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The Role of the Smart Grid in Renewable Energy Progress: Abu Dhabi

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The Role of the Smart Grid in Renewable Energy Progress: Abu Dhabi

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Abstract

The Role of the Smart Grid in Renewable Energy Progress: Abu Dhabi

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Since the inception of the Masdar Initiative in 2006, the Emirate of Abu Dhabi has invested a considerable amount of resources to promote renewable sources of energy like solar and wind. With an aim of achieving 7% of its electricity from renewable sources by the year 2020, there is much that the emirate needs to do in order to reduce its reliance on hydrocarbons while still planning capacity for future electricity demand. This report explores the effectiveness of a smart grid infrastructure as a mechanism to afford the flexibility and functionality required to incorporate renewable energy sources into the electric grid, as well as leveraging a real-time data network to attain reductions in peak demand consumption. Specific regulatory structures that exist in Abu Dhabi's electric and telecommunications markets are evaluated to understand the role they will play in dealing with interoperability standards, privacy concerns, and consumer participation issues that influence the effective integration of smart grid into Abu Dhabi's energy future.

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1. Introduction

The United Arab Emirates has the world's sixth largest proven oil reserves, 94% of which exist in the Abu Dhabi Emirate; these oil reserves, along with an abundant supply of natural gas reserves, account for 70% of the emirate's GDP.[1] The emirate has thus been playing an important role in the global hydrocarbon market. In recent years, however, the UAE has also experienced a significant increase in energy demand. Since the year 1980, the average electricity consumption growth rate in the UAE has been 10%, in comparison to the world average of just 3%.[2] This abnormal rate of growth has led to some unwanted consequences: the country has one of the highest carbon footprints in the world, and the rate of depletion of fossil fuels has increased rapidly.[3] These factors have driven the need to develop policies and initiatives that diversify the emirate's portfolio in renewable energy.

Renewable Energy Progress: The Need for Smart Grid

Abu Dhabi has taken an ambitious step towards the progress of renewable sources of energy with the inception of its Masdar Initiative in 2006. The conglomerate, which includes a research institute funded by an investments arm, is looking to spur innovation in the field of renewable energy technologies. In collaboration with the government-

[1]Elizabeth Harder and Jacqueline MacDonald Gibson, "The Costs and Benefits of Large-scale Solar Photovoltaic Power Production in Abu Dhabi, United Arab Emirates," *Renewable Energy* 36, no. 2 (February 2011): 789–796, doi:10.1016/j.renene.2010.08.006.
[2]Danyel Reiche, "Energy Policies of Gulf Cooperation Council (GCC) Countries—possibilities and Limitations of Ecological Modernization in Rentier States," *Energy Policy* 38, no. 5 (May 2010): 2395–2403, doi:10.1016/j.enpol.2009.12.031.
[3]Toufic Mezher, Gihan Dawelbait, and Zeina Abbas, "Renewable Energy Policy Options for Abu Dhabi: Drivers and Barriers," *Energy Policy* 42, no. 0 (March 2012): 315–328, doi:10.1016/j.enpol.2011.11.089.

operated electricity authority (ADWEA), Abu Dhabi seemingly looks to be on track for achieving its renewable energy targets of 7% installed capacity by 2020. However, the advent of renewable energy sources like solar and wind as viable alternate sources of energy raises an interesting challenge. These sources require a reliable, transmission system integrated with real-time information infrastructure to function effectively. Abu Dhabi's current electricity grid isn't capable of providing this level of functionality; the city runs the risk of derailing its promising work towards a renewable energy future without a concerted effort on developing a comprehensive plan for its future grid. A smart grid, in addition to providing the flexibility required to incorporate renewable sources of energy, also provides other benefits such as increases in operational efficiency, improving delivery and reliability, and consequently helping to reduce the overall consumption of energy through peak demand reductions.

Potential Challenges

Abu Dhabi isn't alone in addressing the issues with an ageing electric grid infrastructure; the United States is well underway with the process of modernizing its grid, spurred on thanks to $4.5 billion in AARA grant funding.[4] However, the implementation of a smart grid isn't as easy as just installing newer transmission lines. The introduction of information - specifically consumer usage data transmitted in real-time - as a critical component of the smart grid system means that care will have to be taken to establish how that data is generated and transmitted. The regulatory structure which governs the

[4]Rebecca Grant, "Smart Grid Implementation - Strategies for Success," *International Association of Electrical Inspectors*, October 2010.

power industry in Abu Dhabi will play a key role in determining the standards that are developed to facilitate rapid adoption of a smart grid infrastructure. Finally, consumer buy-in will be a significant factor in ensuring the effectiveness of programs such as demand-response and real-time pricing structures.

Research Questions

In order to address the related challenges of understanding the role of smart grid in integrating renewable energy inputs, as well as its role in using information to foster conservation, the following research questions were developed:

1. What are smart grid technologies, and what is the potential of smart grid systems in contributing to Abu Dhabi's renewable energy and GHG reduction goals?
2. What are the challenges and barriers to the large scale adoption of smart grid technologies for utilities?
3. What are the specific challenges and barriers to the successful implementation and effective use of smart grid technologies for Abu Dhabi?

Methodology & Report Structure

The research for this report was conducted in a way that most effectively addresses the questions posed above. The report will review literature on the definition of smart grids through various peer-reviewed journals. Information on the benefits of smart grid, including the effectiveness of peak demand pricing programs, are discussed using verified experiment data from utility companies. The analysis of surveys on customer preferences on energy conservation as well as utility trends on smart grid feature selection will also lend insight to this report. In addition to the regulatory frameworks that exist in Abu Dhabi's electricity market, current programs are also evaluated to ascertain their effectiveness in achieving the sustainability goals of the emirate.

The report is broken down in the following way. The first chapter explores Abu Dhabi's motivations for pursuing sustainable development and investing in renewable energy, and includes an analysis of the city's current efforts through the Estidama development code and the Masdar Initiative. The next chapter attempts to address how Abu Dhabi's renewable energy efforts will be greatly supported if the implementation of smart grid is pursued. A detailed definition of smart grid is followed by a comprehensive list of how utility companies, consumers, and regulators may benefit from such an infrastructure. Next, the report attempts to identify the potential barriers that could curtail smart grid implementation, ranging from the relationship between utility companies and their regulatory bodies, to establishing standards of operation, and understanding the role of consumer involvement in smart grid effectiveness. The report then moves on into the specifics of Abu Dhabi's electricity market and structure to define the organizational relationships that could potentially influence the direction of smart grid progress in the region, along with the political framework that these relationships rely on. The penultimate chapter of the report then synthesizes all of this information and attempts to present the implementation catalysts and challenges of smart grid specifically through the lens of Abu Dhabi's renewable energy goals, their electricity market structure, and the nature of their local consumers. Finally, the last chapter provides a recommendation plan on how the Emirate can most effectively leverage smart grid systems as a tool to deal with its increasing electricity demand, and promote the integration of electricity generation from renewable sources of energy.

