Association for Information Systems
AIS Electronic Library (AISeL)

AMCIS 2011 Proceedings - All Submissions

8-6-2011

Demand Management in the Smart Grid: An Information Processing Perspective

Jacqueline Corbett
Queen's University, jcorbett@business.queensu.ca

Demand Management in the Smart Grid: An Information Processing Perspective

Jacqueline Corbett
Queen's University, Kingston, Canada
jcorbett@business.queensu.ca

ABSTRACT

Driven by concerns regarding environmental sustainability, energy security, and economic growth, a fundamental transformation is taking hold in the electricity sector. Advanced communications technologies and information systems (IS) will play a central role in the realization of the 'smart grid', an intelligent and multi-directional electricity supply chain from generation to end-user consumption. IS embedded in the smart grid will provide opportunities for improved business practices such as dynamic, near real-time demand management, allowing a better utilization of existing electricity supply capacity and contributing to reductions in carbon emissions. Although opportunities exist, utilities face challenges adapting to the smart grid environment. Drawing on information processing theory, this paper develops a model of how IS can improve the effectiveness of electricity demand management. The model suggests practical implications for demand management performance of utilities and contributes to our understanding of the role information systems can play in achieving environmental sustainability.

Keywords

Smart grid, electricity demand management, information processing, green information systems, Green IS

INTRODUCTION

Driven by concerns regarding environmental sustainability, energy security, and economic growth, a fundamental transformation is taking hold in the electricity sector. This transformation is often captured within the term 'smart grid', a rather nebulous label that broadly speaks to the modernization of the electricity sector, including the introduction of distributed and renewable energy generation, self-monitoring and self-healing infrastructure, and advanced metering infrastructure (e.g., smart meters). Since the introduction of electricity over a century ago, the traditional electricity grid has developed around a linear one-way model in which there exist large central generation facilities that push electricity downstream to the end users. Enabled by more sophisticated information systems and technologies, the emergent electricity value chain will be characterized by network flows of electricity and new, two-way information flows from the electricity generators, distributors and customers (IBM, 2010). More specifically, then, the smart grid is defined as the suite of advanced information and power technologies deployed in the generation, transmission and distribution of energy and resulting in an intelligent and integrated environment (McDonald, 2008). The smart grid will dramatically change how the power industry operates and the behaviours of all energy consumers. As one observer noted: "borrowing from the lessons learned in telecommunications and information technology, the 'Smart Grid' will one day be an agile, responsive and 'intelligent' network — nearly the exact opposite of what it is today" (Hsuan, 2010).

Although the smart grid hold enormous promise, many hurdles stand in the way of making it a reality: engineering work to upgrade the grid infrastructure (Farhangi, 2010); concerns regarding security and privacy (Cavoukian, Polonetsky and Wolf, 2010); and controversy around time-of-use pricing (Herter, 2007). This has led to predictions of a bumpy road ahead (Haring, 2010) and suggests that more research on the smart grid is required. Thus far, smart grid research has been conducted within the prevue of the energy engineering, ecological economics, and environmental psychology literatures. There has been little investigation regarding the opportunities, challenges and impacts from an information systems (IS) perspective, even though explicating the role of information in the efficient, reliable and secure delivery of electricity falls within the discipline's core expertise and represents a vital contribution to the realization of a 'smart' grid.

The purpose of this paper is to investigate IS impacts within the context of one specific business practice, demand management, associated with reducing the environmental impact of the electricity grid. Around the world, the burning of fossils fuels to generate electricity is a major contributor to greenhouse gas emissions causing significant climate change (Kharecha, Kutscher, Hansen and Mazria, 2010). Although developing renewable energy sources is an important part of the green electricity strategy, demand management, or activities that help to reduce or time-shift demand, are also essential (Browne, O'Regan and Moles, 2009). Electricity demand management (EDM) programs have been in place for many years but have traditionally been passive and educational in nature, rather than actively responding to demand conditions. The introduction of information technologies into the smart grid will change the game of EDM, providing new opportunities and complexities. Thus, this paper seeks to address two questions: What new information processing requirements and capabilities will be necessary to support electricity EDM in the smart grid environment? How will these information processing requirements and capabilities affect EDM effectiveness? To investigate these questions, Galbraith's (1977) information processing perspective provides a valuable theoretical starting point. This paper posits that the smart grid will increase the complexity of EDM, that utilities must respond by developing an appropriate set of information processing capabilities, and that the fit between the requirements and capabilities will influence EDM effectiveness.

