36, 47, 75, 78, 79]. This lack of evaluation against standard benchmark cases, which is common practice in other computational disciplines, leads to frequently isolated evaluations of the proposed schemes and market designs and a patched case-by-case discourse with little consistency of best practices and comparability of approaches for (blockchain-based) P2P market design.

While experimental studies can be found for energy consumption [20, 42], emission trading [3, 14] and in experimental economics not specific to energy questions [57], only few studies target P2P electricity trade (see e.g. [19]), let alone market design (see [43] as a notable exception). Furthermore, experimental tools are strongly focused on hypothesis testing over exploration.

Through this lack of experimental grounding and benchmark infrastructure, comparability of market and system designs is rarely given. Little prescriptive knowledge exists on P2P market design as this is hard to systematically derive without a test bed. This is even more the case with design knowledge based on real-life human interactions. Design knowledge (e.g. in the form of design principles) requires the investigation of socio-technical systems in the respective context of usage [66].

We believe that deriving grounded design principles for effective P2P energy markets would benefit from a laboratory research infrastructure for experimental energy economics (coined *LabChain*) which needs to

1) accommodate the large range of market designs found in academic articles on (blockchain-based) energy trade between peers (*generic*),
2) provide the respective experiment participants with the interaction possibilities required by these market designs (*affordance-centered*), and
3) build upon the fundamental technologies and principles real implementations are expected to be built upon (*technologically grounded*).

In order to fulfill these (meta-)requirements (in the meaning of [69]), a synthetic, experimental laboratory software with a generic and adaptive approach to peer-centered (energy) exchange processes based on blockchain technology and open data was developed, as is detailed in section III. As a technical artifact (in the sense of [22]) designed for studying the interaction of human actors in different roles and market setups in this synthetic market environment, the laboratory constitutes a socio-technical IT system designed for the very purpose of studying the behavior of human actors in an intentionally designed environment. As the branch of information systems (itself the study of socio-technical systems) that studies the design process itself, the development of this laboratory software is contextualized and methodologically grounded in design science research, as further detailed in section II. Finally, the system is discussed in section IV and an outlook for further development and documentation of the process is given.

II. Methodology

Information Systems (IS) as a discipline is not just interested in the information systems themselves, but also the human activity around it [61]. It studies IT artifacts in the socio-technical context they are used in with an interest in their usage, construction and design [25].

As one stream in IS that is employed in understanding information systems through their design, design science research (DSR) aims to shape real-world phenomena, such as market designs and energy systems, through designing artifacts intentionally [56] from a perspective of problem solving [21]. Research questions are addressed through the creation of artifacts within this discipline within IS.

As an artificially and intentionally designed IT artifact addressing the problem of (the lack of) a research platform for P2P energy trade, this design approach seems appropriate for the design of the LabChain system, and the design process is approached through the lens of design science.

Design Science provides a rich basis for constructing and evaluating relevant IT artifacts rigorously, and is well-suited to be employed for the grounded development of the research infrastructure addressed in this article. Due to the scope of the conference article, however, a full design documentation is not feasible, so the article focuses on the description of (the first iteration of) the technical artifact. A full description and discussion of the design process, with a particular focus on the design process, as well as an evaluation within the context of intended use as required by [66] will be addressed in a future full-length article.

With regards to the design process described in [55], this article focuses on identifying the *problem identification* and *objectives definition*, as well as the essence of the components for the initial design iteration (described in section III).

Problem Identification: As laid out in the introduction of this article, technologically grounded P2P market design proposals are highly relevant, but lack comparability and benchmark infrastructure. Coupled with the lack of a comprehensive body of experimental studies in energy economics, laboratory infrastructure allowing for unbiased evaluation of different market design proposals would be very valuable for the research community.

Through addressing this problem, we aim to derive implicit design knowledge by designing an intervention that contributes to a more active discussion on the development of such benchmark environment.

Objective Definition: The objective of this research is to develop a software solution for investigating market and energy system designs in an interactive laboratory context that is generic, affordance-centered and technologically grounded.

III. System Design

Based on the methodological setting discussed in section II, the following details how the (meta-)requirements of the developed system are addressed. For this, the artifact requirements are translated into system requirements for the implementation that realizes this artifact (III-A), upon which the architecture based (III-B). Subsequently, the implementation of the realizing software is discussed (III-C).

A. System Requirements

The objective of this research is to develop a software solution for investigating market and system designs in an interactive laboratory context that is generic, affordance-centered and technologically grounded. In order to implement a software artifact with these properties, they have to be broken down to actionable (meta-)requirements that can easily be translated into features with the contextual knowledge provided in this article.

Generic: In order to address the requirement to be generic, a variety of system and markets setups need to be emulated in the simulation infrastructure. This is particularly the case for market mechanisms, most of all energy bid matching and pricing mechanisms. These can be roughly (non-exclusively) divided in (centrally) optimized trade matching [5, 6, 12, 26, 33, 38, 47, 48, 51, 63, 64, 68, 72, 73], auction mechanisms [9, 10, 18, 26, 27, 31, 32, 36, 39, 40, 53, 54, 59, 64, 67, 68, 75], order-book style matching [11, 41, 74], pooled uniform pricing [8, 29, 37, 41, 46, 65, 77], aggregator-determined pricing [24], communally decided pricing [34, 36, 47, 78], game-theory based pricing [4, 35, 58, 64, 65, 71, 76], and bilateral pricing [37, 44, 64]. The smallest common denominator of these is the individual (bid/ask) **offer** with individual interaction possibilities.

Similarly, numerous articles provide a range of non-peer actors, such as aggregators [5, 8, 10, 24, 26, 52, 58, 64], grid or system operators [10, 18, 27, 31, 44–47, 52, 59, 60, 64, 68, 70, 75, 76], community/trading managers/platform operators [36, 47, 49, 72, 73, 75–78], retailers [5, 18, 49, 65], utilities/suppliers [8, 41, 45, 46, 64, 70, 72, 73, 76–78] and other roles [5, 6, 8–10, 12, 34, 39, 44, 49, 58] (see table II for a more comprehensive overview of roles). What all approaches have in common, however, is the role of the **prosumer** (the peer) as the core entity. For specific approaches or market models, new roles must be easy to incorporate as extensions of a **generic actor**.

