# Watt rules? Assessing decision-making practices on smart energy systems in Dutch city districts

Lammers, Imke; Hoppe, Thomas

**DOI**
10.1016/j.erss.2018.10.003

**Publication date**
2019

**Document Version**
Final published version

**Published in**
Energy Research and Social Science

Energy Research & Social Science 47 (2019) 233–246

Contents lists available at ScienceDirect

Energy Research & Social Science

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

Original research article

# Watt rules? Assessing decision-making practices on smart energy systems in Dutch city districts

Imke Lammers[a,*], Thomas Hoppe[b]

[a] Department of Governance and Technology for Sustainability (CSTM), Faculty of Behavioural, Management and Social Sciences (BMS), University of Twente, 7500 AE Enschede, the Netherlands
[b] Organisation and Governance (OG), Department of Multi-Actor Systems (MAS), Faculty of Technology, Policy and Management (TPM), Delft University of Technology, 2628 CD Delft, the Netherlands

ARTICLE INFO

*Keywords:*
Smart energy system
Institutions
Governance
Decision-making

ABSTRACT

This article analyzes 'rules of the game' that influence decision-making concerning the introduction of smart energy systems. Smart energy systems are considered as a solution to optimize and make energy systems 'future-proof'. Their introduction, however, is challenged by a complex multi-stakeholder configuration, and by 'rules of the game' (institutional conditions) which are essential for the cooperation between stakeholders but perceived to be outdated. To address this issue, the central research question in this article is: '*which institutional conditions enable or disable decision-making processes regarding the introduction of smart energy systems in selected city district development projects*?' We conducted in-depth interviews and collected secondary data for four case studies in the Netherlands. Data were analysed, and cases were compared using the Institutional Analysis and Development framework, and the method of causal process tracing. The results reveal that only stakeholders in the position of project leader were actively pursuing the projects' goals (position rules), legal barriers as well as path dependency of previous decisions limited the available choices (choice rules), and agreement was lacking on sharing costs and benefits (aggregation rules). As 'rules of the game' for decision-making continue to present a challenge for the introduction of smart energy systems, future research and policy-making should pay attention to the creation and adequate orchestration of such rules.

## 1. Introduction

Current energy infrastructures were not designed for handling the increasing demand and supply of energy from distributed, intermittent renewable energy sources. The concept 'smart grid' is often presented as a promising solution to tackle the arising technical challenges in the *electricity* grid [1]. Moreover, a synergy between all energy infrastructures is considered as optimal for the energy system as a whole [2]. This calls for system integration in the form of a 'smart energy system' in which electricity grids, thermal grids and gas grids are combined and all energy flows are balanced with the help of information and communication technology (ICT) [2].

Although the technological components that make up smart grids and smart energy systems are fairly well developed, their introduction into real-life settings still faces many non-technical barriers [3]. One factor is the increasingly complex multi-stakeholder setting. Sataøen et al. [4], p. 185) emphasize that" grid projects must involve all interested actors, and these actors must be given an opportunity to participate substantially in the decision-making process". Upgrading the energy system increasingly entails collective action between a large variety of stakeholders, e.g., policy-makers, technology providers, distribution system operators (DSOs) and different sorts of end users [5].

Thus far, scholars mainly address the introduction of smart energy systems – and smart grids – from a legal context [6–9] or focus on individual stakeholder perspectives, as *ERSS's s*pecial issue on Smart Grids and the Social Sciences from 2015 [10] showed. The contributions in this special issue provided useful insights into the visions and expectations of actors [11], the behaviour of end users [12,13], and household practices [14,15], but did not include research on how stakeholders had established such projects.

Despite this body of research, there is thus a knowledge gap as regards the analysis of decision-making practices among stakeholders, and especially regarding the 'rules of the game' that hinder and facilitate decision-making in projects that aim at realizing smart energy systems. Sovacool [16] analyzed 4444 energy research articles and concluded that only 3.3 percent of these articles deal with "how

* Corresponding author.
*E-mail addresses:* i.lammers@utwente.nl (I. Lammers), t.hoppe@tudelft.nl (T. Hoppe).

https://doi.org/10.1016/j.erss.2018.10.003
Received 26 January 2018; Received in revised form 3 October 2018; Accepted 4 October 2018

humans make decisions and form institutions that craft rules shaping individual behavior" (p. 21). This finding is echoed by Von Bock und Polach et al. [17] who state that "there are relatively few studies that scrutinise how rules and social relations influence the performance of technical systems" (p. 129). In this article we therefore investigate in-depth the institutional rules ('rules of the game') that influence decision-making processes in multi-stakeholder settings. We study the influence of institutional conditions over time on decision-making processes in local projects where stakeholders intend to introduce smart energy systems (or elements thereof). We focus on the Dutch context as the Netherlands is considered one of the countries which allocates a relatively high amount of (public) funding to smart grid demonstration projects in the European Union (EU) [18]. Examples of realized demonstration projects are the twelve Dutch pilots of the 'innovation programme for smart grids' (short IPIN) that took place between 2011 and 2016 [19]. However, overall the deployment of smart energy grids does not occur on a large scale yet [18].

To summarize, the overall aim of this article is to explore which institutional conditions enable or disable decision-making processes on the introduction of smart energy systems, and consequently influence the selection or failure to select smart energy systems to be introduced in Dutch city districts. To capture all relevant institutional factors, we reconstruct the decision-making processes in four projects, and more specifically analyse the institutional conditions (i.e., 'rules') that structure these decision-making processes. The main research question therefore is, '*which institutional conditions enable or disable decision-making processes regarding the introduction of smart energy systems in selected city district development projects in the Netherlands*?' As we analyse the influence of generally applicable institutional conditions, our findings from the Netherlands are relevant to advancing decision-making processes on smart energy system introduction in a variety of contexts.

To answer the main research question we first provide background information on the increased multi-actor complexity and the lack of fitting 'rules of the game' for smart energy system introduction in Section 2. This is followed by a theoretical discussion on the institutional conditions for local energy planning regarding smart energy systems in Section 3. Section 4 explains the research design and methodology, which contains four case studies that are each analysed and compared. The case studies are presented in Section 5, followed by the case comparison in Section 6. After a discussion of these results in Section 7, the article ends with a conclusion and presents recommendations for future research in Section 8.

## 2. The need for 'rules of the game' for smart energy system introduction

Several developments in the energy sector have led to the emergence of a multi-actor complexity and 'rules of the game' that are considered outdated for the introduction of smart energy systems.

With the liberalization of the EU's electricity and gas markets in the late 1990s the "clearly defined position and legally authorized tasks" of actors in the energy sector diminished when the distribution as well as the production and supply of electricity had to be accommodated in separated companies ([20], p. 152). Goldthau [21] argues that, "this push toward the market model in energy has not only increased the number of involved actors and the levels of regulation; it has also enhanced the need for coordination among and between them" (p. 137). This multi-actor setting and need for coordination has grown even more with the increase of renewable energy production at the low- and medium- voltage grid level. In the Netherlands, it is especially electricity that is increasingly produced in a decentralized setting, notably through the use of solar PV panels, combined heat and power (CHP) or small scale wind parks [22]. This development turns consumers into 'prosumers' and multiplies the number of actors in the energy system. This trend is illustrated by a sharp rise in the number of community initiatives for renewable energy in the Netherlands, growing from 40 initiatives prior to 2009 to 360 such initiatives by 2016 [23].

Besides the bi-directional flow of energy from and to end users, the increased exchange of data on these energy flows leads to a situation where, in addition, stakeholders such as data processing companies, technology providers, aggregators, or storage providers want to proliferate themselves in the field of 'smart' renewable energy practices. The terms 'smart grid', 'microgrid' or 'smart energy system' are used to refer to these emerging energy systems. A smart energy system is considered to be the most optimal solution for the overall energy system, as "smart electricity, thermal and gas grids are combined with storage technologies and coordinated to identify synergies between" ([24], p. 5). The 'smart' element of these energy systems refers to information and communication technologies which make it possible to monitor and steer energy flows and thereby efficiently integrate renewable energy sources into an energy system and combine all subsectors (electricity, heat and gas). A smart energy system hence includes an 'ICT layer', an infrastructure that includes local renewable energy sources, energy storage capacity, and allows for the integration of multiple energy sources [3,24]. We argue that the more of these components an energy system entails, the smarter this energy system is.

The increased complexity of the energy system together with the growing multi-actor setting call for new – updated – 'rules of the game' that can help to reduce the uncertainties in the collaboration between stakeholders during energy planning at the local level. Such rules, for example, need to address the existing disagreements regarding "who should be the dominant actor, how should costs and benefits be allocated, who bears which responsibilities [in a smart grid]" ([25], p. 121). However, Wolsink [26] expects a problematic situation as most existing 'rules of the game' are" designed to support the centralised power supply system, [and] will prove to be unfit for creating, operating, and managing microgrids within an integrated smart grid" (p. 832). In this article we will address this issue empirically.

## 3. Institutional conditions for local planning on smart energy systems

To obtain an encompassing account on the institutional conditions that influence decision-making processes on the introduction of smart energy systems in Dutch city districts we draw on the Institutional Analysis and Development (IAD) framework [27,28]. Following North [29] and Ostrom [30] we define institutions as the humanly devised prescriptions that are used to organize human interactions, referred to as institutional conditions or 'rules of the game'.

While the IAD framework has conventionally been applied to the study of traditional common pool resource management, its value has more recently been recognized for research on energy transitions as well [31–33]. Newell et al. [33] point out that institutions and management strategies effect network processes in local renewable energy projects and draw on the seven rules that are part of the IAD framework (see Fig. 1 below) to understand this effect. Iychettira et al. [31] emphasize the importance of institutional context in energy policy design and praise the usefulness of the IAD framework in decomposing socio-technical systems into sub-parts. Additionally, Aligica and Boettke [34] state that the IAD framework is useful for the analysis of complex polycentric institutional arrangements; smart grids and smart energy systems have such polycentric characteristics [35].

