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# Peer-to-peer electricity trading in China and the EU – A comparative evaluation of key policy documents

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## ABSTRACT

Peer-to-peer electricity trading is the exchange of electricity between interconnected participants, such as distributed energy generators, consumers and prosumers. While the term 'peer-to-peer electricity trading' is common in scientific discussions, the term is rarely used in policy language. However, with an increase of distributed energy resources and the need for effective management mechanisms, policy documents of the EU and China in recent years have supported the concept without explicitly using the term. This paper uses qualitative content analysis and examines six relevant policy documents of the EU and China that were issued between 2016 and 2019 to determine to what extent they reflect the concept of the 'peer-to-peer electricity trading' in language and content. Key terms, similarities, and differences in the conceptualisation of peer-to-peer electricity trading in the EU and China are identified. The results show that while the conditions and focus of the documents are different in the EU and China, the concept of peer-to-peer trading is a running theme in both regions.

## 1. Introduction

A 100 % electricity supply from renewable energy sources is not only technically feasible but also viable (Brown et al., 2018), but institutional obstacles often stand in the way of optimal integration of renewable energy resources. With an uptake of distributed energy sources, such as rooftop solar photovoltaics (PV), battery storage and electric vehicles (EVs), it is becoming increasingly complex to manage the multitude of sources and ensure the stability of the grid. A promising solution for distributed energy is peer-to-peer (P2P) electricity trading. At the distribution level of the grid, this describes the exchange of electricity between interconnected participants, such as small-scale energy generators, consumers and prosumers (consumers who also generate electricity). This aids the integration of renewable energy through balancing of local generation and demand and providing flexibility (Mengelkamp et al., 2018; Liu et al., 2018; Zhang et al., 2018), and consumers are empowered to actively engage in the electricity exchange according to their preferences (Sousa et al., 2019; Mengelkamp et al., 2019). While the concept has received significant attention in the literature (Alvaro-Hermana, Fraile-Ardanuy, Zufiria, Knapen, & Janssens, 2016; Giotitsas, Pzaitis, & Kostakis, 2015; Lüth, Zepter, Crespo del Granado, & Egging,

2018; Morstyn, Teytelboym, McCulloch, & Member, 2019; Sorin, Bobo, Pinson, & Member, 2019; Sousa, Soares, Pinson, & Moret, 2019; Tushar et al., 2018; Van Soest, 2019), the term is rarely used in policy language. Policy documents such as the EU's 'Clean Energy Package for all Europeans' (European Commission, 2019) and China's 'Outline of the pilot program for distributed power generation market trading' (NEA, 2017) show that even though the term 'P2P electricity trading' is rarely used in policy language, the concept is present in both regions.

Building on current literature and the microgrid energy market framework by Mengelkamp et al. (2018), we examine relevant policy documents of the EU and China to determine how P2P electricity trading are reflected in the documents in terms of language and content. By doing so, this paper seeks to narrow the gap between the scientific and policy understanding of P2P electricity trading. The new contributions of this paper can be summarised as followed:

1. Review of the policy documents on P2P electricity trading in the EU and China.
2. Identification of key terms that can contribute to understanding in cooperation between the EU and China.

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### 3. Presentation of the similarities and differences in the conceptualisation of P2P electricity trading in the EU and China.

Following the brief introduction to the theoretical background and the microgrid energy market framework by Mengelkamp et al. (2018) in Section 2, an explanation of methodology and materials is provided in Section 3, in which the relevant policy documents are identified. In Section 4 the results of the policy evaluation are presented. Section 5 concludes the paper.

At this point, it is worth mentioning that the energy systems in the EU and China are very different, in terms of the energy mix, the development status of their electricity markets and electricity grid planning. These differences will not be discussed here; a comparison will only be made here on the concept of 'P2P electricity trading' with limited reference to the selected documents. Furthermore, it should be noted that there is some delay between the research and implementation of pilot projects, and the definition of the concept 'P2P trade' in policy making. It is to be expected that this area will continue to develop dynamically in the coming years.

