Learning Strategies in Smart Grid Adoption: An Explorative Study in the U.S. Electric Utility Industry

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Abstract
The U.S. electric utility industry is facing a number of challenges today. In response, utilities are investing in smart grid technologies to mitigate them. Yet, smart grid adoption presents significant knowledge barriers to utilities. This study aims to advance the understanding of IT knowledge challenges in smart grid adoption by focusing on three research questions: 1) what knowledge requirements are critical for smart grid adoption and what knowledge gaps are faced by utilities 2) are utilities responding to these knowledge gaps; and 3) What factors help explain differences in utilities’ responses. Due to the unique nature of the electric utility industry, we take a qualitative, exploratory approach to address these questions. Our analysis reveals five types of knowledge essential in smart grid adoption and uncovers utilities’ responses to these challenges based on an internal vs. external learning framework. Our study also suggests that utilities’ responses depend on a mix of knowledge and organizational factors.

Keywords: smart grid; organizational learning; IT knowledge challenge


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1 Introduction
The U.S. electric utility industry is facing a number of challenges today, including aging infrastructure, growing customer demand, CO2 emissions, and increased vulnerability to overloads and outages. In many areas, integration of distributed energy such as rooftop solar is a growing concern (Department of Energy, 2008; 2104). Utilities are under greater regulatory, societal and consumer pressure to provide a more reliable and efficient power supply and reduce its carbon footprint. In response, utilities are investing in smart grid technologies. Despite various definitions of smart grid, it is characterized by employing a set of sophisticated sensing, processing and communicating digital technologies to enable a more observable, controllable, and automated power supply (Kranz & Picot, 2011).

According to Department of Energy’s categorization (2012), smart grid technologies comprise four sets of subsystems: advanced metering infrastructure (AMI), electric transmission systems (ETS), electric distribution systems (EDS) and customer-side systems (CS). Each system comprises a mix of physical power infrastructure, communication network, and IT hardware and software, as seen in table 1 (Dedrick, Venkatesh, Stanton, Zheng, & Ramnarine-Rieks, 2014; Leeds, 2009). With these IT innovations, smart grid enables a series of capabilities that were missing in the past: two-way communication between utilities and customers, demand-side management and load control, outage management, asset management, dynamic pricing, and integration of distributed renewable energy resources, electric vehicles and other dischargeable sources (Morgan et al. 2009; Kossahl, Kranz, & Kolbe, 2012).

Yet, the deployment and integration of smart grid technologies presents significant knowledge challenges to electric utilities. Studies in IT adoption have pointed out that knowledge barriers are always a big issue in the adoption of new IT innovations (Attewell, 1992; Fichman & Kemerer, 1997), especially when it comes to complex organizational technologies, which “impose a substantial burden on would-be adopters in terms of the knowledge needed to use them effectively” (Attewell, 1992). This is exactly the case in the electric utility industry. Smart grid is primarily a mix of information technologies including digital equipment (e.g. smart meters and sensors), two-way data communications, software programs and data, all of which need to be integrated with each other and with the electrical infrastructure.

<table>
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<th>AMI</th>
<th>CS</th>
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related

systems

Technology features

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Technology requirements refer to the knowledge regarding the hardware and software infrastructure, and
technology features and standards to install, modify, implement and manage the IT technologies or

systems (Benbasat, Dexter, & Mantha, 1980). Business and managerial requirements refer to those

related to the impact of new IT innovations on the current organizational structure as well as the

integration of new technologies and business processes (Armstrong & Samamurthy, 1999; Boynton,

Zmud, & Jacobs, 1994). In one study, Robey, Ross & Boudreau (2002) specially examined the adoption

of enterprise systems (e.g. ERP) and observed that system customization and configuration and business

processes and management structure adaptation are two key requirements for adoption.