Additionally, approaches differ in the design of the peer-driven electricity markets, which exhibit different design regarding remuneration, gate closure, time slices and fee structures. The laboratory software needs to take this into account and is required to offer **flexible market design configuration**. In order to accommodate different energy system setups under investigation, it further needs to allow **heterogeneous prosumer asset setups**, where the individual participants can operate generation, consumption and storage assets with vastly different makeups.

Affordances: In order to study the behavior of human actors within a synthetic laboratory setup that intends to simulate energy systems characterized by prosumer empowerment, participants need to be able to make decisions under (heterogeneous) information and be able to interact with the simulated markets and energy trade capabilities. Prosumers thus need to be able to **operate assets** under their control, **monitor peer-markets**, be able to **make forecasts** on the energy balance in future states and **buy and sell electricity** in the peer-markets.

Technological Grounding: As seen in the introduction of this article, the technological basis of a solution is an important aspect of peer-markets. Especially for blockchain technology, contradictory statements of their properties (e.g. on their scalability) exist [28]. In order to make a fair and grounded assessment of the system properties of P2P markets based on specific technologies, the laboratory software needs to be based on a **real implementation** of the respective technology. This is particularly true for the technologies the data storage and flow is based on, i.e. the **transaction storing blockchain components** (see section III-C1) and the **open data store** (section III-C2), as well as for the **user interface** (section III-C3) the prosumer interacts with. These need to be based on a modern software basis that exhibits the properties of the system under simulation.

B. System Architecture

The (meta-)requirement of being technologically grounded is addressed by integrating core technologies in a layered architecture.

The software consists of four layers:

- the blockchain layer for recording transactions in a secure and transparent way,
- the open data platform as data store,
- the lab core components as a web application for implementing the business logic and user-facing interface of the lab, and
- the experiment coordination layer as a client synchronization backend.

As the core application, the laboratory, implemented as a web app using the Angular framework, is started locally on the participating machines and interacts with the other components via HTTP requests to the respective APIs. The architectural layers are explained in more detail in the following, and depicted in figure 1.

The blockchain layer encompasses two components, namely i) the private Ethereum network and ii) an access-controlled API for easing the interaction with the Ethereum network. The private Ethereum network is hosted on a controlled infrastructure and thus only selected users have access to the network. In addition, several miners and nodes that submit transactions regularly are running on the network thereby ensuring a realistic simulation of the main net. The access-controlled API is implemented as an Express.js application. Express is a web application framework for Node.js and is designed for building web applications and APIs. As mentioned, the API expects HTTP requests which are then translated into blockchain transactions.

The Energy Data Market (EDM) layer is an open data portal based on linked data. Compared to relational data bases, linked data stores its content as triples, built of subject, predicate and object. Linked data is therefore stored as a graph that explains its own semantic. This allows machines to follow the graph and potentially discover the stored data itself. Although the EDM is capable of storing data, an open data portal is a metadata registry and primarily holds metadata instead of the actual data itself. The EDM stores its metadata as triples in a triple store and the actual data is stored as documents in a NO-SQL database. The EDM consists of three main components: i) The UI provides a human-accessible web-interface that enables the user to search, review, create, update and edit metadata and data; ii) the registry is the persistence layer of the EDM and handles all request towards the triple store; finally, iii) the harvester is used for fetching metadata from other metadata portals and make them accessible on the EDM. Every request on the EDM is also represented by an API. The EDM is written in Vert.x, a Java toolkit that is used for asynchronous applications. Every component itself consists of multiple asynchronous micro-services.

The synchronization backend is the only component that is artificial to the laboratory setup and is not expected to be

Post-print, author version of article published on 13.10.2020 in
2020 17th International Conference on the European Energy Market (EEM), DOI: 10.1109/EEM49802.2020.9221919

present in a real-world system implementation. It serves to send a coordination signal when the clients are ready and the experimenter wants to start the experiment in order to create a common temporal context within the experiment.

The user interface is organized through (Angular) modules for the specific roles of experiment participants, as well as through a common module that contains business logic as services and data structures shared between all roles. The user interfaces are organized as hierarchical and dynamic set of components. Data and state are managed locally within the UI layer and communicated with other participants through the data exchange layers, i.e. the blockchain and the open data layers. Actors, i.e. different participants in the experiment, are coordinated through a central backend for relaying messages through websockets, which is used for synchronizing the start of the experiments in the experiment coordination layer. Simulation time is managed locally in the UI Layer and through (relatively) time-stamped blockchain transactions, resulting in an asynchronous setup that is loosely coupled through time-stamped blockchain transactions.

C. System Implementation

1) Blockchain Layer: As already mentioned, the blockchain component is responsible for storing transactions and bids in a secure and traceable way (see figure 1). Several market-related aspects such as bids or resources are represented by Smart Contracts that were developed and are currently running in a private Ethereum network. The provided functionalities of these Smart Contracts are exposed via an access-controlled API thereby facilitating a common communication approach between the components of the prototype as well as ensuring secure access to the sensitive information stored in the blockchain network. Whenever a test user decides to publish a bid, the laboratory component will prepare a HTTP POST request with the required information such as the time frame, the corresponding resource, the amount of energy, the price and an access token. The access token is then validated and in the case of successful validation, the information will be prepared as a blockchain transaction that is published in the network. After a short time, a miner will successfully mine a new block and incorporate all pending transactions in this particular block. After the completion of the block creation, end users can then retrieve or edit their bids via other HTTP requests.

