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Technological Forecasting & Social Change 192 (2023) 122554

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

journal homepage: www.elsevier.com/locate/techfore

# Societal impacts of AI integration in the EU electricity market: The Dutch case

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ARTICLE INFO

*Keywords:*
Artificial intelligence
Electricity markets
Public values
the Netherlands
European Union

ABSTRACT

The European Union (EU) aims for a just energy transition and sees artificial intelligence (AI) as a key instrument to reach it. This paper analyses the societal impact of AI integration in the Dutch electricity market, as part of the EU market. We found that the integration of AI by different actors could increase the electricity market's sustainability, reliability, and affordability, as the increase in accuracy and speed offers more flexibility and allows for further integration of (variable) renewable energy. The effects on the equity and equality and power balances in the electricity market are, however, uncertain. AI may unburden participants from certain tasks and allow for more active participants, but the increased complexity excludes participants with less resources and might harm the equality of opportunities in the electricity market. Moreover, the necessary digital infrastructure challenges the (cyber)security, privacy, the controllability of the technology, and autonomy of market actors. The EU and Dutch government could anticipate the above effects by supporting new market participants (e.g., energy communities and cooperatives) with an open access data base of AI programs, and by creating institutional clarity for system operators when it comes to their additional tasks, giving these actors time to prepare.

## 1. Introduction

According to European Union (EU) policy, the energy transition and digitization are inextricably linked. Digital technologies are seen as crucial for improving the management of electricity production, storage and consumption in an increasingly electrified and decentralized energy system (European Commission, 2022). The EU's Joint Research Centre also views digital technologies as key elements for a more sustainable energy system (JRC et al., 2022). In particular, Artificial Intelligence (AI) is mentioned as a digital technology which has the potential to increase the sustainability of the electricity system. Its development, however, has led to much debate (WRR, 2021a).

Many actors in the electricity system are unsure how to perceive the upcoming integration of AI. In this research, we define AI as a technology with the capacity to gather, process and act on data, and learn from the results of its actions without human interaction (Johnston, 2008; Poole and Mackworth, 2010; Royakkers and van Est, 2015). Some actors see the integration of AI in the electricity system mainly as an opportunity. For example, AI could support the task of transmission system operators (TSOs) and distribution system operators (DSOs) of managing the increasingly complex energy system (AI-Hub Oost-Nederland, 2022; Xu et al., 2019). Energy communities could use AI to manage their energy systems (De Greve et al., 2020). Nevertheless, there are also doubts. It is unclear how the integration of AI decreases privacy, or how the complex automated programs are guided and inspected (Buhmann and Fieseler, 2021; WRR, 2021a). In short, although current literature discusses many possible technical applications of AI in electricity systems (Alfares and Nazeeruddin, 2002; Burghi et al., 2020; Jha et al., 2017; Xu et al., 2019), it lacks analysis of the societal impact thereof and governance strategies to deal with it.

Therefore, in this research, we analyze the impact of the integration of AI in the Dutch electricity market, as part of the EU market. For the electricity system, the electricity market is a crucial element: there, different actors act and react with a well-balanced electricity system as the necessary outcome.[1] Electricity market failures can result in soaring electricity prices or blackouts. The Dutch electricity market is an interesting case: not only does it operate under EU energy market regulations, it also has already welcomed digital technology innovations through various pilots and experiments (Ministerie van Economische Zaken, 2015).

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[1] For further explanation of electricity markets, see Van den Berghe and Wieczorek (2022).

https://doi.org/10.1016/j.techfore.2023.122554
Received 21 June 2022; Received in revised form 22 March 2023; Accepted 27 March 2023
Available online 6 April 2023
0040-1625/

To analyze how AI integration in the Dutch electricity market affects society, we use the public value framework developed by Niet et al. (2021a). This framework distinguishes nine public values which could become further supported or pressured by the integration of digital technologies in electricity systems. This framework includes both 'traditional' values, which have been present in previous electricity governance policies, and 'new' values, which have emerged with the integration of digital technologies. Understanding the impact of the integration of AI on the different public values can form the fundament of electricity governance strategies, as it gives insight in what public values require further support in the development of a more sustainable electricity market.

We start with an exploration of public values, including an explanation of the public value framework we use in our analysis. Next, we clarify which data and methods of analysis we use. This is followed by Section 4, Results. There, we analyze first how AI could be integrated in the Dutch electricity market as part of the EU electricity market. Second, we discuss what impact this integration can have on different public values. This is followed by an exploration of how various governance measures could be employed to steer this change. Finally, we conclude why it is important to act now on the coming integration of AI in the Dutch electricity market as part of the EU electricity market.

## 2. Theory

Studying the societal impact of AI-based electricity markets on public values and its implications includes the analysis of social and ethical issues. To this end, we use public values as categories of societal impact. In literature, public values are described as norms or principles constructed in democratic processes and embedded in institutions, which guide actions towards societal aspirations of what is right or wrong (Dekker and van Est, 2020; Milchram et al., 2018; Moore, 1995; Preston and Wickson, 2016; Susskind, 2020). Considering the Dutch electricity system, or energy systems in general, many studies have highlighted different public values, such as justice (Jenkins et al., 2021; McCauley et al., 2013), control and trust (Hillerbrand et al., 2021), and security and stability (Demski et al., 2015). Similarly, various studies have identified several values that are important in the implementation of AI, or information and communication technologies (ICT) in general, such as privacy and balances of power (Susskind, 2020), equity and equality (van Dijk and Haan, 2000), and autonomy (Royakkers et al., 2018).

In this paper, we use the public value framework developed by Niet et al. (2021a), which identifies nine public values of importance for electricity systems in which digital technologies are extensively integrated. These nine are sustainability, reliability, affordability, security, privacy, balances of power, equity and equality, control over technology, autonomy. A description of these public values can be found in Table 1.