Overall, the IAD framework is suitable for answering the main research question posed in this article as it is considered to be a "conceptual tool for inquiry about how rules affect a given situation" ([36], p. 43). These 'rules' (i.e., institutional conditions) determine the possible interactions that stakeholders involved in city district energy planning can undertake. The IAD framework is thus not an explanatory

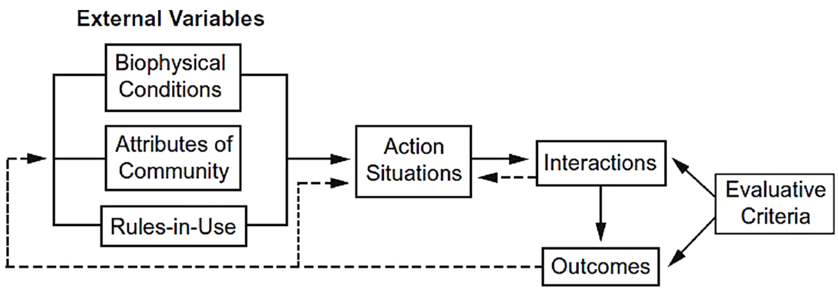


**Fig. 1.** The Institutional Analysis and Development Framework.
*Source:* Ostrom [28]

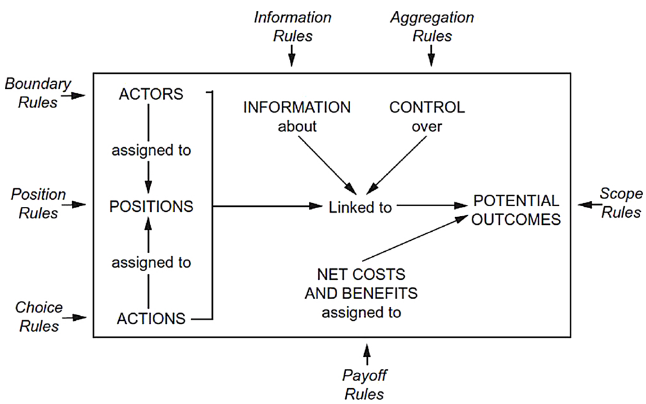


**Fig. 2.** The 'action situation' and the respective rules-in-use.
*Source:* Ostrom [28]

theory that specifies (assumed causal) relations between variables, but a meta-theoretical tool that allows researchers to analyse the institutional setting within which decision-making takes place. The IAD framework includes three external variables, an action situation, patterns of interactions, outcomes and evaluative criteria, as shown in Fig. 1.

The 'action situation' refers "to an analytic concept that enables an analyst to isolate the immediate structure affecting a process of interest to the analyst for the purpose of explaining regularities in human actions and results, and potentially to reform them" ([28], p. 11). The 'action situation' studied in this article is the decision-making process on the introduction of smart energy systems in Dutch city districts.

'Action situations', as portrayed in Fig. 2, consist of seven clusters of elements with their respective 'rules-in-use'. These 'rules-in-use', that we refer to as institutional conditions, are as follows (for a more detailed description please refer to the coding scheme in Annex A):

- *Boundary rules:* Specify the number of actors that participate in the local energy planning project, and how these actors join and leave the decision-making process;
- *Position rules*: Specify the set of positions that actors hold in the local energy planning decision-making process;
- *Choice rules:* Specify the sets of actions that can (could have), may or must not (have) been taken at specific points in time;
- *Information rules:* Specify the amount and type of information available to participants and how this information is used and shared;
- *Aggregation rules:* Specify how decisions are made, e.g., by an individual actor, or in collaboration with others;
- *Payoff rules:* Specify the costs and benefits that derive from particular actions and outcomes;
- *Scope rules:* Specify the set of possible outcomes, as well as the jurisdiction and state of outcomes, e.g., whether they are final or not [28,37].

As shown, the IAD framework is a useful meta-theoretical tool to delineate the institutional conditions for a *static* 'action situation'. As decision-making on energy infrastructure planning is often a lengthy and complex process, its reconstruction calls for the analysis of several 'action situations' over time. Once a change occurs in the combination of institutional conditions, a new 'action situation' comes into existence. Ostrom et al. [36] phrase it as follows: "while the concept of a 'single' [action situation] may include large numbers of participants and complex chains of action, most of social reality is composed of multiple [action situations] linked sequentially or simultaneously" (p. 45). To map institutional settings over time, we need to single out the most relevant sequentially linked 'action situations' for analysis. To do so we conduct causal process tracing (see Section 4.2) and inter alia identify key moments in each decision-making process that allow us to distinguish between 'action situations'. With causal process tracing these key moments are referred to as 'smoking guns', central pieces of evidence that reveal critical moments in the causal process [38]. We define a key moment as an instance in the decision-making process that influenced the outcome of decision-making, i.e., the introduction of a smart energy system. Key moments can for example be important agreements or external events, all of which lead to a change in the existing combination of institutional conditions. For the purpose of analysis, we treat each key moment as a stable point in time during which a certain combination of institutional conditions prevailed.

Considering that all 'action situations' (decision-making processes) consist of the same conceptual elements and are affected by the same set of rules, 'action situations' in different contextual settings can be compared more systematically. Next to analysing decision-making practices in individual projects, we therefore are able to compare these projects in regard to the combinations of institutional conditions that influenced the decision-making processes, as explained in the next section.

## 4. Research design and methodology

To reconstruct and analyse the institutional conditions at play during complex decision-making processes on the introduction of smart energy systems one needs to obtain in-depth, detailed information. An empirical, qualitative case study approach is most suited for this purpose as it allows for "analysing more complex action situations and their linkages" [Yandle, 2001 in [30], p. 35)]. In this article we present the analysis of four case studies.

### 4.1. Case selection

To obtain cases that portray the full range of variation regarding decision-making processes on the introduction of smart energy systems in Dutch city districts, we use a 'diverse cases' case selection approach. "Diverse cases are likely to be representative in the minimal sense of representing the full variation of the population (though they might not mirror the *distribution* of that variation in the population)" ([39], p. 89). We are interested in decision-making processes that portray variation on two aspects. The first aspect is whether high or low smart energy infrastructure ambitions exist. We consider ambitions to be higher when more smart energy system components are to be implemented in a local city District. As introduced Section 2, these components are the amount of local renewable energy sources, energy storage capacity, integration of (multiple) energy sources, and data flows. Second, we seek variation regarding the type of energy infrastructure, being either the electricity or heat infrastructure in a Dutch city district. Energy conservation measures such as thermally insulating residential buildings are not of interest. This variation allows us on to study cases that present the full variation of smart energy system projects in the Netherlands and makes it possible to investigate whether the influence of institutional conditions varied based on the energy system components that are to be implemented as well as the type of infrastructure in question, namely the electricity or heating grid.

Prior to selecting cases we looked at projects that were part of the following Dutch innovation programmes on renewable energy systems: the 'IPIN' programme, 'Switch2SmartGrids' (S2SGs), the 'Green Deal Smart Energy Cities', and the database 'Energy efficient construction'. To be able to address the research question, it was important to select cases that allowed us to obtain in-depth information which are needed for the within-case analysis in the form of causal process tracing. The selection of each of the cases is discussed in Sections 4.1.1 and 4.1.2.

#### 4.1.1. Cases with high smart energy systems ambitions

The projects with high smart energy system ambitions considered were among the Dutch pilot projects that received exceptional financial support under the 'IPIN' programme and the tender 'Switch2SmartGrids'.

The IPIN programme is the Dutch innovation programme for smart grids under which the Dutch government financially supported twelve smart grid pilot projects in the period from 2011 to 2016 [19]. Four of these twelve pilot projects fit the two case selection criteria, and eventually the project *'Intelligent Net in Duurzaam Lochem'* in the municipality of Lochem was selected. The reason for this was the local ambitions to implement several smart energy system components, combined with a multi-actor setting that included a wide range of stakeholders, inter alia a community initiative for renewable energy. The project involved the installation of a smart electricity grid with multiple solar PV parks, electric vehicles (EVs) and sensors for monitoring electricity flows locally in transformers and homes.

The 'Switch2SmartGrids' programme entailed two tenders in 2012, which resulted in governmental co-financing of seventeen smart grid projects for a period of maximum four years [40]. Of these seventeen projects only four focused on residential areas in city districts, and only one of these projects – *'Smart Grid MeppelEnergie'* in Meppel – involved the implementation of technical solutions by stakeholders in practice, i.e., it entailed a decision-making process. In this project the installation of a smart district heating grid based on biogas, combined heat and power and heat pumps was foreseen for a city district that was to be newly constructed.

#### 4.1.2. Cases with a lower degree of smart energy systems ambitions

The projects with lower smart energy system ambitions, that is with a smaller amount of smart energy system components, were selected from the 'Green Deal Smart Energy Cities' and the database 'Energy efficient construction'.

The 'Green Deal Smart Energy Cities' was established for the period from 2014 to 2019 to stimulate public-private collaboration for the upscaling of smart energy concepts in 100,000 buildings in the Netherlands [41]. This program included eleven 'kick-start' projects for whose implementation the project consortia could temporarily ask for the help of experts who would act as 'innovation broker' (finding innovative technologies for a local project) or 'creative producer' (creatively supporting the involvement of end users). The project that most strongly fit the case selection criteria was '*Bothoven-Noord: op weg naar een energieneutrale wijk'* (in English: Bothoven-Noord: towards an energy neutral district) in the municipality of Enschede, a project that aimed at creating an energy neutral district by 2040 by installing solar PV panels and monitoring residential electricity flows.

