Implications in the system integration of a blockchain application unlocking decentralised flexibility in the Dutch electricity sector

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A B S T R A C T

The Netherlands currently lacks a large scale aggregation system which can unlock decentralised flexibility to improve the reliability of the electricity grid in the presence of a significant amount of variable renewable energy sources. In this paper, blockchain technology is perceived as an enabler for a decentralised flexibility model without the need of market intermediation. It is however uncertain how the implementation of a blockchain application simultaneously fits technically and institutionally in the environment of the Dutch electricity sector. This paper analyses implications of blockchain technology in unlocking decentralised flexibility by considering a system integration approach. Using the comprehensive design framework, a conceptualisation of system integration in energy infrastructures, many challenges regarding blockchain as flexibility model have been identified. Challenges cause the disintermediation and self-organisation ability of blockchain, to be very hard in the case of unlocking decentralised flexibility. The benefit of blockchain technology over other flexibility enabling solutions, such as the aggregator, is uncertain in the absence of disintermediation and self-organisation.

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1. Introduction

To preserve a reliable electricity system in the presence of variable renewable energy sources (VRES), the electricity grid is in need for flexibility. Flexibility is defined by Lannoye et al. (2012) as "*the ability of a system to deploy its resources to respond to changes in net load"*. There is expected that Netherlands will be in need for an additional 5 GW peak supply and 2.3 GW of flexible demand in 2023 (CE Delft, 2016). Kondziella and Bruckner (2016) mention back-up plants, energy storage, curtailment of renewable surplus generation, demand-side management, grid extension and the expansion of interconnection as means to increase system flexibility. Due to the increase of photovoltaic (PV) energy penetration, and other emerging decentral energy resources, a trend towards more decentralised energy systems is observed (Blaabjerg et al., 2006). A noteworthy trend in power systems becoming more decentralised is that consumers are tend to behave more and more as prosumers (Schleicher-Tappeser, 2012). Prosumers behave very dynamic and consume, produce and store electricity (Grijalva and Tariq, 2011). The emergence of prosumers provides an opportunity for unlocking decentralised flexibility by means of demand response (DR), also referred to as demand side management (DSM) by Gellings (1985). *"DSM is the planning, implementation, and monitoring of those utility activities designed to influence customer use of electricity in ways that will produce desired changes in the utility's load shape, i.e. changes in the time pattern and magnitude of utility's load"* (Gellings, 1985). Flexibility from the prosumer can be provided by controllable loads, prosumer generation, electricity storage and adaptive EV charging and can serve roughly three market services, portfolio optimisation for balancing responsible parties (BRPs), grid- and congestion management for the DSO and balancing services for the transmission system operator (TSO) (USEF, 2015).

The aggregator is a role frequently mentioned in literatue that is able to unlock decentralised flexibility for a grid scale solution. The aggregator is assumed to provides the linkage of flexibility at a prosumer level with central markets by the functions of information management, bundling of service, matching and market clearing and transaction guarantee (Eid et al., 2015). In fulfilling these functionalities, the aggregator act as an central intermediary, a middleman between prosumers and BRPs, DSOs and TSO (TenneT in the Netherlands). The aggregator, in this model procures decentralised flexibility at the prosumer level, and offers it as an aggregated product in central markets (Dethlefs et al., 2015).

Blockchain technology, the technology behind the Bitcoin and brought to the world by Nakamoto (2008), can be perceived as a technology that can enable unlocking decentralised flexibility. Blockchain is a distributed database that records transactions in a public ledger available to all participants in a network. Because of the feature of immutability. transactions recorded in the blockchain are unalterable which provides a high degree of transparency and trust (Yli-Huumo et al., 2016). The introduction of smart contracts and the connection to IoT allows for the execution of automated contracts (Swan, 2015). Blockchain technology allows for the disintermediation and self-organisation of transactional systems and reduces the need for trust between stakeholders, builds a secure value transfer system, increases record transparency and can streamline processes across entities (Hileman and Rauchs, 2017). Features of blockchain allow for a trusted peer-to-peer transaction system and restructures the way one thought about organising transactional systems. Blockchain can therefore be classified as an innovative institution, which is able to undermine hierarchies, contracts and market structures (Davidson et al., 2016). Blockchain is therefore expected to be able to remove the need for a trusted third party in operating a transactional system. It is expected that disintermediation increases cost effectiveness of the coordination of the transaction (MacDonald et al., 2016). Relating the discussion above, blockchain technology could make the role of the aggregator superfluous.

Many use cases, such as peer-to-peer energy trade (Alliander, 2017; Brooklyn Microgrid, 2017), smart EV charging (Slock.it, 2017; TenneT, 2017b), tracking and tracing of green energy (EY, 2017) and real time energy monitoring (EY, 2017), are currently evolving. This paper argues that because of the interwoven character of the engineering- and institutional dimension in the energy sector the perspective of system integration is very important in analysing the potential of blockchain in the case of unlocking decentralised flexibility. System integration is defined by Verzijlbergh et al. (2014) as: *"the process of jointly shaping the technical and institutional sub-systems in a way that supports the transition to a renewable, affordable and reliable energy system"*. The system integration of blockchain technology in the energy sector is currently rather unexplored.

Prior to the detailed design of a blockchain application in unlocking decentralised flexibility, it is necessary to analyse what implications and challenges arise in considering a system integration perspective. Currently, it is unclear how the system integration of blockchain in unlocking decentralised flexibility fits in the Dutch electricity sector. The objective of this paper is therefore to provide insight in the implications that need to be overcome in order to enable the system integration of a blockchain in unlocking decentralised flexibility. The research question of this is research is therefore defined as:

'What system integration challenges need to be overcome to enable the implementation of a blockchain application in unlocking decentralised flexibility in the Dutch electricity sector?'

This paper shows that many implications arise by analysing the system integration of a blockchain application in unlocking decentralised flexibility. The benefits of disintermediation, self-organisation and the efficiency gains seem very hard to realise in the use case of unlocking decentralised flexibility in the Dutch electricity sector.

The paper is structured as follows. First, some background theory on the Dutch electricity sector and blockchain technology is discussed in section two. Section three discusses the research methodology. Section four elaborates on the conceptualisation of blockchain in the case of unlocking decentralised flexibility and discusses the analysis of implications that arise from the perspective of system integration. The fifth and final section provides the concluding remarks.

2. Background

Before diving into detailed analysis, this section provides a detailed overview of the relevant characteristics of the Dutch electricity sector and blockchain technology in section 2.1 and 2.2 respectively.

2.1. Characteristics of the Dutch electricity sector

The current configuration of the electricity sector is heavily determined by the liberalisation initiatives of the last decades. Activities can be subdivided in competitive- and monopoly activities. Production and retail are characterised as competitive activities and transmission and distribution are prone to state regulation. Liberalisation ultimately led to the full unbundling of former utilities, where distribution, production and retail activities are organised by different entities. The current configuration is optimised from a central perspective, where production and trade of electricity are driven by central entities.

A clear distribution of responsibilities in the operation of the electricity sector is observed. Following unbundling, specific responsibilities have been divided among specific actors. Trade is for example facilitated by EPEX Netherlands and standardised in pre-defined markets. Transmission is operated fully by TenneT, the Dutch TSO, but regulated by ACM, the Dutch regulator. The same holds for distribution, where DSOs are responsible for the distribution of electricity (and gas) and metering of consumption for a specific geographical area. Production and retail are open for competitive parties to enter, but the governance is still in hands of central entities, which for example plan for production capacity.