As explained by Niet et al. (2021a), some of these public values are more 'traditional' for electricity systems, including the electricity market, whereas other values are more connected to the recent integration of digital technologies. The more traditional values are sustainability, reliability, affordability, and security; the values more related to digital technologies are privacy and control over technology. The values of balances of power, equity and equality, and autonomy are not distinctly related to digital technologies, nor are they seen as traditional values. Rather, they have emerged as important over the last few years with the intertwinement of the electricity system and digital technologies. In this research, we analyze all nine values, to understand what societal impacts are associated with the integration of AI in the electricity system, in particular the Dutch electricity system as part of the EU electricity system.

**Table 1**
Public values and description.

| Public values | Description |
|---|---|
| Sustainability | Development meeting the needs of the present without compromising the ability of future generations to meet their own needs. This includes life of dignity for all within the planet's limits, reconciling economic efficiency, and environmental responsibility. |
| Reliability | Security of supply; relative independence and diversification of energy fuels and services and stability of the energy system. |
| Affordability | People can afford energy services, prices are stable and there is equitable access to energy services. It includes lack of energy poverty and fuel poverty and has been one of the reasons to encourage liberalization and privatization of the energy market. |
| Security | Information security, identity fraud prevention, physical safety, and cybersecurity. |
| Privacy | Data protection, mental privacy, spatial privacy, surveillance, and function creep including using data for other purposes. |
| Equity and equality | Division of resources. Preventing discrimination and exclusion, ensuring equal treatment, preventing unfair bias and stigmatization, aiming for due process and inclusiveness. |
| Balances of power | Shifting relations between government, consumers and businesses including fairness of competition (a fair market), non-discriminatory access and terminating exploitation. Preventing the use of resources for unfair market advantages. |
| Control over technology | Control and transparency of algorithms, clear accountability, predictability, and giving both consumers and other market actors enough information. General understandability of technology. |
| Autonomy | Freedom of choice, freedom of expression, preventing manipulation and paternalism, and self-direction. This is also related to self-enhancement, such as building individual and community skills and capacity, and enhancing pride. |

Source: Niet et al. (2021a).

## 3. Methods and data

To understand how AI will be implemented in the electricity market and what societal consequences this could have, we combined two qualitative research methods: document analysis and in-depth interviews. We mapped different stakeholders involved in crucial electricity market processes and, by collecting data from these stakeholders, aimed to gain an overall insight in the perspectives of a broad range of stakeholders. We focused on six major stakeholder groups.

The first two stakeholder groups are the Dutch Transmission Operator (TSO) TenneT, and the six Dutch Distributions System Operators (DSOs) Coteq, Enexis, Liander, Rendo, Stedin and Westland Infra. Both stakeholder groups are market facilitators and therefore responsible for the market infrastructure.

The third stakeholder group that is important for the electricity market are the electricity retailers. In the Netherlands, there are approximately sixty electricity retailers with an active license for electricity market activity (ACM, 2020). Many of these are relatively small retailers, only providing services for a specific group of electricity consumers (such as small industry), or part of a larger retailer. Therefore, for this research, we focus on the three largest electricity retailers on the Dutch market: Eneco, E.ON and Vattenfall.

The fourth and fifth stakeholder groups we focused on, are relevant because of our interest in the impact of AI: ICT-providers and smaller ICT-users (such as ICT-supported energy communities). Although these stakeholders do not affect the electricity markets in the same major way as a TSO, DSO, or even major electricity retailers could, they are the frontrunners in developing and testing out new ICT, including AI. This makes their perspective valuable for this research.

Finally, the sixth stakeholder group we focused on are citizens. Citizens are not directly active on the electricity market. Still, they are affected by electricity market changes and do carry the social impacts. As such, we also consider citizens as important stakeholders.

### 3.1. Data

To gain insight into how these various stakeholders perceive the (future) implementations and impact of AI, we first conducted a document analysis. For this, we used the annual reports of the TSO (Gasunie and TenneT, 2019, 2020; TenneT, 2022b), DSOs (Coteq, 2021; Enexis, 2022; Liander, 2021; Rendo, 2021; Stedin, 2021; Westland Infra, 2021) and the three major electricity retailers (Eneco, 2021; E.ON, 2021; Vattenfall, 2021). These annual reports include information on future endeavors of these stakeholders. The reports also often include how the stakeholders expect their actions to affect society. We also used information provided by the TSO on current digitalization experiments for the electricity market (TenneT, 2020, 2021, 2022a) to gain more detailed insight into what changes are feasible for the electricity market from a legal infrastructural point of view. Unfortunately, such detailed documents spanning expectations for multiple years rarely exist from ICT-providers, (smaller) ICT-users, or citizens. To obtain information about these groups, we therefore relied on aggregated data from (government) advisory groups (Bakker and Korsten, 2021; WRR, 2021a; Faber et al., 2016; ACM, 2021a, 2021b). All the various documents together help to gain insight into the narratives used by these different actor groups and their attitude towards the use of AI in the electricity market.

The above documents were complemented by transcripts of in-depth interviews that aimed to collect the information that could not be distilled from the published and openly available documents. As such, interviews were held with ICT-providers (Next-Kraftwerke, 2021; van Wieren, 2022; van Wieringen, 2021) and ICT-users (Escozon, 2021; van Vliet, 2021), as those groups are underrepresented in published documents. Often, these groups refrain from publishing documents discussing their intended use of AI and the (expected) consequences thereof, as this could interfere with their competitive advantage. In interviews, however, these stakeholders are more willing to share data. Similarly, we interviewed an electricity retailer (Kaus and Dubucq, 2021), to analyze if there were relevant topics not described in the published documents, for example to avoid hindering their business. We also interviewed experts working for the Dutch TSO (Kop, 2022; Wismeyer, 2021), and one of the DSOs (Fonteijn, 2021), to collect data on sensitive topics left out of the published documents. Finally, to gain a better insight into the position of citizens, interviews were held with an independent government advisory group who conducts research from a public perspective (WRR, 2021b), and a researcher working on citizens using ICT for electricity management (Reijnders, 2022). In total, eleven in-depth interviews were conducted.