The database 'Energy efficient construction' of the Netherlands Enterprise Agency 'RVO', includes innovative projects in the built environment [42]. Due to the fact that of the three already selected cases two address electricity grids ('Lochem', 'Bothoven-Noord') and only one focuses on the district heating grid ('MeppelEnergie'), we chose to search for an additional heating grid project. This led to nine innovative projects, three of which fit the case selection criteria, and of which the '*Hart van Zuid*' project was the most interesting as the local government (the municipality of Hengelo) was leading the construction and operation of an envisioned open district heating grid in a cascade setting using industrial excess heat.

To summarize, the case selection resulted in two projects that had high smart energy system ambitions, and two projects that aimed at realizing an energy system with fewer smart energy systemcomponents, as shown in Table 1.

**Table 1**
Selection of four diverse cases.

| | High Smart Energy Infrastructure Ambitions | Lower Smart Energy Infrastructure Ambitions |
|---|---|---|
| Electricity Grid | Intelligent Net Duurzaam Lochem | Bothoven-Noord: op weg naar een energieneutrale wijk |
| Heating Grid | Smart Grid MeppelEnergie | Hart van Zuid |

### 4.2. Data collection and analysis

To obtain in-depth insights into each decision-making process data collection involved both primary (semi-structured interviews and moderate participant observation where possible[1]) and secondary data (project text documents). The interviews were semi-structured and included as many stakeholders as needed to achieve data saturation for each decision-making process, resulting in a total number of 20 interviews (see Table 2 for details).

The interview questions were mostly derived from the theoretical framework, as well as from the aspects linked to the technique of process tracing (see the paragraph below). Additionally, pilot interviews were conducted based upon which several questions were revised, as it turned out that some questions could be merged, rewritten or deleted. All interviews were audio recorded with the permission of the interviewees and were transcribed afterwards. In turn, the interview transcripts and secondary data were coded with the qualitative data analysis and research software tool Atlas.ti (version 7.5.4.) by using a coding scheme that was based on the elements of the IAD framework, the core questions of the causal process tracing approach and on inductively derived codes (see Fig. A1 in Appendix A).

For the within-case analysis of all four cases causal process tracing was undertaken to reconstruct the decision-making processes and map the institutional conditions that influenced each decision-making

[1] The moderate participation observation entailed that the first author of this article was present at eleven consortia meetings concerning the case 'Bothoven-Noord: op weg naar een energieneutrale wijk'. The insights that were obtained through observing the discussions of the consortium members were used to corroborate the data from the interviews and to make the within-case analysis more detailed and nuanced.

**Table 2**
Interviewees of semi-structured interviews per case study.

| Case | Number of interviews | Interviewees |
|---|---|---|
| Intelligent Net Duurzaam Lochem | N = 4 | - member of citizen energy initiative (2x);<br>- researcher working for a university;<br>- DSO project manager. |
| Smart Grid MeppelEnergie | N = 5 | - municipal civil servant;<br>- DSO project manager (2x);<br>- researcher working for a university of applied sciences;<br>- consultant of a networking organization focussed on business and project development. |
| Bothoven-Noord: op weg naar een energieneutrale wijk | N = 6 | - municipal civil servant;<br>- asset manager at DSO;<br>- employee of housing association (2x);<br>- researcher working for a university of applied sciences;<br>- director of a building association. |
| Hart van Zuid | N = 5 | - municipal civil servant (3x);<br>- DSO project manager;<br>- project engineer at an energy supplier. |

process over time. Causal process tracing "is geared toward identifying the causal chains, causal conjunctions, and causal mechanisms that make specific kinds of outcomes possible" ([38], p. 142). This approach fits our research goal as it emphasises timing and temporal sequences. To specify, it involves three different types of observations: comprehensive storylines, the identification of key events in the decision-making process, and "statements about the perceptions, motivations, and anticipations of major actors" ([38], p. 143). With this comprehensive, structured approach we were able to reconstruct the decision-making processes by using the key moments to divide the decision-making processes into sub-parts, i.e., individual 'action situations'. Based on this breakdown we could identify in a structured way the institutional conditions that influenced the decision-making processes during each key moment in the four selected cases.

Following the four within-case analyses, a comparative analysis was conducted to identify patters of institutional conditions that influenced the decision-making processes in the four case studies. For this comparative analysis, the results of the individual case studies were compared with the help of conceptually clustered matrices [43][2] which were based on the theoretical framework and on the empirical findings. The comparison identified whether the seven analyzed institutional conditions had an enabling (+) or disabling (-) influence on the decision-making process on the smart energy system introduction. When an institutional condition was enabling at certain moments in the project, and disabling at other moments, the symbol (+/-) was used.

## 5. Case analysis

This section presents the analysis regarding the institutional conditions that enabled or disabled the decision-making processes on the introduction of smart(er) energy systems in the four studied cases. For each case analysis timelines with key moments as well as tables that summarize the influential institutional conditions at each key moment are added. The extended case narratives and detailed chronological explanations of the influence of each institutional condition can be found in supplementary files A to D.

### 5.1. Intelligent Net Duurzaam Lochem

The reconstruction of the decision-making process in the 'Intelligent Net Duurzaam Lochem' (short: 'Lochem') case resulted in the identification of influential institutional conditions at seven key moments between December 2011 and the April 2015, as shown in Fig. 3, Table 3 and in supplementary file A.

It was especially the *payoff rules* in the form of exceptional investments from the 'de facto' project leader DSO 'Alliander' – next to a subsidy of €1,493,957 from the central government – that enabled the introduction of a smart energy system in Lochem. Additional enabling institutional conditions were the adoption of clear collective decision-making rules (*aggregation rules*) and a project set-up with a steering group and project group (*aggregation rule*). In the second half of the project householders were enabled to gain insight in their energy flows as well as join information evenings and working groups (*information rule),* which ensured their active involvement in the project (*position rule*: from passive to active role of householders). However, the strict rules for householders to join at the beginning of the project (*boundary rules*) led to the situation that fewer householders than expected joined the project (160 instead of 250). Furthermore, the scope of the project was adjusted over time. Initially the set of possible outcomes was limited (*scope rule*) as less financial subsidy than expected was obtained (*payoff rule*) and later on the bankruptcy of energy supplying company 'Trianel' (*boundary rule*) additionally limited the technical options that had been foreseen (*scope rule*). Eventually, it was the technical simulation of the city district's electricity grid in a test lab that enhanced the stakeholders' understanding of the choices that could be made regarding the technical set-up (*choice rule*). This simulation was followed by the 'stress test' that provided valuable insights into the grid's capacity and successfully ended the project. During this stress test residents of three streets simulated a 'typical' Dutch situation regarding supply and demand of electricity in 2025: they charged 20 electric vehicles and baked off 20 pizzas in electric ovens, resulting in a peak load that caused a blackout [44].

### 5.2. Smart Grid MeppelEnergie

Our analysis established six key moments with their respective institutional conditions for the decision-making process in the 'Smart Grid MeppelEnergie' project for the period from spring 2010 to May 2017, as summarized in Fig. 4 and Table 4 and explained in detail in supplementary file B.

The decision-making process regarding the introduction of a smart energy system in a city district in Meppel was initially enabled as the local government had decided in the spring of 2010 (*choice rule*) that no conventional gas grid was permitted to be installed in the district (and established its own energy company, 'MeppelEnergie'). Although several stakeholders joined the municipality's sustainability efforts (*boundary rule*) and a governmental subsidy of €567,439 was granted to the project in October 2012 (*payoff rule*), the decision by the consortium to initially install a natural gas-fed district heating grid and only replace

[2] "A conceptually clustered matrix has its rows and columns arranged to bring together items that 'belong together' [either conceptually or empirically in order to compare cases and generate findings more easily]" ([43], p. 127).

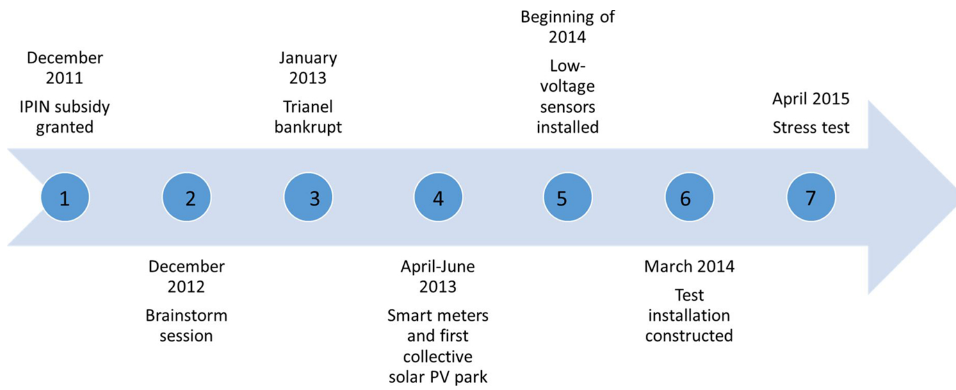


**Fig. 3.** Timeline of the 'Intelligent Net Duurzaam Lochem' case.

**Table 3**
Influential rules-in-use in the decision-making process in the 'Intelligent Net Duurzaam Lochem' case.

| | Key moment | Influential rules-in-use |
|---|---|---|
| 1 | December 2011: IPIN subsidy granted | • Boundary rule: Project initiators University of Twente and community energy initiative 'LochemEnergie' invite other actors to join the project, and apply for a governmental subsidy to run the project.<br>• Payoff rule: The subsidy is granted, but it turns out to be less than expected.<br>• Scope rule: The set of possible outcomes decreases because less subsidy is received than expected initially. |
| 2 | December 2012: Brainstorm session | • Position rule: DSO 'Alliander' becomes 'de facto' project leader.<br>• Aggregation rule: All consortium members discuss the options for the project together. |
| 3 | January 2013: Trianel bankrupt | • Boundary rule: Exit energy supplier 'Trianel' due to bankruptcy; strict boundary rules for householders to join the project.<br>• Scope rule: technical solutions are limited due to the exit of energy supplier 'Trianel'. |
| 4 | April-June 2013: Smart meters and first collective solar PV park | • Position rule: Householders become active resource users.<br>• Information rule: Householders gain insight in energy flows and can join information evenings and working groups.<br>• Payoff rule: DSO 'Alliander' finances smart meters and a first solar PV park on roof of the city hall. |
| 5 | Beginning of 2014: Low-voltage sensors installed | • Aggregation rule: Project set-up in which the steering group decides and the project group implements. |
| 6 | March 2014: Test installation constructed | • Choice rule: A simulation shows which choices can be made regarding the technical set-up. |
| 7 | April 2015: Stress Test | • Payoff rule: DSO 'Alliander' finances electric vehicles. |