The coordination in the Dutch electricity sector is characterised by central coordination mechanisms. Production, trade and consumption is an interplay between balancing responsible parties (BRPs), TenneT and EPEX that coordinate and balance (TenneT) electricity production. Coordination of these activities is organised in centralised spot-markets, E-programmes, and the balancing instruments of TenneT. Transmission and distribution is fully coordinated by the TSO and DSO. Final consumer consumption is an interplay of energy retailers, the TSO and DSOs, where the electricity retailers intermediate between the final consumer and the other parties. The linkage with the final consumer is made by the electricity retailer that manages contractual agreements with consumers and producers and are responsible for passing on grid costs linked to the end consumer.

As observed, the Dutch electricity sector is driven by a central configuration. The dominancy of this central tendency needs to be taken into account in identifying design implications of a blockchain application for decentralised flexibility. The implementation of a decentral flexibility solution namely seems to be at odds with the current central configuration of the electricity sector.

2.2. Blockchain technology

This section zooms in on blockchain technology in more detail by elaborating on the working principle and technical details.

2.2.1. The working principle of blockchain technology

The Bitcoin blockchain introduced a cryptographic solution that solved for the double-spending problem that arise in digital peer-to-per transactions (Nakamoto, 2008). Transactions are recorded in blocks, and as the name already suggests, coupled with previous and following blocks to form a chain. The block in a blockchain contains a list with validated assets and instruction statements referring to the transactions made (Deloitte, 2016). A block is only added to the blockchain by a 5-step process as described by Nakamoto (2008) and Froystad and Holm (2016). A transaction is created and send to the all the nodes of the networks that subsequently check the authenticity and validity of the transaction. Then, a block is created that consists out of a series of transactions, and validated by the validators in the network and connected to the previous block in the blockchain. The blockchain in the use case of decentralised flexibility would exist out of energy transaction between the prosumer and flexibility demanding parties creating a trusty and transparent system.

2.2.2. Technical concepts of blockchain technology

Technical concepts that provide the unique character of blockchain are the combination of hash functions, public-key cryptography, digital signatures, consensus methods, blockchain typology, and smart contracts.

Hash functions

Hash functions allow data files / transactions to be encrypted before transferring. A hash function transforms a data file into a hash, a string of 64 characters, that represents the content of the original data file. Each form of data is represented by an unique hash. Minor changes in the data file will already generate a complete different hash output. The blockchain is continuously checked on validity by checking the hashes of the block sequences. Only the slightest change in the network will alert the network that a block is modified which makes changing the ledger in the blockchain practically impossible (Swan, 2015).

Public-key cryptography

In public-key cryptography, the private key is used to encrypt the hash generated by the hash function. The public key, which is derived from the private key, is used by the recipients of a transaction to decrypt the hash to access the original document (PWC, 2016; Swan, 2015).

Digital signatures

A digital signature is the combination of hash functions and public-key cryptography. The digital signature is send to the recipient that can subsequently verify the transaction by validating whether the sent document matches with the digital signature. Validating the authenticity of the transaction by the recipient is performed by decrypting the digital signature with the public key and the hash created from the document being transferred. When the received hash and created hash correspond, the transaction being sent is considered valid.

Consensus methods

Once a specific transaction is authenticated, the transaction need to be validated by the nodes of the network. This is done by specific consensus method. The leading consensus method is proof-of-work where blocks are accepted based on the majority rule. In order to validate a block, miners need to solve a cryptographic puzzle by finding a hash that start with a number of zero bits. The miner basically invest CPU power to validate the block. Once the proof-of-work has been performed the block is unalterable without redoing the computing work, making the chain of blocks practically immutable (Nakamoto, 2008).

Blockchain network typology

A blockchain can be configured in a public or private typology. In a public blockchain, the blockchain is open to anyone to perform transactions, check data on the blockchain and to participate in the process of consensus. In a private blockchain, the creation on the blockchain is centralised to one organisation. The permission to read on the blockchain is either public or restricted and the validation process might be restricted to assigned entities (BitFury Group, 2015; Buterin, 2015; Hileman and Rauchs, 2017).

3. Methodology

In analysing the design implications of a blockchain application unlocking decentralised flexibility from a system integration perspective, the comprehensive design (CD) framework as developed by Scholten and Künneke (2016) is used to provide an extensive structure for analysis. The CD framework conceptualises an integrative design for energy infrastructures that take into account the strong interaction between technology and institutions. The system integration of energy infrastructures in the CD framework is conceptualised based on the four-layer model as defined by Williamson (1998). Alignment along the several layers is needed to achieve system integration and represented by three design knobs; access, responsibilities and coordination (see Figure 1). The design knobs define the alignment between the systemic environment and institutional environment, design principles and governance and control mechanisms and organisation. For the underlying concepts of these variables, one could consult Appendix A.

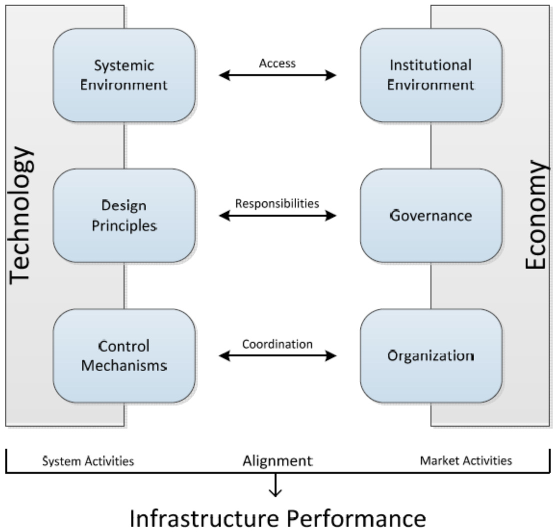

Figure 1: conceptualisation of the CD framework, adapted from Scholten and Künneke (2016)

The layer of access refers to the distinction of closed- and open access and the need for aligning these variables in the systemic and institutional environment. The layer of responsibilities refers to the alignment of specific responsibilities in the management of technical artefacts with responsibilities in the economic dimension (such as decisions on ownership and market rules). The layer of coordination refers to the alignment of the techno-operational activity and economic organisation in energy infrastructures. The framework is considered to be top-down, meaning that upper laying layer constrain choices and performance of lower layers (Scholten and Künneke, 2016).

Although design is the main focus of the CD framework, the underlying principles of the framework provide a substantive structure and support in the analysis of design implications from the system integration perspective. In identifying implications of the blockchain application, both the internal- and external alignment is assessed. The internal alignment refers to alignment of the blockchain application itself, such as the alignment of technical coordination linked to the economic settlement. The external alignment is about implications that arise from integrating the blockchain application in the environment of the Dutch electricity sector and technology and institutions embedded in this sector, such as the alignment between the blockchain application and electricity markets.