### 3.2. Analysis

All collected documents and interview transcripts were subjected to analysis using qualitative data analysis software Nvivo. In Nvivo, the documents were read and coded as individual data points for mentions of AI use and the various public values from the framework developed by Niet et al. (2021a) (Table 1).

First, the segments of texts discussing how AI can be implemented, were categorized based on the aspect of the affected electricity market aspect. These categories are (1) pre-market processes, including the prediction and matching of electricity production and consumption, (2) market processes, supporting the bidding and bidding infrastructure, and (3) post-market processes, such as steering assets to fulfil the bids. Although the stakeholders can differ in their view on how AI can be integrated precisely in these processes, a description of the general narrative on the possible integration of AI in the electricity market is given in Section 4.1.

Second, any segment of text discussing one of the public values was flagged, and it was noted if the text indicates whether the public value in question is supported or pressured by the integration of AI. This additional coding allowed us to gain insight in what opportunities or risks AI integration can create for the electricity market. An example of this coding is shown in Table 2. After this coding exercise of the individual documents, the coded segments of the individual documents were

**Table 2**
Coding examples per code.

| Value | Pressure or support | Coding example |
|---|---|---|
| Sustainability | Support | "At the same time, we aim to minimise individual customers' energy consumption based on a full roll-out of digital smart meters and state-of-the-art digital tools" (Vattenfall, 2021) |
| | Pressure | "But what I think is wrong with the system in the Netherlands at this point is that renewable energy suffers from negative prizing"[a] (Escozon, 2021) |
| Reliability | Support | "New technologies help us mitigate risks related to security of supply, particularly digitalisation has a potential to make optimal use of our grid. For example, data analytics can help us gain insights on how we can use weather predications, assess real-time electricity demand, survey our assets and also help us to keep the grid in balance by connecting to an increasing number of producers and consumers" (TenneT, 2022b) |
| | Pressure | "These parallel trends—more market participants and more renewables feed-in—pose significant technical and organizational challenges for grid management" (E.ON, 2021) |
| Affordability | Support | "Systems coordinate their production and consumption of energy, and predict the energy requirement. This way, energy can be provided at the right moment, at the right time and for the lowest costs"[a] (Eneco, 2021) |
| | Pressure | "Smart use of data technology can threaten existing markets and value chains"[a] (Eneco, 2021) |
| Security | Support | "In our way of effectively facilitating the market and ensuring digital security, we focus on both technology and humans, processes and culture. In 2021, we again test regularly and pro-actively the level of security of our systems, monitor our systems 24/7 and train employees actively in recognizing and preventing cyberthreats"[a] (Enexis, 2022) |
| | Pressure | "(…) but society also becomes increasingly dependent on data and systems. The threat of digital attacks grows worldwide. It is becoming increasingly complex to protect the vital infrastructure, ICT-systems and data against cyberattacks"[a] (Enexis, 2022) |
| Privacy | Support | "By investing in digital security, Stedin minimizes unwanted data exchange. This has a positive effect on the online security of society"[a] (Stedin, 2021) |
| | Pressure | "The availability of training data is a critical factor; the data is often owned by a company or state. With the growing economic and strategic value of AI, the open development culture will probably be pressured further"[a] (Bakker and Korsten, 2021) |
| Equity and equality | Support | "Second, if we produce locally, we, as local people, remain owner of the production. We will gain benefits. We are participants in our own energy supply. And we will reap the benefits of our own energy supply"[a] (van Vliet, 2021) |
| | Pressure | "Using many small assets to deliver aFRR can make it difficult to reach the minimum bid size of 1 MW as many assets are needed before the minimum delivery of 1 MW is reached. It is difficult to bind customers when a BSP is not prequalified yet, but it is not possible to get prequalified before the 1 MW threshold is reached" (TenneT, 2021) |
| Balances of power | Support | "A significant shift is noticeable in which traditional energy related competences are |

(continued on next page)

**Table 2** (*continued*)

| Value | Pressure or support | Coding example |
|---|---|---|
| | | replaced by new competences that most organisations, unrelated to energy, also require because of instance the increasing digitalisation" (TenneT, 2022b) |
| | Pressure | "At the same time: current AI companies are very powerful. Precisely because they own algorithms which steer data streams, they are able to steer discussions and decide which data is available. In that way, the industry is better able to guide the soft aspect, the social aspect of the sociotechnical systems, in a way that is congruent with their own interests"[a] (Bakker and Korsten, 2021) |
| Control over technology | Support | "Because of digitalisation, special skills become more important. One of the dilemmas is: how much do you want to let a third party do. We are in favour of keeping vital tasks internally: leaving it up to a third party might seem cheaper, but it makes our organisation vulnerable. You need to stay vital"[a] (Stedin, 2021) |
| | Pressure | "(…) but society also becomes increasingly dependent on data and systems"[a] (Enexis, 2022) |
| Autonomy | Support | "Digitalisation also results in new opportunities and comfort for companies and consumers"[a] (Enexis, 2022) |
| | Pressure | "Especially when devices operate autonomously, the question is raised in whose interest these devices will operate"[a] (WRR, 2021b) |

[a] This text and quote is originally in Dutch. These were translated to English by the authors.
Source: authors.

grouped per stakeholder group. Next, these segments were counted. The grouping of the different text segments per stakeholder group, allowed us to understand the perspective of each stakeholder group per public value. These perspectives are described in Section 4.2. The quantitative measure of counting the text segments allows for an overview of (1) which different stakeholder discusses which public value and (2) which public value is most discussed overall. This gives insight in what public values are perceived important by which stakeholder and which public value(s) is perceived as generally important by all stakeholders. It also shows which values stakeholders expect to be supported or put under pressure by the implementation of AI. In doing so, it reveals whether stakeholders perceive AI to present, in general, a risk or an opportunity to which public values.

## 4. Results

### 4.1. Possible integration of AI

Before analyzing the societal impact integrating AI in the (Dutch) electricity market might have, it is important to understand in what parts of the electricity market AI can be integrated by which actors. AI can be integrated in all aspects of the electricity market, and, depending on the aspect of the electricity market, various actors are involved.

