Accelerating Design and Implementation of Smart Energy Systems

An Institutional Challenge

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Abstract—**Institutional arrangements facilitating the implementation of Smart Energy Systems (SES) are still rather neglected. The article addresses the question 'which institutional arrangements can facilitate the acceleration of the design and implementation of different configurations of Smart Energy Systems?' We developed an institutionally-grounded tool by drawing on the engineering design process and the work of Elinor Ostrom. The tool covers the wide range of institutional-technical arrangements and is applied to examples from the Dutch context. It can function as accelerator of the design and implementation of SES in local energy planning.**

***Keywords*—smart energy system, smart grid, institutions, design, local energy planning, decision-support tool.**

I. INTRODUCTION

Smart Energy Systems (SES) [1], and smart grids more specifically, are socio-technical systems which can take many different technical and institutional forms. While the technological components of the system have become more well-defined already, the institutional arrangements needed to facilitate the implementation of SES are still rather neglected. Wolsink [2] summarizes that "there remains a complete lack of understanding of the need for institutional change required to establish [Smart Grids]". Renewable energy technologies and SES are new and complex, and local stakeholders lack reference and guidance in particular with respect to energy and spatial planning [3, 4]. Especially the Dutch 'polder model' of consensus based decision-making slows down progress [5]. While the need for institutional change for SES implementation and its related barriers have been identified [2, 6, 7], research so far has only offered general solutions.

This article therefore addresses the research question *which institutional arrangements can accelerate the design and implementation of different configurations of Smart Energy Systems?* We develop an institutionally-grounded tool by applying the engineering design process, drawing on similar socio-technical frameworks and incorporating the work of Schlager and Ostrom [8].

The article is structured as follows: Section II provides the background on current Dutch decision-making practices and on related work on the design of institutional arrangements. Section III specifies the theory used, followed by the method of backcasting in section IV. In section V the institutionally-grounded tool is presented and applied to specific examples. Section VI concludes.

II. BACKGROUND

The Dutch government realizes that the speed and quality of decision-making on energy infrastructures needs to increase and recommends more and earlier participation of all potential stakeholders in decision-making [9]. However, the current consensus-based decision-making process is actually one of the delaying factors in Dutch energy projects [5]. We argue for a reorganization of the democratic process to achieve more efficiency in decision-making. We make participation instrumental to energy transition and to the maximization of sustainable smart solutions. Our approach is inspired by the engineering design process, as little is said about design in social sciences, and even less about institutional design. "Theory offers no clear-cut answer to the question of how to design institutions and what a good institutional design should look like" [10] (p.251).

A few scholars [10-12] developed initial frameworks for designing institutional arrangements related to energy infrastructures, but these approaches are broad and do not focus specifically on SES. Regarding SES and Smart Grids, the European Standardization Organizations' Smart Grid Architecture Model (SGAM) [13]stipulates the following process for mapping use cases: 1.) use case analysis; 2.) development component layer; 3.) development business layer; 4.) development function layer; 5.) development information layer; and 6.) development communication layer. In this article, we focus on the first three steps of the SGAM Framework and enhance these layers by detailing the technological and institutional arrangements for SES, and especially their design.

III. THEORY

Designing institutional arrangements for the implementation (and maintenance) of SES calls for a specification of the rights that everyone will hold in the energy

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system. Schlager and Ostrom [8] identified five property rights for the use of common-pool resources (CPRs), together with their associated positions: access, withdrawal, management, exclusion and alienation [8, 14]. These rights can be summarized in form of several questions: Who finances the technology, who decides on the inclusion/exclusion of others, who is responsible for management, who withdraws resources, who can participate?

In SES, the (desired) rights have to be identified not only for the resource '*energy*', but also for information and money. *Information* plays an important role as ICT enables smart energy systems [15]. *Money* is relevant as resource provision, use and system operation have to be financially compensated [12]. We therefore draw on the work of [16], who identified four (governance) flows in electricity systems: electrons, information, money and rights. Specifying these elements, and presenting them in form of a usable tool box, can help to accelerate the design and implementation of SES.

IV. METHOD

We applied backcasting [17]: we first identified the socio-technical characteristics of the different Smart Energy Systems by means of expert judgement, and based on the outcomes we determined the institutional arrangements that facilitate the implementation of the specific SES.

V. RESULTS

Based on the engineering design process [18], we created a tool for developing institutional arrangements for SES. The six steps of this tool specify which actors need to participate in which phase, and point out the rights and obligations of each participant. It entails: (1) problem analysis, (2) requirements (technical components), (3) conceptual design (core participants: owner and user), (4) detailed design (additional participants), (5) implementation, (6) evaluation. The technical components chosen hereby determine to a large extent which institutional arrangements are needed for the design of the SES and its subsequent implementation. The technical components are specified in terms of energy sources, technologies, ICT etc. For the institutional components the flow of five rights regarding energy, money and information needs to be discussed.

Our analysis of three examples from the Dutch context shows that our approach is especially useful when a collective element comes into play. For example, when an owners' association of an apartment building purchases solar PV panels (i.e. full owner) our framework indicates that this association needs to determine the withdrawal rights for the flows of energy (bi-laterally residents-DSOs), information (bi-laterally residents-DSO/ aggregator) and money (multi-laterally association/ residents/ DSO). These institutional arrangements become even more relevant when collective storage, real-time remote control or islanding are considered.

VI. CONCLUSION

In this article we developed a tool for creating institutional arrangements supporting the acceleration of the design and implementation of different configurations of Smart Energy Systems. We proposed an instrumental view on participation whereby the technical components mainly determine the institutional arrangements, that is the participants needed and the flow of five rights on energy, information and money. Especially due to the collective character of SES, our tool can function as accelerator of the design and implementation of SES in local energy planning.

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