Project management is another dimension considered important in IT adoption (Nambisan &

Wang, 2000). Organizations with project management knowledge and skills are able to complete projects

\begin{table}
\centering
\begin{tabular}{|l|l|l|l|}
\hline
IT systems & Meter data & Energy dashboards and & Two-way SCADA, Wide \\
& management & home energy management & area monitoring system \\
& system (MDMS) & system (HEMS); demand & (WAMS), Automatic recovery \\
& & response management & system \\
& & system (DRMS) & \\
\hline
Communication & Two-way & HAN (home area & Communication \\
network & communication & networks) & infrastructure \\
\hline
Physical Power & Smart meter, in-
Infrastructure & home displays, & Backhaul WAN \\
& home displays, & routers, in-home & between AMI and \\
hardware & servers, relays & displays, electric & utility \\
& & vehicles & \\
\hline
\end{tabular}
\caption{Components of Smart Grid}
\textit{Source: Adapted from Leeds, 2009.}
\end{table}

Compared to many well-studied complex technologies, smart grid is even more challenging in
terms of its scale and complexity, thus creating higher knowledge barriers for adopters. Yet, like many
regulated industries, electric utility companies operate in a relatively predictable and slowly changing
technology environment, often having no incentive to take advantage of technological advances (Energy
Information Administration, 2000). Compared to more innovative companies (e.g. IT companies), utilities
are widely recognized as being slow to innovate, and IT has played only a supporting role in the business.
The fact is that utilities have a lot of knowledge and skills related to electricity, but limited IT expertise. As
a result, utilities are facing a number of knowledge challenges as they move forward with smart grid
deployment (Berst, 2014). For instance, a big headache for many utilities now is big data, which presents
challenges in management, analysis and use (Oracle, 2013).

Given this context, it is important to understand how utilities are overcoming the knowledge
barriers to adopt and integrate smart grid new technologies. This study aims to advance such
understanding by focusing on the following research questions: 1) what knowledge requirements are
critical for smart grid adoption and what knowledge gaps are faced by utilities? 2) how are utilities
responding to these knowledge gaps; and 3) what factors help explain differences in utilities’ responses.

2 Literature Review
In order to answer these questions, we look to the literature in two areas. For question 1, we look at IT
adoption research on the general knowledge requirements and gaps in IT adoption. For question 2 and 3,
we look at organizational learning research on how firms identify and acquire new knowledge as well as
factors might help explain the variance in learning strategies.

2.1 Knowledge Requirements and Gaps in IT Adoption
Four areas of organizational-level knowledge are found critical to facilitating IT adoption, including
technology related, business and managerial related, project related, and data related knowledge.

Technology requirements refer to the knowledge regarding the hardware and software infrastructure, and
technology features and standards to install, modify, implement and manage the IT technologies or

systems (Benbasat, Dexter, & Mantha, 1980). Business and managerial requirements refer to those

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Project management is another dimension considered important in IT adoption (Nambisan &

Wang, 2000). Organizations with project management knowledge and skills are able to complete projects
on time and budget and achieve expected project benefits, laying ground for the long-term business value realization. In general, project related knowledge and skills involve upfront planning in the pre-implementation phase such as clear business visioning and effective planning of education and training (Al-Mashari et al., 2003; Maybert et al, 2003), implementation management during the project stage such as budget tracking and vendor monitoring and management (Abdinnour-Helm et al., 2003; Somers & Nelson, 2004), and post-implementation evaluation (Ross and Vitale, 2000).

Finally, knowledge with regard to data integration, management and mining is found necessary in recent studies (Seddon, Calvert, & Yang, 2010). It is especially important in complex IT adoption where new IT systems integrate various organizational units, and adopting organization needs to pull data from multiple computer-based systems and make good use of them.

It has to be admitted that the specific requirements under each knowledge area likely depend on the technology type. For instance, the findings regarding the technical requirements for enterprise system adoption may not apply to studies examining other IT innovations, such as the challenge of using standardized packages to meet various requirements is unique to the enterprise systems.

What’s missing in the literature is the discussion on knowledge gaps in IT adoption. In many studies, knowledge requirements and gaps are used interchangeably--knowledge gaps identified in many studies actually refer to the knowledge requirements. Yet they are different concepts: companies facing certain knowledge requirements may not see them as barriers as their existing competencies already meet the requirements. In other words, the knowledge gaps associated with an IT innovation equal to the knowledge requirements posed by the innovation minus what the adopting organization already knows. In this sense, understanding knowledge gaps in IT adoption brings more theoretical value, as it depends on the width and depth of an individual organization’s existing knowledge base, which can be affected by a number of factors such as size, organizational prior experience, extent of deployment, culture, etc. Unfortunately, the dearth of research results in a far less understanding here.

