LEADERS OR LAGGARDS? THE EVOLUTION OF ELECTRIC UTILITIES' BUSINESS PORTFOLIOS DURING THE ENERGY TRANSITION

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ABSTRACT

Effectively mitigating climate change requires a fundamental and rapid transition in the way electricity is generated and used. The global electricity sector, however, is still dominated by large incumbent utility companies, which have historically been slow to embrace change. Given this seeming contradiction, in this paper we investigate whether and how 25 of the biggest electric utilities worldwide have adapted their business portfolios during the energy transition from 2003 to 2015. We observe three developments in utilities' business portfolios, namely an increase in (1) de-carbonization, (2) decentralization and servitization, and (3) system integration and balancing. Our results indicate that utilities have been more proactive in embracing de-carbonization as the core goal of the energy transition than the two successive challenges of decentralization and system integration. The lag in system integration is surprising, given that utilities traditionally possess considerable knowledge and assets that they could leverage to integrate decentralized low-carbon generation. We conclude that utilities can play a major role in integrating and balancing the components of a low-carbon electricity system, but that regulatory changes or additional policy incentives may be necessary to spur system integration as a critical part of the energy transition.

Keywords: Electric utilities, energy transition, de-carbonization, decentralization, servitization, system integration

1. Introduction

Urgent societal issues, such as climate change and resource depletion, call for fundamental changes in the way we generate and use electricity (IPCC, 2014). Since a large share of the global greenhouse gas emissions are caused by electricity supply and demand, policy makers around the world have sought to incentivize both the development and use of novel renewable energy technologies, such as solar photovoltaic and wind power (Jacobsson and Lauber, 2006; Mitchell, 2016), as well as energy efficiency measures (Hoffman et al., 2017; Stern et al., 2016). These two endeavors started a profound process of change in the energy sector, which has become known as the energy transition.

Electric utilities play an important role in ensuring a successful energy transition for three main reasons. First, the business of electricity generation and supply is still dominated by large, vertically integrated electric utilities, which produce, transmit, distribute, trade, and sell electricity. In fact, in 2015 the top 5% of utilities in the OECD owned over 50% of the world's electricity generation capacity (Platts, 2015). Second, utilities are traditionally part of, owned by, or at least well connected to public entities and policy makers and therefore likely to be influential in the policy-making process. As a result, failure to consider the interests and capabilities of electric utilities may lead to a situation where utilities undermine political initiatives aimed at spurring the energy transition, e.g., through lobbying activities (Downie, 2017; Jacobsson and Lauber, 2006). Third, due to their long history of operating power plants and supplying electricity, utilities possess considerable knowledge and assets. These capabilities and assets, e.g. the distribution grid and its operation, may be deployed to efficiently manage and execute the energy transition in a way that reaches the ambitious emission targets that have been set to prevent catastrophic consequences of climate change (Ngar-yin Mah et al., 2017).

Getting large incumbent utilities on board with the fundamental changes of the energy transition, however, seems to be a serious challenge, as these players have traditionally been risk averse, slow to change, and have been shown to invest only minimally in innovation (Berlo et al., 2017; Downie, 2017; Richter, 2013a; Shah et al., 2013). This observation—that the electricity sector is in need of major change but is dominated by large incumbents that may show reluctance to change—raises the question of whether and how these central players have adapted their business portfolios during the last years to meet the ambitious climate goals set by policy makers.

The existing literature has suggested frameworks to describe business portfolio shifts of electric utilities. As early as 1982, Lovins and Lovins developed a framework that showed how utilities can change from "vendors of kilowatt-hours to financiers of least-cost energy investments" (Lovins and Lovins, 1982, p. 165). More recently, De Fusco et al. (2016) and Facchinetti et al. (2016) proposed conceptual frameworks for emerging utility business models and business innovations. Scholars have also investigated in detail the drivers and barriers for specific business portfolio shifts of utilities. For example, Helms (2016) identifies the shift from tangible to intangible assets as the most important barrier to utilities becoming energy service providers. Burger and Luke (2017) find that regulatory factors are more important than technological factors in driving a shift to distributed energy resources, whereas Gsodam et al. (2015) show that the proximity to the traditional business directs utilities' preferences for investing in large-scale rather than small-scale renewable energy production. Using the investment in offshore wind energy as an example, Richter (2013b) identifies 10 key drivers for utilities to invest in these technologies, such as marketing and public relations considerations or scarcity of investement alternatives. Finally, Apajalahti et al. (2015) identify conflicting institutional demands, such as unbundling regulations, as key barriers to utilities including energy efficiency services in their business portfolios.

While prior studies have proposed helpful frameworks and provide valuable insights into utilities portfolio shifts, we currently lack a comprehensive worldwide overview of how electric utilities' business portfolios have changed during the energy transition. Such an overview would be a valuable tool for policy makers for two main reasons. First, it would help identify the extent to which the biggest companies contribute to the energy transition targets. Second, and more importantly, such an overview would help determine which specific aspects of the energy transition utilities have embraced and to what extent. These insights might help identify possible frictions throughout the course of the transition that could provide an important basis for future policy interventions. Moreover, analyzing the evolution of utility business portfolios over time can help both managers and policy makers benchmark their current positions in the energy transition to further steer its evolution.

In this paper we investigate whether and how 25 of the biggest electric utilities worldwide have adapted their business portfolios during the energy transition from 2003 to 2015. Drawing on unique qualitative and quantitative data, we show three major developments in utilities' business portfolios, which emerged sequentially and differ in intensity: (1) De-carbonization, (2) decentralization and servitization, and (3) system integration and balancing. While the development toward de-carbonization is very pronounced, system integration activities in particular lag behind. This finding is surprising given that utilities have traditionally played a key role in integrating and balancing the components of the electricity system. As integration efforts remain limited, our findings suggest that additional regulatory changes or policy incentives may be necessary to spur system integration as a critical part of the energy transition.

The paper is organized as follows. Section 2 describes the method underlying our study, providing insights into the sampling, data collection, and data analysis. Section 3 presents the results, including a detailed description of the three developments we identified in the course of our analysis. Section 4 discusses the policy implications of our findings and offers avenues for future research.

2. Methodology

2.1 Sample

We selected our sample from the largest electric utilities globally by revenue (in USD) in 2015. The revenue information was drawn from the Thomson Reuters EIKON database, which covers financial information on all publicly listed companies worldwide (Thomson Reuters, 2015). To derive meaningful implications for policy makers, we strove for an equal representation of countries within our sample. Therefore, we chose a maximum of three utilities from ten different countries as our sample. Due to their considerably smaller size, we excluded the third biggest utility from France and the second and third biggest utilities from Portugal and South Korea since these could not be categorized under the top 200 companies measured by revenue.

In total, our sample covers 25 utilities from ten countries, which generate 47% of the global revenue of electric utilities and independent power producers listed in Thomson Reuters Eikon. The term "independent power producers" captures those electric utility companies that do not own electricity or distribution assets. Table 1 provides an overview of our chosen sample sorted by country and size. In addition, Table A1 in the appendix provides an overview of the regulatory environments of the sample, showing whether a utility company operates in a monopolistic environment, is vertically integrated, or owned by the state. The table shows that the sample utilities differ with regard to the three important factors we analyzed. For example, in contrast to all the other companies we studied, the three Chinese utilities in our sample are all state-owned. Moreover, in several countries, such as the U.S., utilities still operate in monopolized markets.[1]

2.2 Data Collection and Analysis

To analyze the business portfolio evolution of the 25 biggest electric utilities worldwide from 2003 to 2015, we applied a three-step methodology. First, we extracted all business activities from the annual reports of the utilities in our sample and compiled business portfolios for all the firms over time. Second, we complemented our annual report data with quantitative data on business activities where available. Third, we enriched the developments we identified in our data with illustrative quotes from the annual reports that shed light on the rationales behind the observed portfolio changes.