2. Abu Dhabi's Sustainability Efforts

Introduction: Electricity Consumption, Current Needs & Future Growth

Despite recent downturns in the global economy, the UAE has been experiencing rapid economic and demographic growth over the last decade.[5] The installed capacity in the country reached 23.25 GW in 2009, with estimated consumption in 2010 at 79.3 million GWh.[6] More recently, the Emirate of Abu Dhabi saw a 12% increase in their electricity peak demand, as well as a 10% increase in their electricity energy demand from 2010 to 2011.[7] These figures exclude the electricity that Abu Dhabi exports both nationally and globally; the global peak production reached 9,749 MW in 2011[8] and is expected to exceed 10,000 MW in 2012.[9] [10] Future global demand in growth is expected to rise at 13.6% a year between 2011 and 2015, and 10.1% annually between 2011 and 2020.[11] It is forecasted that the peak electricity demand will continue to grow at an increasing rate over the next few decades, reaching an estimated 33,730 MW in the year 2030.[12]

These forecasts are a definite cause for concern for the city, and have led to a creation of a vision plan for the emirate with a focus on sustainable development initiatives.[13] The

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[5]"United Arab Emirates: Country Analysis Brief," *U.S. Energy Information Administration*, October 17, 2012, http://www.eia.gov/countries/cab.cfm?fips=TC.
[6]Ibid.
[7]Keith Miller, "ADWEC Winter 2011/2012 Electricity & Water Demand Forecasts," March 2012.
[8]Ibid.
[9]Ibid.
[10]"Abu Dhabi's peak electricity generation tips 10,000MW," *MEED Middle East Economic Digest,* July 13, 2012.
[11]Verity Ratcliffe, "UAE to see rising demand for power," *MEED Middle East Economic Digest*, March 9, 2012.
[12]Miller, "ADWEC Winter 2011/2012 Electricity & Water Demand Forecasts."
[13]In 2007, the Urban Planning Council of Abu Dhabi created the Abu Dhabi Plan 2030 as the vision framework for how the Emirate would develop over the next few decades. Part of this framework also

emirate has set a goal of achieving 7% of its installed electricity capacity from renewable sources by 2020. The UAE also ratified the UNFCCC in 1996 and the Kyoto Protocol in 2005, aiming to reduce the emissions of key greenhouse gases by an average of five percent below the 1990 level by 2012.[14] Simultaneously, Abu Dhabi has made a concerted effort to dedicate a significant amount of future investments in the generation of electricity from renewable sources. This chapter explains the details of how Abu Dhabi's efforts to promote renewable energy generation are contributing to the region's energy and emissions reduction goals.

Investments in Renewable Energy Sources

The UAE, and Abu Dhabi in particular, have been taking some proactive steps to reshape the renewable energy arena in the past few years. The economy of Abu Dhabi is still based primarily on exporting fossil fuels; the emirate realizes that these resources are finite, and has been looking for ways to diversify their economy.[15] On an international level, there has been a growing demand for alternate energy solutions. In 2006, the Government of Abu Dhabi decided to do something to address the increasing economic and environmental challenges it faced. At the heart of this effort was the formation of the Masdar Initiative.

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included the Estidama development code, which delineates guidelines on how to properly plan, design, construct, and operate sustainable developments with respect to the traditions embedded within the culture as well as the specific climate conditions of the region. "Abu Dhabi 2030," *AMEinfo.com*, n.d., http://www.ameinfo.com/news/Special_Reports/Abu_Dhabi_2030/.

[14] T Mezher, D Goldsmith, and N Choucri, "Renewable Energy in Abu Dhabi: Opportunities and Challenges," *Journal of Energy Engineering* 137, no. 4 (December 2011): 169–176.

[15]Reiche, "Energy Policies of Gulf Cooperation Council (GCC) Countries."

The Masdar Initiative, funded by the government-owned investment arm Mubadala, was formed in 2006.[16] The primary goal of the initiative is to spur innovation by investing in renewable energy and sustainable technologies, along with research and development (R&D) startups to commercial operations. Masdar is striving to establish joint ventures and acquire companies with promising technologies in order to stake its involvement in all parts of the global low carbon value chain.[17] The key initiatives of Masdar are described in Figure 2.1 below:

Masdar units	Functions
Carbon Management Unit	Develops greenhouse gas emissions reduction projects under the provisions of the United Nations' led Clean Development Mechanism (CDM) framework of the Kyoto Protocol
Industries Unit	Invests globally and locally to establish a portfolio of production assets in renewable energy
Masdar Institute of Science and Technology	Offers Master's and Doctoral-level degree programs focused on the science and engineering of advanced energy and sustainable technologies
Property Development	Builds the carbon-neutral, zero-waste Masdar City
Utilities and Asset Management	Uses various investment models to build a portfolio of renewable energy operating assets and to make strategic investments in companies with promising technology

Figure 2.1: The various components of the Masdar Initiative.[18]

[16]"Masdar: A Mubadala Company," n.d., http://masdar.ae/en/Menu/index.aspx?MenuID=42&CatID=12&mnu=Cat.
[17]Ibid.
[18]Danyel Reiche, "Renewable Energy Policies in the Gulf Countries: A Case Study of the Carbon-neutral 'Masdar City' in Abu Dhabi," *Energy Policy* 38, no. 1 (January 2010): 378–382, doi:10.1016/j.enpol.2009.09.028.

Masdar City

Masdar City is one of the Initiative's largest and most significant projects. It is described as a carbon-neutral, zero waste urban community in the heart of Abu Dhabi. Masdar City began with a budget of $22 billion, with $4 billion of the share being funded by Masdar and the rest through other financial instruments including foreign investments.[19]One of Masdar City's defining characteristics is its large scale, integrated application of renewable energy technologies and sustainable living principles in order to achieve comfortable living with minimal environmental impact.[20] Masdar City, covering an area of seven square kilometers once completed, is slated to be completely powered by renewable energy. This renewable energy, be it in the form of wind, solar, biomass or bio-fuels, will provide enough energy to house about 40,000 residents and play host to a commercial and business district of 50,000 more.[21] It has been recognized that the real-world application of these technologies have been on a relatively smaller, piece-meal scale. The lack of a larger scale has also meant that there has been a difficulty to finance such renewable energy systems. As advancements in technologies have begun to drive prices down, the variation in the pattern of costs and costs of improvements have stymied the implementation of renewable energy systems on a larger, utility-level scale.[22] Masdar City is aiming to change this pattern by attempting to integrate various applications of existing renewable technologies in order to position Abu Dhabi as a world leader in renewable energy and sustainability.

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[19]Mari Luomi, "Abu Dhabi's alternative-energy initiatives: seizing climate-change opportunities," *Middle East Policy* 16, no. 4 (Winter 2009): 102+.
[20]"Masdar City," n.d., http://www.masdarcity.ae/en/.
[21]Ibid.
[22]Reiche, "Renewable Energy Policies in the Gulf Countries."

Masdar Power

Masdar Power invests both in renewable energy power projects and in companies with proven clean technologies – within the UAE and internationally.[23] Through this two-pronged investment strategy, the unit helps power companies add renewable energy to their generation mix and provides clean-tech companies with expertise and capital for growth.

As a renewable energy power project developer, Masdar Power adds renewable energy to the electricity generation mix on a world wide scale. The unit makes direct investments in individual utility scale projects in all areas of renewable energy and sustainability, with a focus on concentrated solar power (CSP), photovoltaic solar energy and on- and off shore wind energy.[24] CSP systems, which make up the primary capacity of Masdar Power's renewable energy mix, use mirrors or lenses and tracking systems to focus large amounts of sunlight on water, salts or oils. The heated water directly drives steam generators, while the salts and oils heat water, which in turn runs the steam generators. Masdar Power is developing a 100MW CSP plant in the Western Region of Abu Dhabi Emirate called SHAMS I, with construction scheduled to end in 2012.[25] With SHAMS II and III already slated for future construction, Masdar is looking to build additional CSP plants on a yearly basis until a total capacity of 1,500 MW is reached in 2020.[26] On the PV side, Masdar has developed plans for a 100 MW PV project titled Nour I, which has yet to be

[23]"Masdar Units: Masdar Power," n.d., http://masdar.ae/en/Menu/index.aspx?MenuID=48&CatID=29&mnu=Cat.
[24]Ibid.
[25]Ibid.
[26] Mezher, Goldsmith, and Choucri, "Renewable Energy in Abu Dhabi: Opportunities and Challenges."

built. Abu Dhabi has supplemented these efforts by commissioning a trial project of 2.3 MW of rooftop PV panels, which, if successful, will pilot an expansion to 200 MW of distributed rooftop PV generation.[27] If executed as planned, this added capacity could contribute significantly to reaching the emirate's renewable energy targets.