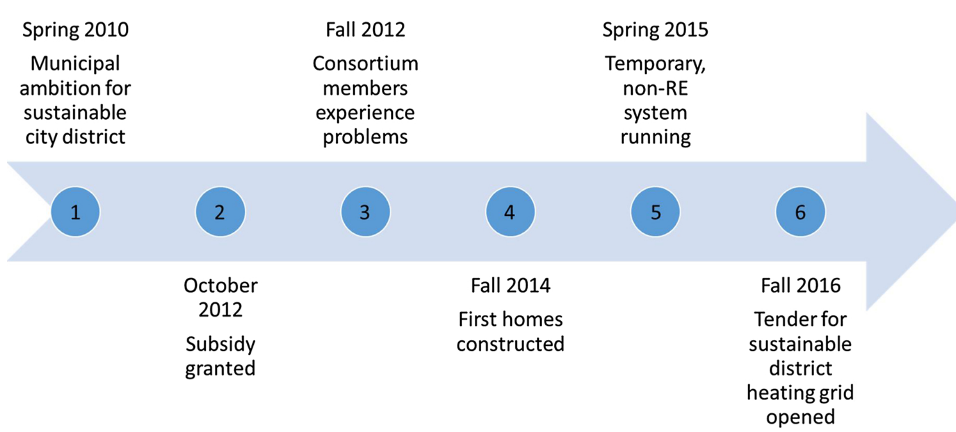


**Fig. 4.** Timeline of the 'Smart Grid MeppelEnergie' case.

it with a sustainable solution once 150 homes had been constructed (*choice rule*), led to path-dependency of the non-renewable gas-grid option as compared to the originally envisioned hybrid smart energy system (*scope rule*). This path dependency was influenced by the disabling *payoff rules*: due to the slow speed of construction the investments in the planned CHP unit and biogas pipeline were considered too high by the consortium members (*payoff rule*) and the more expensive (semi-) detached homes with individual heat pumps were never built (*payoff rule*). At the same time, all consortium members – except for the DSO 'Rendo' – were passively observing the progress made (*position rule*). In the fall of 2016, the sixth key moment, DSO 'Rendo' opened up a tender for local parties to come up with a sustainable solution for the local district heating grid, and in May of 2017 the DSO selected an engineering company to install a heating grid fed from wood-burning stoves. This decision of the DSO was due to legal provisions that mandate DSOs to stick to their core tasks of grid operation in future projects, and not act as an energy supplier anymore (*choice rule*). Yet, the infrastructure that will be installed by the engineering company will

**Table 4**
Influential rules-in-use in the decision-making process in the 'Smart Grid MeppelEnergie' case.

| | Key moment | Influential rules-in-use |
|---|---|---|
| 1 | Spring 2010: Municipal ambition for sustainable city district | ● Choice rule: The local government determines that the city district will get a district heating grid instead of a conventional gas grid.<br>● Boundary rule: The municipality invites stakeholders having expertise, and establishes its own energy company 'MeppelEnergie'. |
| 2 | October 2012: Subsidy granted | ● Boundary rule: networking agency 'EnergyValley' joins (invited by the municipality) and invites experts from its own professional network.<br>● Payoff rule: A governmental subsidy is granted. |
| 3 | Fall 2012: Consortium members experience problems | ● Position rule: DSO 'Rendo' and the water board exercise a less ambitious role; 'EnergyValley' becomes a passive advisor. |
| 4 | Fall 2014: First homes constructed | ● Position rule: All participants except 'de facto' project leader DSO 'Rendo' are passive project participants. |
| 5 | Spring 2015: Temporary, non-renewable energy system running | ● Choice rule: The renewable energy system will be installed once 150 homes have been constructed.<br>● Payoff rule: The renewable energy system with a CHP unit is not profitable for a small amount of homes constructed; the biogas pipeline is deemed to be too expensive.<br>● Scope rule: A temporary, non-renewable energy system is installed. |
| 6 | Fall 2016: Tender for sustainable district heating grid opened | ● Choice rule: The law mandates DSOs to stick to their core tasks for future projects, and not become energy supplier. |

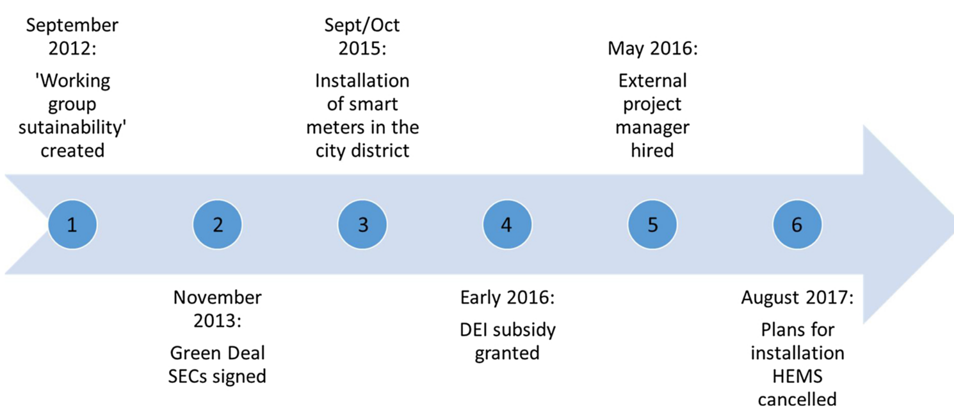


**Fig. 5.** Timeline of the 'Bothoven-Noord: op weg naar een energieneutrale wijk' case.

not be 'smart'; in sum *choice*, *payoff,* and *position rules* drastically disabled the decision-making process so that the originally envisioned smart energy system could not be introduced.

### *5.3. Bothoven-Noord: op weg naar een energieneutrale wijk*

The decision-making process on the project 'Bothoven-Noord: op weg naar een energieneutrale wijk' contained six key moments with their respective institutional conditions in the period from September 2012 to August 2017, as shown in Fig. 5 and Table 5 (for additional details see Lammers and Heldeweg [45] and supplementary file C).

Especially the lack of *payoff rules* had a disabling influence on the decision-making process in the project: no consortium member invested in the project, leading to a lock-in of the status-quo. This situation was related to the *position* and *choice rules*: all consortium members were eager to suggest ideas, but when it came to project implementation they

**Table 5**
Influential rules-in-use in the decision-making process in the 'Bothoven-Noord: op weg naar een energieneutrale wijk' case.

| | Key moments | Influential rules-in-use |
|---|---|---|
| 1 | September 2012: 'Working group sustainability' created | ● Boundary rule: The municipality and the housing associations form and join a 'sustainability' working group. |
| 2 | November 2013: Green Deal Smart Energy Cities signed | ● Boundary rule: Two DSOs and a networking platform join the consortium.<br>● Position rule: The municipality becomes the project leader.<br>● Information rule: The housing associations and the municipality have more information than other partners. |
| 3 | Sept/Oct 2015: Installation of smart meters in city district | ● Position rule: The DSOs install smart meters and thereafter take on take on a role as passive external advisors.<br>● Aggregation rule: Individual organisations decide on renewable energy options, not the consortium as a whole. |
| 4 | Early 2016: DEI subsidy granted | ● Boundary rule: Business developer 'Texel Development' is invited by the consortium and joins the project.<br>● Payoff rule: A governmental DEI subsidy is granted; however no stakeholder is making additional investments.<br>● Choice rule: The law mandates semi-public organisations to focus on their core tasks (which do not concern smart grids).<br>● Position rule: The municipality moves from being project leader to being a passive facilitator. |
| 5 | May 2016: External project manager hired | ● Boundary: An external consultant is invited to join the project as project manager.<br>● Position rule: The project manager is in charge of leading the project; 'Texel Development' only exerts a passive role.<br>● Scope rule: The scope rule is broadened and many ideas and potential technologies are suggested. |
| 6 | August 2017: Plans for installation HEMS cancelled | ● Information rule: 'Texel Development' does not communicate openly about progress (delay) in the development of the HEMS. |