2.2.1 Document Analysis

Annual reports provide a reliable source of historical business activities and also include information on the rationales behind company strategies. Therefore, we collected the annual reports of the sampled companies from 2003 to 2015. For some companies within our sample, annual reports were only available from later years as visible in Table 1. To analyze the data contained in the annual reports, we used the MaxQDA 12 software package and applied a coding scheme, which we developed in a bottom-up manner by identifying business activities in the reports and clustering them into categories (see Table A2 in the appendix). Using this scheme, we coded the annual reports from every second year—173 annual reports in total. In the case of larger changes in the business activities within the two-year timeframe, we checked the annual report for the intermediate year for clarification. In cases of larger

[1] Table A1 indicates that whether firms operate in monopolistic markets, are vertically integrated, or are state-owned barely changes over time, implying that the regulatory environment of utilities remained quite stable. As a result, the regulatory environment itself is unlikely to be the main driver of the developments we present in the results section. Indeed, a more detailed comparison of the regulatory environment with utilities' activities in (1) de-carbonization, (2) decentralization and servitization, and (3) system integration and balancing showed no clear pattern pertaining to whether utilities are more or less active in these activities depending on whether they operate in monopolistic markets, are vertically integrated, or are state-owned. We thus do not believe that using a sample of utilities that operate in different regulatory environments biases our results or undermines our findings.

company mergers or spin-offs, we used the company with the larger portfolio share in the electricity sector. We did not differentiate between domestic business activities and business activities in other countries. Since one of the central changes within the electricity sector is the diffusion of distributed technologies, we used an additional coding dimension to specify whether technologies were deployed in a distributed or in a centralized manner for the firms in our sample. All data was coded by one researcher and checked by a second researcher to ensure coding reliability.

To consolidate the qualitative data from the annual reports into tables and graphs, we created a binary code matrix based on data from all the annual reports. This matrix presents information for each company and year about whether a specific business activity was pursued in a specific year. Based on this matrix, we created "history paths" of business activities on a company level for each electric utility in our sample, showing which business activities utilities had mentioned in their annual reports over time. Using the company-level data, we aggregated the paths for the full sample to be able to identify global developments. To this end, we calculated the percentage of companies that, according to their annual reports, pursued a certain business activity in a specific year. Using this aggregated data, we were able to identify the developments we discuss in Section 3, the results section. To avoid premature conclusions, we went back and forth between the company level and the aggregated dataset to gain a detailed understanding of the origins of these developments.

Owing to the binary nature of our coding scheme, we only know whether a firm was engaged in a specific business activity or not; we do not capture the extent to which this activity was pursued. We addressed this shortcoming in two ways, which are described further in the following sections. First, we used detailed quantitative data to depict changes in the firms' generation portfolios. Second, we drew upon qualitative evidence from the annual reports that reflect the importance of certain business activities.

Code	Company	Country	Total Revenue 2015 in M USD	2003	2005	2007	2009	2011	2013	2015
HPI	Huaneng Power International Inc.	China	19,855.65							
HPIC	Huadian Power International Corporation Ltd.	China	10,938.63							
DIPG	Datang International Power Generation Company Ltd.	China	9,533.17							
EDF	Electricite de France SA	France	81,456.54	n/a						
Engie	Engie SA	France	75,892.96	n/a	n/a	n/a				
E.ON	E.ON SE	Germany	126,212.79							
RWE	RWE AG	Germany	50,343.72							
EnBW	EnBW Energie Baden Wuerttemberg AG	Germany	22,986.83							
Enel	Enel S.p.A.	Italy	79,360.56							
Edison	Edison S.p.A.	Italy	12,285.92	n/a						
A2a	A2A S.p.A.	Italy	5,344.21	n/a	n/a	n/a				
TEPCO	Tokyo Electric Power Company Holdings Inc.	Japan	53,926.15							
Kansai	Kansai Electric Power Company Inc.	Japan	28,837.12							
Chubu	Chubu Electric Power Company Inc.	Japan	25,355.76							
Korea EPCO	Korea Electric Power Corporation	South Korea	50,178.92							
EDP	Energias de Portugal SA	Portugal	16,851.25							
Iberdrola	Iberdrola SA	Spain	34,120.71	n/a	n/a	n/a				
Enedesa	Endesa SA	Spain	22,044.72	n/a						
Acciona	Acciona SA	Spain	7,106.27							
SSE	SSE plc.	UK	41,323.94							
Centrica	Centrica plc.	UK	41,223.55							
National Grid	National Grid plc.	UK	21,701.99							
Exelon	Exelon Corporation	USA	29,447.00							
Duke	Duke Energy Corporation	USA	23,459.00							
Southern Co	Southern Company	USA	17,489.00							
		Total	907,276.37	19	22	22	25	25	25	25

Shaded area shows annual reports that were considered during the analysis.

Table 1: Overview of sampled utilities and annual report coverage

2.2.2 Quantitative Analysis of Utilities' Generation Portfolios

We complemented our document analysis of annual reports with data from the World Electric Power Plant database from Platts (2015). We used this data to determine the utilities' electricity generation portfolios since this is a central, quantifiable element of their business. To determine a firm's generation portfolio, we searched the company's name and the names of major subsidiaries (including joint ventures) and extracted all corresponding plants. We then calculated each company's generation portfolio by allocating the fuel type of each power plant to the following groups: renewables, new renewables (i.e., renewable energy technologies without large-scale hydro), nuclear, and fossil. We did not include fund investments in our analysis if they were not specifically listed in the annual reports, since we are interested in investments in generation assets that are under direct management of the utilities, rather than investments made for purely financial reasons. In order to make sure that the portfolios we extracted from the database are accurate, we conducted random cross-checks with the numbers provided in the annual reports of the companies. These checks revealed that the numbers we calculated are very similar to the ones reported by the companies.

2.2.3 Illustrative Quotes

Finally, to improve our understanding of the rationales behind the developments in utilities' business portfolios, we screened the annual reports for statements that provided more context for the developments that we had already identified during the analysis of annual reports and the electricity generation portfolios. In doing so, we focused on companies that both featured remarkable changes in their business portfolios as well as those whose annual reports actually provided suitable information on the rationale of portfolio changes. We made sure that the referenced quotes generally applied to the overall company as opposed to specific subsidiaries and were drawn from either the letter to the shareholders or sections that describe the strategic approach of the company. Table 2 provides an overview of the annual reports we reference in the results section of this paper. For reasons of readability, we use the document codes D1 through D20 to clarify the sources of quotes.

Code	Document
D1	Annual Report 2005, RWE AG, Essen.
D2	Reference Document 2009, Engie SA, Paris.
D3	Annual Report 2003, Southern Company, Atlanta, GA.
D4	Annual Report and Accounts 2003, SSE plc., Perth, UK.
D5	Annual Report 2003, RWE AG, Essen.
D6	2009 Annual Report and FORM 10-K, Duke Energy Corporation, Charlotte, NC.
D7	Annual Report 2007, EnBW AG, Karlsruhe.
D8	Form 20-F 2007, Korea Electric Power Corporation, Seoul.
D9	Annual Report 2009, Iberdrola SA, Bilbao.
D10	Annual Report 2009, Southern Company, Atlanta, GA.
D11	Annual Report 2009, EnBW AG, Karlsruhe.
D12	Annual Report 2013, Energias de Portugal SA, Lisbon.
D13	Annual Report 2007, Southern Company, Atlanta, GA.
D14	2015 Company Report, E.ON SE, Duesseldorf.
D15	Annual Report 2007, RWE AG, Essen.
D16	Annual Report 2013, EnBW AG, Karlsruhe.
D17	Annual Report 2015, EnBW AG, Karlsruhe.
D18	Annual Report 2015, Edison S.p.A., Milan.
D19	Form 20-F 2015, Korea Electric Power Corporation, Seoul.
D20	Annual Report 2015, RWE AG, Essen.

