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# Emerging Smart Grid Struggles

## 1.1 Vulnerability and Change

At the end of October 2012, more than eight million homes lost power as Superstorm Sandy battered the east coast of the United States. The electricity system disruption from this extreme weather event impacted households and businesses across seventeen states, including those as far west as Michigan. The storm left some without power for weeks, and lower Manhattan was in the dark for several days. The storm closed the New York Stock Exchange, the most powerful market in the world, for two full days, and Broadway shows were canceled for three consecutive days (Webley 2012). The storm forced evacuation of critical care patients and premature babies at New York University's hospital to another hospital in the dark, and flooded substations and downed power lines caused unprecedented levels of disruption to the city's energy systems. As the disaster unfolded, the vulnerabilities of the United States' electric system were broadcast to the world.

In the aftermath of the storm, the region struggled to recover and restore electricity. In some places, the same vulnerable electricity system, with the same basic technologies and same structure, was reinstalled, demonstrating a common and fundamental irony of disaster recovery. Although a disruption provides a window of opportunity to upgrade technology and introduce new approaches to enhance system resilience, established policies and procedures often require investment in and installation of the same infrastructure. But Hurricane Sandy also sparked broad societal discussion on the vulnerability of the electric infrastructure and has encouraged long-term plans and investments to improve reliability and resilience. Investment decisions after a major disruption represent one of many emerging struggles of electricity system change. When the Secretary of the United States Department of Energy, Ernie Moniz, spoke about Hurricane Sandy in his first major policy speech in August 2013, he said: "we have to help this rebuilding in a smart way" (Moniz 2013). In this political statement, Moniz was underscoring this critical challenge in electricity system change. When system disruptions occur, the pressure to "get the lights back on" surpasses all else. A clear tension exists between the immediate need to recover from an outage and the longer-term need for changes to move toward a future system that is more reliable and resilient. Rarely have electric utilities been able to use outage and system disruptions as opportunities to upgrade and update their technologies.

The aftermath of Superstorm Sandy highlights other struggles associated with change in electricity systems. Not only are there limits to the introduction of new technologies during a disruptive event, but also, overlapping jurisdictions and diverse priorities and perspectives among actors make electricity system change extremely challenging. Change in all complex social and technical systems is dependent on struggle and tension, and conflict creates possibilities for new and creative socio-technical norms to emerge. As we confront the challenges and opportunities of electricity system change, understanding how struggles are developing and why tensions are evolving can contribute to creative alignment of interests and priorities.

Multiple tensions and opportunities are currently emerging in electricity systems as the notion of a smarter grid offers both great promise and pitfalls. The term *smart grid* has become a catch-all phrase to represent the potential benefits of a revamped and more sophisticated electricity system that can fulfill several societal expectations related to enhanced efficiency and sustainability. Smart grid is not a single technology but a somewhat ambiguous term that represents multiple visions and technologies throughout the electric system. Smart grid often means different things to different people. Given the breadth of the many promises (and pitfalls) of smart grid, given the complexity of possible technical configurations of smart grid, and given the diversity of societal actors involved and invested in smart grid deployment, understanding the sociotechnical context for smart grid development is challenging and complicated.

Acknowledging the very different perspectives and priorities of the individuals and organizations involved in and impacted by electricity system change, this book explores and explains the dynamic smart grid landscape, exploring how new tensions create opportunities for evolutionary change and the potential for revolutionary change. In this book, we take a broad system-wide perspective to examine the different ways smart grid is meeting the evolving demands of electricity systems. By comparing smart grid development in different regions of the United States and Europe, we demonstrate that how smart grid is fulfilling changing societal expectations of electricity systems depends on social and political contexts, which are often shaped by regionally specific goals, resources, and engaged actors. Which actors and organizations have control and influence over shaping smart grid, and who benefits from smart grid changes, varies considerably among communities, states, regions, and countries.

Different smart grid visions reflect a diversity of social and political landscapes creating an evolving patchwork of smart grid trajectories. The diversity embedded within smart grid visions reflects a new diverse reality for energy systems, energy policy, and energy technologies. There is no silver-bullet solution to the energy challenges facing society. By revealing the diversity of smart grid potentials in this book, we also reveal and showcase the critical importance of context-specific approaches to considering energy system change.