## 2. Theory

Research on P2P electricity trading is often interdisciplinary, with scientists blurring the boundaries between engineering, economics, information technology, and social science subjects. There is therefore no universal definition of P2P electricity trading. Often the terms used to name the concept differ, with most of the studies using either 'local electricity market' (Lüth et al., 2018; Mengelkamp et al., 2017; Le Cadre, 2019), 'P2P electricity markets' (Sousa et al., 2019; Tushar et al., 2018; Morstyn et al., 2019; Parag and Sovacool, 2016; Khorasany et al., 2020; Liu et al., 2019), or a variation of these. With the different terms, however, the scope of the defined concept can change as well. When the term 'local electricity market', 'microgrid market' or 'neighbourhood electricity market' is used, the focus is usually on small-scale distribution grids (Mengelkamp et al., 2018; Uhde and Malima, 2020). The focus is not always on the participation of 'peers', as is the case with the 'P2P markets'. The term 'P2P electricity trading' emphasises that the participants of the electricity exchange are equal 'peers' that are connected in a symmetrical relationship (Van Soest, 2019). This is to be seen in contrast to the hierarchical, unbalanced relationship that is found in retail electricity markets, where the consumer is usually a passive price-taker. Van Soest (2019) emphasises that the participating parties are in a 'equal parties or peers' and do not trade electricity professionally. This paper sets out to find out if such terms can also be found in policy definitions. Studies that use the term 'P2P market' usually refer to a trading mechanism without centralized supervision, which is mirrored in the clearing algorithm of a distributed market, while other terms do not necessarily imply this. However, while most studies focusing on 'P2P markets' mainly investigate microgrid distribution systems, the term 'P2P trading' does not necessarily imply the small scale of the market. Virtual transactions enable prosumers to share their electricity on a larger scale. An example is the P2P sharing concept of 'sonnenCommunity', where residential consumers are enabled to share excess electricity generated by a solar PV system with 'sonnenCommunity' members throughout Germany (sonnenCommunity, n.d.).

This paper argues that these exchanges are all based on the same concept, but with slight variations. Often the same author uses different terms in different studies, or different terms for the same concept within a study. Their unifying concept is based on four main characteristics: consumer and/or prosumer participation, distributed energy as the commodity, the importance of underlying information and communications technology (ICT) and a small-scale operation. In addition to the mentioned factors, several authors emphasize the importance of digitalisation as a key factor for the successful implementation of P2P electricity trading (Lüth, Zepter et al., 2018; Mengelkamp, Notheisen, Beer, Dauer, & Weinhardt, 2017; Parag & Sovacool, 2016). Despite

different terminology, certain similarities of the concept can be determined; Mengelkamp et al. (2018) define seven P2P components for an efficient operating microgrid energy market. Based on this framework, this research evaluates how the trading components are reflected in the regulation, which is itself one of the components.

Since we are examining the components from the regulation perspective, we have changed the order of the components slightly and start with the regulation. Moreover, as regulation, not a specific market case, has been evaluated, the number of components has been reduced from seven to five. This was done by integrating the information system and energy management system (EMTS) in component four (C4) and uniting the market and price mechanism together in component five (C5). Fig. 1 provides an overview of the five components that are described below.

**C1) Regulation:** The legal environment of P2P electricity trading in the electricity sector, including fees, taxes, and the framework for the overall market design. The following components should be at least roughly defined in the regulation:

**C2) Setup:** Definition of participants, the transactional object, the scale, and the objective of the market. This analysis evaluates the government's motivation for supporting P2P electricity trading.

**C3) Grid connection:** Connection of the P2P electricity market to the superordinate electricity grid. The P2P electricity market in a microgrid can function as an island market, however, there is usually a connection to the higher-level network via the existing lines of the distribution network; this is important for balancing.

**C4) Information system:** The information system is the digital infrastructure of the market and enables communication between the participants of the exchange. A software that processes the trading data in real time and offers/buys electricity based on the preferences of the market participants. In the framework by Mengelkamp et al. (2018), the energy management trading system (EMTS) is viewed as a stand-alone component.

**C5) Market and price mechanism:** Market and price mechanisms are at the centre of a P2P electricity market and are supposed to enable an efficient allocation of the available resources. In a perfect P2P electricity market, the price reflects the local supply and demand for electricity. The regulation determines which market mechanisms are

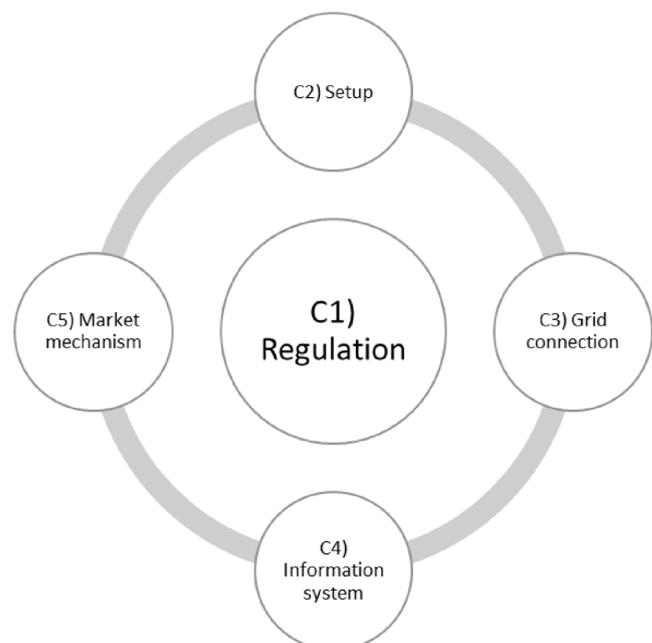


Fig. 1. Overview of the P2P electricity market components. Adopted from Mengelkamp et al. (2017).

allowed, for example a central auction or distributed market mechanisms that do not require a market operator, such as distributed blockchain-based markets. Market mechanisms are cleared according to the price mechanism, e.g., uniform or pay-as-you-bid price mechanisms.