Table 2: Overview of referenced documents

3. Results and Discussion

In this section we describe the results of our analysis. To provide the reader with an understanding of the context, we start by giving a brief overview of the utilities' business activities before the energy transition. We then describe three general developments in utilities' business portfolios, which we have identified as (1) de-carbonization, (2) decentralization and servitization, and (3) system integration and balancing.

3.1 The Starting Point

In the beginning of this century, utilities around the world described their core mandates as being reliable suppliers of electricity. For example, in 2005 RWE stated, "Security of supply is a huge commitment that must be fulfilled anew every single day. 24 hours a day, 365 days.

That's our mission" (D1, p. 1). Engie stated in 2009, "The global energy industry faces […] the challenge of security of supply" (D2, p. 18). Southern Co. wrote in 2003, "Our core business is generating and delivering electricity in the Southeast. We do that very well" (D3, p. 4). And SSE stated in 2003, "SSE's first responsibility remains the provision of a safe and reliable electricity network" (D4, p. 2). Moreover, some utilities were not keen to support the transition to more renewable-based energy generation. For example, in its annual report in 2003, RWE stated, "Promoting renewables-based energy thus continues to burden Germany as an industrial location" (D5, p. 57). And in 2009, Duke wrote, "We simply cannot rely on renewable energy for most of our power. Wind and solar power are intermittent. As such, they are not as reliable and affordable as baseload plants" (D6, p. 13).

3.2 De-carbonization

The focus of utilities' business activities changed considerably when a growing number of countries began to introduce legislation that sought to mitigate climate change and supported renewable energy technologies and energy efficiency. In fact, we observed that all utilities expanded their generation portfolio to more strongly focus on new, carbon-free technologies and energy efficiency as the first development in their business portfolios. In the following, we first discuss our results regarding renewable energy generation and then address the topic of energy efficiency.

In 2003 only 53% of our sample companies produced electricity from new renewable energies. As of 2007 all the utilities in our sample engaged in business related to generation from new renewable energy technologies (see Figure 1).

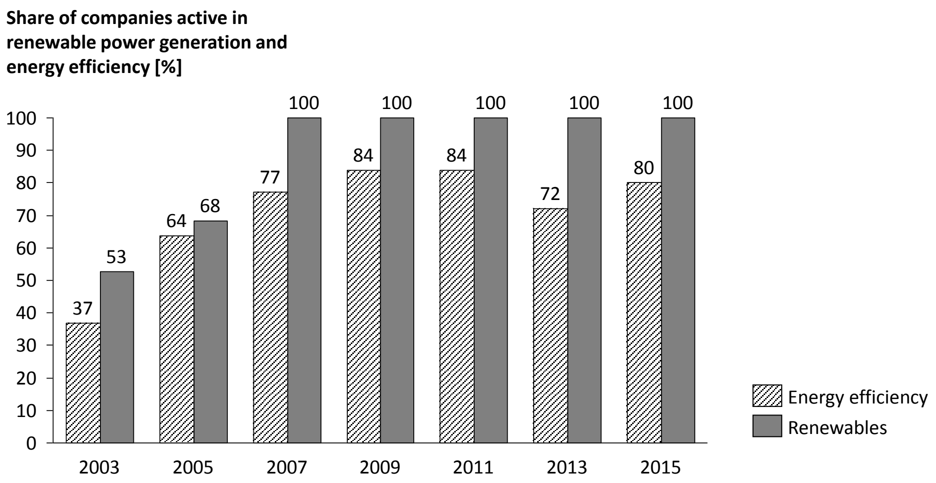

Figure 1: Share of companies active in renewable electricity generation and energy efficiency between 2003 and 2015

Given that our quantitative data from the annual reports only allows us to make a statement on whether utilities engage in electricity production from renewables but does not allow us to capture the magnitude of these engagements, we also evaluated the installed generation capacity of the 25 utilities in our sample between 2003 and 2015. This additional evaluation supports the development toward de-carbonization we identified. Table 3 shows that almost all the utilities in our sample increased the share of new renewables in their generation portfolio between 2003 and 2015, although some by only a small margin. During the observation period, the utilities in our sample more than tripled their new renewable generation capacities, with a total of 51 GW of new renewable capacity additions. However, by reacting more slowly than other companies in the sector, the sampled utilities lost 13% of the global new renewable market share during the observation period (Platts, 2015). Simultaneously, most of the utilities slightly decreased their share of fossil-fired power plants over the same period.

Country	Utility	Utility share renewables 2015[1 2]	Utility share new renewables 2015[1 3]	Change share new renewables 2003 – 2015[1 3]	Change share conventional 2003-2015[1 4]
China	DIPG	17,1	3,8	3,8	-14,7
China	HPI	17,9	3,2	3,1	-11,7
China	HPIC	15,1	2,1	2,1	-2,4
France	EDF	18,9	5,5	5,2	0,7
France	Engie	6,3	4,3	3,7	-5,0
Germany	EnBW	6,8	4,5	4,0	1,5
Germany	E.ON	14,8	8,9	6,3	-3,3
Germany	RWE	6,0	5,0	2,6	-2,5
Italy	A2a	26,4	0,0	0,0	10,4
Italy	Edison	17,5	7,3	5,6	-2,4
Italy	Enel	37,0	12,7	9,1	-5,2
Japan	Chubu	13,9	0,2	0,2	-2,4
Japan	Kansai	18,5	0,0	0,0	7,4
Japan	TEPCO	5,2	0,8	0,1	0,1
Korea	Korea EPCO	80,6	0,4	0,2	0,5
Portugal	EDP	74,7	33,1	26,5	-24,9
Spain	Acciona	100,0	98,5	4,3	-4,3
Spain	Endesa	32,3	3,3	1,4	-1,5
Spain	Iberdrola	55,1	28,9	23,2	-6,6
UK	Centrica	11,9	11,9	11,9	-9,4
UK	National Grid	0,1	0,1	0,1	-0,1
UK	SSE	15,6	13,4	0,1	0,1
USA	Duke	11,8	3,0	3,0	-1,9
USA	Exelon	7,4	3,8	3,8	0,0
USA	Southern Co	1,7	0,4	-1,2	-1,2

[1] Shares calculated based on net capacity [GW]
[2] Renewables include wind power, solar photovoltaics (PV), concentrated solar power (CSP), geothermal, biogas, marine power, and hydro power.
[3] New renewables include all renewables except hydro power
[4] Conventional power includes coal, nuclear, gas, and oil

Table 3: Overview of the utilities electricity generation portfolio for all companies in our sample in 2015 (Platts, 2015)

Annual report statements from utilities from all geographies also support the significance of the development towards renewable energy generation. In 2007, for example, EnBW stated, “We want to expand the business with green electricity considerably. The share of renewable energies used to generate electricity at EnBW will be increased significantly. We have numerous projects in the pipeline” (D7, p. 53). In the same year Korea EPCO wrote, “In July 2005, we entered into an agreement with the Government to invest (Won) 852 billion for the construction of generating facilities using alternative energy sources and spend (Won) 201 billion in research and development related to the development of renewable energy by July

2008” (D8, p. 72). Two years later, Iberdrola declared, “IBERDROLA Renovables is one of the largest growth drivers of the IBERDROLA Group, […]” (D9, p. 22).