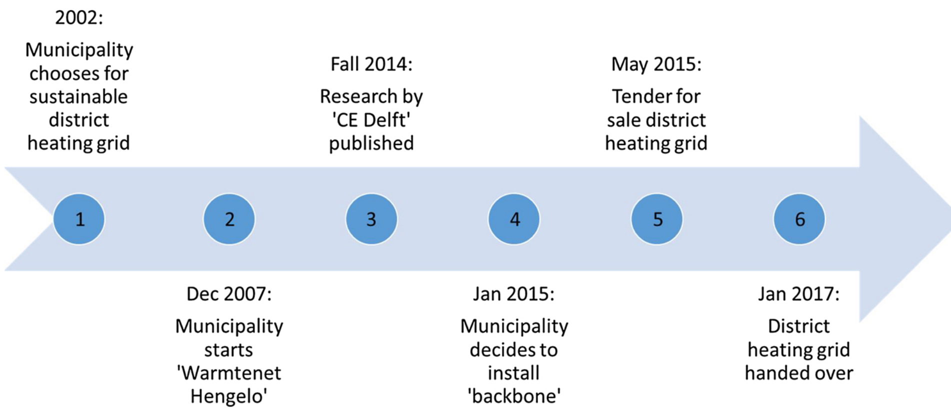


**Fig. 6.** Timeline of the 'Hart van Zuid' case.

were only passively observing the developments (*position rule*) and were not able to invest, inter alia due to legal restrictions (*choice rule*). The broad *boundary rules* and *scope rules* under which several times additional consortium members were invited and the set of possible outcomes was broadened did not help in finding investors and never made it possible for residents to join the project. The lack of information sharing among consortium members (*information rule*) and the absence of a collective decision-making procedure (*aggregation rule*) further disabled the process. In early 2016 a governmental subsidy of €983,894 was granted to a business developer for the roll-out of home energy management systems (HEMS) in 1000 households, 500 of which were to be installed in the Bothoven-Noord district (*payoff rule*) and an external project manager was hired (*boundary rule*). However, in August 2017 the consortium ended the collaboration with the business developer as he was not openly communicating about the delay in the delivery of the HEMS (*information rule*). While solar PV panels had been installed on the roof of an old factory building in the district in July 2017, the 280,000 kW h of electricity that will be produced annually will either be used by companies located inside the building, or fed into the electricity grid; a local smart energy system did thus not come into existence.

### 5.4. Hart van Zuid

For the decision-making process in the 'Hart van Zuid' city district in Hengelo influential institutional conditions were identified for six key moments in the period between 2002 and January 2017 (see Fig. 6, Table 6 and details in supplementary file D).

In the 'Hart van Zuid' case it was mainly the combination of three institutional conditions that slowed down the introduction of an innovative district heating grid that was supposed to be fed with industrial excess heat: payoff rules, choice rules, and information rules. Due to unfavourable *payoff rules* (linked to strict *boundary rules* for companies to join), in the early 2000s the municipality could not find companies that could offer affordable solutions for the planned district heating grid. The municipality's decision to realize a sustainable, 'gas-free' district was initially enabling for the project, but in December of 2007 this *choice rule* eventually forced the municipality to install several non-renewable (based on gas) district heating grids by itself – via the municipal department 'Warmtenet Hengelo' – as homes had been constructed and needed to be supplied with heat. Once research in the fall of 2014 revealed that the information regarding the profitability of these heating grids had been incorrect (*information rule*), *payoff rules* shaped the remainder of the project. As stopping the project would be more expensive than installing a 'backbone' (a pipeline that delivers industrial excess heat to the heating grid in the city district) that could make the project's business case profitable, the municipality decided to invest more money (*payoff rule* and *choice rule*). With the investments into the 'backbone' ensured (and eventually a large financial loss for the municipality), after more than ten years the municipality was able turn

**Table 6**
Influential rules-in-use in the decision-making process in the 'Hart van Zuid' case.

| | Key moment | Influential rules-in-use |
|---|---|---|
| 1 | 2002: Municipality chooses for sustainable district heating grid | • Choice rule: The local government determines that the city district will get a district heating grid instead of a conventional gas grid.<br>• Boundary rule: Strict financial targets are set for companies to join the planned district heating grid project.<br>• Payoff rule: No company can offer an affordable solution. |
| 2 | Dec 2007: Municipality starts 'Warmtenet Hengelo' | • Choice rule: A heating grid must be installed as newly-constructed houses must be supplied with heat – the municipality starts the heating grid project alone. |
| 3 | Fall 2014: Research by 'CE Delft' published | • Choice rule: The construction of the 'backbone' can happen once sufficient end users have committed to being connected to the heating grid, and make the 'backbone' profitable.<br>• Information rule: The municipal government is officially informed that the installed islanded natural gas-fed district heating grids are not profitable. |
| 4 | Jan 2015: Municipality decides to install 'backbone' | • Choice rule: The municipality has to install a 'backbone' in order not to make an even bigger financial loss.<br>• Payoff rule: Stopping the project would be more expensive for the municipality than installing the 'backbone'. |
| 5 | May 2015: Tender for sale district heating grid | • Boundary rule: DSO 'Alliander' and energy supplier 'Ennatuurlijk' join the project via a tender.<br>• Aggregation rule: Transparency during negotiations.<br>• Payoff rule: The municipality sells its non-renewable islanded district heating grids for €1 – losing €8.5 million; unexpected costs to be shared by all partners. |
| 6 | Jan 2017: District heating grid handed over | • Position rule: Two companies, 'Alliander' and 'Ennatuurlijk' have a large role; the municipality gets a small role.<br>• Aggregation rule: 95%/5% influence companies/ municipality, monthly project group meetings. |

**Table 7**
Comparing goals and goal achievement in the four cases.

| | Project name | Time period analysed | Smart energy infrastructure goal | Smart energy infrastructure achievement |
|---|---|---|---|---|
| *Cases with high smart energy infrastructure ambitions* | Intelligent Net Duurzaam Lochem | 2011 – spring 2015 | Renewable energy generation (solar PV panels), ICT for monitoring and steering energy flows, end user involvement, EVs to store energy. | Goals achieved by April 2015 through stress test, but fewer end users involved than originally planned. |
| | Smart Grid Meppel-Energie | 2010 – spring 2017 | Biogas to feed district heating grid, individual heat pumps, ICT for monitoring and steering energy flows, end user involvement. | Goals not achieved (yet), by the end of 2018 renewable energy sources should be used for feeding the district heating grid. |
| *Cases with lower smart energy infrastructure ambitions* | Bothoven-Noord: op weg naar een energie-neutrale wijk | 2012 – early 2017 | ICT for monitoring households' energy flows, active end user involvement, installation of solar PV panels to make the city district energy neutral. | Goals not achieved, plans to install Home Energy Management System cancelled in 2017, solar PV panels installed but electricity not used in district. |
| | Hart van Zuid | 2002 –early 2017 | District heating grid that is fed with industrial excess heat. | Goals achieved, since November 2017 district heating grid is fed with industrial excess heat. |

the project over to independent companies in January 2017; a process that profited from clear position, payoff, and aggregation rules. In November of 2017 then, DSO 'Alliander' and energy supplying company 'Ennatuurlijk' had realized the envisioned renewable energy district heating grid in the 'Hart van Zuid' city district.

## 6. Case comparison: enabling and disabling institutional conditions

In this section the results of the comparative analysis of the four cases is presented. However, first it is important to address whether the projects were successful in meeting the pre-set ambitions in terms of smart energy system installation. The overview presented in Table 7 reveals that the differences in goal achievement between the four cases are not simply related to amount of smart energy system components that stakeholders aimed at introducing, neither to the type of energy infrastructure: all goals were attained within four years in the 'Intelligent Net Duurzaam Lochem' project (electricity grid with high smart energy system ambitions), and in fifteen years the more 'Hart van Zuid' project (heating grid with lower smart energy system ambitions), whereas the other two analysed projects have not (yet) achieved their goals. Neither can the governmental financial subsidies that were received in each project explain the success rates; the 'MeppelEnergie' project, for instance, was subsidized with more than half a million euros in the beginning of 2013, but the energy system was still based on non-renewable energy sources in the summer of 2017. Drawing conclusions on which factors enable or disable decision-making processes on the introduction of these smart energy systems thus requires taking a deeper look at the institutional conditions that influenced the decision-making processes.

Before considering all seven institutional conditions individually, we want to clarify the influence of external events on the decision-making processes under analysis. In the 'Lochem' and in the 'MeppelEnergie' case external events were directly responsible for two key moments. In Lochem energy supplying company 'Trianel' went bankrupt, had to leave the project and thereby partially limited the set of possible outcomes of the project. The legal problems that two consortium members experienced in the 'MeppelEnergie' case led these two stakeholders to take on less ambitious roles in the project. Additionally, the financial-economic crisis of 2008 was responsible for slowing down the construction of homes in the 'MeppelEnergie' and 'Hart van Zuid' cases, making it more difficult to find sufficient end users to make renewable energy options for the local district heating grids profitable.

Besides these three external events, all other key moments resulted from the institutional conditions that influenced the decision-making process between the consortium members. This finding makes it reasonable to assume that institutional conditions were responsible for

**Table 8**
The influence of institutional conditions on the decision-making processes regarding the introduction of smart energy systems in the four studied cases.

| | *High Smart Energy Infrastructure Ambitions* | | *Lower Smart Energy Infrastructure Ambitions* | |
|---|---|---|---|---|
| | Intelligent Net Duurzaam Lochem | Smart Grid MeppelEnergie | Bothoven-Noord: op weg naar een energieneutrale wijk | Hart van Zuid |
| *Goal attainment* | *Yes* | *Not (yet)* | *Not (yet)* | *Yes* |
| Boundary rule | +/- | +/- | +/- | +/- |
| Position rule | + | – | – | +/- |
| Choice rule | +/- | +/- | – | +/- |
| Information rule | + | – | – | – |
| Aggregation rule | + | – | – | + |
| Payoff rule | + | – | – | -/+ |
| Scope rule | – | – | – | – |

enabling or disabling the decision-making processes in the four analyzed cases. We are aware that actors' characteristics also have an influence on decision-making processes, but like Newell et al. [33] we suppose that these characteristics are to a large extent influenced by institutional rules.

In Table 8 we summarize the enabling (+) or disabling (-) influence of all seven institutional conditions (called rules-in-use by Ostrom) on the decision-making processes regarding the introduction of smart energy systems in the four selected city district development projects. In the following, the enabling and disabling influence of each institutional condition will be explained in detail.