2.2 Learning Strategies in Bridging Knowledge Gaps in IT Adoption

In response to the knowledge gaps posed by IT adoption, acquiring and learning new knowledge becomes urgent for adopting organizations (Attewell, 1992; Fichman & Kemerer, 1997). Knowledge acquisition is an important topic in the literature on organizational learning. In an early work, Huber (1991) elaborated four main processes that are integrally linked to organizational learning: knowledge acquisition, information distribution, information interpretation, and organizational memory. He argued that many formal organizational learning activities are intended to acquire new knowledge or information. Building on his work, knowledge acquisition has been increasingly defined in organizational learning where learning is viewed as a knowledge management process that involves knowledge creation/acquisition, storage/retention, transfer and application (Alavi & Leidner, 2001; Argote & Miron-Spektor, 2011). Thus, knowledge acquisition is one critical step through which new knowledge is obtained.

Learning is conceptualized as an iterative cycle that involves many sub-processes and activities (Argote & Miron-Spektor, 2011; Mahapatra & Lai, 2005). Activities related to knowledge acquisition include internal training and education (Edmondson, Bohmer, & Picano, 2001), experiential learning (Cardinal & Hatfield, 2000), knowledge sharing and transfer (Zollo & Winter, 2002), benchmarking (Friesl, 2012), role model imitation (Friesl, 2012), informal contacts (Cooper & Folta, 2000), hiring (Song, Almeida & Wu, 2003), collaboration with third parties and contracting (Grimpe & Kaiser, 2010; Hendry & Brown, 2006; Hibbert & Huxham, 2005) and consulting and advice from experts. Altogether, these studies indicate that learning activities are not confined to the narrow boundary of the organization, but also take advantage of the external environment.

There have been several attempts to systematize learning activities in the literature. Different categorizations also reflect different strategic choices that a firm needs to decide to direct its learning process, given limited resources and management attention (Bierly & Chakrabarti, 1996). These include balancing between internal and external learning (Cohen & Levinthal, 1990; Grant, 1996; Bierly & Chakrabarti, 1996; Clecq & Dimov, 2008), between exploitative and exploratory learning (Bierly & Daly, 2007; March, 1991), between rapid and incremental learning (Bierly & Chakrabarti, 1996), and between the depth and breadth of a firm’s knowledge base (Bierly & Chakrabarti, 1996). In this analysis, we focus on the internal vs. external distinction, as we are interested in the knowledge acquisition process where utilities look for different types of knowledge needed to adopt a complex set of smart grid technologies.

According to Bierly and Chakrabarti (1996), Choi, Poon, & Davis (2008), and Kessler, Bierly, & Gopalakrishnan (2000), the distinction between internal and external learning lies in the boundaries of the activities—"internal learning occurs when organization members generate and distribute new knowledge within the boundary of the firm" whereas "external learning occurs when boundary spanners bring
knowledge from outside sources via acquisition or imitation” (Bierly & Chakrabarti, 1996, p. 124). Internal learning can be realized through reflecting on prior experience, member communication and brainstorming, and internal education and development (Bierly & Chakrabarti, 1996; Grant 1996). In contrast, external learning relies on identifying and transferring knowledge from outside sources such as strategic alliances, consultants, technology vendors, competitors, customers and publications (Inkpen, 1998; Kessler et al, 2000; Yli-Renko, Autio, & Sapienza, 2001). Researchers have recognized the importance of both types of learning: internal learning helps a firm develop core, inimitable capability to maintain its competitive advantage while external learning broadens a firm’s knowledge base by bringing necessary but missing knowledge and increases its adaptability to the changing environment (Bierly & Chakrabarti, 1996). The internal vs. external framework is not without its limitations. Friesl (2012) criticized its lack of ability in clearly categorizing some knowledge acquisition activities. Building on previous work, he extended the internal/external distinction and proposed four types of learning: collaborative learning, internal learning, market-based learning, and practice-based learning. Despite the disagreement, the above studies generally follow a source-based view to differ knowledge acquisition activities.