The remainder of this paper is organized as follows. In the next section the literatures related to information processing theory and demand management are reviewed. Following this, the theoretical model with propositions is developed. The paper then concludes by outlining the contributions and limitations of this work.

LITERATURE REVIEW

Although many questions remain to be answered, there is consensus that the smart grid will add an unprecedented level of complexity to the power network (IBM, 2010). Among the most significant changes is the availability of new and multi-directional information flows. For decades, North American utilities have relied on the manual reading of customers' electricity meters on a periodic basis. Not only is such information not timely in terms of enabling decision-making, it is aggregated at such a level as to be of little value beyond the generation of customer bills (IBM, 2010). Over time, incremental improvements have been made to improve efficiencies in managing the demand side of electricity, such as the use of hand-held remote devices to collect usage data, or internet portals to report and monitor outages. Utilities have made incremental investments in IS to process bills and provide customers with period-to-period usage information. However, with the introduction of new information and communications technologies, the smart grid will dramatically increase the frequency, volume and quality of information that can be collected by utilities. Because information resides at the core of more proactive EDM strategies, the information processing perspective provides an appropriate lens for understanding the impacts of IS.

Information Processing Theory

Information processing refers to the accumulation, analysis, and synthesis of information in the context of organizational decision-making (Galbraith, 1977). Effective information processing occurs when the appropriate information is collected, information is exchanged in a timely fashion, and there is no distortion of information during transmission (Tushman and Nadler, 1978). Organization information processing theory (OIPT) suggests organizational effectiveness is affected by the level of uncertainty, where "uncertainty is the difference between the amount of information required to perform the task and the amount of information already possessed by the organization" (Galbraith, 1977, pp. 36-37). The information required to perform a task depends on a number of factors, specifically the nature of the task, task environment, inter-unit task interdependence, as well as the desired level of performance (Galbraith, 1977; Tushman and Nadler, 1978). Information processing capabilities are a function of prior experience (Galbraith, 1977) and are affected by organizational structures and coordination and control mechanisms (Tushman and Nadler, 1978). In addition to uncertainty, organizations also process information to reduce equivocality, which means ambiguity or the existence of multiple and conflicting interpretations about a situation (Daft and Lengel, 1986). To the extent that uncertainty or equivocality exists in an organization, performance may be hindered (Daft and Lengel, 1986; Galbraith, 1977; Tushman and Nadler, 1978). Information systems and technologies which facilitate gathering of data, transformation of data to information, and communication and storage of information, play an increasingly important role in information processing by organizations (Fairbank, Labianca, Steensma and Metters, 2006).

Building on this seminal work, OIPT has been fruitfully applied in IS research (e.g., Fan, Stallaert and Whinston, 2003; Mani, Barua and Whinston, 2010). Because customer demand represents one end point of the supply chain, the literature related to supply chain management (SCM) is of particular relevance to this research. Research suggests that SCM has additional uncertainties associated with information processing arising from the complexity of integrating across both upstream and downstream partners (Bozarth, Warsing, Flynn and Flynn, 2009). Further, a positive association has been found between information processing requirements and the adoption of internet-based technology (Melville and Ramirez, 2008). Other studies suggest that an organization's use of IS, such as databases, explicative and predictive models, and fact-based management to drive decisions and actions, can affect organizational capabilities (Trkman, McCormack, de Oliveira and Ladeira, 2010) and that fit between information processing requirements and capabilities influences supply chain performance (Premkumar, Ramamurthy and Saunders, 2005). Collectively, this research suggests that effective management of the supply chain from raw material acquisition to delivery to customer relies on the organization's ability to effectively process information.