Other Policy-Oriented Initiatives – Clean Tech Fund, PV, and CCS

Being a multifaceted, regional economic development program, the utilities and asset management of the Masdar Initiative uses various other models to promote sustainable energy. One of them is the Masdar Clean Tech Fund, a $250 million venture capital fund launched in partnership with various European financial conglomerates like Credit Suisse. The Clean Tech Fund deployed its capital in 2007 and 2008, and purchased stakes in a variety of renewable energy companies like Segway, Halosource, Sulfurcell etc. On the other hand, the utilities unit of Masdar Initiative deals with making direct investments in projects in all areas of renewable energy and sustainability. Here are some examples of these investments that Reiche outlines:[28]

- Torreso Energy, a joint venture between Masdar and the Spanish engineering group Sener, already has three solar power plants in Spain with an approximate combined value of 800 million Euros.
- WinWinD, a Finnish manufacturer of 1 and 3 MW wind turbines, received an investment of 120 million Euros from Masdar.

[27] Jim Krane, *An Expensive Diversion: Abu Dhabi's Renewables Investments in the Context of Its Natural Gas Shortage*, Cambridge Working Paper in Economics (University of Cambridge: Electricity Policy Research Group, July 4, 2012), 13, http://www.eprg.group.cam.ac.uk/wp-content/uploads/2012/09/1218-Full.pdf.
[28]Reiche, "Renewable Energy Policies in the Gulf Countries."

The Masdar Initiative also consists of an industries unit, which invests in all markets to establish a portfolio of production assets. Masdar PV (photovoltaic) was formed in April 2008, and is Abu Dhabi's first high-tech manufacturing company. In order for this venture to be successful, Masdar has identified the need to facilitate a technology and knowledge transfer to Abu Dhabi, and has thus decided to invest $600 million in new facilities in both Abu Dhabi as well as Erfurt, Germany;[29] this investment is predicted to raise output capacity to 1 GW.[30]

Masdar has plans to develop the world's largest CCS project to contribute to GHG reductions in the UAE.[31] There is immense potential for developing a successful and technically feasible CCS project in the emirate – Abu Dhabi covers a fairly small area, and the distance between emission sources and oil reservoirs are very short. Moreover, injection of CO_2 into oil reservoirs is dually beneficial. The natural gas that is currently being injected into the reservoirs can be used for more valuable purposes if substituted by CO_2, and CO_2 also dissolves in oil to make it less viscous, hence facilitating a more effective oil recovery process. This process is known as enhanced oil recovery (EOR). The emirate of Abu Dhabi, with the aid of the Masdar CCS project, aims to capture five million tons of CO_2 from power plants and industrial facilities in Abu Dhabi by the end of 2012.[32]

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[29]Ibid.
[30]Luomi, "Abu Dhabi's alternative-energy initiatives."
[31]Sam Nader, "Paths to a Low-Carbon Economy - the Masdar Example," *Energy Precedia* 1, no. 3951 (February 2009).
[32]Ibid.

Constraints of Current Grid on Renewable Energy Adoption

While Abu Dhabi's motives and investments in renewable energy projects are commendable, the generation and distribution of power from renewable sources bring about a set of parameters that current grids can't quite handle. Often referred to as dynamic efficiencies, the integration of electricity from variable sources such as wind farms and solar arrays requires "accurate, real-time information about the supplies and demands influencing the grid at any time, as well as mechanisms to balance loads with generation."[33] Tapping into renewable sources of energy requires more advanced and flexible transmission, which existing grids are not capable of handling.[34] From this perspective, investing in smart grid is an essential cog to ensure the feasibility and utilization of other energy-related investments.

[33]E. L. Quinn and A. L. Reed, "Envisioning the Smart Grid: Network Architecture, Information Control, and the Public Policy Balancing Act," *U. Colo. L. Rev.* 81 (2010): 833.
[34]Fereidoon P Sioshansi, *Smart grid: integrating renewable, distributed & efficient energy* (Waltham, MA: Academic Press, 2011), http://www.myilibrary.com?id=329901.

3. Smart Grid: Definition and Benefits

Defining the Smart Grid

A Combination of Technologies, Infrastructure, and Domains

Before we explore the benefits of implementing a smarter grid, it is essential to delineate what exactly a smart grid encompasses. Very simply put, a smart grid uses digital communication to align energy consumers and suppliers better.[35] In comparison to existing grids, what sets a smart grid apart is the integration of electrical and communications infrastructures with advanced process automation and information technologies within the existing electrical network. A smart grid has also been more specifically defined from the perspective of a utility as "an intelligent, auto-balancing, self-monitoring power grid that accepts any source of fuel (coal, sun, wind) and transforms it into a consumer's end use (heat, light warm water) *with minimal human intervention.*"[36] The National Science and Technology Council of the United States defines smart grid technologies and applications as an encompassing of a diverse array of modern communications, sensing, control, information, and energy technologies that are already being developed, tested, and deployed throughout the grid.[37] The technologies described can be broken down into three basic categories[38]:

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[35]Leo A. McCloskey, "What Makes a Grid Smart?," *Electric Light & Power*, May 2011.
[36]*Xcel Energy Smart Grid: A White Paper 2* (Xcel Energy, 2008), http://smartgridcity.xcelenergy.com/medialpdf/SmartGridWhitePaper.pdf.
[37]*A Policy Framework for The 21st Century Grid: Enabling Our Secure Energy Future* (National Science and Technology Council, Executive Office of The president, June 13, 2011), http://www.nist.gov/smartgrid/upload/nstc-smart-grid-june2011.pdf.
[38]Ibid.

1. advanced information and communications technologies that improve the operation of transmission and distribution systems;
2. advanced metering solutions which improve on or replace legacy metering infrastructure; and
3. smarter technologies, devices, and services that access and leverage energy use information.

From a conceptual standpoint, then, there are some discrete elements of the smart grid that can be identified, even if they do overlap. The National Institute of Standards and Technology (NIST) attempt to categorize the elements of smart grid into certain domains, implying that the process of implementation requires many steps in each domain area[39] (see Figure 3.1):

Domain	**Description**
Customer	The end users of electricity. May also generate, store, and manage the use of energy. Traditionally, three customer types are discussed, each with its own sub-domain: home, commercial/building, and industrial.
Markets	The operators and participants in electricity markets.
Service Provider	The organizations providing services to electrical customers and to utilities.
Operations	The managers of the movement of electricity.
Bulk Generation	The generators of electricity in bulk quantities. May also store energy for later distribution.
Transmission	The carriers of bulk electricity over long distances. May also store and generate electricity.
Distribution	The distributors of electricity to and from customers. May also store and generate electricity.

Figure 3.1: Domains in the Smart Grid Conceptual Model.[40]

[39] Grant, "Smart Grid Implementation - Strategies for Success."
[40] *NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 2.0* (National Institute of Standards and Technology, February 2012).