2) Open Data Layer: As an open data portal, the EDMs main responsibility is to make data accessible. Data in this case are the experiment descriptions, an instance of running experiments and updates during the experiment and the result after an experiment has finished. Each data also has a metadata representation. Both metadata and data are stored via HTTP POST methods, triggered by the Experiment and Client UI (see figure 1). Whenever a new experiment needs to be created the experimenter uses the Experiment UI in order to create an experiment description via the EDM. As soon as an experiment starts, the experimenter creates an experiment instance, based on the experiment description. While an experiment runs, prosumers can use the Client UI in order to update the status of the experiment instance. These updates are also reflected on the EDM. When an experiment ends the experimenter collects the experiments instance data from the EDM and can use it for their analysis. As the data is available as open data, others can also access it and re-use the data for their purposes.

3) User Interface Layer: The user interface is composed of two principle modules. The first one allows the experimenter to design new experiments and configure the prosumers, their assets and market design, as well as controlling the experiment.

The second interface allows the prosumer to interact with their own assets as well as other prosumers via the market interface. The objective of the prosumer depends strongly on the market design and the assumed regulatory context, but is most likely to avoid penalties resulting from grid imbalances caused by their behavior. In order to avoid such fees or to behave strategically through storage management or trading behavior, a prosumer trades energy on the market through posting bid or ask offers consistent with the market design under investigation. Placed offers still have to be accepted by another prosumer in order to be accounted for in the energy balance. To allow for the investigation of coupled grids where a prosumer can fall back on retail trade and feed-in remuneration, unlimited standing orders are included in the offer list as well.

4) Experiment Coordination Layer: The Experiment Coordination Layer is comprised of a Node.js HTTP server running a simple backend using the socket.io framework. This allows for realtime, bidirectional communication between the clients and the backend through the use of web sockets. As static data and client communication within the experiment are addressed by the EDM and the blockchain layer respectively, the experiment coordination layer is only used for synchronization of clients within an experiment.

This is accomplished by allowing experiment participant clients (prosumers) to connect to the backend through incoming sockets, registering to be ready to start the experiment. The clients themselves listen for the signal of the backend to start the experiment on their sockets and commence with the experiment upon reception.

The Experiment Coordination Layer further provides a special client, the experimenter, with the possibility to start the experiment, upon which it emits the start signal mentioned above to all connected clients.

IV. Discussion & Future Work

This articles gives an overview of the design of a laboratory infrastructure developed to study the perception and behavior of human actors in a synthetic environment for the (usually disintermediated) trade of electricity between prosumers.

A discussion on the literature on this topic informed the problem statement and the objective definition of the article, and motivated the need for developing such artifact. It informed a set of three (meta-)requirements that defined the approach of the research (technologically grounded)

Post-print, author version of article published on 13.10.2020 in
2020 17th International Conference on the European Energy Market (EEM), DOI: 10.1109/EEM49802.2020.9221919

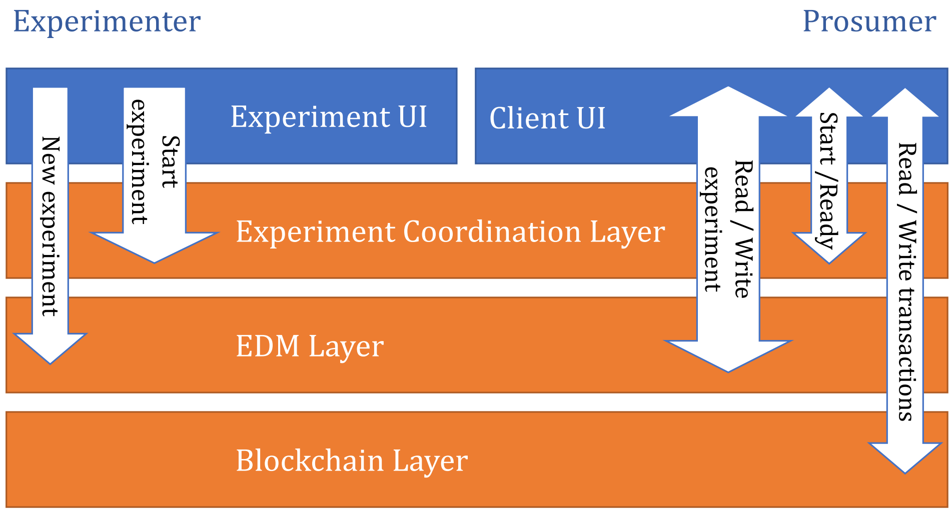

Figure 1. Layered architecture with users and the interaction layer (shown in blue) with the operational layers (orange) of the LabChain prototype.

and the functional design (meta-)requirements (generic and affordance-centered), based on existing approaches in the literature. While the technological grounding is fulfilled by definition (or rather the technical choices made), the latter ones are based on literature. These (meta-)requirements would need to be evaluated thoroughly through a wider review of existing literature (generic) and through interaction of software users in the context of application (affordance-centered). This would allow an evaluation as to whether intention and behavior fall together and whether the right interaction possibilities are provided. The appropriateness of the technological grounding could further be evaluated with expert interviews and is intended to be discussed within the current discourse.

The functional requirements for the software were addressed through a number of features of the implementation as shown in table III.

The designed artifact thus addresses the design requirements 1) – 3) and allows for socio-technical interactions within a range of simulated markets. We believe it is an effective foundation for developing and testing design principles for peer-centered market designs and more participatory, decentralized energy system designs. This allows for systematic contributions to the discourse of P2P electricity market design and would provide comparability of different system designs beyond case-specific analyses.

From the design process perspective, the current article focuses on the problem identification, solution objective and the design part of the initial design (as research process phases in [55]). Within the larger DSR approach, this contribution initiates an active discourse on how to develop such an ambitious research infrastructure that is to be used beyond the scope of this research project. Through this, it also attempts to establish a relevance and rigor cycle (in the sense of the information system research framework introduced in [22]) by actively engaging in the discourse, in order to ensure that the artifact will be relevant for the research community and is informed through this in rigor.

Complementary to approaches of design theory development or devising grounded professional rules on P2P market design (as required by [66]), it intends to pragmatically contribute to the discourse on research infrastructure development allowing for them to be derived and tested systematically and comparatively.