### 3. Material and methods

#### Collection and preparation of materials

As the term 'P2P electricity trading' is rarely used in policy documents, a literature search was first carried out in order to determine key terms which are used to describe the concept of 'P2P electricity trading'. Based on the literature review, five key terms were identified that can represent P2P electricity trading: consumer (participation), distributed energy, market mechanism, small scale, and the use of ICT. Using these terms, government declarations published by the European Commission and National Energy Administration of China (NEA) and / or National Development and Reform Commission (NDRC) were identified and selected. A list of the main policy measures in this context is given in (Uhde and Malima, 2020). See Table 1 for an overview of the policy documents evaluated in this study.

Unbundling of the electricity sector is an important step not only for competition and cost effectiveness in the electricity sector, but also for consumer participation and the creation of P2P electricity trading. In the EU, major energy market reforms are based on the three Electricity Directives, which were adopted by the EU Parliament and the Council in 1996, 2003 and 2009 (European Parliament and Council, 1996; Parliament and Council, 2003; Parliament and Council, 2009). These directives introduced a European electricity market and common rules for an internal electricity market, as well as the unbundling of generation, distribution and transmission systems and enabling consumer rights for the free choice of the provider. With the recasts of the 'Renewable Energy Directive' (RED) and the 'Internal Market Directive' (IMD) as part of the 'Clean Energy for all Europeans' package, the role of 'active consumers' and 'renewable self-consumers' as active participants of the electricity market were defined (Parliament and Council, 2018; Parliament and Council, 2019). Although the implementation of the guidelines may differ in each member state, these directives allow consumers to store, sell and consume their self-generated electricity. Consumers can also participate in demand mechanisms and energy efficiency programs.

China's last round of power market reforms started in 2015, with the 'Deepening Reform of the Power Sector' (Document No.9) (CCPCP, 2015). This reform emphasised market-based instruments and the 'energy internet' i.e., the interconnection of the energy sector with the internet. The energy internet encapsulates energy production, transmission, storage, consumption, and the energy market and can be regarded as China's version of the smart grid (NDRC, 2016). In addition, 'Energy Supply and Consumption Revolution Strategy', and 'Guiding opinions for the Energy Internet' were adopted by the NDRC in 2016. In

2017, NEA announced the implementation of market pilots for distributed energy (NEA, 2017). Details of what these markets could look like were published and put up for discussion one year later in the 'Distributed Generation Management Measures' (DGMM) (NEA, 2018). Most recently in 2019, a list of market pilots for distributed energy was issued by the government (NDRC, 2019).

#### Overview qualitative data analysis

In order to examine and interpret the policy documents in a transparent and reliable manner, qualitative content analysis (QCA) was recommended as a systematic approach (Salehijam, 2018; Kuckartz, 2019). Fig. 2 depicts the QCA process, including data preparation, data coding, inductive formation of subcategories, the reduction of data in summary grids, as well as the evaluation and interpretation of themes. Creswell (2009) emphasises that the process is not hierarchical, but rather interactive with interrelations between the different steps. The analysis was conducted using MAXQDA 2020 software. An application guide for QCA using MAXQDA is given in (Kuckartz and Kuckartz, 2002).

#### Deductive and inductive coding

The focus of QCA is building and working with categories, such as factual thematic, evaluative, analytical, and theoretical categories (Kuckartz, 2019). In order to build these categories, parts of the texts with a similar meaning are marked - the 'coding process'. Building on the microgrid energy market framework by Mengelkamp et al. (2018), the deductive coding process was started with a rough code book reflecting the seven components of the framework: set up (participants, commodities, objective), grid connection, information system, market mechanism, pricing mechanism, Energy Management System (EMTS), and regulation. During several coding cycles, more inductive codes were added until a point of saturation was reached. A description was created for each code in MAXQDA in order to avoid redundant or mislead use of the codes.

#### Reduction of data and interpretation

The coded elements were summarised in summary grids, in order to synthesise the key content. The summary grids, which now provide an overview of the key statements of each policy document in the respective category, helped to compare the policy documents by category. The next step was the interpretation of the statements, based on the research question: How is the concept of P2P electricity trading reflected in the EU and China policy documents?