By looking into specific renewable energy technologies, we identify preferences for some technologies. While firms only moderately increased their activity in marine power generation, offshore wind, geothermal power, concentrated solar power (CSP), and power generation from biomass, the increase in electricity generation from onshore wind and solar photovoltaic (PV) was more pronounced (see Figure 2). Businesses with PV plants have seen a strong rise in particular, from 11% of utilities that pursue electricity generation from PV plants in 2003 to 88% in 2015.

In addition to efforts aimed at de-carbonizing electricity generation, utilities also increased their activities related to energy efficiency. Such products and services aim to decrease the electricity consumption of end customers and were traditionally regarded as cannibalizing the utility business model. This was particularly the case for utilities that focused on power generation and sale as opposed to distribution grid owners, which could leverage energy efficiency for integrated resource planning (Sousa et al., 2013). In light of the changing business environment, however, in which producing and selling electricity had become increasingly unprofitable (Hoppmann et al., 2018; Ossenbrink et al., 2018; Vahlenkamp et al., 2014), this portfolio element experienced a boost similar to the one renewable electricity generation experienced (see Figure 1). Activities related to energy efficiency were embraced early on and then stagnated somewhat at an adoption-rate of roughly 80% from 2009 onwards[2]. Our quanitative data uncovers activities in energy efficiency, but does not reveal their magnitude. However, anectodical evidence in the form of annual report statements

[2] The drop in energy efficiency activities in 2013 can a priori not be explained by our data from the annual reports. Bearing in mind that companies may have specific foci in their annual reports, the drop in 2013 is likely due to the fact that some companies focused on reporting other activities and not due to an actual reduction in energy efficiency activities.

strenghten the picture that energy efficiency-related activities actually became important in utilitites' business portfolios. For example, in 2009 Southern Co. presented the new regime in its annual report by saying, "We continue to invest millions each year in programs designed to help customers use energy more efficiently, thus reducing the need for new generation. So far, we've reduced peak electricity demand by 3,200 megawatts. Now we plan to invest $1 billion by 2020 to reduce peak demand by another 1,000 megawatts" (D10, p. 10). In the same year, EnBW declared that, "Energy efficiency is a key topic for EnBW" (D11, p. 6).

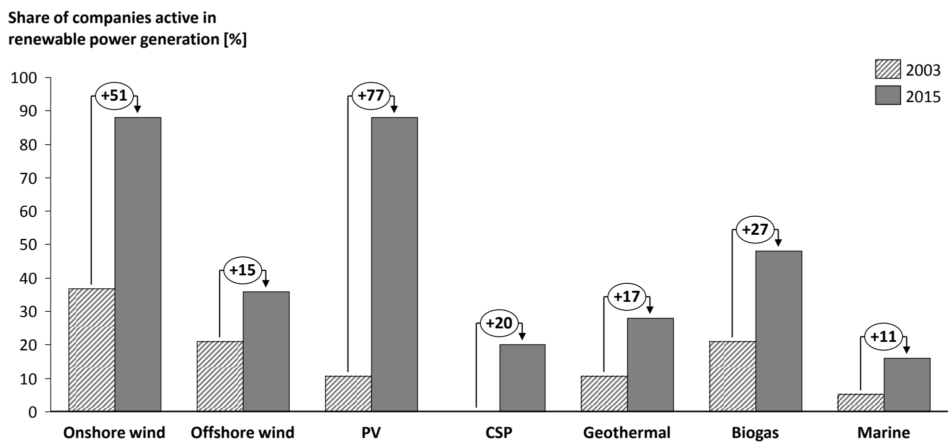

Figure 2: Share of companies active in renewable electricity generation in 2003 and 2015 by technology (differences between 2003 and 2015 are given in percentage points)

Summing up, despite the traditionally skeptical attitude of utilities towards business activities in renewable energy generation and energy efficiency, and despite the fact that utilities could hardly rely on existing capabilities in these fields, almost all utilities pursue these activities today. A quote from EDP's annual report from 2013 illustrates the perceived importance of policy measures in these fields by stating that "the energy sector is experiencing a new reality, one in which fixed costs are increasingly important, given that a higher proportion of the investment is channeled to renewable energy [and therefore] stable and long-term contracting is crucial. This is why we advocate mechanisms of feed-in-tariff and ex-ante auctions […] to remunerate renewable capacity" (D12, p. 7). A statement from EnBW's 2009 annual report saying that they also want to "operate in regulated markets such as […] renewable energies pursuant to the German Renewable Energies Act (EEG)" (D10, p. 16) similarly indicates that policy instruments in these fields have played a major role in incentivizing incumbents to invest in these new areas.

3.3 Decentralization and Servitization

The second development we observe in utilities' business portfolios is decentralization and servitization. This development is coupled with, and partly driven by, the development of de-carbonization for several reasons. First, the increasing use of solar PV and onshore wind have led to an increase in the share of distributed and customer-driven power production. For example, in many countries the emergence of rooftop PV and small wind farms has led to an increasing share of electricity being generated by electricity consumers. Second, amid increasing incentives to save electricity, many utilities have started offering contracting services as part of which utilities helped commercial electricity consumers install and operate energy efficiency solutions. Third, in several countries the increase in renewable energy-generation capacities has contributed to the drop in electricity wholesale prices, which has put strong downward pressure on profit margins, thereby forcing utilities to look for new business models beyond electricity generation (Helms, 2016; Hoppmann et al., 2018; Ossenbrink et al., 2018; Vahlenkamp et al., 2014). In addition to the increasing diffusion of renewable energy and energy efficiency technologies, the development toward decentralization has been fueled by broader technological changes, such as digitization or the electrification of the transport sector.

Together, these developments have created opportunities for utilities to offer products and services closer to the end customer related to energy monitoring and management, such as using smart meters or electric mobility. With the new opportunities downstream in the value chain, utilities ventured into a sphere they were not traditionally active in. For example, by 2007 Southern Co. already identified "the real long-term value of automated metering" toward customers having "more control over how and when they use [their] services" (D13, p. 9). Another example of a company that put a strong emphasis on decentralized services early on was E.ON, which stated in its 2015 annual report that it wanted to "cultivate a strong customer orientation, develop and implement new downstream business models and products, and leverage the digital transformation" (D14, p. 14).

Overall, the share of utilities offering distributed generation and services grew immensely, from 32% in 2003 to 88% in 2015 (see Figure 3). Examples of prominent downstream businesses are products and services related to electricity monitoring and management, such as smart meters and related services. Only 11% of the electric utilities in our sample pursued business in passive monitoring systems at the beginning of the analyzed period. Activities in that field, however, started to take off in 2007. Active energy management devices, on the other hand, only appeared in 2009 and quickly experienced an important increase. In total, 72% of all utilities pursued activities in either active or passive energy monitoring and management in 2015. Moreover, electric mobility, an attempt to electrify an energy application that traditionally runs on fossil fuels and an emerging downstream business, is a good example of a late bloomer in the field of distributed services. While none of the utilities in our sample pursued services for electric mobility or the related charging infrastructure until 2007, more than half of them (52%) did so in 2015.