For starters, AI can be integrated in the pre-market processes of prediction of electricity production and consumption, and the matching thereof. Namely, AI programs can bring together multiple data sources and give a more accurate prediction of the electricity production or consumption than other prediction methods could, often in a shorter time (WRR, 2021a). Electricity retailers, for example, are interested in this data to estimate how much electricity they will need to purchase or are able to sell on the electricity market (E.ON, 2021). The TSO and DSOs are also interested in more accurate predictions, to estimate the capacity needed on the electricity grid and whether electricity demand (consumption) will meet supply (production) (Gasunie and TenneT, 2020). More accurate predictions support early signaling of potential problems, such as blackouts or regular bottlenecks (Stedin, 2021). As such, the integration of AI in the electricity market for faster and more accurate prediction models of electricity production, consumption, and the matching thereof, is a change most actors are interested in.

Second, AI can be used to support bidding programs. Actors active on the electricity market can create AI-based programs which place automatic bids on the electricity market (van Vliet, 2021). For markets with a bidding time of over a day, this optimization of bidding strategies is less pressing than on markets where bidding times are more limited, for example only a few hours or even shorter intervals, from 15 min to 5 min (van Wieren, 2022). Although it is, in theory, possible to have a human place the bids, AI-based programs can judge what bids they can act on and place the bids much faster (van Vliet, 2021; van Wieringen, 2021). This thus allows for shorter, intra-day electricity markets to take place. It also allows smaller electricity market actors, such as (grouped) electricity consumers, to become active participants, as they would no longer need human capacity to place bids (van Vliet, 2021; van Wieren, 2022).

Third, AI can be used to manage the bidding system, including determining the market price, especially for intra-day electricity markets. Based on earlier estimations, the TSO determines the total expected grid imbalance and sets out capacity calls to solve the imbalance (TenneT, 2020, 2021, 2022a). Any capacity (electricity or flexibility) provider can bid on these calls. These bids are ranked in a *merit order* of increasing marginal costs, which includes $CO_2$ emission costs and fuel costs (Wismeyer, 2021). Following the merit order, the program determines which offers are needed to balance the electricity network (TenneT, 2020). These offers are accepted and can be asked to deliver on their offer by bringing their offered capacity online. In some markets, this, too, follows the merit order. The capacity providers are compensated for their actions: the TSO pays the capacity providers the *clearing price*, which is the marginal price of the last accepted offer in the merit order. Again, a human could execute this complex balancing and calculating act, but AI-based programs can execute these tasks much faster (Wismeyer, 2021). The electricity market intervals could be shortened when AI is integrated.

Fourth, AI can be used to steer electricity assets. Using AI, assets such as batteries, heating systems in buildings, and solar panels can be steered to consume or produce more or less electricity by digital programs instead of humans (E.ON, 2021). This allows for faster steering of assets, which can be beneficial for electricity retailers and (groups of) electricity consumers to react to fluctuating electricity market prices (van Vliet, 2021; van Wieren, 2022). This is another way in which the barrier for diverse actors to become active on the electricity market can be lowered, as they would no longer need human capacity available to steer assets.

In short, using AI, different electricity market actors can improve the accuracy and speed of their electricity market activities. It also allows for some electricity market actors to become (more) active in the electricity market. This can result in a more flexible electricity market, with increased opportunities for integrating renewable energy.[2]

At the same time, the integration of AI makes many electricity market activities more complex and dependent on extensive digital infrastructure, and therefore the owners thereof. The functioning of AI programs depends on the availability of large quantities of correct data (van Wieringen, 2021). Often, the different AI programs should also be able to connect with different sensors or other digital programs, for carrying out activities. For example, an AI program for automated asset

[2] For a detailed explanation on why and how much increased flexibility is needed for integrating renewable energy, see Kondziella and Bruckner (2016).

steering would need to be connected with the bidding program, which requires a connection with the prediction programs. As such, although there are many technical opportunities to integrate AI in the electricity market, it is still uncertain how beneficial or problematic this would be.

### 4.2. Societal impact of the integration of AI

Applying the public values framework to the integration of AI in the Dutch electricity market as part of the EU electricity market, we notice that AI can support and pressure each value, depending on how it is applied. This is shown in Tables 3 and 4. Most notable, we find that especially the values of sustainability, reliability and affordability are supported by the integration of AI. In contrast, the values of (cyber)security, privacy, control over technology, and autonomy are subjected to increased pressures. Finally, the effect on the values of equity and equality and balances of power is uncertain.

#### 4.2.1. Positive impact: sustainability, reliability, and affordability

First, the integration of AI in the electricity market can positively affect the values of sustainability, reliability, and affordability. Integrating AI can increase the accuracy in and speed of the electricity market (Enexis, 2022; Vattenfall, 2021; van Wieren, 2022; van Wieringen, 2021). Faster electricity market processes allow for decreasing the market intervals (van Wieringen, 2021). This can result in greater flexibility of the market, increasing the electricity system's reliability. With increased accuracy, the TSO can spot blackouts earlier, and with smaller market intervals, over- or under-capacity can be quickly rectified (TenneT, 2022b).

Furthermore, increased flexibility and smaller market intervals give more room to integrating renewable energy into the electricity system. Renewable energy producing asset holders struggle with being an active participant on electricity markets with long intervals (Escozon, 2021; van Vliet, 2021; van Wieren, 2022). Due to the variability of (mainly weather dependent) renewable energy generators, it is not possible for these actors to make long-term commitments. With shorter intervals, there is more certainty regarding the production capacity of renewable energy producing assets, and their holders can commit to biddings. With more renewable energy in use, both sustainability and affordability of the electricity market increases. Sustainability increases, because fossil fuel providers can be substituted with renewable energy providers with a lower environmental impact. At the same time, the low fuel and emission costs of renewable energy production assets result in a very low market clearing price (Fonteijn, 2021; Wismeyer, 2021). This increases the affordability of the electricity market.