Demand Management

Although SCM by definition involves the complete value chain of a product or service including delivery to the customer, the extant research has focused on optimization of the supply side with relatively little attention given to managing demand (Canever, Van Trijp and Beers, 2008). However, given the importance of managing, rather than reacting to, variations in customer demand, demand management (DM) is becoming a priority in industries such as health care (Jack and Powers, 2009), travel (Anderson and Carroll, 2007), water (Zarghami, 2010), and energy (Mason, Page and Williamson, 2010). DM involves managing overall demand by optimizing use of distribution channels, leveraging customer relationships, and taking effective revenue management actions (Anderson and Carroll, 2007). DM includes numerous activities, including measuring demand across customer segments, estimating customer reactions to DM strategies, and implementing rate and availability controls, and can take many forms. One approach is demand postponement, which involves shifting demand from one time period to another. Being able to postpone demand enables the supplier to decrease initial capacity levels; but it is not without risk as the customer response to postponement may be uncertain (Iyer, Deshpande and Wu, 2003). From an IS perspective, the internet and mobile technologies are beginning to be implemented for DM. For instance, hotels, car rental companies and airlines can use web-based clearing houses (e.g., Expedia) to help manage variations in demand (Anderson and Carroll, 2007), and mobile devices have enabled carpooling programs (Buliung, Soltys, Bui, Habel and Lanyon, 2010).

Despite the complexity associated with DM, effective DM can have significant positive impacts on organizational performance (Jack and Powers, 2009), reducing environmental impacts (McCollum and Yang, 2009), or improving the effectiveness of resource management (Zarghami, 2010). Research models have also found that load shifting (i.e. demand postponement) had the biggest impact on reducing carbon emissions from electricity, highlighting the advantages of DM even with the availability of renewable energy sources (Mason et al., 2010).

In the case of electricity, where there are significant constraints on supply, DM offers the potential for both economic and environmental gains. Besides reducing the height of peak demand, DM strategies reduce the need for capital investment, stabilize loads on existing infrastructure, and allow better utilization of generation capacity (Mason et al., 2010). Historically, EDM has been relatively passive, relying on the building of excess capacity to meet peak demands, education initiatives to encourage conservations, and appliance swap-out programs. These approaches generally do not take into account real-time fluctuations in demand and thus require only low levels of information processing by the utility. However, rollout of the smart gird will provide opportunities for more dynamic EDM activities, such as near-time differential electricity rates, or demand response programs such as automatically adjusting air conditioning levels (Herter, 2007). Additionally, unlike other discrete products, electricity is a taken-for-granted resource consumed in a continuous fashion. As such demand decisions are influenced by a different set criteria and behaviors (Abrahamse and Steg, 2009). Thus, to be effective, EDM strategies will require that utilities be able to collect, analyze, and act on more and complex information, necessitating new information processing capabilities.

THEORETICAL DEVELOPMENT

As outlined, major changes are on the horizon for EDM in the smart grid environment. In developing the theoretical model, the focal point of the analysis is electricity utilities, which includes those organizations involved in the provision of electricity to customers. Although different EDM strategies may be used for residential and business customers; the model does not distinguish between the two.

To construct the theoretical model (see Figure 1), the complexities associated EDM were mapped against the factors affecting information processing requirements. This juxtaposition highlighted five main characteristics of the smart grid environment that are viewed as having the most significant effects on the information processing requirements (task characteristic, task environment, task interdependence, performance and ambiguity) and three mechanisms by which IT can increase information processing capabilities (IT support for data collection and storage, analysis and prediction, and communication).