In analysing design implications, a preliminary design based on the features and concepts of blockchain technology and a broadly acknowledged flexibility model for a decentral level (the USEF framework) are used to draft a preliminary blockchain flexibility configuration. To prevent the analysis from bias and incompletion, a total of ten experts (varying from a professor to a CTO of a Dutch DSO, academics, blockchain experts, and energy consultants, are interviewed to evaluate the identified design implications of the blockchain application. Experts have been selected on their ability of applying a system integrative view on both the blockchain application and the energy sector and their individual specific expertise varying from regulation to electricity markets, blockchain technology, decentralised energy systems and the energy transition. Based on the specific expertise of the interviewee, the interview was focussed on specific aspects. Because of the knowledge specificity these consultation sessions have been organised in a semi-structured way where issues and considerations in the layer of access, responsibilities and coordination were discussed in a consecutive order. The output from the interviews is subsequently used to iterate the initial analysis. A summary of the expert interviews can be found in Appendix B.

4. Results and Discussion

This section elaborates on the conceptualisation of a blockchain application in unlocking decentralised flexibility in section 4.1 and the identification of design implications for the deployment of a blockchain application in unlocking decentralised flexibility in the Dutch electricity sector from a system integration perspective in 4.2. Section **Fout! Verwijzingsbron niet gevonden.** elaborates on how the identified design implication can be bridged towards the detailed design of a blockchain application in unlocking decentralised flexibility. Finally, 4.4 discusses the research results of this paper.

4.1. Conceptualisation of a blockchain application in unlocking decentralised flexibility

The conceptualisation of the blockchain application is based on the USEF framework (USEF, 2015). USEF is a widely supported framework for the aggregator role in unlocking decentralised flexibility. As discussed, a blockchain application could be able to make the role of the aggregator (the third party intermediary) obsolete. Important in providing the full disintermediation and self-organisation ability is that a blockchain application should be able to fulfil all aggregator functionalities. USEF (2015) characterises 5 functionalities in coordinating the aggregator model; contracting, planning, validating, operation, and settling. In the blockchain application, these functionalities are taken over by smart contracts in combination with IoT. Users of the blockchain application can define their specific preferences (e.g. type of flexibility, capacity of flexibility and price of flexibility) in the smart contract. Formalised contracts (contracting) and planning are not necessary since the smart contract automatically matches suppliers and consumers of flexibility when their preferences match. In this way, transactions can therefore be executed automatically and real-time. When DSO data is embedded in the blockchain, the smart contract can also validate whether the execution of the transaction is executable (validating). Linking the smart contract with IoT then triggers the physical flow of electricity from the flexibility application (operation). Finally, the transaction is registered in the distributed ledger of the blockchain where the settlement of the transaction is recorded. Market interactions are therefore completely managed by smart contracts, this is conceptually shown in Figure 2.

4.2. Analysis of design implications of a blockchain in unlocking decentralised flexibility

This section elaborates on the design implications as found in the case of a blockchain application in unlocking decentralised flexibility by using a system integration perspective as structured in the CD framework. Section 4.2.1, 4.2.2 and 4.2.3 discuss implications as found in the internal- and external alignment of the variables of access, responsibilities and coordination respectively. The implications reflect on the preliminary blockchain

4.2.1. Design implications in access layer

Implications identified in the systemic- and institutional environment relate to the level of technology of blockchain and the misalignment of blockchain technology in the layer of access.

4.2.1.1. Underperforming technology

Blockchain technology is prone to some technical barriers. Scalability, slow processing speed, security and the large use of energy resources are currently an issue (Swan, 2015). Speed is however very dependent on the size of the network and the amount of nodes in the network. The Bitcoin blockchain is currently limited to 7 transaction per second. The applicability of blockchain in a real-time management system can therefore be questioned.

4.2.1.2. Central tendency

As observed in 2.1, the current Dutch electricity sector is structured along a central configuration favouring central infrastructures and institutions. It is therefore hard to implement a blockchain implication, that has a more decentral approach, within this current central configuration. In a blockchain application, transactions are executed automatically and trust is placed in the blockchain with its features of cryptography and immutability. This is at odds with the current electricity sector which is dominated by trusted third parties. Besides, the implementation of blockchain is at odds with the central responsibility, which regularly is assigned to established centra parties.

4.2.1.3. Acceptation of end user: security and privacy

Acceptation of the end user can be seen as a major implication. Closely related to the acceptability of blockchain are the issues of security and data privacy (Swan, 2015). Security and data privacy can always be considered as an implication in data driven implications,

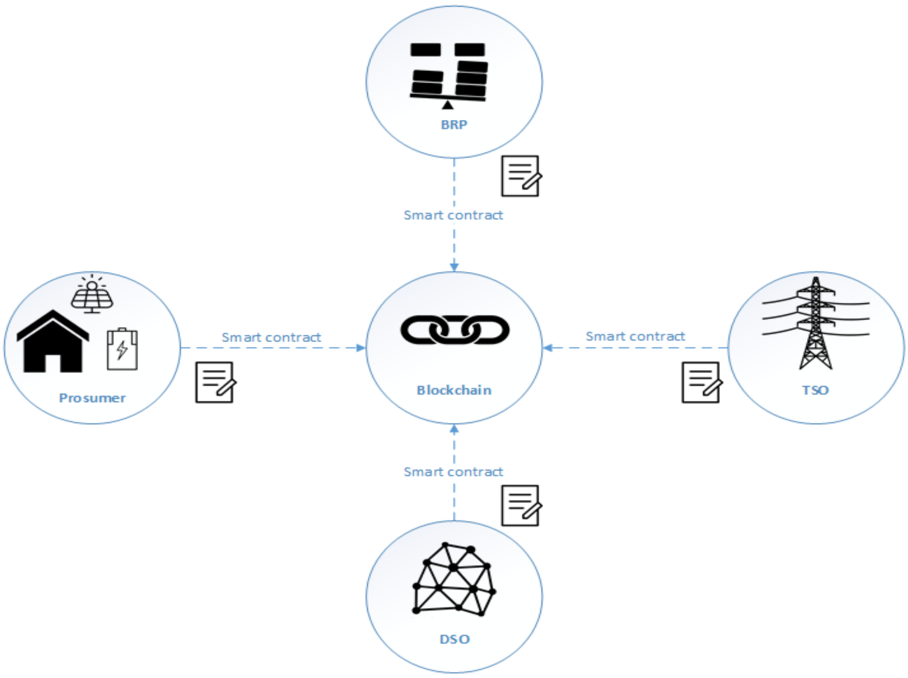

Figure 2: Market interactions managed by blockchain and smart contracts

however the unfamiliar concept of blockchain technology (no trusted third party in control of managing security and privacy) and the lack of knowledge of the end user on how blockchain technology is secured and how it processes individual data.

4.2.1.4. The lack of flexibility models from a decentralised model

Currently, no major implementations of flexibility from a decentralised level exist causing no form of standardisation and practices to be present. Development of real use cases is necessary to create knowledge and standardised practices.

4.2.1.5. Need for prosumer involvement

The blockchain flexibility application falls or stands with the involvement of prosumers on the platform. This is expected to be tricky in two ways. First, it is unsure whether prosumers are expected to actively participate in a blockchain platform since participation can be considered to be a hassle. Prosumers might have a lack of urgency to participate in a flexibility model to save or gain some money. The other implication is that security and privacy issues might form a barrier for prosumers to participate in the blockchain application.