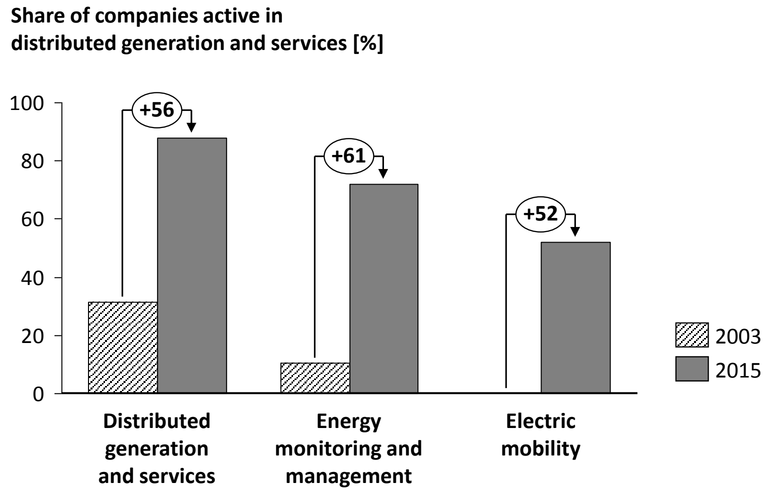

Figure 3: Share of companies active in distributed generation and services in 2003 and 2015 (differences between 2003 and 2015 are given in percentage points)

Altogether, we observe that the development towards de-carbonization in combination with digitalization and the electrification of the transport sector has led to a subsequent development towards decentralization and servitization. Similar to the development towards de-carbonization, decentralization and servitization are not logical continuations of the existing capabilities of utilities. Even in 2015, when talking about customer orientation, E.ON still admitted that the company would have to "develop and refine the necessary expertise" (D14, p. 14). Nevertheless, decentralization and servitization are now explicit elements in many utilities' portfolios.

3.4 System Integration and Balancing

The third development we observe in our analysis is a shift toward system integration and balancing, which is closely coupled with both de-carbonization and decentralization and servitization. Renewable power plants, for example, do not feed constant power into the grid. Therefore, electricity grid operators now must deal with variable patterns of electricity injection. Indeed, some utilities, such as RWE, began highlighting this additional challenge to the energy transition early on. In the R&D section of their 2007 annual report RWE stated, “As electricity from renewables is fed into the grid, there will be significant fluctuations in power supplied” (D15, p. 13). Distributed services, such as electric mobility, also challenge the grid operation and stability on low voltage levels.

These new challenges can be a threat to utilities, specifically those that own grid assets, but may also open up potential new business opportunities for both generation and network utilities. For example, to solve problems with intermittent electricity supply, solutions such as electricity storage, demand response, virtual power plants, or vehicle-to-grid need to be developed and deployed. Whereas storage solutions allow storing the electricity from renewables for later use, the concept of demand-response entails shifting end consumer demand to times of larger electricity supply. Virtual power plants bundle the electricity supply from decentralized plants, thereby enabling the participation of these plants in balancing markets. Vehicle-to-grid technologies, finally, allow integrating electric mobility solutions into the electricity system, e.g., by using the storage capacity in electric vehicles to balance demand and supply.

Overall, solutions in the field of system integration and balancing can complement the actual energy transition (i.e., de-carbonization and customer orientation) and can help integrate distributed generation and services to a functioning whole. In our quantitative assessment, we see that utilities indeed explore business opportunities within system integration and balancing. For example, in 2015 E.ON identified storage systems as a promising opportunity to create additional value through renewable energy generation, stating that, “Renewables like wind and solar have achieved a cost level that is competitive relative to that of conventional generation technologies. In conjunction with batteries and other energy storage systems, renewables represent a viable alternative energy supply for more and more customers” (D14, p. 12). Figure 4 shows that activities in decentralized storage, demand-response, virtual power plants, and vehicle-to-grid experienced an increase similar to the one in renewable energy activities and distributed services. However, this development is less pronounced than the increase in renewable energy activities and distributed services. For example, by 2015 only 56% of the electric utilities in our sample were active in decentralized storage.

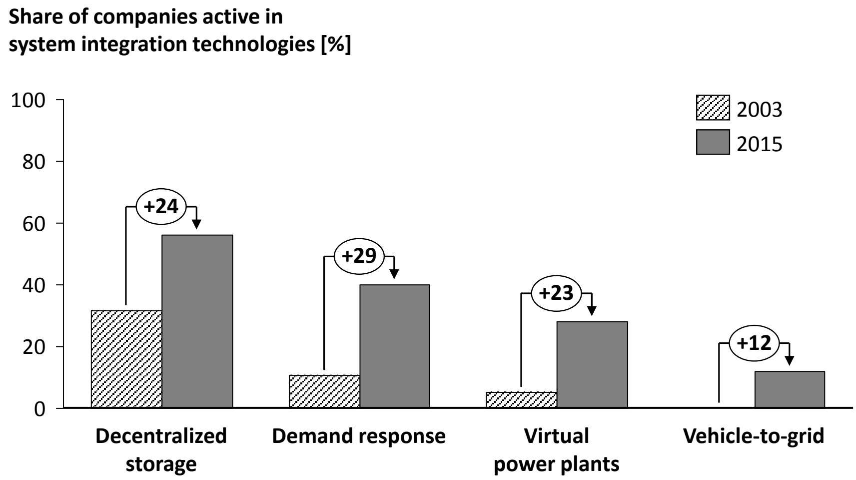

Figure 4: Share of companies active in products and services related to system integration and balancing in 2003 and 2015 (differences between 2003 and 2015 are given in percentage points)

Tables 4 and 5, which summarize utilities' business activities in 2003 and 2015, also confirm our previous finding. These tables show that, while about half of the utilities already pursued activities related to renewable energy and energy efficiency in 2003, business related to decentralization, servitization, and system integration and balancing were much less common at that time. By 2015, utilities had greatly expanded their activities in all fields. However, as Table 5 shows, activities in system integration and balancing, as well as (to a lesser extent) decentralization and servitization, lagged behind utilities' activities related to de-carbonization.

		De-carbonization		Decentralization & servitization			System integration & balancing			
Country	Company	Renewable energy	Energy efficiency	Distributed generation	Energy monitoring & mgmt.	Electric mobility	Decentralized storage	Demand response	Virtual power plants	Vehicle-to-grid
China	DIPG									
China	HPI									
China	HPIC									
Germany	ENBW	X	X							
Germany	EON	X					X		X	
Germany	RWE	X								
Italy	Enel	X			X					
Japan	Chubu		X				X			
Japan	Kansai	X	X	X			X	X		
Japan	TEPCO		X				X			
Korea	Korea EPCO							X		
Portugal	EDP	X								
Spain	Acciona	X		X	X		X			
UK	Centric	X	X							
UK	National Grid									
UK	SSE	X								
USA	Duke									
USA	Exelon		X				X			
USA	SouthernCo	X	X							

Shaded fields indicate that utility is active in business field.

Table 4: Electric utilities' business activities in 2003

		De-carbonization		Decentralization & servitization			System integration & balancing			
Country	Company	Renewable energy	Energy efficiency	Distributed generation	Energy monitoring & mgmt.	Electric mobility	Decentralized storage	Demand response	Virtual power plants	Vehicle-to-grid
China	DIPG	X		X						
China	HPI	X		X						
China	HPIC	X		X						
France	EDF	X	X	X	X	X	X		X	
France	Engie	X	X	X		X			X	
Germany	ENBW	X	X	X	X	X	X		X	
Germany	EON	X	X	X	X	X	X		X	
Germany	RWE	X	X		X	X	X		X	
Italy	A2a	X	X	X	X	X	X	X	X	X
Italy	Edison	X	X	X	X		X			
Italy	Enel	X	X	X	X	X	X	X	X	
Japan	Chubu	X	X	X	X			X		
Japan	Kansai	X	X	X	X	X	X	X		X
Japan	TEPCO	X			X					
Korea	Korea EPCO	X		X	X	X	X	X		
Portugal	EDP	X	X	X	X	X	X	X		
Spain	Acciona	X	X	X						
Spain	Endsea	X	X	X	X	X	X	X		X
Spain	Iberdrola	X	X	X	X	X	X	X		
UK	Centric	X	X	X	X		X			
UK	National Grid	X	X	X				X		
UK	SSE	X	X		X					
USA	Duke	X	X	X	X		X			
USA	Exelon	X	X	X	X			X		
USA	SouthernCo	X	X	X		X			X	X

Shaded fields indicate that utility is active in business field.