Other Perspectives: Developing a Comprehensive Vision

There also exists a school of thought that believes in defining smart grid more through its ultimate applications, uses, and benefits to society at large. In other words, instead of first defining the smart grid and then justifying why it is a great idea, it is perhaps more constructive to examine what is missing or inadequate in current grids.[41] Understanding the current limitations and constraints of how electricity moves has lead to the development of a "wish-list" of concerns that a smart grid needs to address. A comprehensive list of the functions and characteristics of a smart grid can thus be compiled, using the framework that Sioshansi provides in his book, *Smart Grid:*[42]

- it must facilitate the integration of diverse supply-side resources including increasing levels of intermittent and non-dispatchable renewable sources;
- it must facilitate and support the integration of distributed and on-site generation on the customer side of the meter;
- it must allow and promote more active engagement of demand-side resources and participation of customer load in the operations of the grid and electricity market operators;
- it must allow widespread permeation of dynamic pricing to beyond-the-meter applications such as enabling intelligent devices to adjust usage based on variable prices and other signals;
- it must ultimately turn the grid from a historically one-way conduit to a two-way, intelligent conduit, allowing power flows from different directions at different times, from different sources to different sinks;

[41]Fereidoon P. Sioshansi, "So What's So Smart About the Smart Grid?," *The Electricity Journal* 24, no. 10 (December 2011): 91–99, doi:10.1016/j.tej.2011.11.005.
[42]Sioshansi, *Smart grid: integrating renewable, distributed & efficient energy*.

- it must allow for broader participation of energy storage devices on customers' premises or centralized devices to store increasing levels of energy when it is plentiful and inexpensive, to be utilized during times when the reverse is true, and accomplish this intelligently and efficiently;
- it must allow distributed generation as well as distributed storage to actively participate in balancing generation and load;
- it must encourage more efficient utilization of the supply-side and delivery network through efficient and cost-effective implementation of dynamic pricing;
- it must allow storage devices on customer side of the meter, including electric batteries and similar devices, to feed the stored energy back into the grid when it makes economic sense to do so;
- it must facilitate any and all concepts and theories that encourage greater participation by customers and loads in balancing supply and demand in real time through concepts broadly defined as demand response;
- it must make the "grid" - the vast generation, transmission, and distribution network - more robust, more reliable, and more secure to interruptions, and less prone to accidents or attacks of any kind;
- and finally, it needs to accomplish these tasks while reducing the costs of the operation and maintenance of the network, with commensurate savings to ultimate consumers.

Examining the comprehensive list above shows us that not every aspect of the smart grid provides the same amount of benefit to all of the involved actors in the smart grid domain. Some features of the grid are utility-centric, and focus on the reliability, performance, and productivity of a utility in terms of energy generation and transmission. Other features emphasize on the importance of consumer involvement, and are centered on providing quality levels of electricity service at lower rates to consumers. Finally, there are certain aspects of the grid that aim to address environmental concerns relating to greenhouse gas emissions as well as renewable energy integration. These benefits are explained in more detail in the following section.

Benefits of Smart Grid

Utility Benefits: Operational Efficiency, Distribution Losses

The process of electricity distribution in its current form is inherently inefficient. The United States, for example, has dealt with transmission and distribution losses of over 260 billion KWh during 2010,[43] which represents more than 6% of total net generation. The UAE, on the other hand, experienced a 7.3% loss (equating to about 6.7 billion KWh[44]) of total electricity generation through transmission and distribution. In his book *Smart Grids*, Borlase highlights that a variety of technology- and information-related factors of the smart grid - such as power flow monitoring, voltage control improvements, and software automation systems[45] - contribute to the improvement in grid reliability and operational efficiency of utility providers.[46] This will reduce overall energy consumption and related emissions while conserving finite resources and lowering the overall cost of electricity.

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[43]Transmission and distribution loss refers to the electric energy lost due to the transmission and distribution of electricity. Much of the loss is thermal in nature. "International Energy Statistics: Distribution Losses," *U.S. Energy Information Administration*, n.d., http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=2&pid=2&aid=9.
[44]Ibid.
[45]*Technology Roadmaps: Smart Grids* (International Energy Agency (IEA), 2011), http://www.iea.org/publications/freepublications/publication/smartgrids_roadmap-1.pdf.
[46]Stuart Borlase, *Smart Grids: Infrastructure, Technology, and Solutions* (Boca Raton, FL: CRC Press, 2012), http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=490742.

Utilities may further have an inherent advantage in empowering consumers' participation in the smart grid; by giving them access to time-of-use rates and real-time pricing signals, there is a higher chance that power usage may drop during peak hours.[47] A year-long study of smart grid technologies in the Pacific Northwest of the U.S. estimated that power use could be cut by 15%, implying a nationwide reduction of up to $120 billion in spending on new power plants and transmission lines.[48] The reason for this is because peak capacity is usually required for a relatively short amount of time in any given year; in other words, any generation, transmission, and distribution infrastructure that is built solely to accommodate peak demand is being under-utilized during non-peak hours (which constitute the majority of any given year). For example, the peak usage of the California Independent System operator (CAISO) in the year 2005 was 50,085 MW, but the usage exceeds 45,000 MW only 0.65% of the time annually.[49] The provision of additional infrastructure, including additional base-load power plants to accommodate a spike in demand that occurs less than 1% of the time, cannot be viewed as an ideal use of resources. Smoothing the peak demand curve will afford utilities the opportunity to improve overall system delivery efficiency by reducing the number of peak power plants, as well as the total number of transmission lines that need to be built. Indeed, a utility analysis study conducted on data from more than 800,000 residential and commercial utility customers in the 200 largest utility providers in the U.S. showed that nearly all the utilities would save enough in avoided costs with a comprehensive smart grid

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[47]Ibid.

[48]"FACTB0X: What Is a Smart Grid?," *Reuters*, January 9, 2009, http://www.reuters.com/article/2009/01/09/us-usa-obama-energy-factbox-sb-idUSTRE50808B20090109.

[49] *Smart Grid: Enabler of the New Energy Economy* (Electricity Advisory Committee, December 2008), 7, http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/final-smart-grid-report.pdf.

development to at least cover smart grid development and deployment costs.[50] These studies strengthen the case that utilities stand to benefit greatly from the savings in deferring power plant and infrastructure construction.

Additionally, it is important to note that reducing peak demand doesn't directly relate to reducing overall demand. However, it does help utilities to make better use of their resources because a significant portion of the peak traffic reduction reappears during off-peak hours when the grid isn't strained.[51] In this way, moving peak demand loads to off-peak hours will help the utilities maximize their asset utilization.

Consumer Benefits: Real-time Pricing, Demand Response

One of the biggest benefits that a smart grid provides to customers is the fact that they will be able to have a much greater level of control on the energy that they consume. The ability to use electricity when it is cheapest, coupled with the ability to produce and sell power back into the grid during peak demand periods, could mean reduced electricity bills for consumers in the long run. Real-time pricing information and demand response are at the core of enabling this functionality of the grid.[52] Various studies and surveys prove that the utilization of real-time information and pricing models have enabled consumers to cut their consumption by up to 15%.[53] Borlase notes that the use of energy

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[50] Jerry Jackson, *Are Smart Grids a Smart Investment? Hourly Load Analysis of 800,000 Utility Customers at 200 of the Largest US Utilities* (College Station: Harvard Electricity Policy Group, June 24, 2009), http://www.hks.harvard.edu/hepg/Papers/2009/sganal.pdf.

[51] David P. Chassin, "What Can the Smart Grid Do for You? And What Can You Do for the Smart Grid?," *The Electricity Journal* 23, no. 5 (June 2010): 57–63, doi:10.1016/j.tej.2010.05.001.

[52] Borlase, *Smart Grids: Infrastructure, Technology, and Solutions*.

[53] Ahmad Faruqui and Sanem Sergici, "Household Response to Dynamic Pricing of Electricity: a Survey of 15 Experiments," *Journal of Regulatory Economics* 38, no. 2 (2010): 193–225, doi:10.1007/s11149-010-9127-y.

feedback tools like programmable thermostats and smart appliances that engage and empower customers can go on to double those savings.

