Introduction and Overview

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Abstract The policy challenges associated with global warming, the prospect of increasingly expensive fossil fuels, and the recent re-emergence of serious concerns about the safety of nuclear power after the Fukushima accident in Japan are encouraging many western and Asian economies to develop smart grids (SGs) as a component of their energy policy portfolios. This introductory chapter first discusses the evolving definitions of SGs, and the five major applications of these technologies. We will then provide an energy sector outlook, highlighting the major energy developments in the near future that may affect SG deployment. We will conclude with an overview of the objectives and structure of the book.

1 Introduction

The policy challenges associated with global warming, the prospect of increasingly expensive fossil fuels, and the recent re-emergence of serious concerns about the safety of nuclear power after the Fukushima accident in Japan are encouraging

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many western and Asian economies to develop smart grids (SGs) as a component of their energy policy portfolios. SGs are often compared to the Internet and smart phones as one of the major transformational technologies that can potentially reshape economies and societies [1]. Although SGs are defined in various ways in different countries and across institutions [1, 2, 3, 4], they are typically taken to mean a modern grid concept that uses advanced information technology to update and modernize existing power grids to improve reliability, security, and efficiency of electricity supply systems [2].

SGs are widely regarded as one of the key building blocks of a sustainable energy future [3, 5]. These future grids will look very different from those of today. Traditional grids are typically centralized and fossil fuel-based. These smarter grids are essential to enable the wider use of renewable energy and plug-in electric cars as well as to accelerate energy-efficiency efforts—which are the core elements for more sustainable energy systems [2]. They can also reduce transmission and distribution losses, and enhance grid reliability. They are therefore expected to bring economic, environmental, and social benefits in many important ways: revitalizing the economy and providing green jobs, reducing capital expenditure on energy infrastructure [2], reducing power disturbance costs to economies [2] as well as facilitating a low-carbon energy future [2, 6].

SG is a subject that is highly dynamic and rapidly evolving. As an emerging energy-related technology in its nascent phase of deployment [7], SGs involve the integration of a broad range of state-of-the-art technologies that include wind and other renewable energy, electric vehicles (EV), car batteries, microgrids, computer networking, and communication systems [4]. This is an area where rapid innovations in technology are taking place. SGs are highly dynamic because they are also a key to both demand-side (e.g., energy saving and energy efficiency) and supply-side (e.g., renewable energy) management of energy systems, making such technologies a fertile arena in which many possible solutions for a more sustainable future may be located. SGs are an area where many substantive developments are rapidly unfolding. Many countries and cities are piloting SGs—at different scales from small pilots to large demonstration projects, and with varying scope to test technologies, business models, and consumer acceptance [2]. What also adds to the dynamic nature of SGs is their stakeholder landscape. The development of these SGs is a long-term process and a cross-sector effort that requires visionary and strategic planning, and collaboration among policymakers, utilities, the business sector, consumers, and other stakeholders [5, 8].

There has been strong international interest in SGs. Drivers of SG policy initiatives are many: rising energy costs with growing demand for energy, increasing awareness of global climate issues, growing need for energy efficiency, and rapid innovations in technology are just some of them [2]. Many countries and cities have made considerable progress in recent years to develop SGs at various scales and with different objectives in mind. The US national policy framework for SGs announced in June 2011, the European Technology Platform established in Europe in 2005, the four large-scale demonstration projects launched in Japan in 2010, the Korean smart grid vision announced in 2008, and China's smart grid initiatives formulated in 2009 are just some examples of these endeavors (For more details about these international developments, please refer to Part 4 International Case Studies of this book).

2 What Are SGs?

2.1 In What Ways Are SGs "Smarter"?

SGs are regarded as essential for a sustainable energy transformation. In what ways are they "smarter" than conventional systems? How can SGs overcome problems that cannot be solved by traditional grids?

Today's electric grids are using technologies that were state-of-the-art more than a century ago. These traditional grids typically consist of centralized power plants, transmission, and distribution lines. They are highly dependent on fossil fuels, and one-directional [9]. However, these aging grids face a number of challenges, including coping with the continued growth in demand, the need to integrate various renewable energy sources, which may involve intermittent availability, and EV, and the need to improve security of supply [3].

SGs are "smarter" in two ways. First, they have the ability to manage the two-way flow of electricity and information to optimize supply and demand. Traditional electric grids have one-way communication between utilities and customers: that is there is a one-way flow of information from customers to the grid (through meters) and a one-way flow of energy from the grid to customers [5, 9]. In contrast, SGs enable two-way flow of information (through a variety of interfaces) and energy (through distributed generation and storage) [9]. This is achieved through smart metering technologies and sensors that are installed throughout transmission and distribution grids, and which are linked to integrated communication networks to collect and consolidate data [1, 5]. This ability of two-way communication is fundamental to SG operations. Customers, for example, can proactively monitor and manage their electricity use, and can even sell back to the grid surplus renewable electricity that is produced at home [9].