It has to be noted that internal and external learning are mutually interdependent and complementary. On one hand, the ability to identify, interpret and internalize external knowledge depends on the depth and diversity of internal knowledge (Cohen & Levinthal, 1990); on the other hand, external learning is beneficial and necessary when a firm lacks required knowledge to invest successfully in certain domains or technologies (Clecq & Dimov, 2008). Two studies provide empirical evidence that internal and external learning can coexist and achieve a better performance as opposed to a single-mechanism approach (Cassiman & Veugelers, 2006; Grimple & Kaiser, 2010).

However, firms in many situations end up with trading off between internal and external learning, especially when they are constrained by limited financial and management resources or affected by organizational characteristics (Bierly & Chakrabarti, 1996; Kessler et al, 2000). First, different types of knowledge are found to influence a firm’s learning behaviors as well as strategies (Friesel, 2012; Robey et al, 2012; Santhanam et al, 2007). Cohen and Levinthal (1990) and Bierly and Chakrabarti (1996) stressed that firm specific, core knowledge are more likely to be internally developed as opposed to external hiring or contracting. Second, organizational characteristics such as age and size can have an impact on learning choice. Gopalakrishnan and Bierly’s (2006) study indicated that larger firms tend to adopt internal learning to keep pace with the external trends whereas smaller firms rely on both internal development and strategic alliances. They also found that younger firms favor external learning more than older ones. In another study, Jansen, Frans, Bosch, & Henk (2006) revealed that a formalized structure is conducive to internal learning and dense, external relations have a positive impact on both internal and external learning. Finally, the extent of turbulence in the external environment has also been recognized. In a same study, Jansen et al (2006) showed that a more dynamic and changing environment would result in a higher level of external learning as firms tend to avoid obsolesce of their existing knowledge base as well as their core competences.

3 Research Methodology

The literature provides a rich ground in terms of understanding general knowledge requirements in IT adoption and common learning strategies in knowledge acquisition. However, the smart grid context is different in important ways from those in which existing research on these issues has been situated. First, unlike previously studied IT innovations, smart grid adoption entails close interaction with certain stakeholders such as regulators and customers. Hence, knowledge areas that are more specific to the utility industry, like regulatory requirements and customer education, might also be critical in this study. Additionally, the complexity of smart grid as well as the historical lack of innovativeness in the utility industry suggests that utilities will face bigger knowledge gaps in smart grid adoption. Lastly, organization learning is often examined in knowledge-intensive industries characterized as fast change and frequent learning and little work have been done in a regulated, less innovative industry. Given the difference, the knowledge barriers that utilities encounter as well as their learning strategies are expected to be different in this study. Thus we take an exploratory approach to understand how firms operate in this context, rather than a more explanatory approach to test existing theories. Qualitative methods are useful in uncovering context-specific factors and it is especially suited to understanding the adoption of a new, complex set of information technologies and associated knowledge challenges (Creswell 1998; Yin 1994).

We use a series of semi-structured interviews with utility companies to gather detailed information from the electric utility sector. We identified actors that are directly involved in smart grid adoption. Some of these have titles such as Smart Grid Project Manager, while others are managers in engineering,
operations and IT who we identified as having a leadership role. We identified participants from the Department of Energy Smart Grid reports for utilities receiving DOE grants at SmartGrid.gov (https://smartgrid.gov/recovery_act/project_information). Others were identified from news articles about utilities’ smart grid programs.

Between May 2012 and May 2014, we interviewed over 40 individuals in 25 U.S. utilities, including investor-owned, cooperative and municipal forms, covering 16 states with a variety of policy and regulatory contexts. For each participant, we promised the confidentiality of his/her name and the organization and asked for his/her consent on audio recording and transcribing. In one situation, the participant did not allow recording and then notes were taken and later transcribed. In addition to the interview, archival data is a main source of information in our study. We have collected a large number of documents such as industry reports, academic papers, and news articles on knowledge challenges with smart grid adoption. Information from these sources helped to confirm or elaborate on information in the interviews, as multiple data collections help increase the reliability of our findings (Yin 1994).

Transcribed interviews, in conjunction with secondary data, were analyzed using both open and axial coding. During open coding, an initial set of codes was developed. These codes were later read multiple times to be further conceptualized and categorized. Three researchers coded each interview to ensure the inter-coder reliability (Krippendorff, 2004). Then, these open codes were examined to identify the relationships between them—some codes are grouped under a higher order concept during the axial coding. These findings are discussed in the next section.