### 4. Results

The results of the qualitative content analysis showed that although the terms and content found in the policy documents of the EU and

**Table 1**  
Overview of key policy documents on P2P electricity trading regulation in the EU and China.

Year	Government body	Title of the policy document	Relevance for P2P electricity markets
2018	EU	Renewable energy directive (2018/2001 / EU) (Parliament and Council, 2018)	Key documents enabling consumer participation in electricity markets
2019	EU	Directive on common rules for the internal electricity market ((EU) 2019/944) (Parliament and Council, 2019)	
2016	NDRC	National Energy Supply and Consumption Revolution Strategy (2016–2030) (NDRC, 2016)	Enabling consumer participation in micro-balancing and energy markets
2016	NDRC	Guiding Opinions on Promoting the Development of "Internet +" Smart Energy (NDRC, 2016)	
2017	NEA	Outline of the pilot program for distributed power generation market trading (NEA, 2017)	Key documents defining market pilots for distributed energy
2018	NEA	Distributed Generation Management Measures (NEA, 2018)	

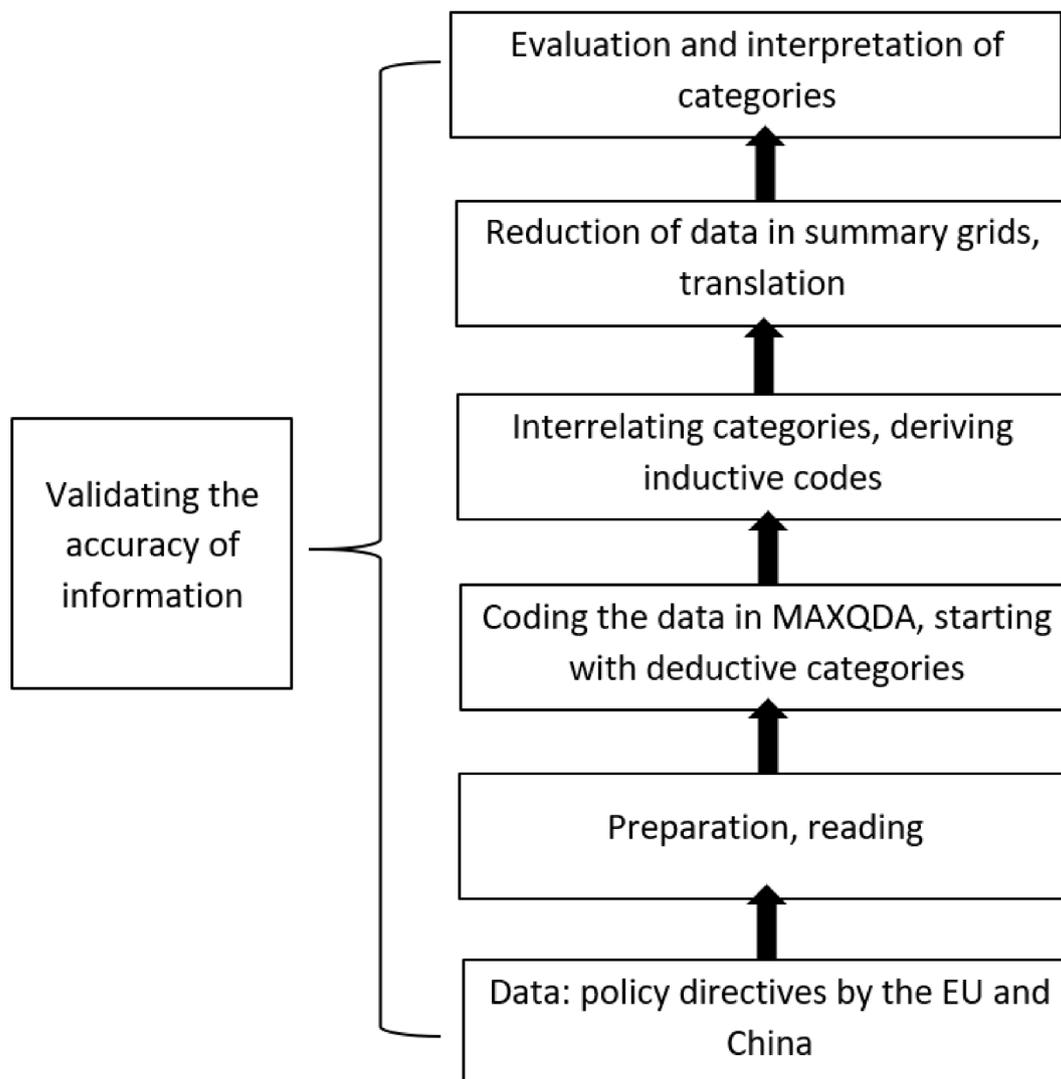


Fig. 2. Qualitative Data Analysis Process. Adopted from Creswell (Creswell, 2009).

China differ, P2P electricity trading concepts can be found in the documents of both regions. Table 2 depicts a summary of the main results.

## C2) Setup

### C2.1) Market Participants

One of the key characteristics of P2P electricity trading is the active participation of consumers. Both in the EU and China's policy documents, the participation of residential consumers, commercial and industrial consumers, participation of EVs and participation of consumer groups in electricity markets is mentioned.