SGs are "smarter" also in the sense that they are capable of integrating a wide variety of energy sources and energy customer services—which are now separately managed in traditional power systems—in highly interconnected electricity systems [2, 5, 7]. SGs also integrate a variety of interfaces, including home energy management systems (HEMS), building energy management systems (BEMS), and advanced metering infrastructure (AMI). SGs can coordinate the needs and capabilities of different generators, grid operators, end users, and electricity market stakeholders to operate all parts of the system efficiently [3]. All these components require the integration of SGs to achieve scale benefits and cost effectiveness [3].

2.2 Five Major Applications of SGs

SGs are complex systems that may provide five major applications:

- Smart systems: SGs can improve resilience to disruptions, attacks, and natural disasters [2]. This can be achieved through advanced sensors and computer-based remote controls. These sophisticated communication technologies and automation can help prevent disruptions rather than simply react to them, and therefore limit outages and network losses [5]. SGs can also identify and fix problems faster [1].
- Smart renewables: Today's grids are mostly designed for centralized supply sources and are therefore less accommodating to renewable resources that are intermittent and widely distributed [2]. SGs can accommodate a variety of generation, including renewable energy resources such as wind and photovoltaic solar, and other forms of distributed generation such as small-scale combined heat and power, and energy storage [1, 3]. SGs are regarded as essential to mainstreaming renewables because through state-of-the-art modeling and decision support tools, wind forecasting, and contingency analysis, for example, can be improved and these can enhance the integration of these intermittent sources into the power system [2, 3].
- Smart consumers: In SG systems, consumers are no longer passive purchasers [1]. SGs can inform and empower consumers to proactively manage their consumption [1]. Consumers can be provided with devices and information to manage their energy usage, and to reduce demand in response to peak load [1]. This can be achieved through smart meters and smart appliances that are connected with sensors to collect electricity consumption data, and which is essential to enable dynamic pricing and consumer participation in demand-side management [7]. Power companies can introduce a variety of demand response programmes. Direct load control programmes, for example, are mainly offered to residential and small commercial customers—in which consumers can choose to allow a programme operator to remotely turn off their appliances or equipment at short notice [9]. Consumers in this way can help reduce peak consumption and reduce the costs of generating expensive power to meet peak demand [2]. Real-time pricing programmes and other dynamic pricing programmes can be introduced to provide incentives for reducing peak load consumption [9]. Interruptible supply contracts, on the other hand, are offered mostly to large industrial or commercial customers. With these contracts, customers curtail their consumption in case of predefined grid contingencies [13].
- Smart transport: EV and plug-in hybrid EV can have a major role to play in reducing emissions. SGs can better manage vehicle charging so that rather than increasing peak loads, the charging can be carried out more strategically, when for example electricity demand is low or when the production of renewable electricity is high. In the long run, SGs can use EV as batteries to store renewable and other sources of electricity for later use [3].

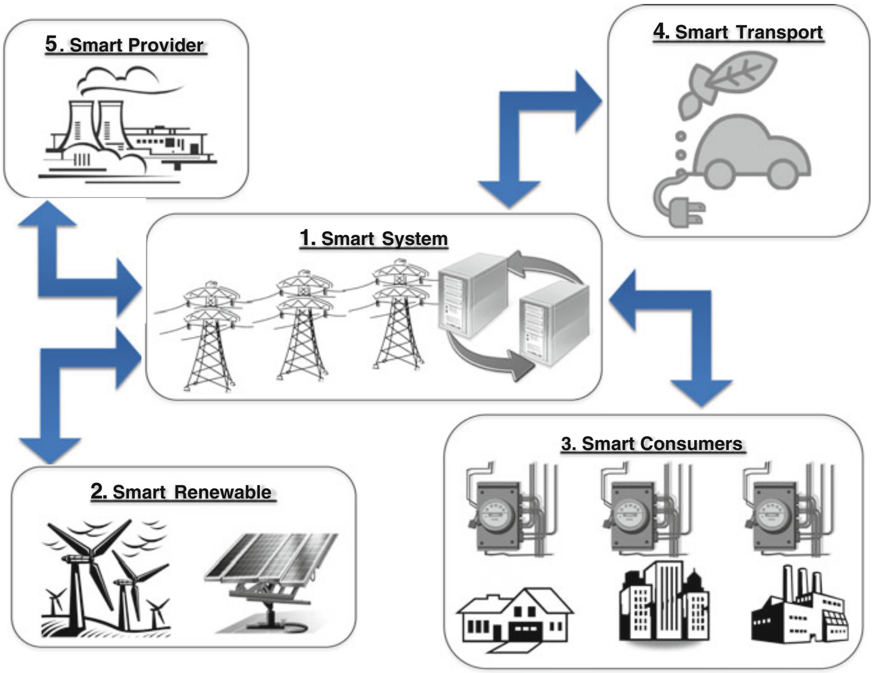

Fig. 1 Five major applications of smart grids. *Source* authors, Computer Networks and Security Lab [31], and HD PLCMAG [32]