#### 4.2.2. Negative impact: (cyber)security, privacy, control over technology, and autonomy

There are also public values which the integration of AI can impact in a mainly negative way. These public values are (cyber)security, privacy, control over technology and autonomy. Most of the societal issues related with these public values occur in general when AI is integrated in a particular sociotechnical system.

For AI to function in any system, including the electricity market, a certain digital infrastructure is necessary. This infrastructure includes a large amount of data to continuously train the AI system and as a basis for analysis, as well as a high interconnectedness of IoT devices to collect the data (Enexis, 2022). The multitude of connected IoT devices increases the options for (cyber)security problems, be those malicious attacks or accidental authorizations (Coteq, 2021; Rendo, 2021; Stedin, 2021). Similarly, the collection of more data likely decreases privacy as such, and increases chances of data breaches (Bakker and Korsten, 2021; WRR, 2021a).

Control over technology and autonomy are the other two public values under pressure by the integration of AI. With the integration of AI, sociotechnical systems become more complex. It is becoming increasingly difficult for humans to check the analysis results of digital technologies and detect mistakes, and, if they have detected mistakes, ensure the issue is properly addressed (WRR, 2021a). This holds especially true in the electricity market, where already complex processes are made even more complex with the integration of AI, and processes often go too fast for a fault to be detected (Fonteijn, 2021; Kaus and Dubucq, 2021; Reijnders, 2022; van Wieren, 2022; van Wieringen, 2021).

Although the automated bidding and steering of assets can lower the barriers of active market participation of some groups, autonomy of small, non-independent actors can decrease. To be able to have an impact on the electricity market or stay true to their advance biddings, aggregators or larger energy market actors might want to pre-emptively steer electricity assets. For example, AI could be used to generate electricity consumption profiles for households (Eneco, 2021). House appliances could be steered in accordance with these profiles (Fonteijn, 2021; van Wieringen, 2021). Such developments would make bidding easier for larger market actors, but also make it more difficult for households to act freely and not be steered by electricity consumption algorithms. It is unsure how realistic this type of AI-steering is in the near future: the TSO and DSOs do not directly perceive this as a likely

**Table 3**
Presence of codes in documents and interviews of different actor groups.

| Value | | Total | Actor group | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pressure or support | | Advisory groups | DSOs | Energy retailers | ICT-providers | ICT-users | Researcher | TSO |
| Sustainability | Support | 24 | 0 | 3 | 8 | 7 | 3 | 1 | 2 |
| | Pressure | 10 | 0 | 1 | 1 | 4 | 1 | 0 | 3 |
| Reliability | Support | 61 | 2 | 10 | 14 | 15 | 3 | 0 | 17 |
| | Pressure | 28 | 0 | 7 | 2 | 12 | 3 | 2 | 2 |
| Affordability | Support | 34 | 0 | 6 | 4 | 11 | 3 | 2 | 8 |
| | Pressure | 13 | 0 | 3 | 1 | 5 | 3 | 1 | 0 |
| Security | Support | 11 | 0 | 6 | 2 | 2 | 0 | 0 | 1 |
| | Pressure | 10 | 0 | 5 | 4 | 0 | 0 | 0 | 1 |
| Privacy | Support | 13 | 1 | 2 | 1 | 6 | 1 | 2 | 0 |
| | Pressure | 13 | 2 | 0 | 1 | 6 | 1 | 2 | 1 |
| Equity and equality | Support | 15 | 1 | 0 | 0 | 5 | 7 | 2 | 0 |
| | Pressure | 41 | 2 | 2 | 1 | 13 | 10 | 8 | 5 |
| Balances of power | Support | 23 | 1 | 0 | 0 | 4 | 14 | 2 | 2 |
| | Pressure | 28 | 3 | 4 | 3 | 7 | 9 | 1 | 1 |
| Control over technology | Support | 24 | 0 | 3 | 3 | 3 | 4 | 2 | 9 |
| | Pressure | 23 | 3 | 6 | 0 | 10 | 1 | 1 | 2 |
| Autonomy | Support | 32 | 1 | 4 | 6 | 11 | 8 | 1 | 1 |
| | Pressure | 14 | 3 | 2 | 0 | 5 | 3 | 0 | 1 |

Source: authors.