This article intents to pave the way to developing a tool that allows to systematically inform this process. Due to the constraints of the format and the state of the discourse, we believe engagement with the community to be more conducive to the development of such research infrastructure. As mentioned, coupling the current development to the relevance and rigor cycle ([22]) is imperative for the appropriate reflection on the system design. This constitutes one line of future work on this artifact. Similarly, investigating detailed case studies will enhance the relevance of the design of this artifact, as it serves to generate insight into different market designs. This systematic evaluation context would allow the assessment of the effectiveness of the artifact in simulating the respective energy systems under investigation. In order to constitute a fully situated implementation in the sense of Gregor and Hevner [17], the evaluation, coupled with iterative adaptions and reevaluation of the design, is necessary for establishing a full design cycle, which is part of ongoing research and will be covered in future full-length articles.

Acknowledgment

This research has been funded by the project "WindNODE" (project number 22041111) of the German Federal Ministry of Economic Affairs and Energy.

References

[1] Faizan Ali et al. "Cyberphysical Peer-to-Peer Blockchain based Energy Trading." In: (2020). arXiv: 2001.00746. URL: http://arxiv.org/abs/2001.00746.

[2] Merlinda Andoni et al. "Blockchain technology in the energy sector: A systematic review of challenges and opportunities." In: *Renewable and Sustainable Energy Reviews* 100 (2019), pp. 143–174. ISSN: 1364-0321. DOI: 10.1016/j.rser.2018.10.014. URL: http://www.sciencedirect.com/science/article/pii/S1364032118307184.

[3] R. Andrew Muller and Stuart Mestelman. "Emission Trading with Shares and Coupons: A Laboratory Experiment." In: *The Energy Journal* 15.2 (Apr. 1994). ISSN: 0195-6574. DOI: 10.5547/ISSN0195-6574-EJ-Vol15-No2-10. URL: http://www.iaee.org/en/publications/ejarticle.aspx?id=1163.

[4] Kelvin Anoh et al. "Energy Peer-to-Peer Trading in Virtual Microgrids in Smart Grids: A Game-Theoretic Approach." In: *IEEE Transactions on Smart Grid* 11.2 (2019), pp. 1264–1275. DOI: 10.1109/tsg.2019.2934830.

[5] Australian Renewable Energy Agency. *Peer-to-Peer Distributed Ledger Technology Assessment*. Accessed: 6-13-2020.

[6] Carsten Block, Dirk Neumann, and Christof Weinhardt. "A Market Mechanism for Energy Allocation in Micro-CHP Grids." In: *Proceedings of the Annual Hawaii International Conference on System Sciences (HICSS 2008)*. 2008, pp. 172–172. ISBN: 0769530753. DOI: 10.1109/HICSS.2008.27.

[7] Vincent Bohlen et al. *Open Data Spaces - Towards the IDS open data eco system*. Accessed: 6-13-2020. 2018. URL: https://www.internationaldataspaces.org/wp-content/uploads/2019/07/Open-Data-Spaces-IDSA.pdf.

[8] Umit Cali and Ozan Çakir. "Energy Policy Instruments for Distributed Ledger Technology Empowered Peer-to-Peer Local Energy Markets." In: *IEEE Access* 7 (2019), pp. 82888–82900. DOI: 10.1109/ACCESS.2019.2923906. URL: https://ieeexplore.ieee.org/document/8740846/.

[9] Sijie Chen and Chen-Ching Liu. "From demand response to transactive energy: state of the art." In: *Journal of Modern Power Systems and Clean Energy* 5.1 (2017), pp. 10–19. DOI: 10.1007/s40565-016-0256-x.

[10] Mehmet Hazar Cintuglu, Harold Martin, and Osama A. Mohammed. "Real-time implementation of multiagent-based game theory reverse auction model for microgrid market operation." In: *IEEE Transactions on Smart Grid* 6.2 (2015), pp. 1064–1072. DOI: 10.1109/TSG.2014.2387215.

[11] Matthew Davison et al. "Decentralised Energy Market for Implementation into the Intergrid Concept - Part I: Isolated System." In: *2018 7th International Conference on Renewable Energy Research and Applications (ICRERA)*. October. 2018, pp. 80–87. DOI: 10.1109/ICRERA.2018.8566753.

[12] Mel T. Devine and Paul Cuffe. "Blockchain Electricity Trading Under Demurrage." In: *IEEE Transactions on Smart Grid* 10.2 (2019), pp. 2323–2325. ISSN: 19493053. DOI: 10.1109/TSG.2019.2892554.

[13] "Directive (EU) 2019/1024 of the European Parliament and of the Council of 20 June 2019 on open data and the re-use of public sector information." In: *Official Journal of the European Union* L172 (2019), pp. 56–83. URL: http://data.europa.eu/eli/dir/2019/1024/oj.

[14] Noah C. Dormady. "Carbon auctions, energy markets & market power: An experimental analysis." In: *Energy Economics* 44 (July 2014), pp. 468–482. ISSN: 0140-9883. DOI: 10.1016/j.eneco.2014.03.013. URL: https://linkinghub.elsevier.com/retrieve/pii/S0140988314000607.

[15] Ali Dorri et al. "Peer-to-Peer EnergyTrade: A Distributed Private Energy Trading Platform." In: *2019 IEEE International Conference on Blockchain and Cryptocurrency (ICBC)*. May 2019, pp. 61–64. DOI: 10.1109/BLOC.2019.8751268. URL: https://ieeexplore.ieee.org/document/8751268/.

[16] Keke Gai et al. "Privacy-Preserving Energy Trading Using Consortium Blockchain in Smart Grid." In: *IEEE Transactions on Industrial Informatics* 15.6 (June 2019), pp. 3548–3558. DOI: 10.1109/TII.2019.2893433.

[17] Shirley Gregor and Alan R. Hevner. "Positioning and Presenting Design Science Research for Maximum Impact." In: *MIS Quarterly* 37.2 (2013), pp. 337–355. ISSN: 02767783. URL: https://www.jstor.org/stable/43825912.

[18] Jaysson Guerrero, Archie C. Chapman, and Gregor Verbič. "Decentralized P2P Energy Trading under Network Constraints in a Low-Voltage Network." In: *IEEE Transactions on Smart Grid* 10.5 (2018), pp. 5163–5173. DOI: 10.1109/TSG.2018.2878445.