Note: The Chinese firms in our sample are independent power producers and are therefore not active in businesses other than electricity generation.

Table 5: Electric utilities' business activities in 2015

Overall, our findings indicate that the world's big utilities were quicker in adopting new businesses directly linked to the energy transition than they were at adopting products and services that complement and integrate the energy transition, into which they ventured only later and to a lesser extent. In Germany, where the feed-in of renewable generation plants is high compared to total electricity generation (Platts, 2015), the integration of these assets into the distribution grid is especially crucial for a successful energy transition. Correspondingly, E.ON argued in 2015 that, "In Germany, about one third of distributed generating capacity subsidized by the Renewable Energy Law is connected to our networks," and describes regional energy networks as "what makes the transformation of the energy system possible" (D14, p. 13).

Considering that maintaining the reliability of the distribution grid is a core capability of traditional electric utilities and that expanding this capability to balance variable renewable electricity injection is greatly needed in some countries, it comes as a surprise that utilities' activities in this field are so limited. In their 2013 annual report, EnBW stated that "Local energy systems are considered to be the most important market in the field of energy services, [albeit they] are currently still generating low revenues but, in the medium term, harbour huge potential" (D16, p. 32). This statement suggests that although system integration and balancing is crucial to the energy transition, often its economic viability is not yet certain.

4. Conclusion and Policy Implications

This study provides an overview of 25 of the world's largest electric utility companies during the energy transition from 2003 to 2015. Our findings can help policy makers identify areas where large utilities—as major players in the electricity sector—are already active. However, we also identify areas where utilities lag behind, thereby revealing where policy interference may be required to leverage utilities' capabilities in favor of the energy transition. Below, we first discuss the implications that our findings have for the literature and for policy makers. Subsequently, we point to a number of limitations of our study and offer directions for future research.

4.1 Policy Implications

Our study shows that incumbent electric utilities have initiated major changes in their business portfolios. Previous studies have displayed utilities as rigid and slow to embrace change (Downie, 2017; Shah et al., 2013). However, we find that the world's largest electric utilities have slowly started to engage in activities that support the main goal of the energy transition, i.e., de-carbonization. This study does not reveal the amount of financial investment (in USD) utilities have made in such activities, nor does it provide an answer to the question of whether the pace at which change is occurring is sufficient to prevent critical climate change. Still, our results indicate that even actors that can be expected to oppose the energy transition make an effort to include energy transition-related business activities in their portfolios.

In order to foster a seamless and fast transition of the electricity sector, it may be beneficial to get incumbent electric utilities on board, rather than trying to rebuild utilities' traditional, existing capabilities, such as system integration and balancing capabilities, from scratch in new organizations. From recent annual reports, we see that utilities are not only prepared but also increasingly willing to tackle the necessary developments. For example, EnBW stated, "We are countering the foreseeable fall in earnings from conventional generation and trading by expanding generation from renewable sources of energy, expanding the stable grids business and engaging in an innovation and service-based campaign to promote business in the area of 'Customer proximity'" (D17, p. 1). Similarly, Edison forecasted in 2015 that the future would be "more sustainable: renewable sources, energy efficiency, new services for customers, digitalization" (D18, p. 1).

However, we find that although utilities have started to adjust their business portfolios, they have mostly done so by engaging in activities related to renewable energy and energy efficiency. Activities that are consequential but not initially tied to the transition, such as decentralization and servitization (e.g., distributed generation and energy monitoring), as well as system integration and balancing (e.g., electricity storage, demand-response, virtual power plants, or vehicle-to-grid), have been addressed by utilities later and are not yet broadly integrated into utilities' business portfolios. Successfully managing the energy transition requires integrating a large set of new and often distributed technologies into the electricity system in order to ensure a clean and reliable electricity supply. Due to their extensive expertise in operating electricity grids and reliably supplying electricity, electric utilities are uniquely positioned to take on this task. However, our analysis shows that utilities have so far made limited investments in system integration and balancing. This comes as a surprise, as the capabilities and assets needed in this field are very close to those necessary to ensure a reliable electricity supply, a mandate that has been central to most electric utilities over decades. In their latest annual reports, several utilities have started to highlight this connection and many mention the development of their network as one of their main strategic aims. For example, in 2015 Korea EPCO wanted to "focus on ensuring stable supply of electricity" by making their "networks 'smarter'" (D19, p. 25). E.ON declared in the same year that "the new E.ON's […] core business is energy networks" (D14, p. 2), and RWE, too, wanted to invest in "maintaining, expanding and modernizing [their] network infrastructure, in order to ensure the reliable distribution of electricity […] over the long term" (D20, p. 18).

Despite synergies between utilities' existing assets and capabilities, only a few utilities have started to engage in system integration and balancing services. Therefore, regulators and policy makers should consider implementing regulatory changes and incentive policies that support system integration to guarantee a seamless energy transition. Fostering system integration would require a shift in the focus of policy incentives from supporting individual low-carbon technologies toward an approach that more strongly considers the interplay of technologies and markets at a systemic level. For example, in order to remove regulatory risks resulting from the integration of decentralized production, regulators could establish a new set of network regulations that includes frameworks on how to deal with the peculiarities of decentralized production, such as self-consumption or re-injection of electricity on low-voltage levels. The latter are new phenomena for grid operators and, as such, are not yet incorporated into the regulatory frameworks of many countries.

Another lever for a more holistic implementation of the energy transition could be changes in regulations that contribute to a redefinition of responsibilities along the value chain, facilitate the management of interfaces, and reduce potential conflicts of interest. For example, in Germany, storage solutions may help reduce investments in the extension of transmission or distribution grids. Yet, while the use of storage solutions is not problematic for power generators, the application by transmission and distribution system operators is currently hindered by an insufficient legal definition of storage solutions. Given these unintended, adverse effects of existing regulation, regulators should carefully consider the ways in which they may need to change regulation to avoid stifling business activities in the field of system integration, as these activities are essential to the future success of the energy transition.

Moreover, instead of exclusively incentivizing the use of renewable energy generation and energy efficiency technologies, policy makers should also focus on incentivizing the use of complementary technologies that help balance distribution grids and therefore contribute to the security of supply, such as batteries or other forms of energy storage. Finally, policy makers could support solutions on an institutional level, such as demand-response management or pooling of decentralized assets for ancillary services. We argue that only by putting more emphasis on such policy incentives that complement ongoing efforts toward de-carbonization and energy efficiency can policy makers leverage the strengths of utilities as powerful and knowledgeable actors in the electricity system and ensure an efficient transition toward a more decentralized energy system based on low-carbon technologies.

4.2 Limitations and Future Research

Our study has several limitations that provide fruitful starting points for future research. First, our study is limited to investigating the business activities of 25 of the largest utilities in 10 countries. We selected these utilities because, due to their size, they play a particularly important role for the energy transition. However, the question remains how smaller utilities and utilities in other countries have adapted their business portfolios during the energy transition. Moreover, our study focuses on the electricity sector as one subsector of the energy sector. While the electricity sector plays a major role in mitigating climate change, future studies should also investigate how companies have shifted their activities in the fields of heat supply.