### 6.1. Boundary rules

The boundary rules in all four projects were enabling as well as disabling each decision-making process. It was enabling (+) that in all cases the project initiators invited experts from their own network to join the project. At the start of the projects in the 'Lochem' and 'Hart van Zuid' cases strict boundary rules (-) that specified the conditions for householders and companies to join the projects, however, made it increasingly difficult to find participants, as shown by the (+/-) symbol in Table 8. In the 'Lochem' case householders had to make a fifteen year commitment by investing in solar PV panels, becoming a member of the community initiative for renewable energy 'LochemEnergie', and switch to a particular energy supplier. In the 'Hart van Zuid' case the local government had established strict financial targets that companies had to meet to be allowed to take on the development of the envisioned renewable district heating grid.

Looking at the stakeholders that joined in the end, it stands out that only in the 'Lochem' case householders were actively involved in the project, whereas this ambition was also set for the cases of 'MeppelEnergie' and 'Bothoven-Noord', but was not proactively pursued by the consortium partners (explaining the =/- symbol for these two cases in Table 8). In the 'Lochem' case householders not only invested in solar PV panels, but also gained access to their smart meter data, and participated in workshops to further energy saving and electric transport – aspects that enabled the successful introduction and a good functioning of the local smart energy system.

### 6.2. Position rules

Except for the position of project leader, the position rules were mostly not clearly communicated in the projects under analysis. We can however identify that some participants took on active roles in the process, while others were passive observers. Yet, these positions did not result from the collective creation of position rules, but were the decisions of individual members. Actually in all but one project, the 'Intelligent Net Duurzaam Lochem' project, the position rules were disabling (-) because all consortium members besides the project leader took on a passive observer role (see Table 9; in the 'Bothoven-Noord' and 'Hart van Zuid' case the project leaders changed during the course of the project). Only in the 'Lochem' project the position rules were enabling (+) and all consortium members actively worked together (under the lead of DSO 'Alliander'), and two years after the start of the project householders were actively involved as well. In the 'Hart van Zuid' case it was only when the local government handed over the project in January 2017 to a DSO and energy supplier that the position rules were enabling; explaining the additional '+' in Table 8. To conclude, in three projects no stakeholder took an active role in pursuing the introduction of a smart energy system, slowing down the introduction of such system. These identified positions were partially related to choice rules, and strongly linked to payoff rules, as discussed in more detail below.

Looking at the type of organisation the consortia members worked in does not provide a direct reasonable argument for their (non-) involvement in some projects. Whereas DSOs were in charge in the projects in the 'Lochem' and 'MeppelEnergie' cases, they did not want to actively contribute in the 'Bothoven-Noord' and 'Hart van Zuid' cases. In the latter case of 'Hart van Zuid' the DSO only joined once the project was sure to be running well. This situation also applies to the involvement of the municipality; in two projects the municipality (i.e., local government) was initially actively involved (i.e., 'Bothoven-Noord' case, 'Hart van Zuid' case), while it was only involved in the background in the 'MeppelEnergie' and 'Lochem' cases. For example, the municipality of Meppel established the energy company 'MeppelEnergie' to run the smart energy system project, and the municipality of Lochem permitted energy cooperative 'LochemEnergie' to install a collective solar PV park on the roof of the city hall [46].

### 6.3. Choice rules

The influence of choice rules on the decision-making processes both enabled and disabled the introduction of smart energy system components in all of the four projects. The decisions of two municipalities to have a district heating grid instead of a conventional natural gas grid installed in city districts can be seen as an initial catalyser for the projects in the 'MeppelEnergie' and 'Hart van Zuid' cases (+). In the 'Lochem' case the simulation of the district's electricity grid in a test location clarified and thereby changed the set of feasible technical options and activities (an enabling choice rule, +) that could be taken, a stepping stone to the introduction of the smart energy system.

On the downside, in two projects choice rules adopted by the consortia members disabled the adoption of smart energy system components as these rules led to a long period of path dependency of the installed conventional, non-renewable energy systems. In the 'Hart van Zuid' case the municipality had to start the project alone with a non-renewable solution as the construction of homes that needed to be connected to the district heating grid (a decision made five years earlier) had started. In the 'MeppelEnergie' case, the consortium's decision to only feed the district heating grid with renewable energy once 150 houses had been constructed as well led to the installation of a temporary natural gas-fed district heating grid.

**Table 9**
Positions of consortia members in the four studied cases.

| | Project leader | Active participants | Passive participants |
|---|---|---|---|
| Intelligent Net Duurzaam Lochem | DSO Alliander | DSO Alliander and all other consortium members (after two years also householders) | / |
| Smart Grid MeppelEnergie | DSO Rendo | DSO Rendo | universities, local government, companies, water board |
| Bothoven-Noord | Local government → consultant | Local government → consultant | DSOs, platform for construction companies, business developer |
| Hart van Zuid | Local government → DSO and energy supplier | Local government → DSO and energy supplier | *Not applicable* |

The influence of choice rules was especially disabling (-) the decision-making process in the 'MeppelEnergie' and 'Bothoven-Noord' cases, as renewed emphasis on the regulations of the Dutch law that mandate DSOs and housing associations to merely focus on their core tasks (i.e., of energy system administration and of the provision of social housing, respectively) severely limited the actions that these organisations could take in the smart energy systems projects.

### 6.4. Information rules

In all projects except for the 'Lochem' case, information rules hindered (-) the decision-making process as information was not shared among all consortium partners, but was rather in the hands of a limited set of actors. In the 'MeppelEnergie' and 'Bothoven-Noord' cases this lack of information sharing was related to the position rules: information was mainly in the hands of the project leaders who were in charge of project planning and operation. In the 'Hart van Zuid' case the municipality was solely responsible for the project for many years, but was still suffering from inadequate internal information sharing regarding the profitability of the chosen natural gas-fed district heating grids.

Additionally, in all cases but the 'Lochem' case householders were not informed about the goals that had been established for upgrading the energy infrastructure in their city district. In Lochem on the contrary householders could participate in information evenings and workshops, and could gain insight into their energy flows (enabling information rule, +). This information sharing with householders helped to motivate them to be actively engaged in the project and enabled the successful introduction of the smart energy system.

### 6.5. Aggregation rules

A project set-up in which a steering group was in charge of strategic decision-making, and a project group was responsible for the execution of strategic decisions, was found to be an enabling aggregation rule (+) in the 'Lochem' project. Likewise, the occurrence of monthly meetings during which agreements were made collectively as well as transparency during negotiations (together with equal information rules) were found to be enabling factors (+) in the 'Lochem' and 'Hart van Zuid' cases. However, having collective monthly brainstorm meetings but in the end relying on individual consortium members to take decisions on the implementation of technical solutions can be regarded as disabling (-), as the 'Bothoven-Noord' case showed. In the 'MeppelEnergie' case the lack of collective aggregation rules was also disabling (-) the decision-making process as the informal project leader DSO 'Rendo' took decisions on its own during the implementation phase and did not consult with others.

### 6.6. Payoff rules

In the cases studied payoff rules strongly influenced the decision-making processes on the introduction of smart energy systems. Whereas subsidies can facilitate the realization of projects, the mere granting of a subsidy is not necessarily sufficient to achieve the established project goals, as the 'MeppelEnergie' case and the 'Bothoven-Noord' case demonstrate. Studying the successful 'Lochem' case revealed that the decision-making process benefits from clear rules on the sharing of costs and benefits (+): all consortium members discussed and agreed upon how costs were to be shared and in the end it was especially DSO 'Alliander' that made significant investments (an option that after the project ended does not exist anymore as current rules of law mandate DSOs to merely focus on energy system administration).

In the 'Hart van Zuid' case the path dependency of choices (a heating grid is needed for houses that started to be constructed) led the local government to take on the investments in a non-renewable heating grid by itself as no company was able to invest (the latter being a disabling payoff rule, -). Seven years later, the payoff rules – again the local government decided to carry the costs of a 'backbone' installation – turned out to be enabling the decision-making process for the 'Hart van Zuid' project (+); following this decision two organizations decided to realize a district heating grid fed with industrial excess heat.

In the other two projects (the 'MeppelEnergie' and 'Bothoven-Noord' cases), the consortium members were unable to invest (disabling payoff rule, -), partially due to legal restrictions for semi-public authorities (see Section 6.3 on choice rules). Additionally, the experiences from the 'MeppelEnergie' and 'Hart van Zuid' cases reveal that it is essential to investigate the exact project costs, including the distribution of costs and benefits, when the project's goals are established to prevent that options get chosen that are too expensive to ever be realized by the consortium.

### 6.7. Scope rules

The sites (i.e., city districts) where each of the smart energy system projects was to take place were identified at the start of all studied projects, but the exact range of possible outcomes regarding the envisioned smart energy systems was either narrowed down compared to the original project goals, or unclear. In three of the analyzed projects the range of possible outcomes turned out to be much smaller when compared to the initial project ambitions (-), while in one project (the 'Bothoven-Noord' case), the scope rules never became evident (-). The analysis reveals that the restricted scope of possible outcomes was hereby not a direct consequence of deliberately adopted scope rules, but was caused by the disabling influence of other institutional conditions. Examples are projects in which less financial subsidy than expected was granted (payoff rule in the 'Lochem' case), or where past decisions led to the installation of non-renewable energy grids (choice rule, 'MeppelEnergie' and 'Hart van Zuid' case).

## 7. Discussion

This study sheds light on the institutional conditions that were responsible for enabling or disabling the decision-making processes in four smart energy system cases. As Verbong et al. [25] and Wolsink [26] anticipated, our analysis confirmed empirically that currently existing 'rules of the game' are not all appropriate for smart energy system developments.