4 Findings

4.1 Knowledge Requirements and Gaps in Smart Grid Adoption

Through the interviews, we confirmed that most utilities are challenged by IT-related knowledge requirements. Although some of them are commonly associated with IT adoption in other industries, others were more specific to the electric grid and not familiar to most IT professionals. In general, we found that utilities investing in smart grid are facing five broad knowledge/skills requirements:

**Technology evaluation, installation and management:** Utilities face a formidable task of testing, installing and managing new technologies. Smart grid technologies are still evolving and many features need to be further polished. Thus, to reduce the risk of deployment failure, utilities need to possess strong technology evaluation skills to test and simulate new applications before large-scale deployment. This is true in other industries, but the risks associated with smart grid technologies go beyond the loss of money or time—they can involve the lives and safety of utility crews and customers. Also, investor-owned utilities usually have to ask regulators to approve adding investments in new technologies to their rate base after they are installed. As a result, in the words of one interviewee at a large utility:

“The first thing we want to do is make it work in a testing environment. And then we will move into a small pilot and make sure we can replicate what we do in the testing environment. And make sure we can replicate that pilot stage and work with the (whole) system. It’s a long process to get things put together and move forward. You need to make sure that people are comfortable with it, (and) the regulators like what we are doing.”

**System integration:** To achieve greater business value, utilities need to break the traditional “system silo” pattern and allow independent systems to communicate with each other to enable a smart, unified grid. This requires utilities to determine what communication platform to build, what data to collect and integrate, and who has the ownership of, and access to, different data. This has not been the case in the past, according to an interviewee:

“That (integration) is a challenging stage for all the utilities because all the facilities we installed, the IT systems in our history were chosen for their own merits and didn’t necessarily link with other systems. Now with increased technology capability and ability to link one system to another, you really need to link them together.”

In addition, there is a need to integrate IT with operational technologies that make up the electric grid, and this presents a different knowledge challenge from those faced in most industries. The people who run the electric grid have always been electrical engineers and technicians without IT skills, and few IT professionals have any background in electric power technologies. In the words of one interviewee:
“Utilities had a lot of technologies but IT was not part of that. So when you go inside a substation, and transmission and distribution, up until the early 80’s, you wouldn’t find any equipment with communications installed, and there is no computing and there is no integration and no IT.”

**Data management, analysis and application:** Big Data is an opportunity and challenge for many industries, but the volume and variety in smart grid stands out. Utilities are receiving 15-minute or even 1-minute interval data from the Advanced Metering Infrastructure (AMI) system, not to mention the large volumes of data available from other sources (e.g., sensors, repair records, customer calls), and some talk of integrating external data such as weather reports or social media. Utilities need to advance their data analytic and management skills to capture, analyze and use all this data. Also crucial to utilities is the data application: utilities need to figure out how to take full advantage of these data to improve their daily operations or customer service capabilities. One example shows how data can be applied to improve functioning throughout the grid:

“(We can) utilize the AMI data for some of the, I guess more operational activities such as outage notification and verify restoration after repairs have been made and terminating the consumption or individual meters but also being able to roll that up to a transformer and understanding a little bit more accurately what type of loads or demands our equipment is experiencing. Then we did our distribution automation project in which we deployed about 1200 automated switches on our 12KV system that have the smart locating, isolation and service restoration capabilities.”

**New business processes:** As smart grid technologies are integrated with legacy systems, IT is built into daily operations, entailing new business processes and work routines. Current processes and related skills, such as meter reading, can become obsolete. This requires utilities to develop new business processes as well as new management structures.

**Project management:** For utilities, smart grid investment involves managing a number of projects in parallel. This requires utilities to develop strong multi-project management skills to meet project goals on time and budget.

Among the five types of knowledge requirements, the biggest knowledge gap is perceived in data management, analysis and application and system integration. Almost all utilities admit that these two areas are a big concern for them, as they never had the experience in handling such big amounts of data. One interviewee stated:

“What we’ve got is 4 different systems: we’ve got an Itron meter data management environment, we’ve got a customer service billing environment, we’ve got the HAN (home area network) environment which you know is the thermostats environment and then we have the substation automation and distribution automation environment. So, all those systems are different platforms that we have to somehow connect to be able to do analytics. Maybe we don’t want to connect them all but that’s our challenge now.”