[19] André Hackbarth and Sabine Löbbe. "Attitudes, preferences, and intentions of German households concerning participation in peer-to-peer electricity trading." In: *Energy Policy* 138 (2020), p. 111238. ISSN: 0301-4215. DOI: 10.1016/j.enpol.2020.111238. URL: http://www.sciencedirect.com/science/article/pii/S030142152030001X.

[20] Andrew Henley and John Peirson. "Residential energy demand and the interaction of price and temperature: British experimental evidence." In: *Energy Economics* 20.2 (1998), pp. 157–171. DOI: 10.1016/S0140-9883(97)00025-X. URL: http://www.sciencedirect.com/science/article/pii/S014098839700025X.

[21] Alan Hevner and Samir Chatterjee. "Design Science Research in Information Systems." In: *Design Research in Information Systems: Theory and Practice*. Boston, MA: Springer US, 2010, pp. 9–22. ISBN: 978-1-4419-5653-8. DOI: 10.1007/978-1-4419-5653-8_2.

[22] Alan R. Hevner et al. "Design science in information systems research." In: *MIS Quarterly: Management Information Systems* 28.1 (2004), pp. 75–105. ISSN: 02767783. DOI: 10.2307/25148625.

[23] Perica Ilak et al. "Decentralised electricity trading in the microgrid. Implementation of decentralized Peer-to-Peer Concept for Electricity Trading (P2PCET)." In: *MEDPOWER2018* (2018). URL: https://www.researchgate.net/publication/329093264_Decentralised_electricity_trading_in_the_microgrid_Implementation_of_decentralized_Peer-to-Peer_Concept_for_Electricity_Trading_P2PCET.

[24] Zejia Jing, Manisa Pipattanasomporn, and Saifur Rahman. "Blockchain-based Negawatt Trading Platform: Conceptual Architecture and Case Studies." In: *2019 IEEE PES GTD Grand International Conference and Exposition Asia (GTD Asia)*. 2019, pp. 68–73. DOI: 10.1109/gtdasia.2019.8715890.

[25] David Jones and Shirley Gregor. "The Anotomy of a Design Theory." In: *Journal of the Association for Information Systems* 8.5 (2008), pp. 312–335. URL: http://aisel.aisnet.org/jais/vol8/iss5/1/.

[26] Jiawen Kang et al. "Enabling Localized Peer-to-Peer Electricity Trading among Plug-in Hybrid Electric Vehicles Using Consortium Blockchains." In: *IEEE Transactions on Industrial Informatics* 13.6 (2017), pp. 3154–3164. DOI: 10.1109/TII.2017.2709784.

[27] Mohsen Khorasany, Yateendra Mishra, and Gerard Ledwich. "Peer-to-peer market clearing framework for DERs using knapsack approximation algorithm." In: *2017 IEEE PES Innovative Smart Grid Technologies Conference Europe, (ISGT-Europe)*. Vol. 2018-Janua. 2017, pp. 1–6. DOI: 10.1109/ISGTEurope.2017.8260107.

[28] Soohyeong Kim, Yongseok Kwon, and Sunghyun Cho. "A Survey of Scalability Solutions on Blockchain." In: *2018 International Conference on Information and Communication Technology Convergence (ICTC)*. 2018, pp. 1204–1207. DOI: 10.1109/ICTC.2018.8539529.

[29] S. Kuruseelan and C. Vaithilingam. "Peer-to-peer energy trading of a community connected with an AC and DC microgrid." In: *Energies* 12.19 (2019). DOI: 10.3390/en12193709.

[30] Kristie Kaminski Küster, Alexandre Rasi Aoki, and Germano Lambert-Torres. "Transaction-based operation of electric distribution systems: A review." In: *International Transactions on Electrical Energy Systems* (2019), e12194. DOI: 10.1002/2050-7038.12194. URL: https://onlinelibrary.wiley.com/doi/abs/10.1002/2050-7038.12194.

[31] Chou Hon Leong, Chenghong Gu, and Furong Li. "Auction mechanism for P2P local energy trading considering physical constraints." In: *Energy Procedia*. Vol. 158. 2019, pp. 6613–6618. DOI: 10.1016/j.egypro.2019.01.045. URL: http://www.sciencedirect.com/science/article/pii/S1876610219300542.

[32] Jason Lin, Manisa Pipattanasomporn, and Saifur Rahman. "Comparative analysis of blockchain-based smart contracts for solar electricity exchanges." In: *2019 IEEE Power Energy Society Innovative Smart Grid Technologies Conference (ISGT)*. 2019, pp. 1–5. DOI: 10.1109/ISGT.2019.8791632.

[33] Chao Liu et al. "Peer-to-peer electricity trading system: smart contracts based proof-of-benefit consensus protocol." In: *Wireless Networks* (Feb. 2019). DOI: 10.1007/s11276-019-01949-0. URL: https://doi.org/10.1007/s11276-019-01949-0.

[34] Nian Liu et al. "Energy-Sharing Model with Price-Based Demand Response for Microgrids of Peer-to-Peer Prosumers." In: *IEEE Transactions on Power Systems* 32.5 (2017), pp. 3569–3583. DOI: 10.1109/TPWRS.2017.2649558.

[35] Chao Long, Yue Zhou, and Jianzhong Wu. "A game theoretic approach for peer to peer energy trading." In: *Energy Procedia* 159 (2019), pp. 454–459. ISSN: 1876-6102. DOI: 10.1016/j.egypro.2018.12.075. URL: http://www.sciencedirect.com/science/article/pii/S1876610218313705.

[36] Chao Long et al. "Peer-to-peer energy trading in a community microgrid." In: *2017 IEEE Power Energy Society General Meeting*. 2017, pp. 1–5. DOI: 10.1109/PESGM.2017.8274546.