Our findings showed that decision-making processes on the introduction of smart energy systems involve a multi-actor setting, a trend that was already foreseen by Künneke and Finger [47] and Goldthau [21] with the liberalization of the European energy markets. However, no specific type of organization played a central role in smart energy system development in Dutch city districts, and in all but in one of the analysed projects householders were not aware of the smart energy system developments that were planned for their city district. Whereas end users are perceived as a potential barrier to the development and implementation of smart energy grids due to concerns for privacy, lack of time and needed behaviour change [25], our research suggests that a preceding barrier consists of the actual engagement of householders.

By studying seven institutional conditions that influence decision-making we were able to identify not only which institutional conditions enable and disable the decision-making processes, but also how these conditions are interrelated. This finding can help overcome the existing "lack of good cooperation and acceptance among project partners", a key barrier for the introduction of smart energy projects ([3], p. 191). Our research especially revealed a connection between three disabling institutional conditions: position, choice, and payoff rules.

Position rules were often not clearly communicated in the projects under analysis and mostly all consortium members besides the project leader took a passive observer role (with the exception of the 'Lochem' case). To what extent this passive position in the decision-making process derived from institutional conditions, or is an inherent part of actors' characteristics cannot be concluded with certainty here. While this might be a potential limitation of this research, we agree with Newell et al. [33] that actors' characteristics are to a large extent shaped by institutional conditions.

Looking at these institutionalized conditions, we can conclude that the passive role of stakeholders in the process is partially linked to choice rules in form of legal barriers for DSOs and housing associations to invest in smart energy projects. Legal barriers have previously been identified to strongly disable the roll-out of smart renewable energy technologies [5,48]. In addition, our research revealed that decisions to initially install temporary non-renewable energy systems (choice rule) have led to a lock-in of non-renewable energy systems and delayed the installation of smart energy systems. In combination, the limitations created by choice rules and the passive positions of consortium members led to a lack of adequate agreements on the sharing of costs and benefits (payoff rules), a clearly disabling institutional condition. While the provision of subsidies has been identified as an important condition that can facilitate the roll-out of renewable energy technologies [3,49], our research has shown that subsidies alone are not enough, but suitable agreements (payoff rules) are needed for the sharing of costs and benefits among consortium members.

Due to the disabling influence of several institutional conditions on the decision-making process, our research demonstrates that the established project goals were over-ambitious, a factor that was also found by Hoppe [49] regarding the implementation of innovative energy systems in social housing projects.

## 8. Conclusion

Against the background of a multi-actor setting and perceived outdated 'rules of the game' for smart energy system introduction, this article set out to answer the research question 'which institutional conditions enable or disable decision-making processes regarding the introduction of smart energy systems in selected city district development projects in the Netherlands?' To answer this question we analysed four projects in which different ambitions existed as regards smartening the energy systems for the local electricity grid or heating grid.

Considering that institutions are often studied as static concepts, we combined the Institutional Analysis and Development framework with causal process tracing in this article, allowing us to conduct a dynamic analysis over time. We were able to decompose the complex multi-stakeholder decision-making processes into sub-parts and to analyse the institutional conditions at play during different moments in time. We recommend this dynamic focus especially for the study of institutional conditions in decision-making process on (smart) energy infrastructure development, as these processes are often lengthy and complex.

Our findings demonstrate that such research is particularly relevant because institutional conditions are foremost responsible for enabling or disabling decision-making processes on smart energy system introduction, whereas external events were also found to be important, but were considered of less influence, generally speaking. Analysing these institutional conditions led to five key results. First, in the cases analyzed no single stakeholder emerged as a dominant player in smart energy system development, but consortia were formed ad hoc, mostly via the invitation of experts from the initiators' own professional networks. However, a second finding showed that it was mainly only the project leader who took an active (and initiating) position in the project, whereas other consortium members took on a rather passive observer role. Third, in projects where decisions were made to initially install temporary energy systems using non-renewable energy sources, a delay in the installation of the originally planned smart energy systems occurred. Fourth, although the provision of subsidies can support the development and operation of demonstration projects, it is especially agreements about the sharing of costs and benefits among consortium members that helps to attain pre-set project goals. Lastly, end users were hardly involved in the development of smart energy systems. To a large extent this was related to the fact that initiatives had a top-down character, often being initiated by local governments or distribution system operators. To conclude, the multi-actor setting with a lack of adequate 'rules of the game' for decision-making continues to present a challenge for the introduction of smart energy systems in Dutch city districts. Due to the general applicability of these institutional conditions to diverse contexts, our findings from the Netherlands can also help advance decision-making processes on smart energy system introduction in other countries.

As exploratory case studies are considered useful for generating hypotheses [50], we used our findings to propose three hypotheses for further research. First, clear communication in the beginning and throughout the project about the positions (position rules) of stakeholders within a smart energy system project will encourage stakeholders to play a more active role in such a project. Second, when project management initially decides to temporarily adopt an energy system using non-renewable energy sources for a city district (choice rule), this is expected to delay the realization of a smart energy system that is based on renewable energy sources. Third, when stakeholders make sound agreements on the sharing of costs and benefits (payoff rule) at the outset of a project, this will clarify positions and choices and limit setting over-ambitious project goals for a city district's smart energy system and will increase the overall feasibility and speed of the project.

To test these hypotheses and investigate other factors that potentially influence the introduction of smart energy systems we recommend to analyse and compare additional smart energy system projects at city district level in the Netherlands as well as in other countries. Furthermore, we can conclude that future research and policy-making should pay attention to the creation and adequate orchestration of 'rules of the game' in decision-making processes on smart energy system planning. This can include the involvement of process architects and process managers, management of expectations, as well as the participation of end users (for example via community initiatives for renewable energy) at specific moments in the decision-making process [51].

## Acknowledgements

This work was supported by the Netherlands Organisation for Scientific Research (NWO), under the URSES project SmaRds (project number 408-13-005). The authors thank all interviewees as well as Maarten J. Arentsen and Michiel A. Heldeweg for their useful comments on previous versions of this article.

## Appendix A

| Elements | Definition |
|---|---|
| ***Bio-physical conditions*** | Physical and material conditions, e.g., type of buildings, existing infrastructure and renewable energy technologies. |
| ***Attributes of Community*** | Characteristics and preferences of the involved community, e.g., socio-economic characteristics, political party in power, home-ownership. |
| ***Boundary rules*** | Specify the number of actors that participate in the local energy planning project (e.g., municipal policy officer), and how these actors join and leave the decision-making process. |
| ***Position rules*** | Specify the set of positions actors hold in the local energy planning process (e.g., project leader, network manager). |
| ***Choice rules*** | Specify the sets of actions that can (could have), may or must not (have) been taken at specific points in time, e.g., deriving from informal agreements or from policy instruments, laws or regulations. |
| ***Information rules*** | Specify the amount and type of information available to participants (e.g., about the technology, policies, meetings, or costs- and benefits) and how this information is used and shared (e.g., boundary spanning). |
| ***Aggregation rules*** | Specify how decisions are made, e.g., by an individual actor, or in collaboration with others (e.g., coalitions, co-creation). |
| ***Payoff rules*** | Specify the costs and benefits that derive from particular actions and outcomes, e.g., costs of project, pack-back time, distribution of costs and benefits among actors. |
| ***Scope rules*** | Specify the set of possible outcomes, as well as the jurisdiction and state of outcomes, e.g., geographic region and events affected, temporary or final status of the outcome. |
| ***Goal attainment*** | Original project goal vs. achieved outcome during the period under analysis. |
| ***Actors' capabilities*** | Actors' resources, valuations, information processing, and selection processes (called perceptions, motivations and anticipations with the method of causal process tracing). |
| ***Key moments*** | An instance in the decision-making process that influenced the outcome of decision-making, i.e., the introduction of a smart energy system. |
| ***Definition smart energy system*** | Definition of the term 'smart energy system' or 'smart grid' used by the interview partners. |

**Fig. A1.** Coding scheme.

## Appendix B. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.erss.2018.10.003.

## References

[1] S. Blumsack, A. Fernandez, Ready or not, here comes the smart grid!, Energy 37 (1) (2012) 61–68, https://doi.org/10.1016/j.energy.2011.07.054.
[2] H. Lund, S. Werner, R. Wiltshire, S. Svendsen, J.E. Thorsen, F. Hvelplund, B.V. Mathiesen, 4th generation district heating (4GDH): integrating smart thermal grids into future sustainable energy systems, Energy 68 (2014) 1–11, https://doi.org/10.1016/j.energy.2014.02.089.
[3] F. Mosannenzadeh, M.R. Di Nucci, D. Vettorato, Identifying and prioritizing barriers to implementation of smart energy city projects in Europe: an empirical approach, Energy Policy 105 (2017) 191–201, https://doi.org/10.1016/j.enpol.2017.02.007.
[4] H.L. Sataøen, O.A. Brekke, S. Batel, M. Albrecht, Towards a sustainable grid development regime? A comparison of British, Norwegian, and Swedish grid development, Energy Res. Soc. Sci. 9 (Supplement C) (2015) 178–187, https://doi.org/10.1016/j.erss.2015.08.011.
[5] S. Muench, S. Thuss, E. Guenther, What hampers energy system transformations? The case of smart grids, Energy Policy 73 (2014) 80–92, https://doi.org/10.1016/j.enpol.2014.05.051.
[6] M.A. Brown, S. Zhou, Smart-grid policies: an international review, Wiley Interdiscip. Rev. Energy Environ. 2 (2) (2013) 121–139, https://doi.org/10.1002/wene.53.
[7] C. Clastres, Smart grids: another step towards competition, energy security and climate change objectives, Energy Policy 39 (9) (2011) 5399–5408, https://doi.org/10.1016/j.enpol.2011.05.024.
[8] N. Friedrichsen, C. Brandstätt, G. Brunekreeft, The need for more flexibility in the regulation of smart grids – stakeholder involvement, Int. Econ. Econ. Policy 11 (1) (2014) 261–275, https://doi.org/10.1007/s10368-013-0243-x.
[9] I. Lammers, L. Diestelmeier, Experimenting with law and governance for decentralized electricity systems: adjusting regulation to reality? Sustainability 9 (2) (2017) 212, https://doi.org/10.3390/su9020212.
[10] T.M. Skjølsvold, M. Ryghaug, T. Berker, A traveler's guide to smart grids and the social sciences, Energy Res. Soc. Sci. 9 (Supplement C) (2015) 1–8, https://doi.org/10.1016/j.erss.2015.08.017.
[11] T.M. Skjølsvold, C. Lindkvist, Ambivalence, designing users and user imaginaries in the European smart grid: insights from an interdisciplinary demonstration project, Energy Res. Soc. Sci. 9 (2015) 43–50, https://doi.org/10.1016/j.erss.2015.08.026.
[12] M.J. Fell, D. Shipworth, G.M. Huebner, C.A. Elwell, Public acceptability of domestic demand-side response in Great Britain: the role of automation and direct load control, Energy Res. Soc. Sci. 9 (2015) 72–84, https://doi.org/10.1016/j.erss.2015.08.023.
[13] M. Nachreiner, B. Mack, E. Matthies, K. Tampe-Mai, An analysis of smart metering information systems: a psychological model of self-regulated behavioural change, Energy Res. Soc. Sci. 9 (Supplement C) (2015) 85–97, https://doi.org/10.1016/j.erss.2015.08.016.
[14] M. Goulden, B. Bedwell, S. Rennick-Egglestone, T. Rodden, A. Spence, Smart grids,