However, one municipal utility mentioned that system integration is not a headache for them as they have been working on the communication platform since late 90’s. One of their managers mentioned:

“I think that’s a big challenge in the smart grid is what communication platform to (adopt)... You know, if you cover 7 states, you are going to have a series of communication environments and getting all those work together. So for us, it is easy and we deployed fully out there.”

Technology evaluation is also perceived as a challenge to many utilities. Although many interviewed utilities have long experience in experimenting with precursor technologies, they admit that the scale of smart grid makes technology evaluation especially challenging. Process assimilation and project management do not pose a big threat to utilities that have rich project experience, however, they result in big challenges for utilities that are less experienced.

It seems that experience is a key factor in moderating the knowledge gaps. Utilities with extensive and long-term experience experimenting with new technologies face a lower level of challenges. The stage of adoption also plays a role here—when utilities are in the piloting stage, many of the knowledge requirements do not seem to pose a threat to utilities, but they became more apparent and urgent during later stage of adoption with full-scale deployment.
4.2 Utilities' Responses to Knowledge Challenges with Smart Grid Adoption

In order to address the aforementioned knowledge and skill gaps, utilities have initiated various learning activities and practices to deal with the challenge. These activities are listed as below:

- Internal training and education: A common practice among utilities is to provide formal training for their employees. The education mainly focuses on the concept of smart grid and more importantly, the new processes and change management issues that are entailed as a result of smart grid adoption. It's interesting to see that training effort varies, ranging from a minimal 20-30 minutes introduction to a more aggressive one. In one case, to make the transition as smooth as possible, a utility has identified and documented over 400 business processes affected. For each process they examine the business and technology requirements, determine process gaps, and prepare knowledge transfer and training. As a result of their aggressive education program, the training involves almost every person within the organization.

- Internal hiring: A few utilities have used internal hiring to overcome knowledge hurdles. They usually create new IT positions and hire people from IT or engineering department with extensive technical knowledge.

- Internal knowledge sharing and transfer: Many utilities also encourage communication between different departments. Such collaboration can happen at different levels, from project staff leads up through the senior officers. These utilities usually hold meetings where all managers or employees representing different parts of the company (e.g. IT, HR, distribution and transmission, customer and regulatory department) can sit together periodically to share their operations issues and solutions with regard to smart grid.

- Internal testing labs: Quite a number of utilities have built their own research labs to simulate and test various new smart grid technologies, such as advanced sensors, meters, and control systems. For each technology, they would test equipment from various vendors and compare their functionalities. The importance of developing internal capability to evaluate new technologies in the lab has been widely acknowledged.

- Hiring new technical people: When specific skills are needed that are not available internally, but are seen as a long-term need, many utilities hire new technical professionals, although this usually is in the range of one to five people.

- Contract with vendors or consultants: All interviewed utilities agree that they do not have all the available skill sets and do not want to hire staff to meet every need. In this case, many work with IT vendors to understand specific technologies, or contract with external consultants to fill the knowledge gaps. This is especially common in implementation of new technologies, but several utilities said that they try to bring the operation of these technologies inside the company for the long run.

- Industry benchmarking: Most utilities state that they learn best practices from other utilities. Sometimes managers directly call their industry peers to share the updates on their smart grid deployment, but the main outlets are through industry conferences, seminars/workshops, and meetings from professional associations where people with various backgrounds can meet and learn from each other. Additionally, utilities can learn from media, industry journals, or even visit other leading utilities. One utility was excited to mention that they have a very big demonstration center showing various cutting-edge smart grid technologies. They usually give 2-3 tours per week and the biggest group in their site visitors is peer utilities that want to learn from their successful experience.

- Collaborating with research institutes: Some utilities choose to collaborate with universities or research agencies on specific tasks or technological solutions. They see it as a complementary to the contracting, as it's always beneficial to learn from multiple sources.