The multifaceted diversity of perceptions of smart grid makes the Indian parable of the elephant and the blind men a useful analogy to understand our goals for this book. This story is often used to demonstrate how any individual's subjective experience may be accurate or true to themselves, but an individual's capacity to know the full truth remains limited. In the parable, six blind men touch different parts of an elephant, experiencing distinctly different realities. The man who touches the elephant's trunk feels a long, strong, thin animal, while the men who touch the hind leg, the tusks, the underbelly, and the tail each experience and envision a very different animal. Each of these individuals' perceptions is informed by the parts of the whole that they experience, but each man has little capacity to understand and interpret the full magnitude or shape of the whole elephant.

Such is the case with smart grid. Just as each blind man experiencing different parts of a large animal is unable to understand the entire elephant, different actors involved in and influenced by smart grid development are each engaged with different parts of the electricity system and have only a limited perspective on the potential and challenges of broad electricity system change. Each individual or organization is able to view only a limited part of the entire system. And the lack of a comprehensive educational approach to energy and electricity systems perpetuates this piecemeal understanding.

The insights we share in this book are built on six years of research that involved talking with hundreds of different people who are engaged in shaping electricity systems. As we listened and learned from people representing a wide range of organizations, from grid operators in the Midwest to small cooperative utilities in Vermont, we attempted to integrate different perspectives and priorities of smart grid with an ultimate goal of understanding the complexity of change and evolution in electricity systems. In this synthesis of our research, we attempt to step back far enough to enable readers to see the entire smart grid animal, but also provide sufficient detail for those who are especially interested in specific components.

## 1.2 The Grid Matters! Why We Care

Most people do not think much about electricity systems. People pay attention to "the grid" only when the power goes out or when a monthly bill is due. System reliability and affordability have been major tenets shaping electric system development for the past 150 years. While the first electric systems focused solely on powering lights, electricity systems have become increasingly critical infrastructure. More than ever before, we rely on electricity for communication, food, health, transportation, and other basic needs. If the power goes out we quickly become paralyzed when we are unable to charge our cell phones, pay our bills, refrigerate our food, and run our businesses and households.

Concern about the social impact of power outages and connections between electricity system vulnerabilities and more intense and frequent extreme weather events has been growing in the United States, as highlighted by Superstorm Sandy. Despite growing acknowledgement of the need to enhance resilience of the electric grid, investment in U.S. infrastructure is low, prompting the American Society of Civil Engineers to assess the U.S. energy system with a grade of D+ on their infrastructure report card (ASCE 2013).

Similar concerns are mounting in Europe, but the debates differ significantly among countries. Some European countries have a higher level of political and societal support and expectation for investing in infrastructure maintenance, so this alters the landscape for considering electricity system change. For example, in Germany, a national-level commitment to transitioning to a renewables-based electricity system has highlighted challenges regarding long-distance transmission planning. Microgrid planning in Denmark addresses system resilience as well as environmental concerns. In Italy, smart meter installations were initially driven by a desire to address electricity theft. In both the United States and Europe, preparing the grid to become more resilient to disruptions has become one of several motivations for growing interest in smart grid innovation.

The term smart grid does not have a precise, uniformly accepted definition. Rather, it is a vague, politically attractive, seemingly benign, and somewhat ambiguous phrase. After all, who would argue for a "dumb grid?" It is an umbrella term that encompasses many different technical and social changes affecting the electricity system. And different individuals and institutions have different perceptions of what specifically a "smarter" grid looks like and what it should do. A common theme across different definitions of smart grid is the further integration of information technology into electricity system management. As such, smart grid includes both hardware and software. It includes a variety of interlinked technologies including advanced meters and sensors, the management of "big data," and other technological configurations that enable increased reliability, more renewable electricity, and improved efficiency, resilience, and flexibility.

The many motivations for smart grid also include the potential to lower the cost of the system through efficiency improvements and managing peak demand. To produce electricity during periods of peak demand, utilities run expensive and inefficient plants, making the electricity more costly; if the demand for electricity during peak hours was reduced, fewer power plants would have to be built or maintained to meet these infrequent high-demand periods. A "smarter" grid could also promote more engaged electricity consumers, supporting both those who install their own renewable generation and those who more actively manage their electricity use. Consumers can track energy use through metering and make electricity use decisions that could save money through dynamic pricing that aligns the time-of-day price of generating electricity to its use. An additional critical motivation is lower carbon and environmental emissions achieved through incorporating renewable generation and more efficient use of electricity. Some visions of smart grid also transform the oil-dependent transportation sector into another component of the electric sector with the integration of electric vehicles. From a societal perspective, smart grid also allows individuals and communities to ask new questions of the electric system. Beyond system reliability and affordable cost, smart grid has potential to spur social and behavioral change, including empowering individuals and communities to have more localized control of and engagement in their energy choices. But, like change in all complex systems, smart grid also poses multiple potential downsides, ranging from increasing rather than decreasing costs and emissions to heightened concerns about cybersecurity, privacy, and health.