**Table 4**
The effect of AI integration in the Dutch electricity market according to different actor groups.

| Value | Actor group | | | | | | |
|---|---|---|---|---|---|---|---|
| | Advisory groups | DSOs | Energy retailers | ICT-providers | ICT-users | Researcher | TSO |
| Sustainability | | | | | | | |
| Support | Not described | DSOs use AI to support investment decisions regarding integration of renewable energy & offer renewable energy products in market | Households & individuals use AI to save energy & AI supports energy retailers with integrating renewable energy with more certainty about supply & non-supply | All actors need AI to improve efficiency & flexibility to save energy & integrate more renewable energy | ICT-users can provide more renewable energy | All actors have more room to integrate renewable energy when net is managed with AI | Renewable energy providers are seen by TSO algorithms as cheapest therefore preferred |
| Pressure | Not described | Algorithms of DSOs not yet attuned to renewable energy | It is unclear how much resources AI programs use | Algorithms of TSO not yet attuned to renewable energy | Energy providers providing renewable energy currently disadvantaged by electricity market programs | Not described | TSO algorithms do not automatically prefer renewable energy sources or sustainable flexibility providers |
| Reliability | | | | | | | |
| Support | ICT-users & energy retailers can supply more flexibility using AI | All actors use AI to increase their flexibility | Energy retailers use AI to manage assets & increase flexibility | All actors use AI to increase their flexibility & forecasting accuracy | All actors make system more flexible & efficient using AI | Not described | All actors use AI to become more flexible & have more accurate forecasting |
| Pressure | Not described | TSO & DSOs do not always have backups in case of malfunctioning ICT systems | TSO struggles managing market when there are more active participants | TSO & DSOs need to prevent systems reacting to each other & creating an imbalance loop | All actors struggle with inoperability between different devices & AI programs | Not all actors always have backup in case of ICT failures | All actors using more innovations & increase of actors makes electricity system harder to manage for TSO & DSOs & increases risks |
| Affordability | | | | | | | |
| Support | Not described | DSOs' algorithms focussed on collecting cheapest bids | Energy retailers use AI to deliver electricity when needed for most profitable prices | ICT-users increase efficiency & options for profit using AI | Smaller flexibility providers can profit by offering flexibility using AI programs | (New) active participants met with decreased energy or operation costs | TSO's algorithm focussed on collecting cheapest bids |
| Pressure | Not described | All actors need to invest more in infrastructure | Work of energy retailers can be threatened by integration of AI | ICT-users struggle with costs of ICT systems & often low profits of using AI | Energy providers providing renewable energy currently disadvantaged by electricity market programs | Individuals unable to actively participate, met with higher operation costs | Not described |
| Security | | | | | | | |
| Support | Not described | DSOs increasingly aware of (cyber) security requirements due to AI | All actors have to deal with increased (cyber)security regulations with integration of AI | ICT-providers focussing more on improving system security | Not described | Not described | TSO views (cyber) security as priority, especially due to AI |
| Pressure | Not described | DSOs realize use of AI increases risks for infrastructure | All actors using AI deal with greater (cyber)security threats | Not described | Not described | Not described | All actors struggle more with ensuring (cyber) security, as they require data from all kinds of sources |
| Privacy | | | | | | | |
| Support | Households & individuals gain more anonymity | DSOs increasingly aware of privacy requirements due to AI | All actors have to deal with increased privacy regulations with integration of AI | ICT-providers focussing more on improving system data privacy | Households & individuals grouping together to become active together strive to keep ownership of data | Households & individuals better informed about data use | Not described |

(*continued on next page*)

**Table 4** (*continued*)

| Value | Actor group | | | | | | |
|---|---|---|---|---|---|---|---|
| | Advisory groups | DSOs | Energy retailers | ICT-providers | ICT-users | Researcher | TSO |
| Pressure | Households & individuals have to supply data | Not described | Households & individuals have to supply data | Households & individuals have to supply data | Households & individuals often trust other actors (including ICT-providers) with their data without informing themselves completely or believe data will be obtained regardless of consent | Households & individuals often trust other actors (including ICT-providers) with their data without informing themselves completely or believe data will be obtained regardless of consent | It is unclear what data TSO needs to function |
| Equity and equality | | | | | | | |
| Support | Households & individuals not subjected to human bias | Not described | Not described | Households & individuals get more opportunities with AI to join an active participant group | Households & individuals get more opportunities with AI to join an active participant group & keep profits & choices local | Households & individuals informed of AI projects | Not described |
| Pressure | Households & individuals can suffer from bias in data | Smaller energy & flexibility providers struggle to meet DSOs' requirements to become an active participant | Smaller actors do not have the capacity to develop (well-)functioning AI | Households & individuals cannot offer flexibility on their own (no resources & limited knowledge) | ICT-providers quickly grow & can dictate processes & actions | Specific individuals (knowledgeable, with ICT/energy skills, & time) (unintentionally) better informed & involved | Smaller energy & flexibility providers unable to participate when they are not grouped, due to requirements of TSO |
| Balances of power | | | | | | | |
| Support | Households & individuals freed from repetitive tasks | Not described | Not described | Households & individuals & other small flexibility providers use AI to become an active participant | Households & individuals get more opportunities with AI to join an active participant group | All actors have to work together better for a functioning system | TSO stimulates the increase of market participants |
| Pressure | ICT companies decide how AI is trained & what information is given | Larger energy or flexibility providers have advantage over smaller providers, due to larger pool of resources | Smaller actors do not have capacity to develop (well-) functioning AI for bidding | Large ICT-users & retailers could use AI to game the market | ICT-providers & large aggregators can dictate processes & actions | ICT-users often bound to hardware & ICT-providers | TSO prefers larger market participants, as they give more insurance for delivery of flexibility |
| Control over technology | | | | | | | |
| Support | Not described | DSOs gain more insight regarding complex electricity system using AI | All actors back up decisions regarding investments & maintenance with AI | All actors use AI to simplify tasks | Households & individuals get more opportunities with AI to keep control over their assets | Households & individuals in closer contact with different actor groups & more informed about procedures surrounding AI & data | TSO gains insight & control in electricity system & system priority using AI |
| Pressure | All actors lose ability to take meaningful decisions & inspect decisions taken by AI | All actors struggle to fully understand AI | Not described | All actors struggle to fully understand AI & inspecting authorities struggle to employ AI experts | TSO bases parts of its inspections on non-updated certificates | Households & individuals do not all have skills to understand AI | All actors struggle increasingly with critically evaluating decisions by AI |
| Autonomy | | | | | | | |
| Support | All actors could not meaningfully engage with complexity of decisions | All actors can become (more) active participants | All actors need to use AI to manage an increasingly complex system & bid on faster markets | Households & individuals can profit from quickly varying prices without spending | Households & individuals get more opportunities with AI to control assets & learn about assets | ICT-users such as communities can decided for how to use profits | All actors use AI for forecasting & maintenance, taking some tasks away |

(*continued on next page*)

**Table 4** (*continued*)

| Value | Actor group | | | | | | |
|---|---|---|---|---|---|---|---|
| | Advisory groups | DSOs | Energy retailers | ICT-providers | ICT-users | Researcher | TSO |
| | | | | additional time & energy | | | |
| Pressure | Households & individuals subjected to interests of others | Households & individuals give autonomy to aggregator which could work with user profiles | Not described | Households & individuals give autonomy to aggregator | ICT-providers & large aggregators can dictate actions | Not described | Aggregators & other flexibility providers can use AI to steer devices in group or individual use |

Source: authors.

risk and ICT-providers are not directly offering this profiling as a service (Fonteijn, 2021; Wismeyer, 2021). However, due to the high and volatile gas prices, dynamic pricing is becoming more popular in the Netherlands (Fonteijn, 2021). Lower income households might be especially susceptible to stay within their electricity consumption profile to avoid financial penalties, limiting their autonomy. Furthermore, electricity retailers currently report on making use of profiling, though only for client contact purposes (Eneco, 2021).