We found that no utilities in our interview have followed a pure internal or external learning strategy, but employ a mixed strategy in addressing these knowledge issues. For instance, although the extent of effort varies, all utilities have components of internal training and education, external hiring or contracting and industry benchmarking. The difference lies in the configuration of various learning activities and the ratio of internal/external learning. Some utilities are very internal oriented although they
still use contracting resources or hiring external people to fill in the knowledge gaps whereas a few others are external-oriented and contract most of their IT demands. The rest tends to make a balance between the two. In fact, utilities’ learning choices really depends on the interaction of a number of factors.

4.3 Antecedents of Utilities’ Responses

Utility strategies for acquiring IT knowledge required for smart grid adoption depend on the types of IT knowledge and skills needed, the nature of the organization, and the external environment.

Types of IT knowledge Required: Skills and knowledge that are likely to be of long-term value, such as technology evaluation, system operation and maintenance, and new business assimilation are generally hosted internally, as utilities see the ongoing value of such skills and knowledge. One interviewee stated:

“There’s a huge learning curve but at the end we’ve now got, you know, a good handful of people who have excellent knowledge of how to run the system, how to operate the system, so through the deployment, we build a strong base…we didn’t want to try to utilize a contractor or consultant or anything like that, because we didn’t want that knowledge to walk out the door. So, we chose to develop the expertise in-house.”

To address these types of knowledge challenges, utilities typically provide formal training and develop internal R&D to meet the demands. Skills in system integration are also critical; however, given the lack of these expertise in the industry in general, utilities are unlikely to have such skills internally. So many choose to buy software from vendors and work with external consultants to deploy and integrate the needed tools, but develop the skills to use those tools internally.

One area that is so early in the adoption stage that it’s difficult to see clear patterns is data management and analysis. Most utilities are either in the piloting stage of the smart grid adoption or use the data in a limited way in which are they are able to handle the amount of data they are facing. Nevertheless, they all admit that data analytics and management will be a big challenge to them once they are dealing with more data. In Texas, the four largest utilities created a common data repository in conjunction with IT vendors rather than try to go it alone, but a similar proposal in California was described by one interviewee as raising significant privacy issues. In terms of technology installation and project management, some utilities choose to hire special professionals or contract it over to consulting firms, but usually in conjunction with internal staff.

Organizational factors: Two organizational factors are found to be influential. First, size and financial resources matter. Small utilities, especially coops, face financial pressure due to the cost of IT solutions and respond by limiting their initial uses of metering and other data—mainly for meter reading, improving billing accuracy and theft detection, or hiring a few IT professionals to address particular problems. To them, hiring is much more cost-effective than contracting. One interviewee explained:

“That [big data] has been a really struggle but that has been a struggle with lots of the coops, a lot of rural coops because you don’t have the room full of IT people and computer science guys to take care of the information. So that’s where the meter data management system has the value to it, especially to a small coop. However, you can’t say ‘hey guys, this is a really great investment that can deal with all information and only by the way it’s $500,000 not to mention the annual maintenance of 20% each year’.”

In comparison, larger utilities including IOUs and some bigger municipals can more readily afford to pay outside consultants. Due to their adequate resources, they are also capable of enabling internal hiring, encouraging internal knowledge sharing, and collaborating with universities or other research institutes to maximize their learning. As a result, they integrate more functions in their data use, including outage detection, load forecasting and management, asset management, and demand response. Whether they use internal or external learning processes depends on the nature of the knowledge, and may vary from one function to another.

Second, utilities with rich prior experience with precursor technologies such as one-way SCADA systems or automatic meter reading generally have accumulated a set of technical, managerial and problem-solving skills and are more inclined to rely on their existing staff to address many of the skills and knowledge challenges. Those with less experience are more likely to outsource.

Less obvious is the influence of ownership structure. It might be expected that investor-owned utilities, which need to justify investments based on financial value, might seek to minimize costs, or to focus on developing knowledge that would directly impact their profitability, but we didn’t see clear evidence of this. It might also be expected that government-owned municipals would be less innovative
and therefore less interested in developing skills and knowledge to support innovation, but we didn’t see this either. Whatever differences we found could be explained by size as well as by ownership.