4.2.1.6. Barriers for local initiatives

Going into a more renewable driven energy system, more and more local initiatives, such as energy cooperatives arise. These parties could play a major role in the enablement of local energy systems, such as the development or implementation of a local blockchain flexibility model. They however, face difficulties in adopting such a role since they are obliged to own a suppliers license, bear program responsibility and need to have a bank guarantee (TenneT, 2017a), which may be considered as a barrier for local, smaller parties.

4.2.1.7. Lack of clear definition of flexibility

In the current regulatory frameworks and legislation, activities in the electricity sector need to be classified either as generation, transmission, distribution, or supply. The potential of flexibility cannot be captured in only one of those activities. Currently, flexibility is usually treated as a generation activity, originating from traditional flexibility services such as flexible power plants and pumped hydro storage. Flexibility as defined in this use case, can operate as generation, transmission asset, distribution asset and load. Using an unilateral definition of flexibility imposes some barriers to the operation and ownership of the assets are present (Anuta et al., 2014; Ruz and Pollitt, 2016). Due to unbundling, network operators are not allowed to perform any activities within a competitive flexibility model (ACM, 2017).

4.2.2. Design implications in responsibilities layer

Implications identified in the layer of responsibilities refer to the design principles and governance of the blockchain application.

4.2.2.1. Assigning responsibilities in a public blockchain

In the drafted configuration, it was assumed that the flexibility model is organised by means of a public blockchain. It is however very hard to assign- and regulate specific responsibilities in a public blockchain. Legislation is not yet developed on the issue of uncertainties on responsibility in a blockchain application (private or public) (de Joode, 2017). The question is to what extent, players can be held responsible in the presence of failures or undesirable outcomes in the blockchain application. It might therefore plausible to assume that a flexibility blockchain need to be organised in a private network. Private networks operated by a trusted party provide the ability of installing safeguards in the network such as removing an opportunistic behaving party from the network to guarantee reliable operation and trust among market players (Hileman and Rauchs, 2017). Besides, many roles relating to blockchain operations are needed, by organising the blockchain in a private network (Hileman and Rauchs, 2017). Assigning a trusted third party and conceptualising these blockchain roles seem to oppose the potential of complete disintermediation and self-organisation of blockchain technology.

4.2.2.2. Unformalised relationships

In the blockchain flexibility model, actor relationships are not formalised. This seems an efficient way of organisation, but also impose some implications from the perspective of responsibilities. The question for example is, whether smart contracts are legally binding. The unclear status of the smart contract induces some implications in managing principal-agent relationships. It is doubtful whether the prosumer can be held responsible for deviating from a transaction as of supply a certain amount of flexibility as determined in the automatic transaction of a smart contract.

4.2.2.3. Prosumer responsibility

In the ideal situation, all blockchain end-users individually define their flexibility preferences in a smart contract. It is however expected that prosumers do not want to bear the responsibility and neither have the knowledge to define a smart contract in the blockchain themselves. Prosumers are in need of a trading agent that features the ability to translate individual preferences in bidding strategy in a smart contract to experience an easy-to-use application (Eid, 2017; Reineman, 2017; Rutten, 2017). The introduction of such a trading agent however, again introduces some sort of intermediation which opposes the full potential of blockchain to operate in a full disintermediated environment.

4.2.2.4. Going into local markets

Blockchain platforms provide the ability to go into local markets, because of the disintermediation ability of markets of smart contracts. This might for example be efficient in the case of offering flexibility to the DSO, where local desirable or undesirable behaviour can be rewarded or penalised based on local conditions. Considering the complete product potential of flexibility, flexibility for grid- and congestion management for the

DSOs, portfolio optimisation for BRPs and balancing services for the TSO, the full potential in terms of demand and price can only be utilised when coupled to the national wholesale model. The shift to local or smaller blockchain specific markets seem therefore not to be efficient from this perspective.

4.2.2.5. Need to revise current roles and responsibilities

A major implication in realising a blockchain flexibility model is that the current sector, both market parties and legislators need to adopt new responsibilities and configurations. It might be expected that these parties have difficulties in adopting changes, since the current responsibilities and configurations are present for many years.

4.2.2.6. Implications in current market configurations

As discussed in 4.2.2.4, flexibility is at its most efficient, offered in the national wholesale market. Many barriers can be found in current market regarding to the product of flexibility from a decentralised level. On the prosumer side, the lack of real-time pricing and the presence of the 'salderings rule', the rule that allows prosumers to feed in decentral generated electricity tax free for a fixed tariff, do not stimulate prosumers to participate in flexibility schemes and invest in hardware that can provide flexibility. On the market side, many markets are prone to minimum technical requirements that cannot be fulfilled by small prosumer loads. Aggregating these loads might be a solution, but most of the Dutch markets, do not allow for aggregated loads. Finally, uncertainties around the price of flexibility exist since currently only the supply of electricity, and not the benefits of flexibility beyond electricity, can be monetised in the markets (Ruz and Pollitt, 2016).

4.2.3. Design implications in coordination layer

Implications identified in the layer of coordination related to the control mechanism and organisation of a blockchain application.

4.2.3.1. Dealing with conflicting incentives

Assuming that the product of flexibility is offered in three markets, conflicting signals from different markets may be generated. It is unclear how the smart contracts in the blockchain should deal with the situation where the TSO procures flexibility from a certain area where the DSO at the same time gives an conflicting signal to prevent congestion on the distribution grid (de Joode, 2017).

4.2.3.2. Linking the physical product of flexibility with the transactional system of blockchain

Linking the physical product of flexibility with the transactional system of a blockchain application is rather difficult. Because of the coupling of a smart meter with the blockchain, the amount of flexibility monitored by the smart meter is recorded in the blockchain as the physical transaction. However, in practice the physical amount registered in the blockchain ledger will not match the actual amount of flexibility delivered by the prosumer, due to system losses etc. This is troublesome since blockchain is unable to check whether the input on the blockchain is correct (garbage in, garbage out) (Hileman and Rauchs, 2017)

4.2.3.3. Issues with consensus mechanisms

In coordinating a flexibility system, the blockchain application need to be settled real-time with fast processing speed. As discussed, the processing speed of blockchain is currently rather low. This is mainly due to the proof-of-work consensus mechanism, the current leading consensus method in blockchain applications. In this consensus method, all transactions need to be validated by every participant of the network. Another issue of proof-of-work is the amount of energy it uses to validate the transaction, which at the end all contributes to the costs of a transaction. Proof-of-stake, currently being researched by Ethereum, however, might solve for some of these issues (coindesk, 2017). Another problem of proof-of-work is the possibility of 51% attacks in majority voting mechanisms (Hileman and Rauchs, 2017).

4.2.3.4. Transaction costs higher than expected

Due to their innovative way of organisation, automated smart contracts in a disintermediated environment, the transactions costs of a blockchain application are expected to be significantly lower than in the presence of a third party intermediary. In the presence of a blockchain, costs can be saved that relate to contracting-, searching, negotiation, and settlement. However, as the implications in this paper show, a blockchain application might be in need for some intermediation in the form of a trusted party operating a private blockchain network, assigning specific responsibilities in a blockchain network and the need for a trading agent that operates on behalf of the prosumer. Literature stating that blockchain application is more efficient in transaction costs assume the complete disintermediation (Davidson et al., 2016; MacDonald et al., 2016). Due to the extent of intermediation needed, the effect on transaction costs in the blockchain application is not as significant as expected.