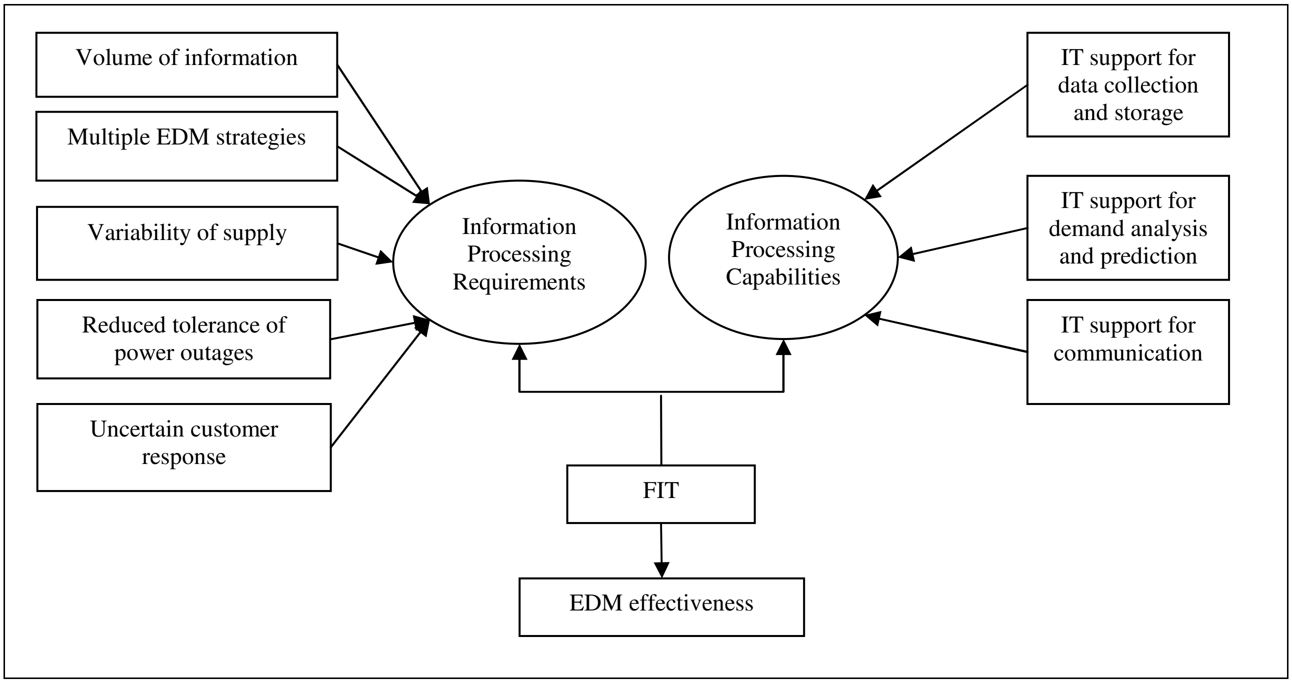

Figure 1: Theoretical Model

Task Characteristic: Volume of Information

DM involves understanding, influencing and managing demand as well as matching demand and supply over time (Lapide, 2006). Traditionally, matching of demand and supply on a near-time or dynamic basis was impossible due to the way in which demand data were gathered. Therefore, EDM activities were limited to consumer education, or static time-of-use pricing mechanisms to try to reduce peak-demand loads. In the smart grid, advanced metering infrastructure, including smart meters which capture real-time usage information, and smart appliances which can be controlled remotely by the utility or homeowner, significantly changes the nature of the task. Instead of periodic usage readings, utilities will have volumes of data at their disposal. This increase in volume will add new information processing requirements in terms of how the data are organized, analyzed and disseminated both within the organization, to consumers and across the supply chain. Thus, it is proposed that:

> P1: The greater volume of collected usage information will increase information processing requirements.

Task Environment: Multiple EDM Strategies

Becoming demand-driven means recognizing that technology alone is not enough and requires a combination of people, process and technologies (Bursa, 2008). Additionally, in certain sectors, such as utilities and other public goods, DM strategies may exist both as a business concern and a legal or regulatory constraint (Buliung et al., 2010). It is also important to recognize that, in the absence of a holistic view of the task environment, different strategies may compete with each other. For instance, in the case reducing traffic congestion, initiatives such as carpooling and flex-time may limit the ability of the other strategy to make significant gains (Buliung et al., 2010). These considerations are important to EDM as utilities may be faced with licensing requirements to achieve conservation targets and must make decisions regarding a variety of different EDM strategies. Accordingly:

> P2: Multiple EDM strategies available in the smart grid environment will increase information processing requirements.