Connecting this to the Dutch electricity market, two major problems occur. First, this is not a sector in which markets can be turned off and on. If control is lost over technology or errors are detected, a reboot is close to impossible without the interruption of core societal processes, like public transport and health care (Kop, 2022; TenneT, 2022b; van Wieringen, 2021; Wismeyer, 2021). This makes faults in electricity market AI systems difficult to correct and breaches in (cyber)security of this infrastructure critical risks.

Second, it is unclear what data or automated steering is needed for the functioning of the electricity system. It might very well be that regional, aggregated data is enough information for the TSO to make the electricity market function correctly, but for many active participants on the electricity market, or even DSOs, a much more detailed level of data is needed (Eneco, 2021; E.ON, 2021; Fonteijn, 2021; Kop, 2022; Vattenfall, 2021; Wismeyer, 2021). Furthermore, automated steering of assets can be used to increase the available flexibility necessary for the electricity market, or to increase possible profits. As different stakeholders have different perspectives on how much data and automated steering is necessary for the functioning of the electricity network, it is difficult to estimate whether the amount of gathered data (and connected breaches of privacy) and the extent of automated steering (and connected limitations of autonomy) are necessary or not in the changing energy system.

#### 4.2.3. *Uncertain: equity and equality and balances of power*

Finally, regarding the public values equity and equality and balances of power, it is uncertain what the impact of AI integration in the Dutch electricity market as part of the EU electricity market will be. These values could be supported or pressured, depending on how AI is integrated, by who and with what goal.

The integration of AI in the Dutch electricity market could make the market more equal and balanced in powers. The use of AI allows smaller actors to automate many (complex) tasks associated with being active on the electricity market (Escozon, 2021; Reijnders, 2022). This reduces the need for skilled professionals to become an active participant (van Vliet, 2021; van Wieren, 2022). Therefore, more actors, also those without great knowledge of the electricity market, have gained the opportunity to become an active participant in the electricity market with the use of AI. This increases equality of the market. An increased number of (possible) active market participants can also result in more balanced powers, as the market no longer relies on incumbent actors (Fonteijn, 2021; Wismeyer, 2021). Instead, new actors play a growing, active role in the future Dutch electricity market, and the EU electricity market.

The integration of AI can, however, also have some drawbacks regarding equity and equality and balances of power. Most of these drawbacks have to do with a general characteristic of AI, namely that its opportunities are more accessible for actors which already have considerable resources, be those financial resources, skills or clients (Reijnders, 2022). Considering equity and equality, for example, the infrastructure necessary for functioning AI programs to participate on the Dutch electricity market (e.g. electricity storage devices, electricity generation devices, and data collection and processing services) is often only obtainable by those actors with enough financial capacity (Fonteijn, 2021; van Wieren, 2022). AI solutions are not subsidized; as such only households and communities with a certain amount of disposable financial means are able to take part in this development and profit from them (Reijnders, 2022; van Vliet, 2021).

Furthermore, although in theory more actors can use AI to become an active participant in the electricity market, in practice, small communities are unlikely to play an impactful role in the Dutch electricity market. Many markets require electricity capacity too high for these smaller actors (van Wieren, 2022; Wismeyer, 2021). Although the TSO and DSOs recognize this problem, requirements will not be lowered anytime soon, as this would result in more instability in the electricity net (Wismeyer, 2021). As such, communities join forces with other communities or projects with renewable energy production or flexibility assets (Reijnders, 2022; van Wieren, 2022). Often, they do this by joining an aggregator. The aggregator, then, acts on the different electricity markets (van Vliet, 2021; van Wieren, 2022; Wismeyer, 2021). As a result, the power is not balanced between traditional market participants and newer communities, but traditional market participants and (new and old) aggregators. In addition, an increasing amount of power is shifted from electricity communities and traditional electricity market participants to ICT parties. A growing number of electricity market participants, including the TSO and DSOs, are increasingly dependent on ICT parties (van Wieringen, 2021). This dependency, too, reduces the balances of power in the electricity market.

## 5. Discussion

Taking into consideration how the integration of AI could alter almost all aspects of the electricity market and affect public values in doing so, it is important to discuss how this development can be guided. As improving sustainability and maintaining reliability while further digitalizing the Dutch and EU electricity system are key aims of current Dutch and EU policies, we take this as a starting point. At the same time, other public values should not be neglected.

First, to improve affordability, equity and equality and balances of power, it is advisable to further stimulate the establishment of (local) energy communities and cooperatives. This would increase the number of actors on the electricity market, increasing affordability and balancing powers. As these communities often rely on renewable energy generators and flexibility devices, they also increase sustainability and reliability. Currently, energy communities are often set up in an experimental form, which means that it is a project operational for a limited period (Ministerie van Economische Zaken, 2015). Additionally, they have to compete with major electricity market actors with more advanced AI programs. By allowing energy communities to go beyond the experimental phase and supporting their operations, the Dutch government could level the electricity market playing field. One very concrete way of supporting energy community operations without giving them unfair market advantage, is by stimulating the creation of an open access database with AI programs for energy communities and setting up standards for interoperability of software and hardware (Dekker et al., 2022).

Second, the (cyber)security, privacy, control over technology and autonomy should be safeguarded. The EU is currently in the process of setting up a framework for the development and use of AI: the EU AI Act (European Commission, 2021). Unfortunately, these general measures describe no clear regulations for the electricity system (Niet et al., 2021b). From its draft version, it could be concluded AI programs in electricity systems will be regarded as high-risk AI and therefore be subjected to strict controls. What these regulations entail and who needs to inspect the AI programs are left unclear. To safeguard (cyber)security, privacy, control over technology and autonomy, the EU or Dutch government has the opportunity to fill this gap in regulation with security standards, privacy-ensuring measures, and limits on how much human control, oversight and steering can be automated (Dekker et al., 2022). It should also be made more explicit who is accountable for what type of errors, as this can quickly become muddy in the complex electricity market.