Second, our study is necessarily limited by the data sources it builds upon. Although annual reports represent a reliable data source that allowed us to compare utilities' business activities over time, utilities may choose to emphasize certain activities or not to publish information in annual reports for strategic reasons. To avoid biases, we conducted plausibility checks of our data and triangulated the annual report data with interview data we gathered in previous projects on electric utility companies in several countries. Nevertheless, we call for future research that complements our analysis by conducting in-depth analyses of utilities' changes in business portfolios, e.g., drawing on case study analysis or ethnographic techniques. While there are studies investigating utility companies using case study methodology, most rely on publicly available data and shed limited light on the internal processes of change.

Third, and finally, our study focuses on investigating the activities of the utilities and provides limited insights into the factors driving the dynamics we observe. We believe, however, that investigating how utilities' business portfolios changed during the energy transition is an important first step toward investigating why these changes occurred. The qualitative evidence we present, for example, suggests that policy incentives (e.g., support programs for renewables, emission trading systems, or energy efficiency standards) or the regulatory environment (e.g., the degree of market liberalization or grid codes) have played a role in stimulating changes in business activities. Another driver for the developments we observe may be technological progress, which supports or inhibits certain business activities, but may also be directly influenced by the utilities themselves, which can invest in R&D to spur development of novel technologies. The different drivers (policy incentives, regulation, technological change, firm strategies) operate in parallel and may conflict somewhat. To allow for more conclusive statements about the drivers of changes in utilities' business portfolios, it seems necessary to have quantitative, longitudinal analyses that shed a more detailed light on firm-internal and firm-external drivers of change. A better understanding of the relationship between policies, technologies, and changes in the largest electric utilities' business portfolios is critical for policy makers and corporate managers to help steer these firms onto pathways that are aligned with global efforts for mitigating climate change.

References

Apajalahti, E.-L., Lovio, R., Heiskanen, E., 2015. From demand side management (DSM) to energy efficiency services: A Finnish case study. Energy Policy 81, 76–85. doi:10.1016/j.enpol.2015.02.013

Berlo, K., Wagner, O., Heenen, M., 2017. The incumbents' conservation strategies in the german energy regime as an impediment to re-municipalization—An analysis guided by the multi-level perspective. Sustainability 9, 1–12. doi:10.3390/su9010053

Burger, S.P., Luke, M., 2017. Business models for distributed energy resources: A review and empirical analysis. Energy Policy 109, 230–248. doi:10.1016/j.enpol.2017.07.007

De Fusco, L., Lorenzi, G., Jeanmart, H., 2016. Insight into electric utility business models for high-share renewables and storage integration, in: International Conference on the European Energy Market, EEM. pp. 1–5. doi:10.1109/EEM.2016.7521259

Downie, C., 2017. Business actors, political resistance, and strategies for policymakers. Energy Policy 108, 583–592. doi:10.1016/j.enpol.2017.06.018

Facchinetti, E., Eid, C., Bollinger, A., Sulzer, S., 2016. Business model innovation for local energy management: A perspective from Swiss utilities. Front. Energy Res. 4, 1–13. doi:10.3389/fenrg.2016.00031

Gsodam, P., Rauter, R., Baumgartner, R.J., 2015. The renewable energy debate: how Austrian electric utilities are changing their business models. Energy. Sustain. Soc. 5, 1–12. doi:10.1186/s13705-015-0056-6

Helms, T., 2016. Asset transformation and the challenges to servitize a utility business model. Energy Policy 91, 98–112. doi:10.1016/j.enpol.2015.12.046

Hoffman, I.M., Goldman, C.A., Rybka, G., Leventis, G., Schwartz, L., Sanstad, A.H., Schiller, S., 2017. Estimating the cost of saving electricity through U.S. utility customer-funded energy efficiency programs. Energy Policy 104, 1–12.

doi:10.1016/j.enpol.2016.12.044

Hoppmann, J., Naegele, F., Girod, B., 2018. Boards as a source of inertia: Examining the internal challenges and dynamics of boards of directors in times of environmental discontinuities. Academy of Management Journal, forthcoming.

IPCC, 2014. Climate change 2014: Synthesis report. Geneva.

Jacobsson, S., Lauber, V., 2006. The politics and policy of energy system transformation—explaining the German diffusion of renewable energy technology. Energy Policy 34, 256–276. doi:10.1016/j.enpol.2004.08.029

Lovins, A.B., Lovins, L.H., 1982. Electric utilities: Key to capitalizing the energy transition. Technol. Forecast. Soc. Change 22, 153–166. doi:10.1016/0040-1625(82)90020-8

Mitchell, C., 2016. Momentum is increasing towards a flexible electricity system based on renewables. Nat. Energy 1, 1–6. doi:10.1038/nenergy.2015.30

Ngar-yin Mah, D., Wu, Y.Y., Ronald Hills, P., 2017. Explaining the role of incumbent utilities in sustainable energy transitions: A case study of the smart grid development in China. Energy Policy 109, 794–806. doi:10.1016/j.enpol.2017.06.059

Ossenbrink, J., Hoppmann, J., Hoffmann, V.H., 2018. Hybrid ambidexterity: How the environment shapes incumbents' use of structural and contextual approaches. Working paper.

Platts, 2015. World electric power plants database.

Richter, M., 2013a. Business model innovation for sustainable energy: German utilities and renewable energy. Energy Policy 62, 1226–1237. doi:10.1016/j.enpol.2013.05.038

Richter, M., 2013b. Business model innovation for sustainable energy: how German municipal utilities invest in offshore wind energy. Int. J. Technol. Manag. 63, 24–50. doi:10.1504/IJTM.2013.055578

Shah, A.N., Palacios, M., Ruiz, F., 2013. Strategic rigidity and foresight for technology adoption among electric utilities. Energy Policy 63, 1233–1239.

doi:10.1016/j.enpol.2013.08.013

Sousa, J.L., Martins, A.G., Jorge, H., 2013. Dealing with the paradox of energy efficiency promotion by electric utilities. Energy 57, 251–258. doi:10.1016/j.energy.2013.02.040

Stern, P.C., Janda, K.B., Brown, M.A., Steg, L., Vine, E.L., Lutzenhiser, L., 2016. Opportunities and insights for reducing fossil fuel consumption by households and organizations. Nat. Energy 1, 1–6. doi:10.1038/nenergy.2016.43

Thomson Reuters, 2015. EIKON database.

Vahlenkamp, T., Leger, S., Bauer, K., Enkvist, P.-A., Puzderca, O., Purta, M., Tryggestad, C., Volpin, A., 2014. Beyond the storm—value growth in the EU power sector. Duesseldorf.