Another important factor about the smart grid that contributes to consumer benefits is the implementation of demand response programs. With real-time pricing information readily available, the smart grid greatly expands on the list of potential participants who can use this new information infrastructure to proactively respond to electricity demand.[54] Peak demand pricing information, coupled with consumer preferences on electricity consumption (which are propagated and automated through smart appliances, for example) has been shown to reduce peak residential demand by 16%, and average demand reductions of 9% - 10%.[55] The extensive pilot experiments conducted by Faruqui and Sergici revealed the potential that different types of pricing programs like time-of-use (TOU), critical peak pricing (CPP), and real-time pricing (RTP) had on reducing peak demand for various utilities (Figure 3.2). The experiments made a key distinction between trials that were run with and without enabling technologies on the customer side like smart thermostats, smart dishwashers etc.

[54]Borlase, *Smart Grids: Infrastructure, Technology, and Solutions*.
[55]Davis Vadari, *Investigating Smart Grid Solutions to Integrate Renewable Sources of Energy in to the Electric Transmission Grid* (Battelle Energy Technology, 2009).

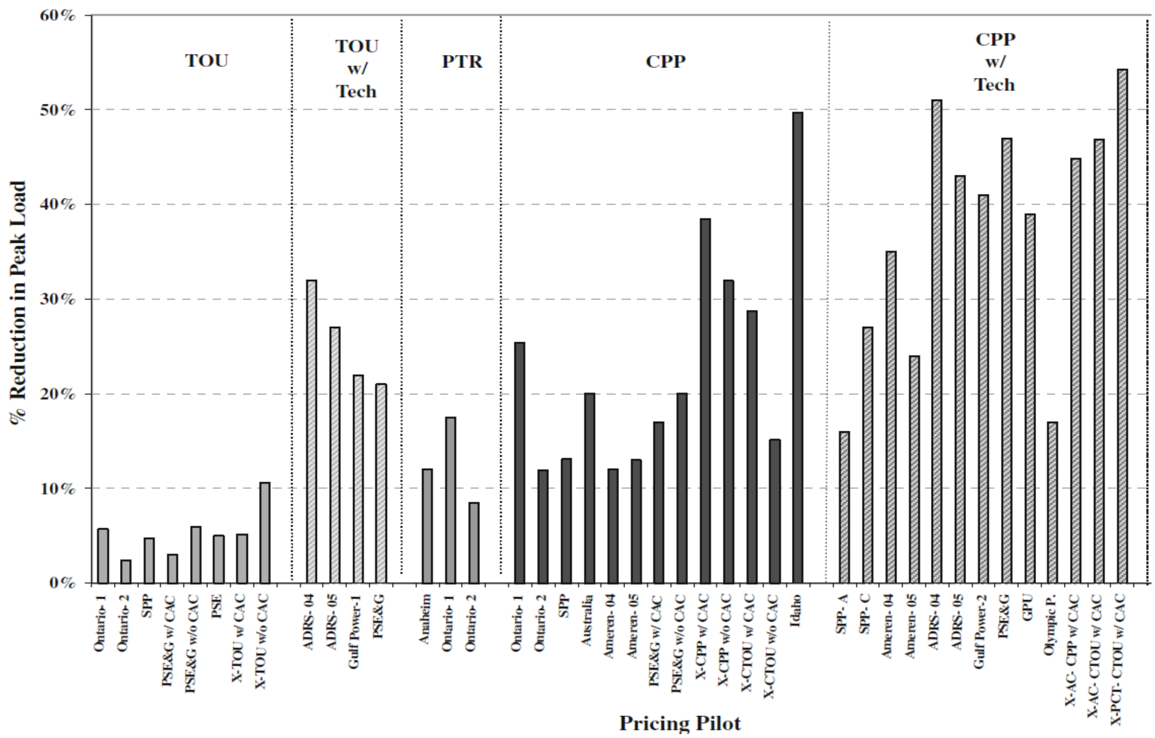

Figure 2.2: A summary of the potential savings from various dynamic pricing trials. Source: Faruqui.[56]

The results of course varied depending on the utility and the type of program implemented; for example, during 2006 and 2007, the Public Service Electric and Gas Company in New Jersey (PSE&G) ran a pilot with two sub-programs. Named *myPower Sense* and *myPower Connection*, both programs incorporated TOU and CPP strategies for pricing with the difference being that the latter program also included a free programmable communicating thermostat (PCT) that received price signals from PSE&G and adjusted their air-conditioning. The results of the experiment showed that the *mypower Connection* customers reduced their peak demand by 21% due to TOU-only

[56] Faruqui and Sergici, "Household Response to Dynamic Pricing of Electricity."

pricing, and by an additional 26% on CPP event days.[57] In contrast, the *myPower Sense* customers achieved 6% peak reductions on TOU-only days and 20% on CPP event days.

In addition to highlighting the general potential for peak demand reduction through dynamic pricing, the study also showed the positive effect of enabling technologies on the savings for customers. The reduction in peak demand itself has far reaching benefits to both customers and utilities: if expensive peak plants do not need to be turned on during peak hours, the overall costs for utilities are reduced, and these savings are passed on to the consumer in the form of lower rates.

Environmental Benefits: Emissions, Eco-systems, and Health

Peak demand reduction through demand response further lends itself to the cause of reducing pollution levels of greenhouse gases. PJM[58] Interconnection released a report in 2010 that shows the average amount of CO_2 emitted for marginal units (those units that are the last to be brought online, and set the price for energy for the consequent five-minute increment) during both peak and off-peak periods.[59] PJM was able to receive 94,000 MWh of energy from all demand side resources in 2010; 60% of this energy depended directly on responding to price signals. A combination of demand response and avoided energy consumption ended up equating to about a 77,000 ton reduction in the

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[57] Faruqui and Sergici, "Household Response to Dynamic Pricing of Electricity," 211.
[58] PJM is aregional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of 13 states and the District of Columbia. PJM coordinates and directs the operation of the region's transmission grid, which includes 6,038 substations and 56,350 miles of transmission lines; administers a competitive wholesale electricity market; and plans regional transmission expansion improvements to maintain grid reliability and relieve congestion.
"PJM Interconnection: About PJM," n.d., http://www.pjm.com/about-pjm.aspx.
[59]"PJM Reports New Carbon Dioxide Emissions Data," accessed November 11, 2012, http://www.prnewswire.com/news-releases/pjm-reports-new-carbon-dioxide-emissions-data-89137272.html.

annual CO_2 emissions for that year. This is a clear indication of the impact that smart grids can have in achieving environmental goals.

There also exists literature that further attempts to price the environmental impacts of energy use and production. The National Academies Press published a report in 2010 that highlighted the severity of this issue: in 2005 alone, environmental externalities from U.S. electricity production cost $120 *billion*.[60] While the study wasn't able to accurately estimate the costs of climate change or damage to ecosystems, it was able to establish that around 50% of this cost was a direct result of coal-fired electricity generation at 406 plants; damages from SO_2, NO_x, and particulate matter resulted in an average cost of about $1.56 million per plant.[61] Additional research from California grimly indicates - perhaps characteristically - that "costs in the water, energy, tourism and recreation, agriculture, forestry, and fisheries sectors will be as high as $23 billion annually, with another $24 billion annually in public costs."[62]

Implementation of smart grid has the potential to alleviate many of these concerns, because it provides a means of reducing the reliance on the coal- or natural gas-powered plants that have higher GHG emissions factors to begin with. Coupled with the promotion of energy conservation and cleaner sources of energy, the smart grid is a strong

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[60]Committee on Health, Environmental, and Other External Costs and Benefits of Energy Production and Consumption; National Research Council, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use* (Washington, D.C.: The National Academies Press, 2010).
[61]Ibid.
[62]David Roland-Holst and Frederich Kahrl, *California Climate Risk and Response* (UC Berkeley: Department of Agricultural and Resource Economcis, November 2008), http://www.nextten.org/pdf/report_CCRR/California_Climate_Risk_and_Response.pdf; Borlase, *Smart Grids: Infrastructure, Technology, and Solutions*.

proponent of an energy future with environmental responsibility as a critical consideration.