Acknowledging this intriguing landscape, in this book we explore both the social and technological complexities of electricity system change. Recognizing that electricity systems are composed of interlinked technologies, social practices, people, and organizations, we investigate these relationships. In the first half of the book we explore the heterogeneity of smart grid by describing variation in its promises and pitfalls, its technological configurations, and the actors and organizations involved in and influencing how smarter electricity systems are developing. The second half of the book moves beyond these heterogeneities to compare specific aspects of smart grid development: deployment of smart meters, integration of large-scale wind power in the electric system, community-based small-scale grid innovations, and connections with climate change. These latter chapters contextualize smart grid development through the exploration of geographic and social heterogeneity in different places by focusing on the struggles surrounding who has control and who benefits. By focusing on control, we are interested in the dynamics of who, where, when, and how different system actors are able to shape the electricity system. By focusing on perceived benefits of electricity system change, we are interested in who, where, when, and how different system actors benefit from smart grid. We explore the dynamic evolution of grid innovation, and we connect these changes with larger societal issues.

We focus on the social dimensions of smart grid, and also explore how they interact with the technological challenges. Our attention to the interactions between social and technical developments is intentional; this book is not a conventional engineering or technology text. Several other recent books and countless articles focus on the technologies of smart grid, and in Chapter 3 we will review the major categories of technologies that are often included under the smart grid umbrella. Rather than focusing primarily on the technological or engineering challenges, our approach to understanding smart grid is to explore the coevolution of social and technical systems and explore how they influence one another in expected and unanticipated ways.

## 1.3 Who Are We?

We are writing this book on smart grid and electricity system transformation because over the past decade we have become increasingly aware of the cultural and political embeddedness of energy system change. We are three professors who use interdisciplinary approaches to research the complexities of energy systems, environmental science, and engineering, policy, law, and environmental communication. We are motivated by a fundamental interest in the interconnected links between energy systems, societal change, and the environmental challenges associated with energy. Within the research community studying climate change and energy, a technological focus and accompanying economic logic dominate much of the research and associated policy discussions. But our perspective is different. Throughout the past decade our work has highlighted interconnected and embedded energy and climate challenges. Each of us has become increasingly aware of the often unrecognized social and political influences shaping energy systems. This book is an attempt to integrate and consolidate these less well-explored, yet critical, dimensions of energy system change.

Our work on energy systems reflects our own varied regional experiences. The three of us each work in different universities located in different parts of the United States and Europe, so we are experiencing electricity system changes in different contexts within our communities in New England (Vermont and central Massachusetts), in the Twin Cities area in Minnesota, and in central Texas and Sweden. We each have also lived at different times in our lives in different countries (including Australia, Belgium, Burundi, China, Ireland, Kenya, Sweden, and Tanzania). So our integrated perspective presented in this book is the culmination of our collective experiences and backgrounds and our interest in energy as a critical global concern.

In addition to being researchers and educators, all three of us are also mothers, sisters, daughters, and partners. We care about electricity systems and the potential changes that smart grid offers because we are deeply concerned about the future of the world our children and grandchildren will inherit. Each of us has a strong passion for understanding energy and environmental concerns, but we also have found a collective passion to better understand the dynamics of change and wrestle with why energy system change is so difficult. Our three-way collaboration has grown over the past decade in a way that has strengthened both our individual passion for understanding and revealing the complexities of energy system change and our humility in facing the magnitude of change. Together we challenge one another to broaden our individual tendencies to focus on particular aspects of the elephant. Our long-term collaboration has forced us to talk, think, and write in synergistic ways that result in more comprehensive reflections than any of one of us could produce by herself.