#### Consumer participation in the EU

According to EU policy documents, all consumer groups, including industrial and commercial consumers, have the right to trade their flexibility and self-generated electricity on electricity markets (Parliament and Council, 2019).

'In the past, electricity customers were purely passive, often buying electricity at regulated prices which had no direct relation to the market. In the future, customers need to be enabled to fully participate in the market on equal footing with other market participants and need to be empowered to manage their energy consumption.' EU (2019/943) Electricity Regulation – Internal Market, p. 2.

Under RED and the IMD, consumers have been assigned a new role, that of 'renewable self-consumers' (Art. 21 of the RED) and 'active consumers' (Art. 15 of the IMD). Under this regulation, consumers are entitled to consume, store and sell their excess generation and to participate in flexibility and energy efficiency schemes. The selected EU policy documents emphasise non-discrimination of residential market participants repeatedly. Residential consumers are legally equated with other market participants.

'Member States shall ensure that final customers are entitled to act as active customers without being subject to disproportionate or discriminatory technical requirements, administrative requirements, procedures and charges, and to network charges that are not cost-reflective.'

EC (2019/944): Electricity Directive, p. 26.

In the key EU policy documents, consumer groups are defined under two terms: 'citizen energy communities' (Art. 22 of the RED) and '(local) renewable energy communities' (Art. 16 of the IMD). These energy communities are legal entities on a voluntary and open participation basis that are able to engage in a wide variety of energy sector activities, including generation, supply, consumption, distribution and aggregation of electricity (Parliament and Council, 2018; Parliament and Council, 2019). However, regulations that are intended to facilitate market access, e.g., for the renewable self-consumer, do not apply to

**Table 2**  
Overview of the results.

	EU	China
<b>C2) Set up</b>	Residential consumer, community energy initiatives, citizen energy community, renewable energy community, renewables self-consumers', electric vehicles	Distributed power generation project ( <i>including commercial and industrial</i> ), residential consumers, electric vehicles
Market participants	Distributed energy, focus on renewable energy; flexibility	Distributed energy, including renewable energy, gas, geothermal; flexibility
Transactional object		
Scale	<ol style="list-style-type: none"> <li>1. Local participation</li> <li>2. Communities</li> <li>3. Virtual market</li> </ol>	<ol style="list-style-type: none"> <li>1. Users within the same power supply range (distribution grid)</li> <li>2. Pilot areas, i.e., economic development zones and industrial parks</li> </ol>
Objective	<ol style="list-style-type: none"> <li>1. Decarbonising the energy system</li> <li>2. Making use of all available sources of flexibility</li> <li>3. Consumer empowerment</li> <li>4. Environmental, economic or social community benefits</li> </ol>	<ol style="list-style-type: none"> <li>1. Develop and utilize renewable energy</li> <li>2. Build a multi-energy complementary distributed clean energy supply system</li> <li>3. Support end users to achieve equal participation and energy sharing based on the Internet platform</li> <li>4. Develop an integrated energy microgrid that supports distributed energy transactions</li> </ol>
<b>C3) Grid connection</b>	The EU provides non-discriminatory access with simplified procedure for installations with a capacity of 10.8 kW or less.	The grid company is responsible for the investment and construction of the external connection facilities of distributed power generation and the part of the public grid transformation caused by the connection
<b>C4) Information System</b>	Energy management system, smart grid	Energy management system, "Internet +"
<b>C5) Market mechanism</b>	To be specified by member states: <ol style="list-style-type: none"> <li>1. Market participation</li> <li>2. Sale of excess production (unspecified) p</li> <li>3. Power purchase agreements,</li> <li>4. Peer-to-peer trading</li> </ol> Individual participation, as well as participation in markets through aggregators/third-party companies.	To be specified on provincial/local level: <ol style="list-style-type: none"> <li>1. Direct electricity transactions with electricity users</li> <li>2. Entrusting power grid companies to sell electricity on their behalf</li> <li>3. Sales to grid</li> </ol> Individual participation, as well as participation in markets through aggregators/third-party companies.

non-residential self-consumers that store or sell electricity as their primary business activity ([sonnenCommunity, n.d.](#)).

EVs are rarely mentioned in the EU key documents, however, their potential role as a flexibility resource is recognised ([Parliament and Council, 2019](#)).

#### Consumer participation in China

In China's 13th Five Year Plan (FYP) for the electricity sector, communities are encouraged to invest in distributed energy resources for self-consumption. However, specific rights and obligations are not defined ([NDRC, 2016](#)). For power transmission, grid enterprises with social capital investment on distribution level are encouraged to organise market-based transactions of distributed energy resources ([NEA, 2017](#)). While the active participation of users (用户) and consumers (消费者) is underlined, no distinction is made between commercial and non-commercial participants. The term 'distributed power generation projects' (分布式发电项目) includes both commercial and non-commercial participants, who can pursue this activity as a sideline or main business ([NEA, 2017](#)). Businesses are also encouraged to participate in micro-balancing markets ([NDRC, 2016](#)).