Appendix

Country	Code	2003 Monopoly position	2003 Vertically integrated	2003 State-owned	2015 Monopoly position	2015 Vertically integrated	2015 State-owned	Comment
China	HPI			Grey			Grey	Active only in generation
China	HPIC			Grey			Grey	Active only in generation
China	DIPG			Grey			Grey	Active only in generation
France	EDF		Shaded	Grey		Shaded	Grey	85% state-owned; data from 2005
France	Engie			Shaded		Shaded	Shaded	More than 33% state-owned; data from 2009
Germany	E.ON	Shaded	Shaded		Shaded	Shaded		Subsidiaries in monopoly regions
Germany	RWE		Shaded	Shaded		Shaded	Shaded	Largely community-owned
Germany	EnBW		Shaded			Shaded		
Italy	Enel		Shaded	Shaded		Shaded	Shaded	State owns minority share
Italy	Edison							Data from 2005
Italy	A2a		Shaded	Shaded		Shaded	Shaded	Largely community-owned; data from 2009
Japan	TEPCO		Grey			Shaded		
Japan	Kansai		Grey			Shaded		
Japan	Chubu		Grey			Shaded		
South Korea	Korea EPCO	Grey	Grey	Shaded	Grey	Grey	Shaded	51% state-owned
Portugal	EDP	Shaded	Shaded	Shaded	Shaded	Shaded		
Spain	Iberdrola	Shaded	Shaded		Shaded	Shaded		Data from 2009
Spain	Enedesa	Shaded	Shaded		Shaded	Shaded		Subsidiaries in monopoly regions; data from 2005
Spain	Acciona							Active only in generation
UK	SSE		Shaded			Shaded		
UK	Centrica							Active only in generation
UK	National Grid							Active only in transmission & distribution
USA	Exelon	Shaded	Shaded		Shaded	Shaded		
USA	Duke	Grey	Grey		Shaded	Shaded		Activities in deregulated regions
USA	Southern Co	Grey	Grey		Grey	Grey		

Empty fields indicate that the utility does not have a monopoly position / is not vertically integrated / is not state-owned

Shaded fields indicate that subsidiaries of the utility have a monopoly position / are partially vertically integrated / are partially state-owned

Grey fields indicate that the utility has a monopoly position / is fully vertically integrated / is state-owned

Table A1: Overview of the regulatory environments of the chosen sample

Code	Definition
Electricity Generation	Generation of electricity through both renewable and conventional primary energy sources.
Fossil Power Plants	Generation of electricity with fossil fuels as primary energy source.
Coal	Generation of electricity with coal as primary energy source.
Gas	Generation of electricity with gas as primary energy source.
Oil	Generation of electricity with oil as primary energy source.
CCGT	Generation of electricity with gas as primary energy source using a CCGT process as conversion technology.
CHP	Generation of electricity with fossil fuels as primary energy source using a CHP unit as conversion technology.
CCS	Generation of electricity with fossil fuels as primary energy source using CCS technology to extract CO2 from the combustion gas.
Nuclear Power Plants	Generation of electricity with nuclear fuels as primary energy source.
Hydro Power Plants	Generation of electricity with hydro energy as primary energy source.
Fuel Cell	Generation of electricity using fuel cells as conversion technology.
Renewable Energy Power Plants	Generation of electricity with renewable energy sources as primary energy source excluding hydro.
Wind Onshore	Generation of electricity using land-sited wind turbines as conversion technology.
Wind Offshore	Generation of electricity using offshore-sited wind turbines as conversion technology.
PV	Generation of electricity using photovoltaic cells as conversion technology.
CSP	Generation of electricity using heat generated through solar irradiation as conversion technology.
Geothermal	Generation of electricity using geothermal heat as primary energy source.
Biomass/Biogas	Generation of electricity with biogas as primary energy source.
Marine Technologies	Generation of electricity using wave or tidal energy as primary energy source.
Electricity Bundling	Aggregation of electricity from multiple sources, to be controlled by one entity. Includes only generation or storage assets.
Neighborhood Management Solutions	Solutions for the aggregation of distributed generation assets to be controlled and managed as one entity on a local level.
Virtual Power Plant	Solution for the aggregation of distributed generation assets to be controlled and managed as one entity with no geographical restrictions.
Electricity Balancing	Services to support and maintain system stability on a local and grid level.
Grid Anciliary Services	Stabilizing and balancing power services for grid operators based on a bilateral contract or auction mechanism.
Power Plants	Stabilizing and balancing power services using power plants to provide services.
Demand Response	Stabilizing and balancing power services using aggregated demand response to provide services.
Storage	Stabilizing and balancing power services using pumped hydro storage assets to provide services.
Local Balancing Energy	Local stabilizing and balancing power services based on bilateral agreements.
Power Plants	Stabilizing and balancing power services using power plants to provide services.
Demand Response	Stabilizing and balancing power services using aggregated demand response to provide services.
Storage	Stabilizing and balancing power services using new technology storage assets to provide services.
Electricity Transportation	Transmission and distribution of electricity.
Electricity Transmission	Transmission of electricity.
Electricity Distribution	Distribution of electricity.
Electricity Trading & Wholesale	Buying and selling of standardized and non-standardized contracts on electricity and specified associated markets. This does not include trading of primiary energy carriers and contractual relations between divisions or subsidiaries of unbundled companies.
Electricity	Activities related to trading and wholesale of electricity as a commodity.
Hedging	Trading activities associated with risk reduction against changing market prices using financial instruments such as options and futures. Involves physical assets or retail business.
Speculation	Trading activities associated with realizing profits from changing market prices using financial instruments such as options and futures.
Price Arbitrage	Trading activities associated realizing profits from price differences at different times or markets.
Capacity Market Bidding	Trading activities associated with supplying long term power capacity through a market mechanism.
Electricity Market Bidding	Trading activities associated with a purchase or supply of a given quantity of electricity at a given price through a market mechanism.
Bilateral Contract (PPAs)	An agreement between two parties on the purchase or supply of electricity.
Green electricity certificates (RECs)	Trading activities associated with a purchase or supply of certified green electricity certificates.
CO2 certificate trading	Trading activities associated with a purchase or supply of certified CO2 certificates This includes activities acc. to the Kyoto protocol, like CDM and JI.
Electricity Retail	Activities related to selling electricity related products to end-customers. This does not include sales of physical equipment.
Regulated Electricity Supply	The retail of purchased or generated electricity to end-customers.
Green Electricity Supply Options	Sale of electricity from renewable energy sources.
Deregulated Electricity Supply	Activities associated with facilitating the sale of electricity related services and products to end customers (on behalf of one or more supply partners).
Metering & Billing	Activities related to energy billing management for end-customers or suppliers.
Electricity Shifting	Shifting electricity generation or consumption in time with dedicated technologies.
Vehicle-to-grid	Shifting electricity generation or consumption in time using plugged-in electric vehicles.
Demand Response	Shifting electricity generation or consumption in time involving end-customer electricity consumption reduction or shifting during period of high prices or insufficient supply.
Pumped hydro power plant	Shifting electricity generation or consumption in time using pumped hydro power plants.
Storage	Shifting electricity generation or consumption in time using technologies other than pumped hydro power plants.
Electricity Saving	Products and services related to reduction of electricity consumption. This also includes physical equipment.
Energy Efficiency	Products and services related to reduction of electricity consumption.
Energy Efficiency Credits	Trading activities associated with securities that certify a energy consumption reduction.
Electricity Monitoring	Products and services related to monitoring and managing electricity distributed generation and consumption.
Electricity Forecasting	Activities related to the prediction of electricity production or consumption.
Energy Monitoring Systems	Solutions for monitoring energy generation, consumption and performance.
Energy Management System	Solutions for monitoring, controlling and optimizing energy consumption and performance.
Energy Auditing	Services related to the inspection of energy usage and flow within a building.
Energy Management Services/ Data Analytics	Activities related to the analyzing of electricity data to draw conclusions and recommendation for cost-reduction and/or efficiency measures.
Electric Mobility	Activities related to infrastructure for enabling electric mobility services.
EV Charging	Activities related to electric mobility infrastructure.
Distributed Products & Services	Products, services and activities employed on medium and low voltage grid areas or at end-customers.

Table A2: Coding scheme used to classify utilities' business portfolios

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