We began writing this book while staying in a net zero-energy passive-house renovated Irish cottage on the rugged and remote northwestern coast of Donegal in the summer of 2013. This house, which is the home of Jennie Stephens' parents, Cathal and Sarah Stephens, was recently renovated by Cathal Stephens, an architect with a keen interest in demonstrating the possibilities of technical and social change toward making buildings more sustainable (Stephens 2011). The home is powered by its own 6.6 kW wind turbine that takes advantage of the steady, strong winds of coastal Donegal. During a weeklong writing retreat that we spent at this house, we solidified our appreciation for the powerful feeling associated with the reliable and clean independence of working and living in a house that generates its own electricity. As we spent hours researching, writing, organizing our ideas, and structuring this book, we drank tea (ate chocolate) and gazed at the shifting colors of Trawenagh Bay. The window framed both the small turbine that powered the house and, in the distance across the Bay, several large industrial-scale wind turbines that spun steadily. Within this setting we were aware of the rapidly changing roles of energy and the growing role of wind resources in Ireland and around the world.

## 1.4 Emerging Tensions and Power Struggles

Stories of smart grid development are useful for studying and understanding energy system change because of the multiple tensions that emerge among the different actors' visions and interpretations of smart grid's promises and pitfalls. Power struggles are emerging in multiple complex ways in different regions, with different consequences. While the dominant paradigm of smart grid remains one of technological progress and utilitarian efficiency, smart grid development also highlights multiple emerging and entrenched struggles. Some of these struggles and tensions are demonstrated in the September 2013 release of the independent film *Take Back Your Power*, in which multiple skeptical views about why smart grid is being pushed, who may benefit, and who may pay the price are communicated in an investigative journalistic style. Our book, in contrast, is based on two multiyear, National Science Foundation-funded research projects in which we have analyzed hundreds of documents and interviewed dozens of individuals from many institutions who are involved and engaged in energy systems. Our research has led us to consider big and small questions, ongoing and emerging challenges, and the multiple tensions, coalitions, and inherent power struggles in creating the future electricity system. These tensions include incumbents versus new actors, perceived costs versus benefits, and questions of who pays, who plays, and who writes the rules. Questions of the timescales and the spatial scales over which costs and benefits are to be distributed come to the fore. Another set of tensions relates to actors' perceptions on whether smart grid should be oriented toward promoting a more centralized or a more decentralized electricity system, and/or whether both centralization and decentralization can and should be promoted simultaneously.

Another key tension in smart grid development relates to whether smart grid technology empowers consumers with more autonomy and control to manage their energy systems, or whether smart grid changes could result in disempowerment through a loss of privacy and control by individual households and electricity consumers. At this point it seems like smart grid could contribute to either and both – a more centralized electricity system and/or a more decentralized system; more opportunities for customer involvement in the energy system, or less. Other key tensions include whether a smarter grid would provide enhanced security to our current system or create new vulnerabilities for potential cyberattacks on the grid, and whether a smarter grid will accelerate a reduction in fossil fuel reliance by facilitating more renewables or whether fossil fuels will remain dominant and influence smart grid development in such a way that smart grid investments contribute to perpetuating fossil fuel dependence. Of course, the dichotomies are neither straightforward nor clearcut, as the case studies included in this book illustrate. Smart grid could enable increased renewables *and* an increase in coal use, as is the current situation in Germany. Smart grid could allow for distributed generation to enhance system reliability through the creation of microgrids *and* unintentionally exacerbate local air pollution. Smart meters and dynamic pricing could lower consumer costs for ten months out of the year and create a public (and political) revolt when high prices are passed on to unwilling electricity customers in an effort to link the price of electricity production and consumption during the peak summer months. We find the study of smart grid so interesting because the circumstances are rarely black and white, but rather marbled, shaded, and embedded within specific contexts.

An emerging struggle in many regions relates to how and to what degree solar PV owners should pay to maintain the distribution network. Homes and businesses with their own onsite solar electricity generation still rely on and benefit from being connected to the larger grid. When the sun does not shine these systems do not produce power. Unless the owners have invested in battery storage, they are dependent on purchased electricity for the hours in which the sun does not shine. They are also dependent on the larger grid to take any excess generated power that they do not use on-site. But how and to what degree these customers should support grid services when they are not purchasing much electricity from the utility remains unresolved. As solar PV produces power during the middle of the day, its value is often quite high. The challenge electric utilities face from high levels of solar and other forms of distributed generation is often (and dramatically) termed “the utility death spiral,” as it undercuts utilities’ current basic business model.

Whether or not smart grid is a useful term remains open for debate. While its widespread use in the past decade suggests that many seem to find it a convenient label to describe general electric system change, some people scrupulously avoid the term. We have already mentioned how it is an ill-defined, ambiguous, umbrella term that means something different to different people. Many have asked: is such a vague term useful? A 2011 MIT report entitled "The Future of the Electric Grid" intentionally avoided the label smart grid (MIT 2011). The authors of this report explained explicitly that they refrained from using this phrase because of its ambiguity. Other technical authors have also balked at its ambiguity and meaninglessness. Within the power sector, there seems to be a general shift toward the less polarizing term "grid modernization." However, smart grid retains its cachet.