In the DGMM, residential consumers (家庭用户) are only mentioned four times while individuals (个人) are mentioned three times ([NEA, 2018](#)), and in the 'Outline of the pilot program for distributed power generation' ([NEA, 2017](#)), individuals are only mentioned once to specify that 'distributed generation units' include residential consumers. An exception here are the 'Guiding Options for the Energy Internet', in which the involvement of residential consumers in a 'micro-balancing market' is clearly mentioned:

'Encourage enterprises, residential users and distributed resources, power load resources, and energy storage resources to conduct local autonomous transactions through the micro-balanced market, guide energy production and consumption behaviour through real-time transactions, and realize the integration of distributed energy production and consumption.' NDRC (2016): Guiding opinions of the "Internet Plus" Action Plan, Pos. 50.

The participation of EVs in direct energy trading is specifically encouraged in this document as well:

'Actively develop the smart charging and discharging business of electric vehicles, and explore new models for electric vehicles to use the Internet platform to participate in direct energy trading and power demand response.' NDRC (2016): Guiding opinions on the "Internet Plus" Action Plan, Pos. 59.

Overall, the EU documents tend to emphasise the rights of consumers, while the Chinese documents tend to refer to obligations, i.e., consumers in the EU are entitled to receive their own data, while the Chinese key documents indicate that market participants 'should cooperate in providing relevant information' ([NEA, 2018](#)). These include distributed energy resources, flexibility services, storage capacity, and other 'smart services'. The definitions on both sides leave space for innovative energy products. The EU documents reviewed focus on the sale of self-generated electricity by consumers and the provision of flexibility using batteries or EVs ([Parliament and Council, 2019](#)).

'Consumers should be able to consume, to store and to sell self-generated electricity to the market and to participate in all electricity markets by providing flexibility to the system, for instance through energy storage, such as storage using electric vehicles, through demand response or through energy efficiency schemes. New technology developments will facilitate those activities in the future.' EC 2019 944 Electricity Directive, P. 6: 3106

While the EU documents centre around distributed renewable energy, the Chinese documents mention distributed gas, distributed geothermal and other small-scale generation in addition to distributed renewable energy ([NEA, 2018](#)). Here, too, the possibility of offering flexibility is often mentioned, especially in connection with EVs ([NDRC, 2016](#)).

'Actively develop the smart charging and discharging business of electric vehicles, and explore new models for electric vehicles to use the Internet platform to participate in direct energy trading and power demand response.' NDRC (2016): Guiding opinions of the "Internet Plus" Action Plan, Pos. 59.

On both sides, space is left for different commodities and business models yet to be developed.

## C2.2) Objectives

The documents examined present the policy objectives, not the motives of the individual trading projects. Recurring objectives on both sides include consumer empowerment, integration of renewable energy, increase flexibility, decarbonisation, creation of incentives for (social) investments, and the affordability of energy products. Decarbonisation can be found on both sides as the main target. With the decarbonisation target, the share of renewables in the system increases, and with it the need for flexibility options. The importance of flexibility and the role of active consumers in creating flexibility is recognised in the documents both in the EU and in China:

‘Consumers have an essential role to play in achieving the flexibility necessary to adapt the electricity system to variable and distributed renewable electricity generation. (...) By empowering consumers and providing them with the tools to participate more in the energy market, including participating in new ways, it is intended that citizens in the Union benefit from the internal market for electricity and that the Union’s renewable energy targets are attained.’ EC (2019/944): Electricity Directive, p. 2.

‘Build a comprehensive energy micro-grid that accepts a high proportion of renewable energy, promotes flexible and interactive energy use behaviour, and supports distributed energy transactions.’ NDRC (2016): Guiding opinions of the “Internet Plus” Action Plan, Pos. 34.

As these quotations show, consumer participation is not an end in itself, but supports the overarching goals of integrating renewable energy by creating flexibility via time-varying electricity prices that reflect actual local demand and supply and thus helping to achieve the government’s goals of decarbonisation. In the EU key documents, consumer empowerment is a reoccurring theme. Community energy initiatives in particular are primarily intended to create ‘environmental, economic or social community benefits to its members’ and offer energy products and services in a cost-effective manner (Parliament and Council, 2019). Non-discrimination, open systems and the protection of vulnerable consumers in particular are emphasised (Parliament and Council, 2018; Parliament and Council, 2019). In the key Chinese documents, dismantling of barriers and equal participation of users is mentioned in addition to the integration of renewable resources, the development of flexibility resources and incentives for investments in distributed energy (NDRC, 2016; NDRC, 2016). Overall, however, non-commercial consumers do not play a central role as in the Chinese policy documents and the choice of language is oriented towards the technical aspects of grid integration.