smart users? The role of the user in demand side management, Energy Res. Soc. Sci. 2 (0) (2014) 21–29, https://doi.org/10.1016/j.erss.2014.04.008.
[15] J. Naus, B.J.M. van Vliet, A. Hendriksen, Households as change agents in a Dutch smart energy transition: on power, privacy and participation, Energy Res. Soc. Sci. 9 (Supplement C) (2015) 125–136, https://doi.org/10.1016/j.erss.2015.08.025.
[16] B.K. Sovacool, What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda, Energy Res. Soc. Sci. 1 (2014) 1–29, https://doi.org/10.1016/j.erss.2014.02.003.
[17] C. Von Bock und Polach, C. Kunze, O. Maaß, P. Grundmann, Bioenergy as a sociotechnical system: the nexus of rules, social capital and cooperation in the development of bioenergy villages in Germany, Energy Res. Soc. Sci. 6 (Supplement C) (2015) 128–135, https://doi.org/10.1016/j.erss.2015.02.003.
[18] F. Gangale, J. Vasiljevska, F. Covrig, A. Mengolini, G. Fulli, Smart Grid Projects Outlook 2017: Facts, Figures and Trends in Europe, Publications Office of the European Union, Luxembourg, 2017.
[19] RVO, Smart Grids En Slimme Enerigesystemen, Retrieved from (2016) http://www.rvo.nl/onderwerpen/duurzaam-ondernemen/energie-en-milieu-innovaties/smart-grids.
[20] M.J. Arentsen, J.W. Fabius, R.W. Künneke, Dutch business strategies under regime transition, in: A. Midttun (Ed.), European Energy Industry Business Strategies, Elsevier, Oxford, 2001, pp. 151–194.
[21] A. Goldthau, Rethinking the governance of energy infrastructure: scale, decentralization and polycentrism, Energy Res. Soc. Sci. 1 (0) (2014) 134–140, https://doi.org/10.1016/j.erss.2014.02.009.
[22] ECN, Energietrends 2016, Retrieved from (2016) https://www.ecn.nl/publicaties/PdfFetch.aspx?nr=ECN-O–16-031.
[23] M. Oteman, H.-J. Kooij, M. Wiering, Pioneering renewable energy in an economic energy policy system: the history and development of Dutch grassroots initiatives, Sustainability 9 (4) (2017) 550, https://doi.org/10.3390/su9040550.
[24] H. Lund, P.A. Østergaard, D. Connolly, B.V. Mathiesen, Smart energy and smart energy systems, Energy (2017), https://doi.org/10.1016/j.energy.2017.05.123.
[25] G.P.J. Verbong, S. Beemsterboer, F. Sengers, Smart grids or smart users? Involving users in developing a low carbon electricity economy, Energy Policy 52 (2013) 117–125, https://doi.org/10.1016/j.enpol.2012.05.003.
[26] M. Wolsink, The research agenda on social acceptance of distributed generation in smart grids: renewable as common pool resources, Renew. Sustain. Energy Rev. 16 (1) (2012) 822–835, https://doi.org/10.1016/j.rser.2011.09.006.
[27] E. Ostrom, Governing the Commons: The Evolution of Institutions for Collective Action, Cambridge University Press, Cambridge, 1990.
[28] E. Ostrom, Background on the institutional analysis and development framework, Policy Stud. J. 39 (1) (2011) 7–27, https://doi.org/10.1111/j.1541-0072.2010.00394.x.
[29] D.C. North, Institutions, Institutional Change and Economic Performance, Cambridge University Press, Cambridge, 1990.
[30] E. Ostrom, Understanding Institutional Diversity, Princeton University Press, Princeton and Oxford, 2005.
[31] K.K. Iychettira, R.A. Hakvoort, P. Linares, Towards a comprehensive policy for electricity from renewable energy: an approach for policy design, Energy Policy 106 (2017) 169–182, https://doi.org/10.1016/j.enpol.2017.03.051.
[32] A.M. Koster, J.M. Anderies, Institutional factors that determine energy transitions: a comparative case study approach, in: E. Michalena, J.M. Hills (Eds.), Renewable Energy Governance: Complexities and Challenges, Springer London, London, 2013, pp. 33–61.
[33] D. Newell, A. Sandström, P. Söderholm, Network management and renewable energy development: an analytical framework with empirical illustrations, Energy Res. Soc. Sci. 23 (Supplement C) (2017) 199–210, https://doi.org/10.1016/j.erss.2016.09.005.
[34] P.D. Aligica, P. Boettke, The Two social philosophies of Ostroms' institutionalism, Policy Stud. J. 39 (1) (2011) 29–49, https://doi.org/10.1111/j.1541-0072.2010.0000395.x.
[35] I. Lammers, M.J. Arentsen, Polycentrisme in lokale besluitvorming over duurzame energie: de casus slimme netten, Bestuurswetenschappen 70 (3) (2016) 20–31.
[36] E. Ostrom, R. Gardner, J. Walker, Rules, Games, and Common-Pool Resources, The University of Michigan Press, Ann Arbor, 1994.
[37] M.M. Polski, E. Ostrom, An Institutional Framework for Policy Analysis and Design. The Vincent and Elinor Ostrom Workshop in Political Theory and Policy Analysis (W98–27), (1999).
[38] J. Blatter, M. Haverland, Designing Case Studies: Explanatory Approaches in Small-N Research, Oalgrave Macmillan, Hampshire, UK & New York, USA, 2012.
[39] J. Gerring, Case Study Research: Principles and Practices, Cambridge Universtity Press, Cambridge, 2006.
[40] Agentschap NL, TKI Switch2SmartGrids 2012, Retrieved from (2013) https://www.rvo.nl/sites/default/files/TKISG01002%20tot%20en%20met%20TKISG02021.pdf.
[41] greendeals nl, GD155 – Smart Energy Cities, Retrieved from (2013) http://www.greendeals.nl/gd155-smart-energy-cities/.
[42] RVO, Database Energiezuinig Gebouwd, Retrieved from (2017) http://www.rvo.nl/initiatieven/overzicht/27008.
[43] M.B. Miles, A.M. Huberman, Qualitative Data Analysis, SAGE Publications, Thousand Oaks, California, 1994.
[44] G. Hoogsteen, A. Molderink, J.L. Hurink, G.J.M. Smit, B. Kootstra, F. Schuring, Charging electric vehicles, baking pizzas, and melting a fuse in Lochem, CIRED - Open Access Proc. J. 2017 (1) (2017) 1629–1633.
[45] I. Lammers, M.A. Heldeweg, Smart design rules for smart grids: analysing local smart grid development through an empirico-legal institutional lens, Energy Sustain. Soc. 6 (1) (2016) 36, https://doi.org/10.1186/s13705-016-0102-z.
[46] T. Hoppe, A. Graf, B. Warbroek, I. Lammers, I. Lepping, Local governments supporting local energy initiatives: lessons from the best practices of Saerbeck (Germany) and Lochem (the Netherlands), Sustainability 7 (2) (2015) 1900–1931, https://doi.org/10.3390/su7021900.
[47] R.W. Künneke, M. Finger, The governance of infrastructures as common pool resources, Paper Presented at the Workshop on the Workshop (WOW4) (2009).
[48] S. Luthra, S. Kumar, R. Kharb, M.F. Ansari, S.L. Shimmi, Adoption of smart grid technologies: an analysis of interactions among barriers, Renew. Sustain. Energy Rev. 33 (0) (2014) 554–565, https://doi.org/10.1016/j.rser.2014.02.030.
[49] T. Hoppe, Adoption of innovative energy systems in social housing: lessons from eight large-scale renovation projects in the Netherlands, Energy Policy 51 (2012) 791–801, https://doi.org/10.1016/j.enpol.2012.09.026.
[50] B. Flyvbjerg, Five misunderstandings about case-study research, Qual. Inq. 12 (2) (2006) 219–245, https://doi.org/10.1177/1077800405284363.
[51] I. Lammers, M.J. Arentsen, Rethinking participation in smart energy system planning, Energies 10 (11) (2017) 1–16, https://doi.org/10.3390/en10111711.