Lastly, creating the right conditions for effective inspection of AI programs in specific parts of the electricity market is also crucial for ensuring the integration of AI in the electricity market does not conflict with public values. In their adopted common position on the EU Artificial Intelligence Act, the Council of the European Union allocated national authorities as the authorities to analyze the societal impact of AI programs and verify whether they are allowed or not allowed to be integrated (Council of the European Union, 2022). In the case of integration of AI in the Dutch electricity market, this means that the burden of the market facilitating and controlling tasks would therefore fall with the TSO, DSOs, the Netherlands Authority for Consumers and Markets (ACM) and the Dutch Data Protection Authority (AP). These actors, however, already struggle to find professionals specialized in AI and/or the electricity system. It is therefore important for these bodies to know in advance how the integration of AI in the Dutch electricity market as part of the EU electricity market will broaden their task. This could help them to create the right conditions needed to timely execute their tasks. These preparations could include (re)training new and old professionals to become proficient in spotting the issues emerging when AI and the electricity market are combined, and collaborating with other authorities to divide tasks or exchange experiences.

## 6. Conclusions and policy implications

Many actors perceive the integration of AI in electricity systems a crucial part of the energy transition. This development includes the integration of AI in the electricity market. Focusing on the Dutch electricity market as part of the EU electricity market specifically, we conclude that different actors in the electricity market can use AI to improve the market's accuracy, speed and accessibility, and to increase its flexibility. This can improve the market's sustainability, reliability, and affordability. At the same time, the electricity market would become more complex and dependent on an extensive digital infrastructure. This gives rise to concerns regarding (cyber)security, privacy, control over technology and autonomy. Additionally, there are uncertainties concerning the effect of AI integration in the Dutch electricity market on equity and equality and balances of power. Although AI could unburden small actors from many complex electricity market tasks, allowing them to actively participate, AI programs are costly to operate and improve. As such, the technology is not yet widely available and major market parties often have better functioning programs.

## 7. Policy recommendations

Considering the societal opportunities and risks the integration of AI in the electricity market brings for the Dutch society, we advise the EU and Dutch government to support new market participants such as energy communities and cooperatives, and the TSO and DSOs.

Support for new market participants such as energy communities and cooperatives is needed to level the electricity market playing field. Not all actors who want to become an active participant on the electricity market, are able to do so. This has to do with the high costs of the digital and energy infrastructure needed to reach current benchmarks to become active. These actors thus require additional support, for example in acquiring or training AI programs.

The EU and Dutch government should ensure their policies create institutional clarity for the TSO and DSOs, the ACM and the AP. In the proposed EU AI Act, the integration of AI in the EU electricity market was labelled as 'high-risk', which means the integration should meet additional (security) standards and be subjected to checks and controls (European Commission, 2021). The content of these additional measures was, however, not explained. The Council of the European Union has adopted a common position, which goes more into detail of the practicalities of the EU AI Act (Council of the European Union, 2022). For example, as noted before, the Council of the European Union designated the national authorities (in the case of the Netherlands, especially the AP) as the actors responsible for the verification and admittance of AI systems in EU societies. Further elaboration regarding standards, responsibilities and accountability would support the establishment of a framework of sustainable and safe integration of AI in the electricity market, in line with public values. First, implementing additional (cyber)security standards, privacy-ensuring measures and limits on what AI can be used for without human oversight results in necessary clarity for all electricity market actors. These standards and limits also makes the added tasks of TSO and DSOs, the ACM and the AP more straightforward, specifically for those authorities, such as the AP, without specific knowledge and expertise regarding the electricity market. Second, when national authorities such as the TSO, DSOs, ACM and AP are notified of their roles in the verification and admittance of AI systems in the Dutch electricity market, they can prepare accordingly, including training (new) professionals and setting up collaborations with other authorities.

## 8. Future research

Following the results of this research, there are two areas we wish to highlight for future research. First, this study focusses on the Dutch electricity market as part of the EU electricity market, and research into other electricity markets can be beneficial for comparisons on national, regional and EU level. In the Netherlands, experiments with AI integrations are allowed and taking place to a certain extent. However, in some countries, experiments are much more limited, whereas in other countries, AI integration already goes beyond the experimental frame. A change of context could influence actors' perceptions of AI integration, as some public values might be more or less pressured than expected or visible in an experiment. Additionally, a comparison between EU Member States could allow broader insight into what electricity market or AI regulation can be improved on an EU level, and what can be more efficiently handled on a national level. This research can therefore be a steppingstone for research regarding the multilevel governance within the EU context.

The second area for further research, is to extend the current research to other aspects of the sociotechnical electricity system. It is highly unlikely electricity markets will be the only part of electricity systems in which AI will be integrated. Depending on the integration, the impact on and prioritization of public values can change. When AI programs are used for household electricity management, for example, values such as autonomy and control over technology might become much more prominent. Therefore, future research can focus on the societal impact of the integration of AI in different parts of the electricity system.

## Funding

This work was supported by the Eindhoven University Fund (Stichting Universiteitsfonds Eindhoven) [project: Governance van artificiële intelligentie in de energietransitie] and by Interreg NWE as part of the cVPP project [588].

## CRediT authorship contribution statement

**Irene Niet:** Conceptualization, Methodology, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration. **Laura Van den Berghe:** Methodology, Validation, Investigation, Resources, Writing – original draft. **Rinie van Est:** Conceptualization, Validation, Writing – review & editing, Visualization, Supervision, Funding acquisition.

## Data availability

The data file is included as supplementary material. The interview data is available upon request.

## Acknowledgements

The authors would like to give special thanks to our interviewees for the time, effort and knowledge they provided to this research. We also thank all colleagues, editors and reviewers who provided us with their constructive feedback.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.techfore.2023.122554.

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