## C2.3) Scale

The scale of a P2P electricity exchange can be limited to a microgrid or neighbourhood at the distribution grid level, or it can be extended virtually beyond physical boundaries. The EU documents don’t specify whether P2P electricity trading is to take place in a local market or on a broader scale, while the framing in the Chinese documents is clearly local. Under RED, the renewable self-consumer is supposed to operate ‘within its premises located within confined boundaries or, where permitted by a Member State, within other premises’. Depending on the regulation of the member state, P2P trading can be restricted to a microgrid or a neighbourhood, as well as being allowed across local borders (Parliament and Council, 2018). The regulation stresses that the markets should be open to all potential local members on the basis of objective, transparent and non-discriminatory criteria. In the Chinese policy documents, it is repeatedly specified that market pilots for distributed energy will take place between ‘nearby power users in the distribution network’ (NEA, 2017). The limit is set with the power range, trading should take place at the distribution grid level – and thus

trading is also geographically limited.

## C3) Grid connection

Grid access plays an essential role in consumers’ ability to trade electricity; without grid access cost-intensive infrastructure has to be built. Otherwise, trading will be limited to purely virtual electricity trading. The EU documents repeatedly point out that consumers must not be discriminated against when it comes to grid access. It is the responsibility of the member states to ensure this:

‘Member States shall establish a simple-notification procedure for grid connections whereby installations or aggregated production units of renewables self-consumers and demonstration projects, with an electrical capacity of 10,8 kW or less, or equivalent for connections other than three-phase connections, are to be connected to the grid following a notification to the distribution system operator.’ EU (2018/2001): Renewable Directive, p. 35.

In addition, EU member states are required to ensure the necessary infrastructure without disproportionate costs (Parliament and Council, 2019). However, these rights do not come without obligations on the part of the consumer. For example, active customers that own an energy storage facility must ensure that all necessary conditions are met, including balancing responsibility and adequate metering. For installations or aggregated resources with a capacity of above 10.8 kW and up to 50 kW, simplified notification procedures are in place, provided that stability, reliability and safety of the grid are maintained (Parliament and Council, 2018). In the event of ‘justified grounds of safety concerns or technical incompatibility of the system components’, distribution system operators may reject the connection or propose an alternative grid connection point (Parliament and Council, 2018).

In the assessed Chinese documents, it is clearly defined that the grid company is responsible for the infrastructure and local network operators are responsible for ‘regularly publishing sub-voltage levels (...) that can accept distributed generation capacity, load conditions, and other information required for distributed power generation and grid connection with the power grid companies in the region’ (NEA, 2018). The documents do not explicitly mention non-discrimination in grid access, however, the provision of ‘convenient grid access’ for distributed generation projects is stated:

‘Grid companies are responsible for the investment and construction of the external connection facilities of distributed power generation and the part of the public grid transformation caused by the connection, and provide convenient, timely and efficient grid access services for distributed power generation, and the project units that invest in and operate distributed power generation facilities (or self-employed, household users) sign a grid connection agreement.’ (NEA, 2018): Distributed Generation Management Measures, Pos. 26.

This means that grid access for P2P electricity trading is assured by policy in both the EU and in China.

## C4) Information system

The information system provides the essential infrastructure for the communication of trade between participants. Digitalisation is recognised as a supporting factor for market transactions and new business models and the need for energy management systems is pointed out in general terms by both the EU and the Chinese government (Parliament and Council, 2019; NDRC, 2016). However, the technology sections are general, and the ICT infrastructure mentioned is not framed in terms of P2P trading.

Where the EU uses the term ‘smart grid’, the Chinese government describes an ‘energy internet’. The term includes the concept of a

globally encompassing smart network, but the guiding options published by NDRC also specifically deal with electricity and balancing markets on a micro level (NDRC, 2016).

‘Build an energy monitoring, management, and dispatch information platform, service system, and industrial system based on big data, cloud computing, and Internet of Things technologies. Create a platform for energy companies to “mass entrepreneurship and innovation”, and comprehensively promote crowd-creation, crowd-sourcing and crowd-funding in the energy sector.’ NDRC (2016): Energy production and consumption revolution strategy, P. 24: 47.

In the EU documents, the roll out of smart meters in the member states is frequently mentioned as a measure to empower consumers, and rules for security and data protection are laid out (Parliament and Council, 2019).

‘Member States shall ensure the deployment in their territories of smart metering systems that assist the active participation of customers in the electricity market.’ EC (2019) Electricity Directive, P. 30: 618.

#### C5) Market mechanisms

The market mechanism determines how electricity is allocated between market participants. In the EU documents, the description of market mechanisms tends to be broad. A more precise market definition is made at member state or project level and the mechanisms need to be tailored for each project. In general, the sale of ‘excess electricity’ is permitted.

‘Member States shall ensure that renewables self-consumers, individually or through aggregators, are entitled: (a) to generate renewable energy, including for their own consumption, store and sell their excess production of renewable electricity, including through renewables power purchase agreements, electricity suppliers and peer-to-peer trading arrangements, without being subject: (...)’ EU (2018/2001): Renewable Directive, p. 39.

