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Solving infrastructural concerns through a market reorganization: A case study of a Danish smart grid demonstration

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ABSTRACT

Following the rapid growth of wind power in Denmark in the past 20 years, energy infrastructure has become increasingly politicized. Fluctuating renewables not only contest the dominant 'logic' of operating the system, namely 'supply-follows-demand', but it also introduces new actors like aggregators and reconfigures existing market actors. In this paper, we study a case, EcoGrid 2.0 on the Danish island Bornholm, as a case of a 'marketized' solution to the infrastructural concerns emerging from the large share of fluctuating wind power in the system. The market design involves transforming 'flexible consumption' into an exchangeable good, as well as a transformation of households into 'distributed energy resources', making it possible to capitalize on the existing infrastructure in new ways. We end the paper with a discussion of the implications for infrastructure; when households become balancing entities and a digital and smart infrastructure is made indispensable to the operation of the system, the infrastructure grows significantly in terms of scope and complexity eventually introducing yet new challenges.

1. Introduction

Against all odds, wind power in Denmark has developed into a massive success. The integration of wind power into the electricity system has grown from constituting 10% of total national electricity consumption in 2000, to 42,1% in 2015 [1]. This success can be traced back to the 1970s [2], where the oil crises exposed Denmark's critical dependence on oil producing states. For the first time energy became a political matter [3]. Partly as a consequence of the oil crises, wind power gained increasing interest as a means of suspending the dependence on foreign states [3], and in these early years, the role of wind power was intimately connected to concerns of security of energy supply. During the 1980s, the dominant political concern associated with energy shifted towards the environmental effects of energy production. Gradually, wind power became requalified as 'clean', 'renewable' and a solution to the environmental effects of industrialization. In the 1990s, this agenda was reinforced. Politically, wind power was increasingly backed, yet large parts of the industry remained critical: wind power was argued to be an expensive, intermittent energy that threatened the stable operation of the electricity infrastructure [3]. In sum, wind power which was initially framed as part of the solution to security of supply, experienced substantial development rates as part of an ambition to decarbonize energy production and ended up becoming a challenge to the stable operation of the system.

Today, almost 20 years later, the stable operation of an electricity system with high shares of fluctuating renewables has been practically achieved. Yet, the political ambition of further radical increases in wind power problematizes the future operation of the infrastructure. Smart grids and flexible consumption are seen as representing the "best socio-economic method for handling the future challenges inherent in using large volumes of wind power" [4] and a key element in becoming a carbon neutral nation by 2050 [5]. Such a transformation of the energy system, from the historical regime of supply-follows-demand to demand-follows-supply [6], through the idea of flexible consumption, in turn grants a new role to the consumer (e.g. [7]). As an example, consumers are imagined to adjust their consumption to the intermittent generation of wind power or other renewables. In fact, protagonists of smart grid technologies envision consumers as new and central constituents to the stable operation of the system—and thus the future security of energy supply [8].

In this paper, we study a large scale demonstration of flexible consumption, namely EcoGrid 2.0, as it seeks to produce flexible consumption by means of markets. Based on observations, interviews and document analysis of this Danish smart grid demonstration, we describe how the infrastructural challenge of security of supply in a wind power dominated system is pursued through a market design. Drawing on New Economic Sociology and Science and Technology Studies, we discuss and problematize the politics of this type of market solution to public

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concerns [9] as a particular redistribution of roles and responsibilities vis-à-vis the electricity infrastructure. We end by a discussion of the implications for the boundaries of infrastructure; a new digital infrastructure is introduced and households are made active and controllable elements in the balancing of the system, which eventually challenges the distinction between (public) infrastructure and private homes.

2. The case of EcoGrid 2.0

The object of this study is EcoGrid 2.0, an ongoing large-scale smart grid demonstration on the Danish island Bornholm. The ambition of EcoGrid 2.0 is to demonstrate the possibility of realizing flexible power consumption through the design and implementation of a new market platform. The demonstration is publicly funded, and is constituted by nine partners, including two Danish universities, the local utility of Bornholm, software developers, and behavioral designers. The project involves app. 1000 households on the island, and provides each participating household with a smart meter and automated devices.[1] As part of the demonstration, two so-called aggregators control the households' heat pumps and electrical heating (within predefined temperature intervals or set points depending on the type of equipment). Aggregators can, through their control of the individual households' heat pumps and electric radiators, 'aggregate' flexibility across a larger subset of houses, allowing them to offer larger pools of flexibility in the so-called flexibility market (see Fig. 1[2]). Developing interoperability in the flexibility market is a crucial part of the demonstration in order to set the conditions for future competition between aggregators. In other words, consumers should be able to shift, by simple means, between competing aggregators.

As the *2.0* in the name indicates, EcoGrid 2.0 succeeds a previous project called EcoGrid EU. EcoGrid EU was an EU funded project, running from 2011 to 2015 and comprised largely the same participants at Bornholm as the current project. EcoGrid EU involved the design and development of a so-called real-time market, introducing variable electricity prices at five-minute intervals to retail consumers [10]. Consumers' responses to real-time price signals were partly manual, and partly automated. Based on the experiences of the first project, EcoGrid 2.0 does not include variable prices, but instead adds a new flexibility market and aggregators to the previous arrangement. A relatively new player in a Danish context, aggregators are to offer new products and services, making consumers willing to grant the aggregator external control of their heat pumps and electric radiators (e.g. see [11]). Aggregators are to compete for consumers, and these will be able to choose freely between aggregators and their services. 'Choice' and 'competition', in other words, are among the main novelties characterizing the current EcoGrid 2.0 setup.

Bornholm, which hosts the demonstration, is located in the easternmost part of Denmark. The island is considered particularly well-suited for demonstration projects like EcoGrid 2.0, amongst others because of the configuration of the electricity grid; the island is largely representative of the Danish grid, and has only one sea cable connecting the island to mainland Sweden. This implies that the local system can be, and sometimes is, operated in island mode [12]. Finally, the island has clear ambitions in terms of reducing the island's greenhouse gas emissions, "...Bornholm wants its future to be 100% green; a carbon-neutral community based on sustainable, renewable energy" ([13], p. 1). Since early 2017, electricity produced by the local utility is – under normal operation – based entirely on wind, sun and biomass.

[1] The equipment installed in the participants' homes are either Greenwave or Siemens.

[2] The abbreviations mentioned in the figure are TSO: Transmission System Operator, DSO: Distribution System Operator; BRP: Balance Responsible Parties; AGG: Aggregator.

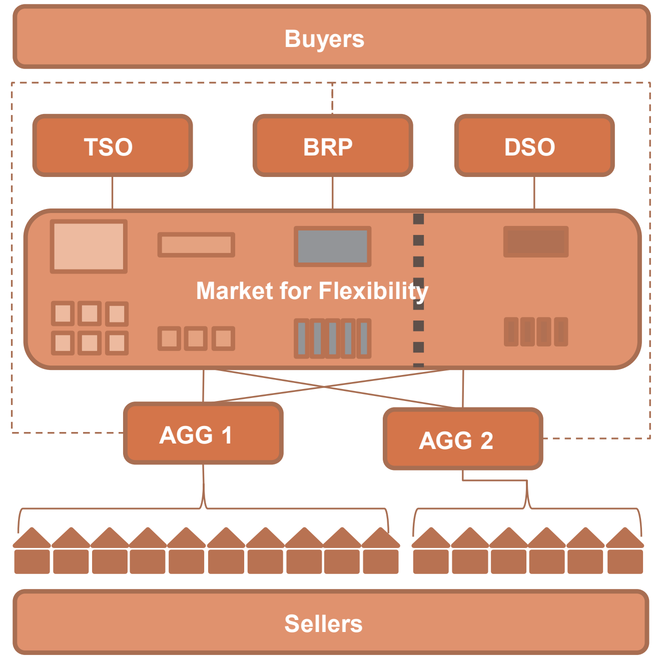

Fig. 1. EcoGrid 2.0 outline.
Source: EcoGrid 2.0 [52].

3. Market solutions, agencies and commodities

This paper is concerned with the design and deployment of marketized solutions to infrastructural challenges. Energy infrastructures are usually portrayed as co-evolving with institutions, organizations, technologies, raw materials, social norms etc. (e.g. [14–16]), something which is often used to explain their inertia against change [17,18]. In these studies, markets and economics have traditionally been viewed as co-constituents of infrastructure, but only rarely as the principal 'change agents'. More recently, however, a number of studies have pursued a particular interest in the role of economics in reorganizing energy infrastructures ([19–21]; see also [22]). Here, economics and market design are not just 'simple' tools for optimizing the existing infrastructure, but also shape infrastructures concretely, and society more broadly.

To study markets as solutions to complex societal challenges, such as climate change or security of supply, we draw on a more recent turn within the 'New Economic Sociology' [23]. This strand of research has studied the diverse array of agents and devices involved in making 'market encounters' possible, situations characterized by calculative agents and calculable goods [24–26]. Among the most important contributions made to the new economic sociology is the illustration of the elaborate organization of the sociomaterial infrastructure making calculations by agents possible, regarding the value of well-defined goods [27,28]. Where economics usually assume agents to be calculative a priori, and markets to somehow spontaneously emerge or pre-exist [29], social studies of markets have demonstrated how agents must be equipped to become calculative, and goods must be stabilized and framed in order to make exchange possible [24,26]. Economics as a discipline is itself portrayed as a central constituent in achieving such outcomes, however, not as a passive observer, but by performing the (abstract) models of their textbook [30,31]. The main claim advanced by these authors is that markets and calculative agents are outcomes – outcomes that should be made objects of analysis in their own right [32,23].

A number of case studies, notably of the energy sector, have described the entanglements of processes of politicization and economization in markets [33,34]. In parallel, scholars have started