4.3. Towards a detailed design of a blockchain application in unlocking decentralised flexibility

After the identification of design implications, the question rises how the results of this research can be used in the detailed design of a blockchain application in unlocking decentralised flexibility. Design implications have been classified into three categories; design implications that reflect on the performance of the blockchain application, design implications that need to be removed or significantly improve to make the system integration of a general flexibility solution possible, and design implications that need to be incorporated in the detailed design of the blockchain artefact in unlocking decentralised flexibility. The first classification can be used by policy makers, and parties interested in operating a flexibility model in comparing a blockchain flexibility model with other flexibility providing solutions (such as the aggregator). The second and third classification, comprises variables that need to be designed for in a detailed design by policy makers, parties interested in operating the blockchain application, and blockchain developers. The second classification refers to boundary conditions for the successful system integration of a blockchain flexibility model, whereas the third classification refers to design choices that need to be made in the detailed design process of the blockchain artefact.

4.3.1. Design implications defining blockchain performance

Ultimately, policy makers and potential developers will compare a blockchain application with other flexibility solutions at a decentralised level such as the aggregator. From the conceptualisation of the blockchain model and design implications identified in this paper, a general overview of blockchain performance is provided in Table 1.

Table 1:Blockchain performance

	Blockchain
Fit with current environment	At odds with current sector and activities of established parties due to the use of decentral sources and disintermediation of organisation
Technical complexity	Technical very immature. Few use cases, technology is emerging and complex.
Governance	Technology automatically manages the linkage between prosumers and central markets.
Regulating ability	Due to disintermediation uncertain how the activity within the blockchain can be regulated
Coordination complexity	No need for formalisation of relationships due to the usage of smart contracts
Transaction costs	Relatively low transaction costs due to efficient coordination

4.3.2. Design implications that need to be overcome

This classification focusses on the high over design implications that are present which currently hamper the possible implementation of a blockchain flexibility model. Removing or significantly improving these design implications can be seen as a boundary condition for the system integration of a blockchain flexibility model. These implications refer to technical-, regulatory-, and market barriers as identified in this paper which are present in the electricity sector. The technical barriers refers to the lack of standardisation and practices. Regulatory barriers refer to the need for revision of current roles and responsibilities, the current central tendency in the electricity sector environment and the unclear and unilateral definition of the product of flexibility. The market barriers refer to the current barriers in electricity markets, such as the prohibition of aggregated loads and minimum technical requirements of electricity markets, and the inability to fully monetise the product of flexibility within current markets. Without designing for solving these issues, it is expected that the system integration of a blockchain application in unlocking decentralised flexibility is rather cumbersome.

4.3.3. Future design choices

Once decided that a flexibility model at a decentralised level should be organised by means of a blockchain application, future design choices that deal with design implications become relevant. These design choices specifically deal with design implications identified in this paper that are applicable to the individual artefact of blockchain technology (internal alignment). Future design choices are:

- Specific roles and responsibilities in the blockchain application
- Specific rules and regulation relating to activities in the blockchain application
- Specific design of a blockchain platform
- Blockchain control strategies
- Specific network typology
- Safeguards for data privacy and security

4.4. Discussion

This research started with the assumption that blockchain technology is able to disrupt the use case of unlocking decentralised flexibility by the features of disintermediation and self-organisation, being an inventive way of organisation. As this paper shows, the complete disintermediation and self-organisation is very hard to establish in the use case of unlocking decentralised flexibility in the Dutch electricity sector. Because of the strict institutionalised environment of the Dutch electricity sector, there is a need to be able to assign responsibilities to a central trusted party in deploying and operating the blockchain application. Besides, a central party is needed to provide the linkage between prosumers and the blockchain application. Finally, the linkage with national wholesale markets is needed to utilise the full potential of the product of flexibility. The complete disintermediation is therefore observed to be very hard causing the positive effect on operating efficiency and transaction costs in the case of blockchain being less significant as expected. It is therefore doubtful whether blockchain technology can actually provide the institutional innovation as referred to in Davidson et al. (2016) and MacDonald et al. (2016). It can therefore be argued that a blockchain application in this specific use case should be seen as an inventive way of coordination rather than organisation, since it differs not that much from the classical intermediation way in terms of organisation. A point of attention in future research is therefore to evaluate the benefit of blockchain in the case where complete disintermediation is impossible.

In evaluating the performance of a blockchain application, blockchain need to be compared with existing flexibility organising methods such as the aggregator. The aggregator role is currently one of the leading solutions in unlocking decentralised flexibility where the aggregator functions as the third-party intermediary between prosumers and markets. Often discussed in the interviews was the possibility to use blockchain as a coordination mechanism of the aggregator, to improve its operational efficiency. This also relates to the previous point of discussion where was stated that blockchain might need to be considered as a way of coordination. In evaluating the performance of blockchain technology, blockchain then should be compared to existing coordination and operation mechanisms such as central database solutions. A point of attention in future research is therefore to research the benefits of blockchain technology within a central organisation as the aggregator over existing coordination and operational mechanisms.

Assumed to be a system that enables complete disintermediation and decentralisation, this research shows that the impact of blockchain across sectors need to be nuanced. Due to energy sector characteristics and the difficulty of disintermediation, within the specific use case discussed in this paper, blockchain cannot foresee in the complete potential as promised by blockchain enthusiasts. This research even concluded that blockchain technology might be considered as a coordination mechanism rather than a mechanism of governance. Yet, some blockchain applications, such as Everledger and Bitcoin, have proven to be successful in the disintermediation of market-structures and institutions. It is therefore necessary that each individual use case is in need for a customised assessment to evaluate the potential of blockchain. Only then, the current hype will lead to the development of real and beneficial use cases. A point for future research is the development of an assessment framework of blockchain technology that is able to evaluate where blockchain technology could play a role.

Finally, the design implications within this research have been classified in three categories to set up the bridge with future detailed design. This provided insight in design implications that need to be overcome and future design choices. It remains however uncertain, how a detailed design of a blockchain application unlocking decentralised flexibility look like. A final point of attention for future research is therefore the detailed design of a blockchain application unlocking decentralised flexibility. Besides, uncertainties, uncertainties around the market size- and need for flexibility, that may hamper the ultimate success of a blockchain application in unlocking decentralised flexibilities are still present.

5. Conclusions

As observed in this paper, the complete disintermediation and self-organisation in the case of a blockchain application in unlocking decentralised flexibility seems impossible. Blockchain is perceived as a technology that could disrupt a variety of sectors by gaining efficiency by cutting out the third-party intermediary. This paper identified design implications of a blockchain application in unlocking decentralised flexibility by considering a system integration perspective by answering the following research question:

‘What system integration challenges need to be overcome to enable the implementation of a blockchain application in unlocking decentralised flexibility in the Dutch electricity sector?’

Flexibility is expected to be offered in three markets, flexibility for grid- and congestion management for the DSO, flexibility for portfolio optimisation for BRPs and flexibility for balancing services for TenneT. The system integration perspective is conceptualised by the CD framework, a framework that structures system integrative design on three levels of alignment, access, responsibilities and coordination.