Task Interdependence: Variability of Supply

Effective DM involves the matching of demand with the available supply in a responsive and agile manner (Anderson and Carroll, 2007). For true optimization, this may require proactive strategies and a tighter coupling between SCM and DM (Lapide, 2006). Traditionally, electricity was supplied by large generators which fed electricity one-way down the lines to meet customer demands. As the smart grid enables smaller, local generation facilities to feed into the grid, additional volatility is introduced on the supply side, particularly since renewable energy sources, such as wind or solar, are more variable depending on climatic conditions. For EDM, an increase in the volatility of the supply means that a higher degree of coordination is required between both sides of the electricity value chain. Therefore, it is proposed that:

> P3: Greater volatility in the supply of electricity from distributed electricity generation will increase information processing requirements.

Performance: Reduced Tolerance of Outages

Since the introduction of electricity, our society has become dependent on this essential resource. Power outages due to short supply or natural disasters are not only inconvenient, but also have financial ramifications. In addition, electricity is vital to human security and well-being, where the consequences of an absence of service may be a matter of life or death (Jack and Powers, 2009). Therefore, unlike other products where there may be an economic rationale for product or service outages (Iyer et al., 2003), decreasing performance levels is not feasible in the electricity sector. Moreover, with the smart grid, new technologies that can detect problems and provide self-healing hold promise for addressing reliability, resulting in an even greater pressure on the electricity sector to improve performance. Thus:

> P4: Customers' reduced tolerance of power outages will increase information processing requirements.

Ambiguity: Uncertain Customer Response

Given that advanced metering infrastructure is still relatively novel, there is limited research to indicate how customers will respond to 'smart' EDM strategies. US pilot studies have found that smart metering and flexible pricing can lead to drops in electricity consumption (Smith, 2010). To save electricity, customers are most likely to raise the temperature of the air-conditioner, shut off the hot-water heater and change when the laundry is done (Hartway, Price and Woo, 1999). However, it has also been noted that only 15-20% of customers are willing to sign up to demand response programs and 35% say they would never allow a utility to control home thermostats (economist.com, 2010). Since customer reaction to EDM strategies is critical to overall EDM effectiveness, this ambiguity raises information processing requirements by requiring that different scenarios and analyses be considered in devising and implementing strategies. Therefore, it follows that:

> P5: Uncertainty regarding customer responses to EDM strategies will increase information processing requirements.

When changes occur to increase task uncertainty, OIPT suggests that there are two general approaches that organizations can take: reducing information processing requirements or increasing the organization's information processing capabilities (Galbraith, 1977). Having discussed the information processing requirements of the smart grid environment, the paper turns now to consider how the use of IT and IS can enhance information processing capabilities relevant to EDM.

IT Support for Data Collection and Storage

As discussed, the smart grid will dramatically change the amount of information collected by utilities. In particular, smart meters that enable near real-time logging of usage, will enable utilities to capture thousands of data points regarding electricity demand under different conditions, customer segments and time of use (Raftery, 2010). In this respect, smart meters can be likened to electronic point of sale devices that provide demand information to retail organizations. However, previous research shows that both large and small companies have challenges dealing with the volumes of data, largely as a result of a lack of resources (Taylor and Fearne, 2009). In order to deal with the increase in information processing requirements of the smart grid, utilities can invest in IT to support the efficient collection and storage of this data. Thus:

> P6: Investments in IT support for data collection and storage will increase utilities' information processing capabilities.