[37] Alexandra Lüth et al. "Local electricity market designs for peer-to-peer trading: The role of battery flexibility." In: *Applied Energy* 229.August (2018), pp. 1233–1243. ISSN: 0306-2619. DOI: 10.1016/j.apenergy.2018.08.004. URL: http://www.sciencedirect.com/science/article/pii/S0306261918311590.

[38] Javier Matamoros, David Gregoratti, and Mischa Dohler. "Microgrids energy trading in islanding mode." In: *2012 IEEE Third International Conference on Smart Grid Communications (SmartGridComm)*. February 2017. 2012, pp. 49–54. DOI: 10.1109/SmartGridComm.2012.6485958.

[39] Esther Mengelkamp, Johannes Gärttner, and Christof Weinhardt. "Decentralizing energy systems through local energy markets: The LAMP-project." In: *MKWI 2018 - Multikonferenz Wirtschaftsinformatik*. Vol. 2018-March. 2018, pp. 924–930.

[40] Esther Mengelkamp et al. "A blockchain-based smart grid: towards sustainable local energy markets." In: *Computer Science - Research and Development* 33.1 (2018), pp. 207–214. DOI: 10.1007/s00450-017-0360-9.

[41] Esther Mengelkamp et al. "Designing microgrid energy markets: A case study: The Brooklyn Microgrid." In: *Applied Energy* 210 (2018), pp. 870–880. ISSN: 0306-2619. DOI: 10.1016/j.apenergy.2017.06.054. URL: http://www.sciencedirect.com/science/article/pii/S030626191730805X.

[42] Esther Mengelkamp et al. "Quantifying Factors for Participation in Local Electricity Markets." In: *2018*

15th International Conference on the European Energy Market (EEM). IEEE, June 2018, pp. 1–5. ISBN: 978-1-5386-1488-4. DOI: 10.1109/EEM.2018.8469969. URL: https://ieeexplore.ieee.org/document/8469969/.

[43] Esther Mengelkamp et al. "Trading on local energy markets: A comparison of market designs and bidding strategies." In: *2017 14th International Conference on the European Energy Market (EEM)*. [Piscataway, New Jersey]: IEEE, 2016, pp. 1–6. DOI: 10.1109/EEM.2017.7981938.

[44] Yeray Mezquita et al. "Multi-agent architecture for peer-to-peer electricity trading based on blockchain technology." In: *019 XXVII International Conference on Information, Communication and Automation Technologies (ICAT)*. 2019, pp. 1–6.

[45] Mihail Mihaylov et al. "NRG-X-change a novel mechanism for trading of renewable energy in smart grids." In: *SMARTGREENS 2014 - Proceedings of the 3rd International Conference on Smart Grids and Green IT Systems*. INSTICC. SciTePress, 2014, pp. 101–106. ISBN: 978-989-758-025-3. DOI: 10.5220/0004960201010106.

[46] Mihail Mihaylov et al. "NRGcoin: Virtual currency for trading of renewable energy in smart grids." In: *11th International Conference on the European Energy Market (EEM14)*. 2014, pp. 1–6. DOI: 10.1109/EEM.2014.6861213.

[47] Fabio Moret and Pierre Pinson. "Energy Collectives: A Community and Fairness Based Approach to Future Electricity Markets." In: *IEEE Transactions on Power Systems* 34.5 (2019), pp. 3994–4004. DOI: 10.1109/TPWRS.2018.2808961.

[48] Thomas Morstyn and Malcolm D. McCulloch. "Multiclass Energy Management for Peer-to-Peer Energy Trading Driven by Prosumer Preferences." In: *IEEE Transactions on Power Systems* 34.5 (2019), pp. 4005–4014. DOI: 10.1109/TPWRS.2018.2834472. URL: https://ieeexplore.ieee.org/document/8356100/.

[49] Thomas Morstyn et al. "Using peer-to-peer energy-trading platforms to incentivize prosumers to form federated power plants." In: *Nature Energy* 3.2 (2018), pp. 94–101. ISSN: 20587546. DOI: 10.1038/s41560-017-0075-y. URL: http://dx.doi.org/10.1038/s41560-017-0075-y.

[50] Jordan Murkin, Ruzanna Chitchyan, and Alastair Byrne. "Enabling peer-to-peer electricity trading." In: *ICT for Sustainability 2016*. Atlantis Press, 2016, pp. 234–235. DOI: 10.2991/ict4s-16.2016.30.

[51] Jordan Murkin, Ruzanna Chitchyan, and David Ferguson. "Goal-based automation of peer-to-peer electricity trading." In: *From Science to Society*. Ed. by Benoît Otjacques et al. Springer, 2018. DOI: 10.1007/978-3-319-65687-8_13. URL: https://link.springer.com/chapter/10.1007%5C%2F978-3-319-65687-8_13.

[52] Bogdan-Constantin Neagu et al. "A New Vision on the Prosumers Energy Surplus Trading Considering Smart Peer-to-Peer Contracts." In: *Mathematics* 8.235 (2020), p. 25. DOI: 10.20944/preprints202001.0013.v1.

[53] Dinar Orazgaliyev et al. "Towards the Application of Blockchain technology for Smart Grids in Kazakhstan." In: *2019 21st International Conference on Advanced Communication Technology (ICACT)*. 2019, pp. 273–278. ISBN: 9791188428021. DOI: 10.23919/ICACT.2019.8701996.

[54] Jema Sharin PankiRaj, Abdulsalam Yassine, and Salimur Choudhury. "An Auction Mechanism for Profit Maximization of Peer-to-Peer Energy Trading in Smart Grids." In: *Procedia Computer Science* 151 (2019), pp. 361–368. ISSN: 1877-0509. DOI: 10.1016/j.procs.2019.04.050. URL: http://www.sciencedirect.com/science/article/pii/S1877050919305125.

[55] Ken Peffers et al. "A Design Science Research Methodology for Information Systems Research." In: *Journal of Management Information Systems* 24.3 (Dec. 2007), pp. 45–77. ISSN: 0742-1222. DOI: 10.2753/MIS0742-1222240302. URL: https://www.tandfonline.com/doi/full/10.2753/MIS0742-1222240302.