In the layer of access, implications arise in the underperformance of blockchain technology, the radical character that opposes current activities in the energy sector, the acceptation of the end user and the concern of end users towards security and data privacy, the lack of standardisation and implementation on flexibility models, the need for prosumer involvement that seems tricky, the difficulty of going into local initiatives because of access requirements, and the unclear and unilateral definition of the product of flexibility. Relating to the external alignment in the layer of access, the inertness and the heavily institutionalised environment of the electricity sector optimised on central configuration seem the biggest barrier in overcoming implications for a blockchain application. Implications from the internal alignment mainly considers the radical innovative character of blockchain technology and the issues relating to that.

In the layer of responsibilities implications arise from the fact that it is rather hard to assign responsibilities in a blockchain application because of the difficulty in managing unformalised relationships, prosumers are not able to bear the responsibility of smart contract definition and defining bidding strategies, the difficulty of going into local markets since flexibility can only be used at its full potential once coupled to central markets, the, roles and responsibilities and the implications from the perspective of current responsibilities and market configurations. In the external alignment, there is a seemingly mismatch in technical design principles and economic governance with the current energy sector. Internally, the alignment in the layer of responsibilities mainly concerns the implications of blockchain in assigning specific responsibilities to within a blockchain application. A blockchain application in the use case of decentralised flexibility might therefore be in need to be operated by a central trusted party, assign responsibilities relating to the technical blockchain development and operation, and the need for a centralised trading agent that can establish the linkage of prosumers with the blockchain platform.

In the layer of coordination implications arise in the presence of conflicting incentives from the three market services, linking the physical flexibility product with the transactional system of blockchain and issues of consensus mechanisms. At the end there can be expected that the operation efficiency and transaction costs of a blockchain application might improve compared to original types of organisations, but not as significant as expected in the case of complete disintermediation and self-organisation by blockchain.

The design implications as found within this papers are classified in three categories to form the bridge of this paper with future detailed design of a blockchain application unlocking decentralised flexibility. Design implication in this paper can basically be classified in the performance indicators that discusses the functioning and implications of the blockchain application in this use case, implications that need to be overcome to enable successful system integration, and design choices that need to be made in the future detailed design. It however remains uncertain how a detailed design should look like. The detailed design of a blockchain application unlocking decentralised flexibility is therefore a point of attention in future research. Because of the need for some trusted operational party, blockchain seem not be able to make the role of a third-party intermediary obsolete. In this use case, blockchain technology can therefore be considered as an operationalisation of the aggregator role, a third party intermediary that is broadly researched to play a role in flexibility models. Blockchain however may provide the aggregator a mean to improve its operational efficiency. The benefit of blockchain in this use case without the possibility to go into full disintermediation and self-organisation need to be a point of attention in future research. More specifically, future research need to look in the benefits of blockchain when it cannot provide the full disintermediation and self-organisation in a specific use case.

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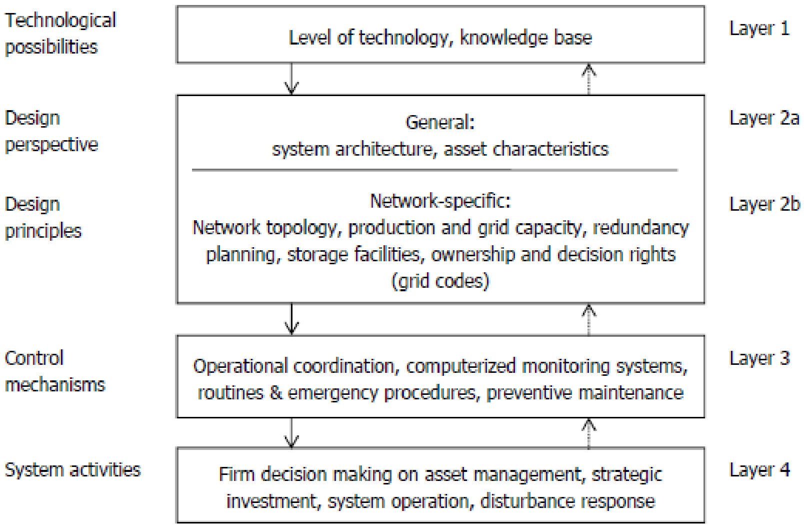
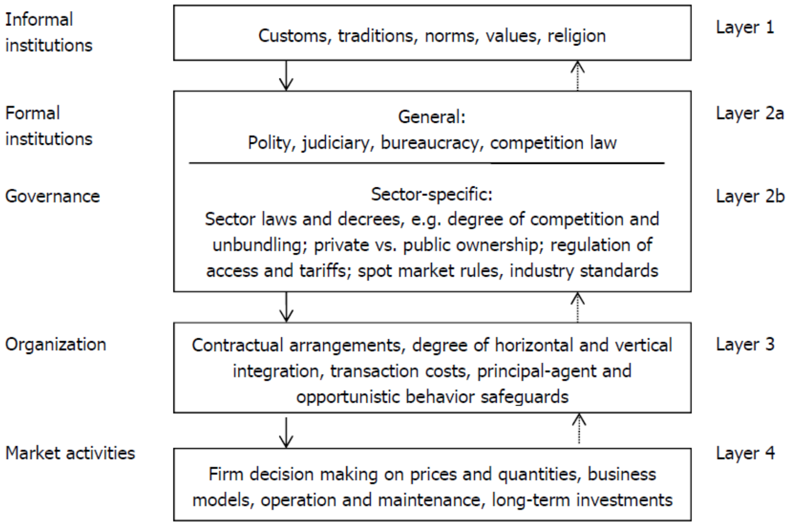
Appendix A

This appendix provides a more detailed insight of the engineering and economic layers as conceptualised in the CD framework. The upper image represents the engineering perspective and the lower image reprenst the economic perspective.





Appendix B

This section provides the summaries of the expert interviews as used in this research. The interviewees have given their written consent on publishing the summaries as presented in the remainder of this section.

Cherrelle Eid

Access

The aggregator-role is slowly emerging for end users located at the distribution grid and already a big step for the energy sector. A direct innovation towards a blockchain application can therefore be considered as too radical. The acceptation from the end consumer for a blockchain application can be considered as a barrier. Blockchain however can be considered as a possibility for an efficient way of dealing with the role and operations of an aggregator.

Responsibility

The aggregator role is a role not worked out in detail yet. Roles and responsibilities therefore still need to emerge. A key is that regulatory frameworks need to be adapted to be able to adopt new roles such as the aggregator.

The aggregator is characterised by several activities (from data management to physical aggregator and market clearing). It is necessary to evaluate what party can fill in what activity (for example, the DSO, an independent aggregator or another entity). This doesn't necessarily need to be assigned to one specific party. Furthermore, the role of data management is a very sensitive activity and might require a regulated party (like the DSO) to be made responsible.

Prosumers might generally not want to bear the responsibility of flexibility offering or some sort of program responsibility. It is therefore necessary to have a trading agent operating on behalf of the prosumers.

Coordination

The Blockchain technology is an operationalization of the role of the aggregator role where blockchain is considered as a coordination mechanism. This basically provides the aggregator a way to become more efficient. In a competitive market, an aggregator can distinguish itself from other aggregator by means of a blockchain operationalisation.

Theo Fens

Responsibility

With a proper functioning blockchain, there is essentially no need for the role of the aggregator for both forecasting as well as settlement. However, the program responsibility within a blockchain should be assigned to an actor, this could for example be an aggregator (or a distribution network operator for that matter) since prosumers do not want to bear this responsibility.