- Smart electricity service providers: Utility companies will not be the only significant players in SGs. SGs create new markets as these technologies are conducive to new products and energy services, and also new market players. Energy efficiency and intelligent appliances, smart meters, new sensing and communications capabilities, and passenger vehicles are some examples of these new products [2]. SGs, therefore, tend to bring major changes in the market place—they rely on numerous third parties, including energy-service providers and brokers to provide core and additional services [1]. Energy-service providers, such as home energy monitoring service and energy-service companies (ESCOs) can analyze customer energy usage and provide customized energy services to meet customer needs. They can also perform direct load control or provide financial incentives for customer-responsive demand in homes and businesses [14] (Fig. 1).

3 Energy Sector Outlook

A recurring theme in this book is that the overall context for energy production and use is progressively moving in a direction that will support SG initiatives. This context reflects not just the global concern with climate change and the need to use energy more wisely and efficiently but also the kinds of energy that will be produced and the nature of the power grids that will deliver electricity to end users. A brief commentary on some important global energy and energy-related trends is, therefore, needed to contextualise SG initiatives. We emphasize, however, that this is not a book about energy policy. Rather, our focus is on the way in which thinking about SGs is developing, how the concept is being translated into practice and the kinds of technical, policy, and governance issues that surround such grid transformations.

Clearly, international thinking on energy and energy policy over the past 20 years has been profoundly influenced by global climate change concerns. The latest assessment by the intergovernmental panel on climate change (IPCC) published in September 2013 concludes that human influence on the climate system is clear, and it is extremely likely that human influence has been the dominant cause of the observed warming since the mid-twentieth century [14]. While CO_2 emissions in some countries have either slowed or declined, most notably the USA as a result of the switch away from coal to natural gas in electricity production, global energy-related CO_2 emissions increased by 3.2 % over the 2010 figure to reach 31.2 Gt in 2011. Much of this increase was the result of the increasing use of coal in China and India. Effective and widespread decoupling of emissions and economic growth has yet to be achieved [15].

Global electricity demand is expected to continue to increase—by 70 % in the period to 2035—and approximately half of this increase in demand is expected to arise in the coal-dominated energy economies of China (38 %) and India (13 %) [15].

In terms of sectoral demand for electricity, industry will remain the largest electricity consumer, accounting for 2.3 % increase in demand per year and over 40 % of total demand in 2035 [15]. The other major demand sectors will remain the residential and service sectors [15]. The transport sector is expected to experience a significant and substantial increase in demand for electricity as a result of the deployment of EV [15]. Hybrid-electric (HEV) and EV sales passed 1,000,000 and 100,000 in 2012 at growth rate of 43 % and more than 200 %, respectively [16]. Japan and the United States of America continue to lead the electric vehicle market [16]. Increasingly, governments around the world are providing various types of support for EV deployment including vehicle tax breaks and programmes to encourage the installation of charging stations. In India, for example, the government plans to get 6 million EVs and HEVs on the road by 2020, with half of the investment cost (US$4.2 billion) supported by government funding [16].

In terms of energy production, output from various forms of renewables continues to grow at a rapid pace. In 2012, solar PV electricity output grew by 42 % and wind power by 19 % [16]. The share of renewable in world electricity generation is projected to grow from around 20 % in 2010 to 28 % by 2020 and almost 60 % by 2050 [16]. The diffusion of renewables has already spread well beyond the developed OECD economies such as the USA and those in Europe and is well established in developing economies such as Brazil, China, and India. In fact, non-OECD countries account for 53 % of world renewable electricity production [16]. Furthermore, China has itself become a major player in the renewables technology area and is the world's largest solar panel producer [17].

Nuclear power continues to represent a key element of the generation mix in a number of countries and although the Fukushima accident resulted in a widespread revisiting of nuclear expansion plans around the world new nuclear projects increased from four in 2011 (the year of the accident) to seven in 2012 [16]. Nuclear seems to be slowly regaining public support since 2011, a trend that is the most pronounced in the USA, China, and France, although local support for nuclear continues to fall in Japan, Poland, and Spain [16]. Nonetheless, as a non-carbon-emitting option (at least insofar as the process of generating electricity is concerned) nuclear will doubtless continue to figure on the energy policy agenda in coming decades.