IT Support for Demand Analysis and Prediction

New capabilities for demand sensing, such as analyzing characteristics of demand, and demand shaping are increasingly available to organizations (Bursa, 2008). It has also been suggested that sophisticated demand modeling and predictions without knowing actual demand will be crucial (Iyer et al., 2003). In the future, EDM will require that utilities undertake programs beyond customer education or static time of use pricing. Other initiatives may include demand response programs or more dynamic pricing. For these programs to meet their expected targets, demand data must not only be accurate and complete, but it must be appropriately analyzed to inform real-time decision-making. Therefore, it is proposed:

> P7: Investments in IT support for demand analysis and prediction will increase information processing capabilities.

IT Support for Communication

As compared to other organizational tasks, SCM is more complex because of the need to integrate across partners within the supply chain. As a result, organizations are investing in IS that allow coordination and communications between firms (Melville and Ramirez, 2008). With the increase in two-way information flows and the addition of more volatile renewable electricity in the smart grid, coordination and integration between the supply side and demand side activities of the utilities will also become essential(IBM, 2010). Therefore, utilities will benefit from investments in IT that enable communication across internal departments, supply chain partners and EDM functions. Accordingly, it is proposed that:

> P8: Investments in IT support for communications will increase information processing capabilities.

Fit Between Information Processing Requirements and Capabilities

According to OIPT, the fit between information processing requirements and information processing capabilities has a major influence on organizational effectiveness (Galbraith, 1977). Since being proposed, the concept of fit has been further refined (Venkatraman, 1989) and applied extensively in the IS literature to explain the effect of IT alignment on organizational performance (Chan and Reich, 2007). In the context of an interorganizational supply chain, Premkumar et al. (2005) found support for OIPT in that the fit between information processing requirements and capabilities results in better performance. Consistent with the theory and these findings, it is expected that the fit between the information processing requirements of the smart grid and the capabilities that utilities develop through investments in IT will have a positive influence on EDM performance. Therefore, the final proposition is:

> P9: The extent to which there is fit between information processing requirements and information capabilities will have positive effects on electricity demand management effectiveness.

CONCLUSION

Over the course of the next century, the electricity sector will undergo a major transformation as the smart grid becomes a reality. By investigating the impact of the smart grid on EDM, this research makes several contributions. First, the paper extends OIPT into the domain of demand management and identifies new characteristics that may give rise to additional task complexity, particularly with respect to continuous, utility-type services such as electricity. In doing so, this research may highlight information processing requirements and capabilities that have applicability beyond the electricity sector to other industries, such as cloud computing. Second, the paper responds to calls for research on green IS (Dedrick, 2010; Watson, Boudreau and Chen, 2010) and contributes to the literature by examining one particular application of how IS can support environmental sustainability at a societal level (Corbett, 2010). At a practical level, this paper may provide guidance to industry participants as they prepare for the smart grid. For instance, a logical progression of the model suggests that different types and levels of IS support may be necessary depending on the type of EDM strategy that is put in place. Therefore, rather than investing indiscriminately on IS, utilities may benefit more by developing and implementing IS that target specific information processing requirements.

Despite the contributions of this paper, there are two main limitations. First, the model requires empirical testing to be validated and enhanced. This work is ongoing as continuation of the research program. To this end, the constructs and relationships in the model will be explored using a combination of archival data and surveys of utilities, following the approach of other research in this area (Mani et al., 2010; Premkumar et al., 2005). A second limitation is that this paper explores only the information-related elements of DM. Experience in other areas has identified that behavioral shifts are necessary to make such programs effective (Mason et al., 2010). Given the need to contain the scope of this paper, these aspects are not contemplated, but would represent a valuable area for further investigation.

Since the introduction of electricity, our society and economy have become dependent on affordable and reliable electricity. With the negative effects of climate change becoming more apparent, we now also require green electricity. The smart grid, in part through new EDM strategies, provides the opportunity to deal head-on with these conflicting challenges. Information systems, which provide the capabilities to deal with the complexities of EDM, will play a central role in the transformation of the electricity grid and by extension, the extent to which we are able to achieve global environmental sustainability.