Because of slow processing speeds associated with a global blockchain implementation and issues of scalability, a local (based on a geographical area) blockchain solution with a smaller network and less nodes may be an efficient solution. The aggregator can be the operator of a private network in this configuration. With a trusted party operating the blockchain, the issue of trust is not the main justification for using a blockchain.

The expectation is that the product of flexibility will become very important for the security of supply in the electricity sector. One could think of organising flexibility as a utility product as it is currently used in the balancing mechanism by the TSO. One way of doing this is cascading the flexibility mechanisms as we know it at the TSO level down to the DSO level where the DSO could locally balance the distribution grid.

Flexibility may be organised in a local retail market decoupled from the APX wholesale market.

Coordination

The market mechanisms of flexibility are very much related to supply and demand. At the level of the distribution grid one should come up with the right signals. For a blockchain application it should be defined how local balancing can be coordinated in smart contracts, this may well be a regulatory issue.

It is expected that the market for flexibility is not that big, especially when the commodity of electricity becomes a marginal product in the context of abundant renewables and storage. The economic value of flexibility will therefore not be very significant. Considering this, a blockchain application might be more desirable because of its low costs for transactions and thereby no need for an expensive aggregator.

All the measurement equipment and paying the network validators that are needed for real-time smart contract operations add up to the transaction costs in a blockchain application. The actual transaction costs are therefore unknown. Measures for keeping transaction costs as low as possible concerns the size of the blockchain, a localised (private?) blockchain may well be an economically viable solution.

Richard van Gemert

Access
Energy sector is currently not ready for the implementation of both systems. Parties however are looking into these type of solutions.

Responsibility
Institutionally, there is no design yet that enables the deployment of both systems. We need to look in new institutional designs that allow such systems to be deployed. Important is to look beyond current roles and responsibilities

The role of the aggregator need to be an independent role, this not necessarily means that it should become an utility. But it is not desirable to organize this in a competitive way because of the importance of flexibility in the future.

The DSO can be involved in the flexibility steering of congestion management. Very important to operate this by capacity flexibility (e.g. a DSO communicates the capacity available on the distribution grid) and not the flexibility of electricity supply.

Coordination
In a blockchain application, the linkage of the physical product of flexibility with the transactional blockchain system is difficult. It's very hard to make it traceable from feed-in to consumption. In practice, line losses and deviations from the promised feed in can occur. It's very uncertain how this is corrected for in blockchain technology.

Blockchain can also be considered as an operationalisation of the aggregator role where the aggregator aggregates independent blockchains and the information which is embedded in that blockchain to come to a flexibility price. The DSO can be connected to this blockchain where it passes on information on grid capacity. The aggregator can where necessary embed a time-of-use price in the transaction of flexibility suppliers and consumers.

Sjors Hijgenaar

Responsibility
Prosumer are capable of defining their preferences, but not on strategies to bid in their flexibility. Some sort of service provider is needed in providing the linkage between prosumers and the flexibility market. This is where new roles will emerge that can be adopted by current established energy retailers that might lose business because of the decentralisation of the energy sector.

Scalability of a blockchain solution is mainly dependent upon the number of nodes in the network.

It's basically impossible to have a public blockchain configuration in the presence of a physical infrastructure such as the electricity sector. Because of the critical function of the electricity sector there is a need to have some sort of accountability present in the blockchain network. There should be safeguards to enable action against those that bring the operation of the grid in danger. This also generates trust among other market players and consumers.

Coordination
It is currently unknown what right pricing mechanisms would provide the efficient supply/demand mechanisms of flexibility.

The system of the aggregator can be very complex (because of the increasing trend of decentralisation) and expensive in terms of operation. Operation and transaction costs are very high because of the need of significant computer power. In a blockchain operation, the need for computing power is distributed over the entire network.

Jeroen de Joode

Access
ACM has regulatory oversight over the actors in the energy sector. As part of its duties ACM reviews how activities fit in within the current legal and regulatory framework. Sometimes activities contributing to the energy transition are performed by market actors that are not allowed to do so under current regulatory frameworks. ACM is looking into interpreting current frameworks in such a way, activities contributing to the energy transition can be placed within that frameworks. Unlocking decentralised flexibility is seen as an important condition for an energy transition at the lowest cost to society. So far the aggregator role got ACM its attention and access to the market is considered as important. However the goal is not to facilitate independent aggregators at all cost, but to allow for access to the market for all actors in a level playing field. This role of aggregators could also be established within the roles and responsibility of current parties and the current framework.

Currently, there are some signals that market access for new aggregation entrants can be problematic to smaller/local parties because of the requirements associated with obtaining a retailers license with ACM and program responsibility with Tennet, and because of some minimum technical market requirements. The ACM is going to explore whether these requirements are a barrier for potential entrants to access the market. When this is the case, we will analyse and implement potential remedies within the regulatory framework and when relevant advise the Ministry on adaptations in the legal framework. An example of such a policy instrument is the creation of a 'license light'. Such a 'license light was part of an earlier proposed law (STROOM) that was halted in the First Chamber of Parliament.

Privacy and security issues can form a major barrier on the side of the prosumer. Nowadays, data driven application such as the aggregator role and a blockchain application face major attention when it comes down to data management. Prosumers will be suspicious towards the way data is being managed in both systems. However, there can be expected that this is a bigger issue in the case of a blockchain application since this is a disruptive unknown type of technology. Maybe blockchain could therefore only serve a niche market for prosumers interested in blockchain technology.

Big established energy retailers are not yet used to going into decentral solution such as an aggregation system. However there can be expected once there is proven that this can be a viable business, all established parties will evolve a business in this. A trend is already notable with initiatives such as Powerpeers and Peeks.

Responsibility
ACM considers the market for aggregation to be sufficiently competitive as the retail market in the Netherlands also shows sufficiently competitive levels. The entrance of new actors with aggregation services would even add to this . This could make the sector robust to opportunistic behaviour related to market power. When profit margins will become too large, other potentially take over the market share of that particular party. This is based on the assumption of sufficiently large switching behaviour. This is still a bit of an issue in the current retail market as a large share of retail customers has never switched supplier since the start of market liberalisation although price differences between retail suppliers can be large..

A big issue in a blockchain application is the assignment of specific responsibilities when coordination and decisions are managed on a decentral level. Within an aggregator model, these responsibilities are assigned to the aggregator. How this relates to a blockchain application is uncertain. Currently, legislation is not able to deal with this issue of blockchain technology.

The flexibility brought to the market by aggregators can serve roughly 3 markets: congestion management for DSO, portfolio optimisation of BRPs and balancing mechanisms for TenneT. Important for the efficiency and competitiveness is that the flexibility product could be offered in all these 3 markets. There should therefore always be a linkage to national wholesale markets. In the case where only a local market is considered without a link to the national system and the price signals stemming from the national markets, a suboptimal situation is created.

Coordination
Considering that the flexibility product is most efficiently offered in 3 markets it's uncertain how an aggregation system deals with conflict signals from the different markets. How should be dealt with the situation where TenneT is in need for flexible supply, but the distribution grid is limited and the DSO sends a counter flexibility signal. The fact that there are differing signals is not a problem as they signal different energy system needs, the issue is whether the allocation of flexibility at each time interval can be done efficiently, responding to these sugnals.