While much attention is naturally given to the fuel and technology mix options used to generate electricity, the means by which electricity is distributed and delivered to end users is just as important an issue. As the focus of this book itself indicates, power grids themselves have moved center stage and are now seen as a critical element in progress toward a low-carbon economy. The scale of investment in power grids in coming decades will be enormous, possibly up to $17 trillion of investment is expected worldwide for grid infrastructure upgrades to meet growing energy demand by 2035 [15].

In a world still hungry for more energy and with a range of difficult choices facing policy-makers, local communities, and power utilities regarding the fuel/technology mix to be deployed as well as how best to manage the demand for electricity and to ensure its efficient use, the context for energy policy-making will continue to pose difficult and serious challenges. Our concern here is with just one part—albeit a very significant component—of this bigger system but one that will nonetheless play a critical role in shaping electricity system management and consumer usage patterns in future decades.

4 The Development of SGs at the Global Level

The prospects for future SG development are very favorable. Key drivers such as the continuing growth in the deployment of renewable energy technologies, especially wind and solar power, growth in electric transport, and overall increases in the demand for electricity look set to create a positive environment for SGs over the period to 2020 and beyond. By 2020, renewable capacity is expected to increase by around 300 %, electric transport, including cars, by 45 %, and electricity demand itself by 27 % [16].

Between 2008 and 2012 the number of smart meter installations around the world grew more than fivefold from 46 to 285 million. The number is expected to reach 1 billion by 2018 [16]. A number of European countries have been making rapid progress in smart meter deployment: more than 36 million have been installed in Italy, two million in Denmark, and over two million in France. Installations in France are expected to reach 35 million by 2035 [18].

But it is not only in the hardware area that progress has been made. Although by no means as widely deployed as smart metering, dynamic pricing of electricity is beginning to appear but despite a series of pilot programmes since the late 1990s, recent policy initiatives concerning this pricing mechanism have been limited in scale and primarily confined to the United States. US-based programmes tend to take on a mandatory form such as the hourly pricing system in New York [19] and the mandatory time-of-use and optional critical-peak pricing in California [21].

Consumer engagement in matters related to power access provision has also proceeded although again at a far from uniform pace. Consumers in European countries are typically more engaged in electricity markets and cost reductions due to the widespread liberalization of electricity markets between 1995 and 2007 [22]. In the United States of America, progress with market reforms various markedly between the different states. For example, it has been relatively slow in California and but more progressive in Texas. Overall, however, in a growing number of Western countries liberalization has allowed consumers to make proactive decisions regarding their choice of electricity provider [22]. This is not, however, the case in Asia-Pacific countries. Here, customer choice and participation remain low because most electricity markets remain highly regulated [22]. Nonetheless, there are a few examples of community-based SG projects that have taken place with active consumer involvement. These include the four smart city demonstration projects in Japan, which involved more than 5,000 households, and the SG test-bed project on Jeju Island in South Korea.

Some examples of international collaboration in the SG area have also emerged in recent years. These include STRONGrid which involves five European countries, NASPI between Canada and the USA, and other demonstration projects in Italy, South Korea, and India [16].

SGs are not only attracting widespread international attention but are also the focus of very substantial capital investment as countries update and modernize their power grids. In 2008, SG-related investment was estimated at around US$3.4 billion. By 2012, this figure had reached nearly US$14 billion and is expected to grow to US$25 billion by 2018 [16]. Over half of the SG investment in 2012 took place in the USA (36 %) and China (26 %), while the global cumulative costs and benefits of SGs may reach US$738 billion and US$3,179 billion, respectively, by 2020 [16].

5 Policy Support Mechanisms and SG Initiatives

The more widespread diffusion of SG technologies in coming decades will depend on a wide variety of factors. There will be a number of crucial policy drivers for SGs that will provide a positive environment for such developments and which will facilitate grid enhancements. Some of the most important are linked to government initiatives to better manage energy demand and to enhance energy efficiency. This will be particularly important in non-OECD countries which will account for a very high proportion of primary energy consumption growth over the next two decades. Between 2011 and 2030, energy consumption in non-OECD countries is projected to grow by 61 % and is expected to account for 65 % of total global consumption [20].

A key element in creating a favorable context for SG initiatives will be governments' determination to pursue energy-efficiency initiatives. This is already underway in various developed economies with the USA, for example, committed to improving building and appliance efficiency through extensive energy-efficiency standards [23]. In the European Union, an Energy-Efficiency Directive has been introduced to support its 20 % efficiency improvement target by 2020 and beyond [23].

Elsewhere, developing economies are grappling with the problem of managing energy demand more effectively. China, for example, incorporated energy consumption caps, energy intensity reduction targets, and CO_2 per capita reduction targets in its 12th Five-year plan and has set out energy saving programmes in its energy efficiency plans [23].