Renewable Energy Integration

Perhaps the most important benefit of a smart grid is its ability to seamlessly integrate the generation of energy from renewable sources. The environmental concerns about clean energy generation have spurred various government initiatives to promote the adoption of renewable sources of energy. The EIA forecasts in its *International Energy Outlook for 2011* report that over the next 23 years, renewable energy sources will be the fastest growing sources of electricity generation at a rate of 3.1% per year.[63] While the conventional grid has served remarkably well to deliver cheap power to a broad population, it isn't particularly well-suited to fluctuating power sources like solar and wind.[64]A coal plant can be turned online or offline at will (cost-permitting); however, energy generation from solar arrays or windmills rely significantly on the relatively unpredictable nature of the weather. The intermittent nature of these sources implies that in order to effectively use such renewable sources, the grid will have to be flexible enough to lack of continuity of generation at varying frequencies. The technological and informational infrastructure of a smart grid affords operators the ability to use real-time information to manage and respond to this type of generation, be capable of dealing with multidirectional power flows, while maintaining the quality of power and service within

[63]*International Energy Outlook 2011* (U.S. Energy Information Administration (EIA), September 19, 2011), http://www.eia.gov/forecasts/ieo/more_highlights.cfm#world.
[64]David Talbot, "Lifeline for renewable power: without a radically expanded and smarter electrical grid, wind and solar will remain niche power sources," *Technology Review (Cambridge, Mass.)*, February 2009.

the system.[65] [66] An added advantage of a smarter grid which complements the integration of renewable sources of energy is making use of the availability of energy from decentralized sources. Often referred to as distributed generation (DG), these sources require a grid to facilitate connection and operation of generators of all sizes and technologies while ensuring the quality and security of supply for consumers.[67] In planning for rooftop solar panel pilot projects, Abu Dhabi is already considering the benefits of DG by adding incremental supply closer to where it's needed. Small scale renewable generation like rooftop solar panels can be sited where distribution lines already exist, eliminating the need for additional transmission lines.[68] Given the shorter distances that this power has to travel, efficiency improvements are also an added benefit of DG.

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[65]Borlase, *Smart Grids: Infrastructure, Technology, and Solutions*.
[66]*Technology Roadmaps: Smart Grids*.
[67] W.T. Shang and M.A. Redfern, "Enhancing the Contribution from Distributed Generation Using Smart Grids," in *2010 China International Conference on Electricity Distribution (CICED)*, 2010, 1 –6.
[68] Gail Reitenbach, "The Smart Grid and Distributed Generation: Better Together," *Power* 155, no. 4 (April 2011): 46–51.

4. Evaluating the Frameworks that Affect Smart Grid Adoption

After focusing on the benefits of smart grid in the previous chapter, the primary goal of this chapter is to evaluate the frameworks within which the various actors which are most likely to be involved in smart grid development interact with each other. The section begins with an assessment of the relationship between utilities and the regulatory structures that govern them. The topics of networks and standards are explored next, before ending with an evaluation of the changing role of consumers. In each case, the potential barriers that these issues pose are also discussed.

Relationship between Utilities and Regulatory Structures

An assessment of the historical development of interactions between utility companies and the regulatory environment within which they function can give us many insights into their motivations for or against adoption of smart grid. Utilities have historically performed the role of generating, transmitting, and selling electricity at rates sufficient to recoup costs.[69] The utility's investment decisions and its fundamental identity is that of a generator and seller of electricity. Quinn and Reed point out that these characteristics of a typical utility company are critical to the deployment of smart grid technologies for two reasons: Firstly, the smart grid represents a type of investment very different from the investments historically made by utilities, because it attempts to control and shape demand rather than simply satisfying it with generation. Secondly, potential functions of the smart grid like total demand reduction through in-home feedback displays, or the

[69]*Energy, Economics and the Environment: Cases and Materials*, 3rd ed, University Casebook Series (New York, NY: Foundation Press, Thomson Reuters, 2010).

derivation of consumer behavioral trends from detailed usage information, may be seen as new capabilities that fall outside the fundamental purpose of utilities.[70]

The authors astutely observe that this leads to a nuanced bias in development priorities for smart grid from the utilities' perspective: they will more likely focus their efforts on smart grid functions that offer cost reductions and load shifting through dynamic pricing, and other actions that are clearly revenue-positive, and have less of an inclination towards working on enhancing consumer awareness of environmental footprint, true demand reduction, or opportunities for innovative use of detailed data. This mentality is highlighted in a recent survey on advanced metering: home area networks, which are one of the few technologies that allow consumers to control home loads in response to utility price signals, were reported as the least used feature by entities developing smart grid infrastructures.[71] Another study done by Oracle for the EMEA region (Europe, Middle East, and Africa) reported that utilities were using smart meters for these top five reasons: reading usage information from a meter on demand; load limitation; supporting pre-pay applications; remotely turning power on/off to a customer; and detecting and communicating service outages.[72] The study further discovered that high percentages of utilities didn't have in place a communications program to inform customers about the service benefits delivered by the technology (60%), the impact on their billing (50%), why Smart Meters are being installed (56%), and the security and privacy implications

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[70]Quinn and Reed, "Envisioning the Smart Grid."
[71]*Assessment of Demand Response & Advanced Metering: Staff Report* (U.S. Federal Energy Regulatory Commission, December 2008), http://www.ferc.gov/legal/staff-reports/12-08-demand-response.pdf.
[72]*The EMEA Smart Grid Rollout* (Reading, UK: Oracle, 2010).

involved (62% and 78% respectively). These figures indicate the influence that utilities can have on the direction of smart grid development without well-defined regulation.

Economic Regulation

A significant factor that contributes to shaping the development framework for power industries is the economic regulation of investor-owned electric utilities (IOUs). Traditional IOUs have been typically described as natural monopolies, because they require massive fixed-cost capital investments.[73] The building or purchasing of central power plants, transmission lines, substations, and distribution lines create very high barriers of entry for any competing firms looking to enter the market. It is seen as more efficient and desirable for a single company to serve an area within which it controls this infrastructure, because introducing a competing set of infrastructure is perceived as a waste of societal resources.[74]

Since the natural tendency of a monopolist is to sell a lower quantity of goods at a higher price than what would occur in a competitive market, governments regulate natural monopolies in an attempt to better represent an equitable and optimal market.[75] The role of regulators in these cases is usually to assess the operations of the IOU and make projections on current and future needs. For example, regulators determine how much the shareholders of an IOU may earn, the maximum possible rates that can be charged to ratepayers for expense recoupment, and how to expand capacity in order to meet future

[73]Quinn and Reed, "Envisioning the Smart Grid," 845.
[74]*Energy, Economics and the Environment*, 52.
[75]Kenneth Train, *Optimal Regulation : The Economic Theory of Natural Monopoly* (MIT Press, 1991).

demand.[76] These issues are comprehensively evaluated in the process of rate cases; electricity demand, as projected by and perceived by the utility providers and regulators respectively, have a significant role in determining the rate that can be charged to consumers. Consequently, the annual revenues of the utility company are also affected.