Market activities
At the end, the aggregator and blockchain could compete with each other. The application that at the end offers the best client solution is expected to gain the biggest market share.

DSOs can fulfil a facilitating role in decentralised flexibility when it provides insight in where flexibility is needed the most, thereby indicating the value of flexibility at specific locations.

Machiel Mulder

Access
The trend of decentralisation is quite unsure since we finally have a wall organised European electricity market with less and less restrictions on interconnection. Only a small trend to decentralisation is notable with more and more small players become active. This is however insignificant with only a maximum of 10% of the electricity consuming population. Consumers do not have the desire of demand response activities where an aggregator or blockchain application steer their energy behaviour. Prosumer therefore do not feel the urge to participate in these type of activities. There can therefore be expected that the market of aggregation is relatively small.

Besides, there is no strong trend in the Netherlands towards decentralisation with the implementation of large central wind farms on- and offshore. Imbalances on the DSO grid are therefore negligible.

Responsibility
Current flexibility mechanisms at the wholesale model have proven to be sufficient. There is therefore no need to establish a new type of flexibility mechanism on a decentralised level. When imbalances on the distribution grid occur it's the responsibility of TenneT to solve for this.

The need for flexibility is more urgent for the central wholesale markets. Congestion management might be in need for local solutions, but this is already embedded in the current responsibility of the DSO.

The activity of aggregation is clearly a competitive activity, since no monopolist characteristics or economies of scale are related to this activity. Besides, there is no public activity involved, blockchain technology and the aggregator are a technology and an organisation respectively. No need to let this be a regulated activity.

There can be expected that the aggregator role or blockchain technology are activities that are going to be fulfilled within the activities of current energy retailers. There is therefore no need to redefine the roles and responsibilities as we know now.

Coordination
New innovative solutions such as the aggregator role or a blockchain application need to be compared with the elements of flexibility currently present in the electricity market.

Another way of dealing with congestion management for the DSO is the introduction of dynamic network tariffs where usage of the distribution grid is penalized at times disadvantageous for grid utilization. Important in establishing dynamic network tariffs is the fairness towards society, where higher returns because of the dynamic network tariffs need to flow back towards society.

Market activities
At the end, new applications such as the aggregator role and a blockchain application will only be adapted when they proof to be more efficient than the current system elements.

Roelof Reineman

Access
Decentralisation and peer-to-peer markets will become very important in the energy transition. The role of energy retailers will therefore be subject to change. Those that are not able to adapt this change will encounter difficulties in maintaining their market position. Parties and consumers are not ready for some sort of decentral management yet.

The role of the aggregator could be considered as an intermediation solution with introducing a party with lag, the need for agreements and the possibility of fraud. The aggregator could therefore be considered as a step forward, but not as an end-game. The aggregator can subsequently be made more efficient by means of the blockchain. This however very path dependent. At this moment, blockchain is still a step too far, especially a public blockchain.

Responsibility
Regulations in a blockchain is hard. Legislation is not ready to facilitate this.

Aggregator should be place as a service within the current market. This could however be operationalised by blockchain. The energy retailers eminently are the parties that could develop this function. Responsibilities then can be regulated via the service provider.

Blockchain could provide energy retailers with a future proof business model in a decentralised energy sector.

Guy Rutten

Access
Current market mechanisms have to change when we consider the implementation of an aggregator role or a blockchain application. Currently, the system is too much focussed on the central configuration of the energy sector. The Ministry of Economic affairs is also very conservative in initiating new type of systems such as the aggregator role or a blockchain application.

Responsibility
There is a need for a service provision in providing prosumers with smart contracts. This enables current parties to establish business round a blockchain application.

Jeroen Scheer

Access
An end application for the prosumer need to be easy to use and safeguard privacy issues relating to data. For the prosumer, it doesn't really matter whether this is facilitated by the aggregator or blockchain technology. The question however is whether prosumers give their consent on the exchange of individual data.

The current tendency is that traditional parties evaluate everything from their current role and perspective.

Responsibility
Within a public blockchain you have the a self-organised organisation whereas a private blockchain allows to assign certain responsibilities to specific parties. In this way trust between participating parties is easier to accommodate. The question however is who is allowed to be in charge of a private blockchain. Market parties and energy retailers won't accept the DSO as the one in charge since they see this as a competitive party and a way to extend their business. Strict regulation of a blockchain application is not necessary since it is a self-organising technology. Rules to guide to blockchain would be sufficient.

The USEF aggregator framework has a strong linkage with the national wholesale model. The aggregator is therefore in need of all sorts of data to operate their business; commercial portfolio data, DSO data and data of individual prosumer. Without the incorporation of any safeguards or regulation, the aggregator than can easily manipulate market outcomes. Imagine the situation where an energy retailers is also in charge of the role of the aggregator and therefore has insights on points of congestion and prosumer data to optimise its own portfolio.

USEF generates one price based on the national wholesale model. But locally, different prices for flexibility arise. The aggregator model in USEF is not able to reward- or penalize local desirable- or undesirable behaviour. To enable this the price of flexibility need to be decoupled from the APX national wholesale model.

The responsibility for the development of a blockchain application is uncertain. A stimulation could be an open data platform where parties can develop some sort of app and if they satisfy certain criteria and requirements they can be allowed to operate on the market. EDSN than can possibly operate as the so- called trusted party that oversees the whole.

There is a need for a party that can make the linkage between prosumers and their preferences with a blockchain platform.

Coordination
Congestion management from the DSO can easily be put in smart contracts on a blockchain application where the physical limits of the distribution grid can trigger the transaction of a smart contract.

Opportunism is more a problem in the aggregator role than in a blockchain application. In the competitive aggregator role, the party in charge will strive for profit maximization. In a blockchain application, transactions are triggered by smart contracts. A to opportunistic smart contract will basically not be triggered because of the merit-order effect.

System- and market activities
The market of flexibility is not as big as expected.

There should be room for experiments to explore the unknown. For DSOs, the involvement of market parties is necessary.

Leon Straathof

Access
The inertness of the energy sector is a barrier for decentral energy solutions such as the aggregator role or a blockchain application in unlocking decentralised flexibility. Especially blockchain technology will change the energy value chain compared to the value chain as we know it now. The established parties though have a tendency to stick to the usual responsibilities and activities. This is maintained by the fact that the established parties are the party's in lead at steering groups etc.

This characteristic causes the energy sector to lack a pro-active and progressive attitude when it comes down to innovation. There is a need for a coordinated, programmatic approach in guiding the sector in the energy transition.

The aggregator role fits better within the current assets and configuration. Blockchain technology can therefore be seen as a second phase in innovation, an update of the aggregator role (only when it is an efficiency gain compared to the aggregator role).

For the end consumer, the prosumer, ease-of-use in the end application is very important. The average prosumer probably don't care about supplying flexibility.

Responsibility

Since the end consumer doesn’t care about supplying flexibility, a service provider could emerge to make the linkage between the prosumer and the flexibility market. The big question is what type of parties are willing to try to take the lead in establishing such a service.

In establishing new innovative systems such as the aggregator and a blockchain application the energy sector need to look beyond current roles, and responsibilities. Regulation should therefore be adapted to create room for innovations and the unknown.

Flexibility can evolve as a public task. However, the main question is whether it’s the most efficient way to organize this as a public activity or competitive activity.