ACKNOWLEDGEMENTS

The author would like to thank Jane Webster, Brent Gallupe, Chialin Chen, Sandy Staples, Kathryn Brohman, and two anonymous reviewers for comments on an earlier version of this paper. Financial support for this research was provided by the Social Sciences and Humanities Research Council of Canada.

REFERENCES

1. Abrahamse, W., and Steg, L. (2009) How Do Socio-Demographic and Psychological Factors Relate to Households' Direct and Indirect Energy Use and Savings?, *Journal of Economic Psychology*, 30, 711-720.
2. Anderson, C.K., and Carroll, B. (2007) Demand Management: Beyond Revenue Management, *Journal of Revenue and Pricing Management*, 6, 260-263.
3. Bozarth, C.C., Warsing, D.P., Flynn, B.B., and Flynn, E.J. (2009) The Impact of Supply Chain Complexity on Manufacturing Plant Performance, *Journal of Operations Management*, 27, 78-93.
4. Browne, D., O'Regan, B., and Moles, R. (2009) Use of Ecological Footprinting to Explore Alternative Domestic Energy and Electricity Policy Scenarios in an Irish City-Region, *Energy Policy*, 37, 2205-2213.
5. Buliung, R.N., Soltys, K., Bui, R., Habel, C., and Lanyon, R. (2010) Catching a Ride on the Information Super-Highway: Toward an Understanding of Internet-Based Carpool Formation and Use, *Transportation*, 37, 849-873.
6. Bursa, K. (2008) How to Effectively Manage Demand with Demand Sensing and Shaping Using Point of Sales Data, *The Journal of Business Forecasting*, Winter 2008-2009, 26-28.
7. Canever, M.D., Van Trijp, H.C.M., and Beers, G. (2008) The Emergent Demand Chain Management: Key Features and Illustration from the Beef Business, *Supply Chain Management: An International Journal*, 13, 2, 104-115.
8. Cavoukian, A., Polonetsky, J., and Wolf, C. (2010) Smartprivacy for the Smart Grid: Embedding Privacy into the Design of Electricity Conservation, *Identity in the Information Society*, April.
9. Chan, Y., and Reich, B.H. (2007) IT Alignment: What Have We Learned?, *Journal of Information Technology*, 22, 297-315.
10. Corbett, J. (2010) "Unearthing the Value of Green IT," *Thirty First International Conference on Information Systems*, St. Louis, MO.
11. Daft, R.L., and Lengel, R.H. (1986) Organizational Information Requirements, Media Richness and Structural Design, *Management Science*, 32, 5, May, 554-571.
12. Dedrick, J. (2010) Green Is: Concepts and Issues for Information Systems Research, *Communications of the Association for Information Systems*, 27, 173-184.
13. economist.com (2010) "Home Sweet Passive Home." *The Economist online* Retrieved May 1, 2011, from http://www.economist.com/science-technology/displaystory.cfm?story_id=15585504
14. Fairbank, J.F., Labianca, G., Steensma, H.K., and Metters, R. (2006) Information Processing Design Choices, Strategy, and Risk Management Performance, *Journal of Management Information Systems*, 23, 1, 293-319.
15. Fan, M., Stallaert, J., and Whinston, A.B. (2003) Decentralized Mechanism Design for Supply Chain Organizations Using an Auction Market, *Information Systems Research*, 14, 1, 1-22.
16. Farhangi, H. (2010) The Path of the Smart Grid, *IEEE Power & Energy Magazine*, January/February, 18-28.
17. Galbraith, J.R. (1977). *Organization Design*. Reading, MA: Addison-Wesley Publishing Company, Inc.
18. Haring, B. (2010) "Bumpy Road Ahead for Smart Meter." *CleanTechies* Retrieved April 25, 2010, from http://blog.cleantechies.com/2010/10/19/bumpy-road-ahead-for-smart-meters/
19. Hartway, R., Price, S., and Woo, C.K. (1999) Smart Meter, Customer Choice and Profitable Time-of-Use Rate Option, *Energy*, 24, 895-903.
20. Herter, K. (2007) Residential Implementation of Critical-Peak Pricing of Electricity, *Energy Policy*, 35, 2121-2130.
21. Hsuan, A. (2010) "Smart Grid's Long Road Ahead," in: *CleanTechies*.
22. IBM (2010) "Switching Perspectives: Creating New Business Models for a Changing World of Energy," IBM Corporation, Somers, NY.
23. Iyer, A.V., Deshpande, V., and Wu, Z. (2003) A Postponement Model for Demand Management, *Management Science*, 49, 8, 983-1002.
24. Jack, E.P., and Powers, T.L. (2009) A Review and Synthesis of Demand Management, Capacity Management and Performance in Health-Care Services, *International Journal of Management Reviews*, 11, 2, 149-174.
25. Kharecha, P.A., Kutscher, C.F., Hansen, J.E., and Mazria, E. (2010) Options for near-Term Phaseout of Co2 Emissions from Coal Use in the United States, *Environmental Science & Technology*, 44, 4050-4062.