These unresolved tensions and emerging power struggles result from a complex landscape of competing priorities and concerns. In this book, we explore this complexity by telling multiple stories about smart grid development in different places and across different scales. In these narratives, we demonstrate how individuals' perceptions of smart grid depend on their worldview and the priorities established within their cultural and professional spheres. Different actors support different dimensions of smart grid development, and see smart grid as fulfilling different societal goals. Some actors, particularly those who are skeptical and unsupportive of smart grid development, see smart grid as increasing risks associated with big government and corporate control in society, raising negative health and safety issues from smart meter radiation, reducing privacy from data energy consumption data, and enhancing the vulnerability of the grid to cyber-sabotage.

## 1.5 Our Approach

Electricity systems are an increasingly critical complex infrastructure that most people do not know much about. One goal of this book is to reveal and explain some of this complexity. A secondary goal relates back to the parable of the elephant and the blind men. Even among those who are well informed about the electricity system either through their professional work or their personal interest, it is clear that individuals and organizations (and even individuals within an organization) have very different perspectives, priorities, and understanding about the electricity system and its potential for change. So another goal of this book is to shine light on different aspects of the electricity system by exposing to all the breadth of smart grid visions, priorities, and perspectives. Perhaps with additional insights and understanding about others' perspectives, some of the tensions and struggles can be reduced. With enhanced mutual understanding made possible by the broad perspectives and narratives within this book, greater alignment of interests and priorities may evolve in way that accelerate positive system change.

For both experts and non-experts alike, understanding smart grid and the potential for electricity system change is based on their particular background and cultural, professional, and political values. Our goal in writing this book is to tell the story of smart grid from multiple different perspectives in such a way that any reader, whether new to the area or an experienced electricity system professional, will learn and gain understanding of the larger smart grid landscape. Given the critical importance and large scope and scale of electricity systems in our world, it is difficult to understand the whole system and all of the different perspectives within the system. This book attempts to shine light on multiple perspectives with an ultimate goal of helping different actors understand each other's priorities. We are writing this book to unpack and make sense of some of this complexity.

The opportunities and challenges of smart grid development vary significantly across countries and within regions of a single country. Electricity system change includes complex jurisdictional challenges. While this book incorporates mention of smart grid priorities and challenges throughout the world, many of the stories will focus on the United States, both because the U.S. context is the geographic and political area of the world in which we have the most experience, as citizens, electricity consumers, and researchers, but also because we seek to highlight the regional heterogeneity in smart grid development within the United States and illuminate the rich debates and discussions occurring across multiple contexts. We also draw on examples from Canada and Europe, and recognize that issues associated with grid development extend beyond these two continents.

An important perspective that we bring to our review and analysis of smart grid is that of sociotechnical systems. Central to this perspective is the notion that large technical systems coevolve with associated social, cultural, and political institutions. The trajectory of all technological change is intricately linked to social factors, and the trajectory of social change is intricately linked to technological factors. Constant, dynamic interactions among social and technological dimensions shape an interconnected complex system. This sociotechnical systems perspective has roots in sociological (Bijker, Hughes, and Pinch 1987) and historical (Hughes 1983) accounts of technological change, as well as in evolutionary economics and other influences.

Sociotechnical systems include technology, infrastructure, maintenance networks, and supply networks, as well as regulations, markets, user practices, and cultural meaning. Sociotechnical systems can become quite stable and resistant to change when the social and technical dynamics form reinforcing mechanisms to protect and promote the entrenched regime (Turnheim and Geels 2013). The status quo is perpetuated and strengthened as established actors, institutions, and technologies contribute to maintaining current arrangements. But a sociotechnical system can become unstable when there is alignment of pressures pushing toward system-wide change (Geels 2005). When this happens the system can transition to a novel configuration that could eventually stabilize as a different system.

In this book we take a systems approach to move beyond the conventional linear view of science, technology, and innovation that assumes scientific research leads to technology advancements which lead to innovations (Keller 2008, Luhmann 1989). We embrace a broader view that incorporates the social dimensions of system change and acknowledges inevitable negative social and environmental consequences of technological development. We integrate our varied backgrounds and experiences