[56] Sandeep Purao. "Design Research in the Technology of Information Systems : Truth or Dare College of Business Design Research in the Technology of Information Systems : Truth or Dare." In: (2002). URL: https://www.researchgate.net/profile/Sandeep_Purao/publication/228606379_Design_research_in_the_technology_of_information_systems_Truth_or_dare/links/0fcfd5115dfda361ad000000/Design-research-in-the-technology-of-information-systems-Truth-or-dare.pdf.

[57] Alvin E. Roth. "The Economist as Engineer: Game Theory, Experimentation, and Computation as Tools for Design Economics." In: *Econometrica* 70 (July 2002), pp. 1341–1378. DOI: 10.1111/1468-0262.00335. URL: http://doi.wiley.com/10.1111/1468-0262.00335.

[58] Moein Sabounchi and Jin Wei. "A Decentralized P2P Electricity Market Model for Microgrids." In: *2018 IEEE Power Energy Society General Meeting (PESGM)*. 2018, pp. 1–5. ISBN: 9781538677032. DOI: 10.1109/PESGM.2018.8586257.

[59] Moein Sabounchi and Jin Wei. "Towards Resilient Networked Microgrids: Blockchain-Enabled Peer-to-Peer Electricity Trading Mechanisms." In: *2017 IEEE Conference on Energy Internet and Energy System Integration (EI2)*. 2017, pp. 1–5. DOI: 10.1109/EI2.2017.8245449.

[60] Olga Saukh, Franz Papst, and Sergii Saukh. "Synchronization Games in P2P Energy Trading." In: *2018 IEEE International Conference on Communications, Control, and Computing Technologies for Smart Grids (SmartGridComm)*. IEEE, 2018, pp. 1–6. ISBN: 9781538679548. DOI: 10.1109/SmartGridComm.2018.8587421.

[61] Stefan Seidel and Richard T. Watson. "Improving the Societal Effectiveness of IS Research: The Pursuit of

Prescriptive Accuracy." In: *SSRN Electronic Journal* (Aug. 2018). DOI: 10.2139/ssrn.2477917.

[62] Ashish Shrestha et al. "Peer-to-Peer Energy Trading in Micro/Mini-Grids for Local Energy Communities: A Review and Case Study of Nepal." In: *IEEE Access* 7 (2019), pp. 131911–131928. DOI: 10.1109/ACCESS.2019.2940751.

[63] Etienne Sorin, Lucien Bobo, and Pierre Pinson. "Consensus-Based Approach to Peer-to-Peer Electricity Markets with Product Differentiation." In: *IEEE Transactions on Power Systems* 34.2 (2019), pp. 994–1004. DOI: 10.1109/TPWRS.2018.2872880.

[64] Falti Teotia and Rohit Bhakar. "Local energy markets: Concept, design and operation." In: *2016 National Power Systems Conference (NPSC)*. 2017, pp. 1–6. DOI: 10.1109/NPSC.2016.7858975.

[65] Wayes Tushar et al. "A motivational game-theoretic approach for peer-to-peer energy trading in the smart grid." In: *Applied Energy* 243 (2019), pp. 10–20. ISSN: 0306-2619. DOI: 10.1016/J.APENERGY.2019.03.111. URL: https://www.sciencedirect.com/science/article/pii/S0306261919305185.

[66] Joan Ernst van Aken. "Management research based on the paradigm of the design sciences: The quest for field-tested and grounded technological Rules." In: *Journal of Management Studies* 41.2 (2004), pp. 219–246. DOI: 10.1111/j.1467-6486.2004.00430.x. URL: https://www.researchgate.net/publication/4868922.

[67] Piyush Verma et al. "EnerPort: Irish Blockchain project for peer- to-peer energy trading." In: *Energy Informatics* 1.1 (2018), pp. 1–9. DOI: 10.1186/s42162-018-0057-8.

[68] Perukrishnen Vytelingum et al. "Trading agents for the smart electricity grid." In: *The Ninth International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2010)*. 2010, pp. 897–904.

[69] Joseph G. Walls, George R. Widmeyer, and Omar A. El Sawy. "Building an Information System Design Theory for Vigilant EIS." In: *Information Systems Research* 3.1 (1992), pp. 36–59. DOI: 10.1287/isre.3.1.36. URL: https://www.jstor.org/stable/23010780.

[70] Shen Wang et al. "Energy Crowdsourcing and Peer-to-Peer Energy Trading in Blockchain-Enabled Smart Grids." In: *IEEE Transactions on Systems, Man, and Cybernetics: Systems* 49.8 (Jan. 2019), pp. 1612–1623. DOI: 10.1109/TSMC.2019.2916565.

[71] Yuan Wu et al. "Cooperative distributed energy generation and energy trading for future smart grid." In: *Proceedings of the 33rd Chinese Control Conference*. 2014, pp. 8150–8157. DOI: 10.1109/ChiCC.2014.6896365.

[72] Yuan Wu et al. "Optimal management of local energy trading in future smart microgrid via pricing." In: *2015 IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS)*. 2015, pp. 570–575. DOI: 10.1109/INFCOMW.2015.7179446.

[73] Yuan Wu et al. "Optimal pricing and energy scheduling for hybrid energy trading market in future smart grid." In: *IEEE Transactions on Industrial Informatics* 11.6 (2015), pp. 1585–1596. DOI: 10.1109/TII.2015.2426052.

[74] Pingping Xie et al. "Conceptual Framework of Blockchain-based Electricity Trading for Neighborhood Renewable Energy." In: *2018 2nd IEEE Conference on Energy Internet and Energy System Integration (EI2)*. 2018, pp. 1–5. ISBN: 9781538685495. DOI: 10.1109/EI2.2018.8581887.

[75] Xing Yan et al. "P2P Trading Strategies in an Industrial Park Distribution Network Market Under Regulated Electricity Tariff." In: *2017 IEEE Conference on Energy Internet and Energy System Integration (EI2)*. 2017, pp. 1–5. DOI: 10.1109/EI2.2017.8245684.