Over the next two decades, it is widely expected that renewables will account for an increasing proportion of energy consumption. BP's Energy Outlook 2030 sees renewables growing at 7.6 % per annum over the period to 2030 [20]. More than 100 countries had national renewable electricity policies in place by 2010 [16]. In some countries, such as Germany, Italy, and Spain, financial incentives for renewables have been reduced as they become more competitive, while in other countries, such as Japan, China, and South Korea, efforts are still being made to improve incentive schemes through feed-in tariffs, renewable portfolio standards, renewable energy certificates, tax incentives, and other mechanisms [16]. In some countries, these policies are being further reinforced by policies to phase out fossil fuel use over coming decades. For example, in 2011, Denmark announced its long-term goal of fossil-fuel independence by 2050 [24].

Another policy area of great significance to future SG developments will be the trajectory of the nuclear industry. While the Fukushima accident in 2011 encouraged some countries to reconsider their nuclear policies (e.g., Japan has shut down most of its nuclear plants, and France is considering reducing nuclear electricity from 79 to 50 % by 2025), other countries have continued to proceed with planned nuclear expansion programmes (e.g., U.S. began to build four reactors in 2012, China has resumed nuclear plant construction after a brief halt in the approval process for new plants in the immediate wake of Fukushima, while Russia and India continue to expand nuclear capacity by 15 to 20 GW each by 2025) [16].

Another critical element in relation to the further development of SGs will be development and innovation in business models. In light of the substantial capital investment required as well as the sizable potential global market for new energy products and services, the development of new business strategies to achieve economies of scale and risk sharing will require effective collaboration between the government and the business sector [25].

Moving now to the actual process of planning for SGs, there are clear indications that this has been gathering momentum since approximately 2009 although it is still far from being a global phenomenon. Early initiatives to establish long-term strategic plans/policies to facilitate SG deployment include roadmaps and other policy initiatives developed by countries such as Italy and the United States of America [16]. In the EU, SGs are seen as one of the keys to achieving the 20/20/20 European targets (i.e., 20 % increase in energy efficiency, 20 % reduction in CO_2, and 20 % renewables) set for 2020. The European Commission released mandates for smart meters in 2009, for EV in 2010, and for SGs in 2011 to provide reference architecture, standardization tools, and consistent standards for European Standards Organizations [26].

Elsewhere, in 2011, South Korea enacted the Smart Grid Stimulus Law to provide legislative support for SG planning and to tackle potential barriers [16], while in Japan, after the Fukushima accident in 2011, the Japanese government reviewed its Basic Energy Plan and consulted the public with energy mix scenarios—pursuing 0, 15, or 20–25 % nuclear [27, 28]. However, recent government changes have created uncertainty on Japan’s position regarding nuclear power. In China, SGs are being addressed as one of the important elements of the current national energy plan [29].

This brief summary of some of the recent trends involving SGs suggests that while international interest in such grids has grown markedly over the past 5 years progress in the implementation of facilitating policies and the introduction of comprehensive grid enhancement programmes has been rather uneven. This is perhaps to be expected. SGs have been passing through what might be termed “the conceptual stage”. The overall policy environment for SGs is, however, becoming increasingly favorable and supportive. A growing number of countries are moving to the stage of developing more extensive programmes for SG implementation. The key hardware and software elements are already available and we expect to see the diffusion of operational SGs rapidly gathering momentum over the period to 2020. But a cautious note on these trends is that the existence of competing priorities among stakeholders represents one of the major challenges to advancing SGs [30]. It is still uncertain whether SG developments will be able to introduce radical changes into existing power systems, or whether such developments may in fact result in only incremental changes, and re-inforce the dominant role of traditional, centralized power systems by making them smarter [30].

6 About This Book

With new technological and policy advances in SGs being announced almost from month to month, there is a need to contextualize and analyze these developments and to bring their impacts and significance to a wider audience. Hence, the basic rationale for this book. We caution, however, that the development of SGs is such a dynamic area that any book or paper can at best provide a snapshot of the situation at a given point in time. Given the rapid diffusion of SG technologies and developments in related areas such as ICT the picture will almost certainly look very different in 5 years time. Nonetheless, it is important to document and review the progress that has been made and to offer some observations on the possible trajectory of SG initiatives over the short to medium term.

6.1 Our Perspective

Meeting today's energy and climate challenges requires us to expand the scope and diversity of energy technologies as well as policy options. This requires new interdisciplinary, forward looking, and more participatory approaches to problem solving. More traditional approaches are unlikely to provide the innovative and imaginative approaches required to address such major challenges.

We have designed the structure and content of this book with four principal considerations in mind:

An interdisciplinary approach: SG technologies and their application are inherently interdisciplinary as they involve expertise not only from power system professionals but also from specialists in areas such as information systems, transport, and buildings. But the effective implementation of SGs requires more than technological advances. Policy supports, often involving new policy perspectives and approaches, are needed to make these technologies practical, useful, cost-effective, and socially relevant. This book focuses not only on the technological issues involved but also the perspectives of various stakeholders. It also provides a number of national case studies that demonstrate progress with SG implementation and provide insights into the opportunities, challenges, and barriers that currently exist. Coverage of these complementary dimensions allows this book to adopt an interdisciplinary approach to SGs from the perspectives of science and technology, economics, and governance and policies.

Global and Asian perspectives: Many SG developments are taking place in developed economies (including the USA, Europe, and Australia), industrialized countries in Asia (such as Japan and Korea) and in emerging countries such as China. Current studies on the topic of SGs have tended to focus primarily on Western developed economies. In an attempt to address this imbalance in coverage, the case studies presented this book include both Western developed economies (i.e., the US and Europe) and a number of Asian economies (i.e., China, Korea and Japan). This broader geographical perspective allows us to inject an Asian view to the global discussion in this important area.

Learning from international case studies: SGs are a new, highly dynamic and significant component of energy planning and management around the world. R&D breakthroughs and market applications, policy developments and piloting projects, successes and failures in our case study countries may reveal important similarities as well as interesting differences. This book aims to provide insights derived from these empirical experiences. Good practice demonstrated by policy initiatives in various countries is vitally important to policy-makers for the purposes of policy learning and diffusion.

Theoretically informed and empirically based: A number of chapters in this book focus on multi-stakeholder perspectives and international experiences. The analysis in these chapters is underpinned by key social science theories concerning governance, policy, and politics. This theoretical underpinning is intended to provide coherence in the analysis throughout the book.

6.2 Objectives of the Book

Our aim in compiling this book and drawing together the valuable work of our contributing authors is to provide the reader with an interdisciplinary, informative, and comprehensible introduction to SG technologies in the context of increasing interactions between technological innovation and sustainability, between government, business and society, and between economic, political and social developments. Clearly, it is not feasible to provide coverage of each and every SG-related issue but our objective here is to provide the reader with a comprehensive understanding of the key issues associated with SG development and to illustrate how such grids are rapidly taking shape in many parts of the world.

This book, therefore, showcases state-of-the-art R&D developments and policy experiences. All aspects of this book are designed to contribute to a better understanding of governance, institution, and policy challenges and help formulate policy recommendations for successful SG deployment.

We hope that this book will be of interest to and meet the needs of not only academics, but also government policy-makers, those in energy and environmental consultancies and utility planning, and in international institutions as well as NGOs. It is also intended to meet the needs of undergraduate and postgraduate students wishing to gain a more comprehensive understanding of the technical and policy backgrounds to SG applications.

6.3 Structure and Content: A Brief Overview

We have selected the chapters that appear in this book on the basis of the four considerations or guiding principles outlined earlier. Our contributing authors come from a variety of academic and professional backgrounds and their work draws on a variety of national contexts and experiences. All are either active researchers or managers/practitioners in the area of SGs. We hope that this direct involvement in SG work on the part of our authors will help to convey to readers not only the key technical and policy issues involved but also the significance and the dynamism of the field.

The book itself is organized into five sections: Part 1 provides an overview of SGs. Part 2 deals with the technological aspects of SGs. It introduces important technical characteristics of these grids and showcases state-of-the-art R&D developments for different SG technologies. It also highlights the interdisciplinary and wide-ranging nature of SG technologies. Part 3 integrates a multi-stakeholder perspective into our discussion of SGs. The aim here is to provide a better understanding of the interests involved, the ways in which different stakeholders use their power, and how conflicts among power utilities, policy-makers, market regulators, consumers, environmental NGOs and other stakeholders can emerge and be resolved, and the implications of these issues for policy-making. Part 4 offers a collection of international case studies of SG development to showcase policy experiences in both Western and Asian countries. Part 5 consists of a postscript which aims at sharing insights, identifying the lessons learnt, highlighting the policy implications of the discussions in the various chapters of the book.

Part 1, comprising two chapters, is an overview of SGs. In this chapter, the editors provide an historical overview of SGs. It discusses the basic (often varied) definitions of SGs, the evolution of SGs as a concept and as a practice. In chapter "A Holistic View on Developing Smart Grids for a Low-Carbon Future", John Cheng presents a holistic overview of the development of smart grids as an essential element for a low-carbon future. It examines how four key aspects, technology, economies, regulation/policy, and social acceptance, are complementary and therefore need to be considered in a holistic manner for the deployment of smart grids.

Part 2 includes four chapters related to SG technology development. In chapter "Statusand Prospects of European Renewable-based Energy Systems Facilitated by Smart Grid Technologies", the plans and status of renewable energy resource development and energy policy in Europe are introduced. The development of SG technologies in the European Union is also discussed. Chapter "Arcturus: An International Repository of Evidence on Dynamic Pricing" is a comprehensive study on dynamic pricing, reviewing results from 163 pricing treatments offered in seven countries located in four continents. It was found that customers respond as the peak to off-peak price ratio increases, by lowering their peak demand, and as the price continues to increase, they continue to lower their demand, but at a decreasing rate. In addition, the use of enabling technologies boosts the amount of demand response. Chapter "Microgrids and Distributed Energy Future" reviews the concepts and models of microgrids, describes its evolution from the traditional power system, and studies issues related to microgrid operations, including grid-connected and islanding operations, operation and control strategies, and economic issues. Existing microgrid projects from around the world are described. Chapter "Communication and Network Security Requirements for Smart Grid" focuses on the communication technology of SG. It is noted that deployment of SG requires technologies on sensing and measurement, advanced control methods, advanced components, improved interfaces and decision support, and integrated communications. To achieve the full functionalities of such SG enabling technologies, communication technology plays a fundamental role. This chapter describes a communication-oriented SG framework, identifies the communication requirements, and the security and privacy requirements.

Part 3 of the book, comprising three chapters, focuses on stakeholder perspectives in SG development. In chapter "Smart Grids: The Regulatory Challenges", Mah, Leung and Hills examine some of the regulatory challenges associated with SG systems. Working from the position that a successful transition to SGs requires not only technological advances but also the need to overcome various regulatory barriers, the authors review the changing regulatory context for grid development. They argue that SGs present new and different challenges for regulators. These include disincentives to utilities, pricing inefficiencies, and cyber security and privacy concerns. Drawing upon case studies from North America and Europe the authors demonstrate that a variety of regulatory initiatives have emerged to facilitate SG development from which they conclude that a mix of regulatory approaches will most likely be needed to achieve a successful transition to SGs. Furthermore, with the more complex and dynamic stakeholder landscape that has emerged in relation to SGs, the authors also suggest that future regulatory frameworks will need to be more open and participatory if they are to respond effectively to the challenge of SGs.

Chapter "*i*-Energy: Smart Demand-Side Energy Management", by Matsuyama, provides valuable insights into novel research that explores the potential for smart demand-side energy management. This chapter views SGs from a different perspective, arguing that these grids aim at achieving more effective energy management from the supplier's viewpoint but that what is also required is a consumer perspective. Matsuyama, therefore, proposes the concept of i-Energy which emphasizes the importance of energy management from the consumer's side. The chapter discusses four steps in the realization of the i-Energy concept: the Smart Tap Network for monitoring electricity consumption patterns, the Energy on Demand Protocol to achieve a priority-based best-effort supply mechanism, Power Flow Coloring to allow versatile power flow controls, and, finally, the Smart Community for bi-directional energy trading among households, offices, and factories.

Chapter "Switching Perspectives: Creating New Business Models for a Changing World of Energy", the final chapter in this part of the book, examines the need to develop new business models for the rapidly evolving energy scene. Valocchi, Juliano and Schurr argue that new technologies, policy changes, and more demanding consumers are driving the need for a revamp of traditional electric utility business models and the traditional "grow and build" mindset. These are rapidly becoming outdated and inappropriate. The foundations on which these traditional business models were based, namely one-way flows of power and information, declining costs with increased usage, passive consumers, easy access to cheap carbon fuels and regulatory protection from threats to core business interests, are being eroded. A new kind of "grow and build" era is upon us, one in which there must be a switch to new business models that will facilitate and support information exchange, consumer participation, and new services. The future is not so much about energy itself but information and services.

Part 4 provides a collection of international case studies of SG developments to showcase policy experiences across the Western and Asian countries. Our case studies of Europe (chapter "Smart Transmission Grids Vision for Europe: Towards a Realistic Research Agenda"), a comparative study of the USA and Europe (chapter "Comparison of Smart Grid Technologiesand Progress in the USA and Europe"), Japan (chapter "Towards Sustainable Energy Systems Through Deploying Smart Grids: the Japanese Case"), Korea (chapter "Governingthe Transition of Socio-Technical Systems: a Case Study of the Development of Smart Grids inKorea"), China (chapter "Developing Super Smart Grids in China: Perspective of Socio-Technical Systems Transition"), and Australia (chapter "Exploring the Value of Distributed Energy for Australia") provide a better understanding how countries differ in their deployment of SGs with different aspirations, approaches, and focus. These case studies, together, highlight the key issues, opportunities, and barriers to the large-scale deployment of SGs, which involve not only the technological aspects but also the financial as well as regulatory ones. Furthermore, the adoption of the same theoretical perspectives of the socio-technical systems in the case studies of Korea and China (chapters "Governingthe Transition of Socio-Technical Systems: a Case Study of the Development of Smart Grids in Korea" and "Developing Super Smart Grids in China: Perspective of Socio-Technical Systems Transition") has guided us to examine the complexity of the energy system transition, which can be enabled by the deployment of SGs, from the macro, meso, and micro levels.

Starting with Europe, in chapter "Smart Transmission Grids Vision for Europe: Towards a Realistic Research Agenda", Vanfretti et al. advocate for a realistic turn in SG research if the overwhelming challenges posed by their deployment are to be met. If SGs at the transmission level are to become a reality, there needs to be an alignment in the current research practices integrating complex interactions between policies, the regulatory background, technology maturity, and socially responsible and farsighted investment. The different time frames in which the transmission system is managed are pivotal in the appreciation of SGs. "Smarter" grids require adjustments in the operations and the operational planning phase as well. On the operational side, an increased use of AMI, for instance from phasor measurement units, can be expected to bring considerable advantages to the power system. Nevertheless, challenges such as standardization, big data management, and ICT requirements remain important. If these challenges can be met, the measurement data can be applied to improve system operations, for instance through the provision of improved control and protection functions. The uses of new ICT technologies, and especially the possibility of visualization, allow the operators to become better aware of the system state to take the appropriate actions. However, the main challenge may lie in development of new reliability concepts which can be implemented in realistic power systems to provide a maximum social welfare to the users, and for which adequate tools are still under development.

Chapter "Comparison of Smart Grid Technologies and Progress in the USA and Europe", by M. Godoy Simões and his colleagues, provides a comprehensive account of the major historical and technical events of SG developments in the USA and Europe. By contrasting these technical, legal as well as policy developments in these two major economies, the authors provide a full understanding of how and why SGs are developed in various pathways across places.

Chapter "Towards Sustainable Energy Systems Through Deploying Smart Grids: the Japanese Case", by Amy Poh Ai Ling, is a case study of Japan. Poh discusses the aspirations, concepts, and elements of SG deployment in Japan. Poh highlights that SGs are a part of the government's "go green" effort to elevate Japan to a leading country in green growth. Poh also provides an overview of Japan's major initiatives on SGs, which include smart communities, large-scale city-based pilot projects as well as overseas collaboration.

In chapter "Governing the Transition of Socio-Technical Systems: a Case Study of the Development of Smart Grids in Korea", Mah, van der Vleuten, Chi-man Ip and Hills show how driven by its "Green Growth Vision", Korea embarked on its SG initiatives in 2009. Within just 3 years, the country has made some important progress in the development of SGs. Grounded in a perspective of governance and innovation systems as a general analytical framework, the chapter first reveals the complexity of the socio-technical system by highlighting the breadth and depth of factors influencing SG development in Korea. The convergence of policies, business incentives, and consumer motivations is critical to drive changes in socio-technical systems. Various factors spanning from macroeconomic policies and global views, to partial electricity market reform and public distrust, and to experimentation in a demonstration project are found to be crucial in the socio-technical system for SGs in Korea. The presence of partial electricity market reform and public distrust has created barriers to develop some of the favorable conditions for change, such as policy consistency, second-order learning, and the development of financially viable business models, still lacking in Korea.

Chapter "Developing Super Smart Grids in China: Perspective of Socio-Technical Systems Transition" by Yuan Jia-Hai in turns considers the prospects for SG developments in China. It shows that technological development in renewable energies industries will not be sufficient to ensure a transition toward a cleaner and more efficient energy system for China. Indeed such a transition will require the separation of generation, transmission, distribution, and retail prices, which in turn, calls for a new perspective on the regulation of transmission and distribution network. Given that there is deep-rooted origin of the current tariff policy, pricing reform can be regarded as a cornerstone for the Chinese Government in its energy policy. The integration of medium-and-small scale renewable generation as well as pricing mechanism reform also calls for the gradual redefinition of the power grids and restructuring of the utility companies. This certainly poses the most difficult institutional puzzle for developing SG in China. Powerful grid companies would have no incentive to develop SG if it was destined to be dismantled. Therefore, the lock-in effect of energy systems is particularly active in China and a subtle design to synchronize the SG roadmap with power sector deregulation is necessary. Potential strategies to overcome institutional loopholes include empowering the National Energy Administration to be responsible for national strategy formulation, the creation of a think-tank to support policy innovation and the establishment of an industry-government consortium to provide integrated translation research and strong front end support. At the same time, restructuring of the power sector should be synchronized with the development of SG. Dismantling the Grid Companies into regional transmission companies and provincial distribution companies should provide public goods to private users. Leveling the playing field in both technology and investment and opening the power sector to private investors seems of critical importance.

The final chapter in this section examines the important role of distributed energy in smart grid diffusion in Australia. Based on the findings of a major government-funded study, William Lilley and his colleagues examine the opportunities of and key barriers for large-scale uptake of such distributed systems.

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