Potential Barriers

The nature of this relationship between the regulators and utility providers, especially when it comes to determining electricity rates, unearths a dilemma to deal with. As Quinn and Reed explain, the rate is directly proportional to the revenue requirements of the utility, meaning that rates will increase as investments in capital assets increase.[77] Similarly, if the sales level of the utility drops, higher rates are required in order to capture the same amount of revenue. However, since the rate that is decided upon during a given period cannot be altered, changes in consumption can lead to the utility earning more or less revenue than what the regulator has stipulated as required. The scenario that the utility is more inclined to see play out is, predictably, one where they maximize sales so as to be rewarded for selling more power than it anticipated, experiencing higher revenues.[78] An utility company operating in this traditional framework, then, will potentially be resistant to technologies and policies - like demand-side management programs - which are designed to reduce consumption, and could consequently reduce the utility's required revenues. Utilities are also not traditionally profit-maximizing; since their returns are guaranteed by regulators, they have little incentive to examine new

[76]Quinn and Reed, "Envisioning the Smart Grid," 846.
[77]Ibid.
[78]Ibid., 847.

business models, products, or ideas outside their core competency of selling electricity to consumers. This is especially relevant because taking these kinds of risks could result in higher costs being passed on to the consumer.[79]

These circumstances mean that, while utilities aren't going to shy away from investing in smart grid technologies, they will do so in a manner that addresses their supply-side needs, and will only consider consumer interaction when it is a necessity to achieve their objectives. One of the key ways in which to address this problem is through the process of decoupling a utility's revenue stream from the amount of electricity it sells. The benefits of decoupling will be addressed later on in this report.

Network Architecture & Standards

The nature of smart grid infrastructure is such that it involves the interaction of multiple complex components, at several points of the model, to form a seamless flow of data. It is crucial for these components to have a common language to interface with each other. Solutions that work with proprietary software will be unable to fit into this model; open-architecture solutions and agreed standards for smart grid devices are therefore a key factor in the success of smart grid.[80]

The definition of standards early on in the process has a huge role in plotting the direction of development for the network architecture of smart grid as a whole. In the case of consumer electricity usage data, for example, there are multiple systems within which that information can be generated and transmitted. If this high-resolution information is

[79]Ibid., 849.
[80]Grant, "Smart Grid Implementation - Strategies for Success."

gathered by a smart meter which was installed as part of an infrastructure build-out by a public utility, then it is likely that the trading or movement of that data is subject to the internal regulations of the agency that governs the utility.[81] On the other hand, if this data is generated and collected in a system that exists exclusively from the utility infrastructure, a different set of rules is likely to govern how the information can be disseminated.[82] The significance of the medium of data generation is illustrated in the case of Xcel Energy, which developed a smart grid project in Boulder, Colorado. As part of the infrastructure, Xcel Energy laid its own fiber to facilitate the transmission of metering information, with future deployments likely to rely on wireless data transmission.[83] Quinn and Reed argue that under traditional circumstances, the data could be viewed as ancillary to the primary purpose of a utility of providing electricity; however, the advent of more proactive information management of this data in the future could perhaps be seen as something under the regulation of the Federal Communication Commission (FERC).[84] Indeed, Duke Energy's application for development of a smart grid project in Indiana faced opposition from a local telecommunications provider under the argument that a smart grid would be positioned to improperly compete with a telecommunications network already regulated as a monopoly.[85]

81 Quinn and Reed, "Envisioning the Smart Grid," 863.
82 Ibid., 864.
83 *Xcel Energy Smart Grid: A White Paper 2*.
84 Quinn and Reed, "Envisioning the Smart Grid," 865.
85 Ibid.

Potential Barriers

It is easy to see how the lack of standards can prove to be an impediment for the development of a smart grid. Without set standards, companies who are involved in research and development of the technological components of smart grid may exhibit trepidation in terms of the direction of progress. When the governance and regulation of data - which is such a critical commodity in the smart grid network - comes into question, the need for a common standard arises in order to coalesce effective development and implementation.

The generation, relay, and regulation of sensitive consumer usage data from remote control systems also pose challenges with security. If information solutions are designed around existing internet infrastructures, both utilities and consumers are exposed to the risk of cyber-threats. If network vulnerabilities are discovered, an attacker could potentially penetrate the network, gain access to control software, and alter load conditions to destabilize the grid in unpredictable ways.[86] More sophisticated attacks involving subtle changes to individual usage or even large scale attacks on the electric grid are possible, especially with research showing that "worms" are capable of existing on smart meters.[87] Setting network standards with fail-safe security mechanisms are therefore equally important in ensuring grid stability.

[86]Grant, "Smart Grid Implementation - Strategies for Success."
[87]P. McDaniel and S. McLaughlin, "Security and Privacy Challenges in the Smart Grid," *IEEE Computer Society* 7, no. 3 (May 2009): 75 –77, doi:10.1109/MSP.2009.76.

Smarter Consumers in Participation

Perhaps the most critical challenge for the successful implementation of a smart grid system is to fully understand the role of the consumer. Electric and natural gas utilities have sophisticated systems that perform highly accurate projections of expected consumption and cost;[88] yet, within the energy sector, millions of potential participants in the market (residential consumers) have little or no access to information, and consequently little impact on prices.[89] Consumers need to be given access to information on energy flow if they are to participate as an essential cog in smart grid development. As evidenced in previous sections of this paper, regulators and utility companies in charge of determining the direction of the smart grid will have a distinct bias towards promoting the features of smart grid that favor their operations. However, it will do well for them to remember that the customer is ultimately the stakeholder that the entire grid was created to support. Implementing smart grid will depend on resolving two critical factors that will redefine consumer interaction with their electric utility:[90]

- the consumer's embrace of the two-way monitoring technology that helps to control peak power requirements
- implementing dynamic pricing that provides incentives for consumers to change their energy-use patterns

As the surveys from Oracle and FERC showed, consumer participation does not rank highly in terms of the current priorities for utilities. Additionally, information technology

[88]John J. Marhoefer, "Intelligent Generation: The Smart Way to Build the Smart Grid," *Natural Resources & Environment* 23, no. 1 (Summer 2008): 19–34.
[89]Ibid.
[90]Grant, "Smart Grid Implementation - Strategies for Success."

hasn't traditionally been a strong point of the traditional utility. While smart meters have seen an increasing rate of installations,[91] there hasn't been a push from the utilities to disseminate information to the consumers about their role in the process.

Potential Barriers

The lack of involvement of consumers poses a potential problem for smart grid implementation. Many of the goals of implementing smart grid in the first place - demand response, reducing peak loads, using smart appliances - require significant input from the consumer in order to be successful. A lack of understanding of what exactly smart grid can achieve for the consumer could greatly hamper the effectiveness of the system. Utility companies must also be wary of facing potential backlash from misinformed consumers, who may perhaps feel like they may have to personally shoulder the burden of investment in smart grid infrastructure and technology through increased electricity rates.[92] Similarly, consumers who do not completely understand the concepts of peak demand and real-time pricing may misinterpret the strategy of raising prices during peak hours; they may also question the credibility of utilities accumulating sensitive consumption data from them.

[91] A survey found that approximately 13.6 million homes in the U.S. had installed AMI (Advanced meter infrastructure) devices as of December 2009. Ibid.
[92] Ibid.

5. Structural Characteristics of Abu Dhabi as Factors in Adoption

The intent of this chapter is to delve into the specifics of the environment within which a smart grid infrastructure could potentially develop in Abu Dhabi. This chapter begins with the background of the political structure which has defined the effectiveness of decision-making in the UAE. It will then outline the dynamics that exist between the various entities in Abu Dhabi's power industry, and end with a brief synopsis of the rules that govern information and data privacy.