P2P electricity trading, is defined as direct or indirect trade between market participants is supported:

‘Peer-to-peer trading’ of renewable energy means the sale of renewable energy between market participants by means of a contract with pre-determined conditions governing the automated execution and settlement of the transaction, either directly between market participants or indirectly through a certified third-party market participant, such as an aggregator. The right to conduct peer-to-peer trading shall be without prejudice to the rights and obligations of the parties involved as final customers, producers, suppliers or aggregators; ‘ EU (2018–2001) Renewable Directive, p. 22.

As the quote indicates, trading via aggregator, i.e., energy service companies (ESCOs) is possible, with aggregators acting as an intermediary that provides services to the participants.

In the Chinese policy documents (DGMM), three market mechanisms are defined, with leeway for more detailed design at the local level:

‘According to the characteristics of various distributed power generation and related policies, distributed power generation projects can either conduct direct power transactions with power users, or entrust power grid companies to sell power on behalf of them, or use the full sales-to-grid method.’ (NEA, 2018): Distributed Generation Management Measures, Pos. 24.

The first defined mechanism, ‘direct power transactions’, enables market participants to trade electricity without an intermediary. This

means that this mechanism allows for design interpretation without a market operator. In the research literature, this is also called a ‘full P2P electricity market’ (Sousa et al., 2019). Under the second mechanism, ‘entrusted sales’, an intermediary, such as the grid company or a commissioned trading agency conducts the trade on behalf of the participants. The third mechanism is not a market mechanism in the common sense; here, the electricity is sold to the grid company at a fixed tariff. What all mechanisms have in common is that a local network operator may prohibit transactions. This could be the case, for example, if the energy balance cannot be maintained.

Though aggregators are not directly named, this indirect participation in electricity markets is also provided for in Chinese policy documents. Besides bilateral agreements between distributed generation companies and consumers, market participation via grid companies or third-party providers is possible.

‘Promote integrated energy services, and build new models for user side smart energy consumption; nurture new types of market players such as virtual power plants and load integrators, and establish reasonable and flexible resource compensation mechanisms; encourage to provide more and differentiated energy goods and services, and develop new models of value-added services of smart energy consumption; and encourage the development of third-party operation and maintenance (O&M) entities, and foster the DG O&M industry.’ (NEA, 2018): Distributed Generation Management Measures, Art. 24.

## 5. Conclusions

Peer-to-peer electricity trading is considered a social innovation that enables consumers to participate in electricity markets, while providing incentives for the investment in distributed energy resources and load adjustment according to the availability of electricity. Although the term “peer-to-peer electricity trading” rarely appears in EU and Chinese policy documents, the concept is present, as the study’s qualitative content analysis of six key policy documents from the EU and China shows. Building on a simplified version of the microgrid energy market framework by Mengelkamp et al. (2018), this study evaluated the extent to which the five framework components: regulation, market setup, grid connection, information system, as well as market and price mechanism, are reflected in the documents. The main findings show that the concept is present in both the EU and China, but differs in its specification. While the EU documents mainly focus on the new role of consumers as more active market participants, the Chinese documents focus on the technical implementation of markets for distributed energy. Consumer participation in EU electricity markets is defined with the new consumer roles ‘renewable self-consumer’ and ‘active consumer’, with a particular focus on residential consumers. Meanwhile in the Chinese regulation, active participation of users (用户) and consumers (消费者) is underlined, but no distinction is made between commercial and non-commercial participants. Both sides not only support direct trading, but also participation through aggregators, e.g., in the form of energy service companies. While in the EU, the market design is to be set on the member state or even on project level, the Chinese documents define technical details and three concrete ‘market mechanisms’. The results support the understanding between scientists and policy makers, as well as the understanding of cooperation partners between the EU and China.

The scale of trade is not specified in the EU policy papers, so both neighbourhood trade on microgrids and virtual trade across physical borders could take place. In the Chinese documents, the scale of trade is clearly defined as being local, i.e., at the distribution grid level. In the area of implementation, the importance of ICT is emphasised on both sides, but concrete details of which technologies are needed are missing and need to be defined at project level.

Since the microgrid energy market framework was actually created

as a design aid for specific markets rather than as an evaluation tool for policy documents, not every component is described in detail in the documents. Policy documents only provide the framework; the details are defined at local level. The findings of this study can be understood as a primary investigation on how the concept is reflected in the regulation. It should be noted that peer-to-peer trading and aggregation are complex issues. The interpretation and implementation of EU policy into national law, as well as the implementation of central Chinese policy at a local level, takes different forms. The concept is expected to mature and stabilise in the coming years. It should also be noted here that although this novel possibility of consumer participation is possible in theory, it has not yet caught on with the broad majority in either the EU or China. The extent to which practical implementation will proceed in the coming years remains to be seen, apart from pilot projects and in a few showcase municipalities.

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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