26. Lapide, L. (2006) Demand Management Revisted, *The Journal of Business Forecasting*, 25, 3, 17-19.
27. Mani, D., Barua, A., and Whinston, A.B. (2010) An Empirical Analysis of the Impact of Information Capabilities Design on Business Process Outsourcing Performance, *MIS Quarterly*, 34, 1, 39-62.
28. Mason, I.G., Page, S.C., and Williamson, A.G. (2010) A 100% Renewable Electricity Generation System for New Zealand Utilising Hydro, Wind, Geothermal and Biomass Resources, *Energy Policy*, 38, 3973-3984.
29. McCollum, D., and Yang, C. (2009) Achieving Deep Reductions in Us Transport Greenhouse Gas Emissions: Scenario Analysis and Policy Implications, *Energy Policy*, 37, 5580-5596.
30. McDonald, J. (2008) Leader or Follower: Developing the Smart Grid Business Case, *IEEE Power & Energy Magazine*, November/December, 18-24, 90.
31. Melville, N., and Ramirez, R. (2008) Information Technology Innovation Diffusion: An Information Requirements Paradigm, *Information Systems Journal*, 18, 247-273.
32. Premkumar, G., Ramamurthy, K., and Saunders, C.S. (2005) Information Processing View of Organizations: An Exploratory Examination of Fit in the Context of Interorganizational Relationships, *Journal of Management Information Systems*, 22, 1, 257-294.
33. Raftery, T. (2010) "Are Utility Companies Ready for Full Smart Grids?" *GreenMonk: the blog* Retrieved February 5, 2011, from http://greenmonk.net/utilities-ready-for-full-smart-grids/
34. Smith, R. (2010) "Regulators --- What Utilities Have Learned from the Smart Meter Tests...And Why They Aren't Putting Those Lessons to Use," in: *The Wall Street Journal*. p. R6.
35. Taylor, D.H., and Fearne, A. (2009) Demand Management in Fresh Food Value Chains: A Framework for Analysis and Improvement, *Supply Chain Management: An International Journal*, 14, 5, 379-392.
36. Trkman, P., McCormack, K., de Oliveira, M.P.V., and Ladeira, M.B. (2010) The Impact of Business Analytics on Supply Chain Performance, *Decision Support Systems*, 49, 3, 318-327.
37. Tushman, M.L., and Nadler, D.A. (1978) Information Processing as an Integrating Concept in Organizational Design, *The Academy of Management Review*, 3, 3, 613-624.
38. Venkatraman, N. (1989) The Concept of Fit in Strategy Research:Toward Verbal and Statistical Correspondence, *Academy of Management Review*, 14, 3, 423-444.
39. Watson, R.T., Boudreau, M.-C., and Chen, A.J. (2010) Information Systems and Environmentally Sustainable Development: Energy Informatics and New Directions for the Is Community, *MIS Quarterly*, 34, 1, 1-16.
40. Zarghami, M. (2010) Urban Water Management Using Fuzzy-Probabilistic Multi-Objective Programming with Dynamic Efficiency, *Water Resource Management*, 24, 4491-4504.