[76] Chenghua Zhang et al. "A Bidding System for Peer-to-Peer Energy Trading in a Grid-connected Microgrid." In: *Energy Procedia* 103.April (2016), pp. 147–152. ISSN: 18766102. DOI: 10.1016/j.egypro.2016.11.264. URL: http://www.sciencedirect.com/science/article/pii/S1876610216314746.

[77] Yanglin Zhou et al. "A new framework for peer-to-peer energy sharing and coordination in the energy internet." In: *2017 IEEE International Conference on Communications (ICC)*. IEEE, 2017, pp. 1–6. DOI: 10.1109/ICC.2017.7996424.

[78] Yue Zhou, Jianzhong Wu, and Chao Long. "Evaluation of peer-to-peer energy sharing mechanisms based on a multiagent simulation framework." In: *Applied Energy* 222 (2018), pp. 993–1022. ISSN: 0306-2619. DOI: 10.1016/j.apenergy.2018.02.089. URL: http://www.sciencedirect.com/science/article/pii/S0306261918302149.

[79] Yue Zhou et al. "Performance Evaluation of Peer-to-Peer Energy Sharing Models." In: *Energy Procedia* 143 (2017), pp. 817–822. ISSN: 1876-6102. DOI: 10.1016/j.egypro.2017.12.768. URL: http://www.sciencedirect.com/science/article/pii/S1876610217365323.

Post-print, author version of article published on 13.10.2020 in
2020 17th International Conference on the European Energy Market (EEM), DOI: 10.1109/EEM49802.2020.9221919

Table I: Motivation Blockchain technology for Peer-to-Peer energy trade

Motivation	**References**
Performance	
Settling time reduction / Improved System efficiency	[5] / [8]
Overcome scalability bottleneck of centralized systems / Efficiency	[11] / [23, 74]
Less vulnerable than centralized solution / Scalability	[16] / [59, 67]
Higher operation speed / Cost-efficient transactions of smallest quantities	[53] / [41, 74]
Information Quality	
Source of Truth / Quality tracking / Auditability / Transparency	[5] / [8] / [15, 33] / [16, 40, 41, 62, 74]
Traceability / Transaction accuracy / Robustness / Credibility	[16, 74] / [50] / [53, 58, 67] / [74]
Transaction authentication or authenticity / Security / Data integrity	[50, 52] / [15, 23, 24, 26, 32, 44, 50, 52, 53, 58, 59, 67] / [53]
Empowerment	
Prosumer emp. / Decentralization / Anonymity / Consensuality / Distr. architecture	[11] / [15, 26, 44] / [15] / [16] / [24]
Privacy-preservance / Fairness / Disintermediation / User friendlyness	[15, 26] / [32] / [33] / [40, 41]
Control shift to participants / Resolving conflicts of interest / Information symmetry	[41] / [41] / [41]
Operational Parameters	
Operat. simplif. / Dec. RT transact. en. man. / Network monitoring and control[1]	[5] / [53] / [62]
Organizational Design	
Regulation streamlining / Societal benefit[2]	[5] / [41]
Market Provision	
Dec. market platform provision / Trustless market prov. / Trading rules impl.	[11, 18] / [11] / [62]
Price-discriminatory market provision / Market requirement suitability[3]	[58] / [67]
Transaction Execution	
Condit. or autom. contract ex. / Power of smart contr. / aut. operation / Trade enf.	[11, 53, 74] / [23] / [23, 44, 59, 74] / [67]
Coord. for P2P trading / Record of traded electricity / Secure and reliable transac.	[33] / [37] / [59]
Settling	
Cap. for fin. transac. / Transp. autom. settlem. sys. / Adapt. and secure fin. model	[11, 44, 74] / [37] / [59]
Transp. autom. settlement system / Double-spending risk mitigation / Quick, guaranteed and cheap payment	[37] / [41] / [67]
Trust and involved parties	
Trusty[4] / Tackle rel. on trust. parties / Increased resil. and trust in microgrids	[12, 16, 23, 26, 32] / [15] / [41]
Oper. wout cent. superv. / Certifiability / 3rd party man. possibility / Openness	[39] / [59] / [67] / [74]
Technology Management	
Adressing need for innovative ICT / Online-interruption possibility / Interoperability	[29] / [67] / [67]

Table II: Roles in reviewed P2P electricity trade proposals

Roles	**References**
aggregators / retailers / energy sharing provider	[5, 8, 10, 24, 26, 52, 58, 64] / [5, 18, 49, 65] / [34]
grid or system operators / utilities/suppliers / wholesalers	[10, 18, 27, 31, 44–47, 52, 59, 60, 64, 68, 70, 75, 76] / [8, 41, 45, 46, 64, 70, 72, 73, 76–78] / [5]
community/trading managers/platform operators	[36, 47, 49, 72, 73, 75–78]
auctioneers / controllers / liquidity provider	[58] / [6] / [12]
governmental authorities / load balancing authorities / central market player	[8] / [9] / [39]
DER vendor / various specialized agents	[49] / [10, 44]

Table III: Artifact Features addressing Design Requirements

Requirement	**Feature**	**Layer**
offer	Offer Interface, Offer Transaction	User Interface, Blockchain Layer
prosumer	Prosumer Module	User Interface
generic actor	Generic Actor Module	User Interface
flexible market design configuration	Market Data Structure	EDM platform
heterogeneous prosumer asset setups	Prosumer Asset Configuration	EDM platform
operate assets	Asset Dispatch Component	User Interface
monitor peer-markets	Market View Component	User Interface
make forecasts	Feed-In Obligation Display Component	User Interface
buy and sell electricity	Market Component	User Interface, Blockchain
real implementation	Software Implementation	All
transaction storing blockchain components	Transaction-comprising Blocks	Blockchain
open data store	EDM Platform	Open Data Layer
user interface	Angular Web-app	User Interface

[1] Allowing system operators to monitor and control the network.
[2] Potential to benefit economic, political, humanitarian and legal sectors.
[3] Of markets requiring automation, self-regulation and scalability.
[4] Allows transactions without mutual trust.