**Environmental factors:** In addition to the aforementioned knowledge and organizational factors, we also looked at whether state regulatory environment or competitive environment plays a role in utilities’ responses. As we noted above, utilities are regulated companies and state regulators’ attitudes and regulatory process greatly influence and constrain utilities’ investments in smart grid (Dedrick et al., 2014). We did see some possible effects; for instance, traditional utilities in Texas no longer compete in retail markets, and were willing to work together on Smart Meter Texas data repository. But we did not see systematic evidence of differences across states—such evidence might require a larger sample to show up.

5  Discussion

In summary, our analysis reveals five types of IT-related knowledge that are essential in smart grid adoption and uncovers utilities’ responses to these challenges by linking learning strategies, knowledge acquisition activities, and explanatory factors in a qualitative research design. Our findings regarding the knowledge requirements is largely consistent with the IT adoption literature but we have filled an important gap in the literature by identifying knowledge gaps in the context of smart grid technology adoption by regulated utilities. Our study also indicates that these knowledge gaps depend on the depth and width of utilities’ existing knowledge base, which is further affected by the extent of smart grid adoption as well as the length and richness of utilities’ prior experience with precursor technologies. It turns out that the more extensive the smart grid investments, the bigger the knowledge hurdles. However, they can be mitigated if utilities are technologically experienced.

Second, our findings support the argument that internal and external learning are complementary, as firms cannot rely on a single approach to acquire all needed knowledge and skills. We found that, on one hand, the most internally-oriented utilities still hire external people or use contracting resources occasionally to meet specific demands or send their staff to various industry conferences and workshops to benchmark with their peers; on the other hand, the most externally-oriented utilities would develop some knowledge internally to retain their core competencies. As one interviewee pointed out,

“The effectiveness of contracting depends on your internal knowledge capabilities. You should have enough staff to understand and communicate with the consultants.”

We also found that internal training and lab testing are the most frequently employed practices in internal learning to overcome knowledge barriers, whereas external hiring and contracting are the most common forms of external knowledge acquisition. Although many utilities also adopt practices such as internal knowledge sharing and industry benchmarking, they regard these as supportive as opposed to aforementioned decisive activities. Our analysis further implies that the configuration of these learning activities is determined by a mix of knowledge and organizational factors. We argue that the knowledge types, utility size and prior experiences together shape utilities’ responses to knowledge challenges with smart grid adoption.

Finally, it’s somewhat surprising that differences in state regulation doesn’t appear to play a big role in utilities’ learning choices. One explanation would be that regulatory environment mainly influences utilities adoption decision with regard to smart grid technologies (Dedrick et al., 2014), but once utilities decide to invest in smart grid it’s up to internal factors to impact their responses to knowledge challenges.

6  Conclusions and Future Research

IT knowledge barriers have been widely acknowledged as one of the main factors influencing organization’s IT adoption outcomes and learning is needed to address such challenges (Attewell, 1992; Fichman & Kemerer, 1997). However, few studies examine this topic in regulated industries. This study enriches both IT adoption and organizational learning literature by exploring the types of IT knowledge required and learning strategies in the context of a slow-moving industry suddenly faced with disruptive new technologies. Specifically, we contribute to the existing literature by proposing a more comprehensive taxonomy of knowledge requirements in such a unique context, uncovering knowledge gaps in these knowledge domains, and understanding firms’ learning behaviors by identifying the underlying learning activities as well as the dynamics among these activities.

This study also has implications for utility companies, as it’s urgent for them to address knowledge barriers to continue their smart grid adoption and use. Smart grid requires new knowledge in areas such as technology evaluation, system integration, and data management and analytics, and
utilities need to make a series of decisions regarding what skills are developed internally and what activities are contracted out to overcome knowledge gaps. For would-be adopters, our findings would inform them the types of knowledge challenges they would encounter and what learning choices they have to smooth their adoption. For those that are already invested in smart grid and facing the knowledge challenges, our study could help them better evaluate their learning behaviors and identify possible adjustments to their existing strategies.

Our understanding of organizational learning would benefit from quantitative analysis of a larger sample of utilities. Further research could build on the notion of learning activities and statistically investigate the configuration of these activities and its antecedents. Moreover, future research could investigate how these learning strategies would impact adoption outcomes and long-term performance of utilities.

7 References:


