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Organizing consumers for a decarbonized electricity system: Calculative agencies and user scripts in a Danish demonstration project

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ABSTRACT

This paper studies a Danish smart grid experiment, EcoGrid EU, designed to sustain the increase of wind power in the electricity system. EcoGrid EU is designed as a real-time market, through which engineers seek to realize price responsive electricity consumers through the introduction of smart meters, variable short-term price signals and training users. Based on observations and interviews with scientist, consumers and technicians, this paper analyses the attempt to produce a new kind of electricity consumer. Drawing on social studies of markets, we argue that the project entails constructing a new form of calculative agency. We illustrate the extensive work put into the creation of a new, reconfigured electricity consumer, as well as the challenges associated with the construction of consumers willing and able to act in accordance with the EcoGrid script. On one hand, this study adds to the growing critique raised by practice scholars, most prominently, regarding technically trained system designers' 'reductionist' approach to users. On the other hand, the paper argues that the social sciences must move beyond a mere identification of complexity and 'messiness' to provide constructive contributions to the ongoing work of designing and producing new well-functioning sociotechnical systems, including new types of 'sustainable' users.

1. Introduction

Decarbonization of the Danish electricity sector has primarily been approached through radical increases in wind power. Meanwhile, the rising percentage of fluctuating electricity generation has led to concerns of grid balancing, and various initiatives have been developed and deployed to ensure adequacy of the means for electricity system management in the long term, all the while supporting the further growth of renewable energy in the system. Among these initiatives, smart grids are envisioned to play a key role [1,2]. Accordingly, several smart grid demonstrations have been deployed in Denmark, EcoGrid EU (EcoGrid from here on) being the largest so far. EcoGrid took place on the Danish island Bornholm, and involved 2000 households. EcoGrid was designed around the transmission of 'real-time' price signals, reflecting the current production of wind power, to the households, where users were expected to adjust their electricity consumption accordingly. Smart grids, including EcoGrid, are seen as representing a shift towards a 'user-centric' approach to energy supply [3], implying a fundamental repositioning of the electricity consumer vis-à-vis the operation of the system [2]. In short, with smart grids, policy makers and system designers alike foresee a future in which users are made part of the crucial grid balancing.

Within the social sciences the advent of new user roles associated with smart grids has received a substantial amount of attention (e.g. [4–8]). The vast majority of these studies remain somewhat skeptical towards the possible realization of the user roles conceived of and inscribed in new retail electricity market arrangements by smart grid designers (e.g. [9,10]). In particular, consumer conceptions build on assumptions of (rational) decision-making individuals have raised concerns [11,12]. In contrast, a number of analyses of smart grids have been based on a 'practice perspective' (e.g. [13,14]), positioning social practice as the central unit of analysis [14–16,8]. These contributions have come far in demonstrating the challenges facing policy makers and smart grid designers in their efforts to facilitate a large-scale transition of the energy system based on the flexible use of electricity, by providing accounts of energy consumption as constituted through situated social practices.

Representing consumers as fully informed utility maximizing agents acting under resource scarcity is considered unmerited within social practice theory, because doing so entails an assumption which is far removed from empirical reality. But how, then, can we explain that electricity consumers sometimes do act as rational economic agents? In the following, we draw on the social studies of markets [17–19], to adopt a pragmatic position and treat consumers as potential calculative agencies [20]. In other words: "*homo economicus* really does exist", but

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not as an inherent feature of man, instead "[h]e is formatted, framed and equipped" ([18], p. 51). An electricity consumer – smart grid compatible or not – is an outcome. Our contention is that the social scientific understanding of smart grids can benefit from inquiry into how calculative agency is sought achieved through practical processes of organizing. The pragmatic approach can supplement the insights produced by means of economic and practice perspectives on smart grid development by making clear how a rational economic agent and calculative economic agency more generally comes into being, fails to be realized or materializes to a limited extent.

In this paper, we follow the configuration of a calculative, price sensitive electricity consumer. This consumer is not naturally occurring, but rather inscribed into the EcoGrid design and purposefully created. Through observations (of consumers, technicians and project managers); interviews (with scientists and consumers), and document analysis (of exemplary texts), we follow the inscription of a price responsive electricity user into the EcoGrid market design, alongside attempts to realize this calculative user through instructions, training and the installation of technical equipment in the domestic setting. We demonstrate that consumers indeed do calculate and that these calculations appear across situated social practices; sometimes calculations appear to comply with the EcoGrid script, at other times they follow competing scripts. The article proceeds as follows: first we introduce EcoGrid. Here we highlight the design and a number of assumptions built into the 'real-time' market arrangement. Then we introduce the theoretical underpinnings of our argument, in particular ideas of distributed agency and the equipped calculative agency. Subsequently, we unfold the argument by describing attempts at making the consumer willing and able to act according to the EcoGrid script. We end by discussing tensions and opportunities in the pursuit of long term electricity system adequacy by means of demand response.

2. EcoGrid – a real-time market for retail consumers

EcoGrid was launched in 2011 on the Danish island Bornholm, as an EU supported large-scale smart grid experiment including 2000 electricity consumers (approximately a tenth of the island's population) [21]. The experiment ended in 2015, but is partly continued in a new demonstration project called EcoGrid 2.0. EcoGrid was designed to solve a rather specific challenge, namely the management of renewable—and fluctuating—energy in the electricity system. Denmark has over the past decade increased the percentage of wind power in the electricity system to a current total of around 40% of domestic electricity consumption [22]. The large amount of input from volatile energy sources has in turn presented Denmark with what is more widely known as the intermittency problem [23]. Considering that electricity cannot be stored without conversion implying significant losses (e.g. [24]), and that input must equal output in the electricity system at all times if breakdown is to be avoided [25], EcoGrid seeks to mobilize demand as an active component in electricity system management.

EcoGrid is framed as a demonstration of a *market concept* designed to transform consumption patterns through changes in information and the making of distinct incentives, which grant electricity consumers an new role in the maintenance of the necessary balance between demand and fluctuating supply in the electricity system, turning buyers on the retail electricity market into 'distributed energy resources' [26]. The construction of flexible consumption implies two major goals in the form of temporal shifts in the demand for electricity: moving demand away from periods of peak consumption (e.g. late afternoon and early evening), and moving demand towards periods of peak production (e.g. when the wind is blowing). These shifts are pursued by sensitizing consumers to a new form of continually publicized electricity price signals.[1] Realizing variable prices, and consumers willing to adapt their demand according to them, here involves the introduction of consumer instruction sessions, demonstration sites, calculative equipment, on site consumer training, and automation of certain appliances. These appliances are operated within temperature intervals defined by the consumer; room temperature will be set at upper and lower tolerances, e.g. between 18 and 21°. When the price of electricity is high, the temperature will drop until the lowest point in the spectrum (18) is reached. The temperature will then stay at this level until a sufficient drop in the price of electricity is encountered. In contrast, when prices are low, the temperature will raise to the upper point (21). Such temperature intervals can be defined for specific rooms of the house, e.g. living room and bedroom.

The design of the EcoGrid real-time market was led by the Department for Electrical Engineering at the Technical University of Denmark (for a thorough review of the EcoGrid design, see [28]). The local utility, Østkraft, recruited participants among their existing customers. Also, Østkraft was responsible for training participants, installing and maintaining the equipment, and communicating with participants. The Danish Transmission System Operator, Energinet.dk, and a number of other partners were involved, and took part in designing and installing EcoGrid across Bornholm.

3. From rational agents to calculative agencies

In economic theory, the consumer is often portrayed as a rational (and atomized) agent in pursuit of self-interest; or a 'consistent set of preferences' ([29]: 3). Though the lacking reality of such assumptions is widely acknowledged within the economics discipline, models and theories remain built around a figure of the consumer who acts *as if* rational. For decades, this view has been stubbornly rejected by sociologist studying economic life [30–32]. Instead, economic action is explained as a form of social action, socially situated, and performed within socially constructed institutions [32]. Economic action, in short, is embedded in social relations [30]. In between these two positions, on the one hand the inherently rational free-floating agent, and on the other hand, action determined by institutions or cultural norms, this paper adopts a middle ground, first carved out by contributions to the social studies of markets (e.g. [18,33,34]). Instead of critiquing the implausible assumptions of economics, it starts by an acknowledgement that *homo economicus* does exist. But, more importantly, he exists only because he has been formatted, framed and equipped [18]. Calculative agencies are practical achievements that exist only as outcomes of the socio-technical networks by which they are constituted.

As such, recent contributions to social studies of markets seek to sidestep struggles between the 'under-socialized' agent portrayed by economics, and the 'over-socialized' agent of sociology. Instead, they transform the question of rationality into a question of calculability by asking the question: how do calculating agents emerge? Calculability cannot simply be explained by either cognitive or institutional competences. Defined broadly as the distinctions between things or 'states of the world', and the estimation of courses of action associated with those – and not least their consequences – calculation is an effect of networks made up of social ties as well as distinct instruments and tools [35,20]. Instead, agency is distributed across human actors, artifacts, rules and routines [36,37]; an understanding of agency as constituted by socio-material assemblages that draws heavily on Actor-Network-Theory [38]. Accordingly,

> "[e]conomic calculation is not an anthropological fiction, precisely because it is not a purely human mechanical and mental competence; it is distributed among human actors and material devices" ([20], p. 1245).

Accordingly, calculation is neither an inherent capacity of humans per se, nor something we can simply ignore; instead, it is suggested, the sources of calculation lie in the equipment of agencies [18].

Empirical studies tracing the sources of such calculative agencies include the role of calculative devices embedded in mathematical

[1] Identical to what Darby and Mckenna [27] refer to as real-time pricing.