Government Structure

The Emirate of Abu Dhabi is the capital of the United Arab Emirates. Unlike other countries in the Gulf Cooperation Council (GCC), the political system of the UAE is a federation.[93] Decisions on policies relating to foreign affairs, security, and defense are handled at the federal level, whereas issues like electricity, education, and health are dealt with at the state or emirate level.[94] The governance structure of the UAE, however, is biased, especially on the federal level.[95] Abu Dhabi and Dubai enjoy more power than the other five emirates of Sharjah, Ajman, Umm al-Quwain, Ras al-Khaimah, and Fujairah. The reason for this dates back to the inception of the UAE in 1971. A power sharing agreement was reached between Abu Dhabi and Dubai, considered the two most important emirates on account of the relative abundance of resources available to them. This agreement stipulated that the ruler of Abu Dhabi would be the President of the UAE,

[93]Laleh Khalili, *Politics of the modern Arab world : critical issues in modern politics* (London; New York: Routledge, 2009).
[94]Reiche, "Energy Policies of Gulf Cooperation Council (GCC) Countries."
[95]Khalili, *Politics of the modern Arab world*.

while the ruler of Dubai would act as the Prime Minister.[96] In other words, the Prime Minister was the head of the UAE government and the President the head of the state, a hierarchy that is followed even today. The UAE government has also established the Supreme Council as a top policy-making body. Even though all emirates are represented by their leaders in this council, the rulers of Abu Dhabi and Dubai have a veto power over matters of national importance.[97]

On the local or emirate level, governance is largely centralized. Decision-making power lies mainly with the ruling families. In all the emirates, the presence of political parties or any other institutions or organizations that deal with politics is prohibited.[98] The constitution of the UAE further lends itself to facilitate local decision-making; for example, it stipulates that the local governments of the emirates have full legal control over oil and natural gas reserves. Each emirate is also responsible for its own electricity generation, transmission, and distribution network structure. This kind of system, although hardly democratic, allows for effective implementation of policy decisions.

Evolution of Power Sector Structure

The organization of entities responsible for the different stages of generation and distribution of power and water in Abu Dhabi underwent a process of restructuring in the past decade. In 1999, separate water and electricity companies were created as a result of

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[96]Christopher M. Davidson, "After Shaikh Zayed: The Politics of Succession in Abu Dhabi and the UAE," *Middle East Policy* 13, no. 1 (2006): 42–59, doi:10.1111/j.1475-4967.2006.00237.x.
[97]Reiche, "Energy Policies of Gulf Cooperation Council (GCC) Countries."
[98]Ibid.

breaking up the old Water and Electricity Department (WED).[99] This 'unbundling' process included the formation of the Abu Dhabi Water and Electricity Authority (ADWEA), tasked primarily with the research and development of ways to "more efficiently produce, distribute, and consume water and electricity."[100] Five subsidiaries were established under the parenthood of the ADWEA to aid these specific purposes.[101] The Abu Dhabi Water and Electricity Company (ADWEC) is one such wholly owned subsidiary, and is the single buyer and seller of water and electricity in the Emirate of Abu Dhabi.[102] ADWEC defines its key role as that of a guarantor of the security of supply of water and electricity to consumers in Abu Dhabi, and aims to achieve this through "careful short-term and long-term balancing of supply and demand, through long-term power and water purchase agreements (PWPAs), through the bulk supply tariff (BST) sales agreements with the distribution companies (DISCOs) and fuel supply agreements (FSA)."[103]

ADWEA has also established the Transmission & Dispatch Company (TRANSCO), which is the subsidiary responsible for developing, operating, and maintaining the high voltage power transmission network within the Abu Dhabi Emirate.[104] Al Mirfa Power Company (AMPC) is responsible for the generation of power and cleaning of water,[105] while the Abu Dhabi Distribution Company (ADDC) is tasked with distribution of water

[99] *Water and Electricity: Sector Overview, 2010 -2013* (Regulation & Supervision Bureau, 2010).
[100] Ibid.
[101] "Abu Dhabi Water and Electricity Authority (ADWEA): Subsidiaries," n.d., http://adwea.ae/en/about-us/our-subsidiaries.aspx.
[102] "Abu Dhabi Water and Electricity Company (ADWEC): Role," n.d., http://www.adwec.ae/Role.html.
[103] Ibid.
[104] "Transmission & Dispatch Company (TRANSCO)," n.d., http://www.transco.ae/.
[105] "Abu Dhabi Water and Electricity Authority (ADWEA): Subsidiaries."

and electricity through the Emirate.[106] All these subsidiaries are monitored by a separate and independent entity, the Regulation & Supervision Bureau (RSB), which enforces the laws that are meant to govern Abu Dhabi's power sector.

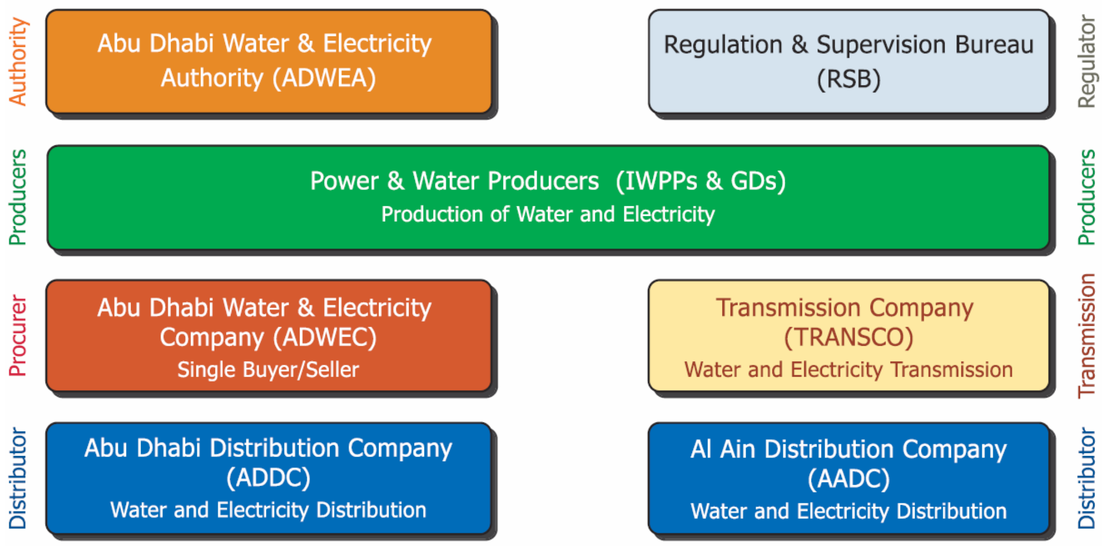

Figure 5.1: Organizational structure of the power industry in Abu Dhabi.[107]

One of the key elements that arose from this restructuring process was the introduction of private capital in the generation of water and electricity. The majority of current large-scale production companies are privately operated, but are only partly owned (up to a maximum of 40%) by foreign investors.[108] Two or more Joint Venture partners may own 40% of a project, but RSB ensures an avoidance of collective ownership of more than 25% of the market by capacity.[109] Regardless of the source of generation, all electricity and water output is purchased by ADWEC, which functions as the single buyer.[110]

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[106]Ibid.
[107] ADWEC Corporate Brochure - 2011 (http://www.adwec.ae/Documents/Corporate/Bruochure2011.pdf).
[108]*Water and Electricity: Sector Overview, 2010 -2013*.
[109]Ibid.
[110]Ibid.

ADWEC enters into what are known as "off-take agreements", a common term for PWPAs, for periods that usually span 20 years;[111] this single buyer model affords a high level of certainty between the producers and ADWEC.

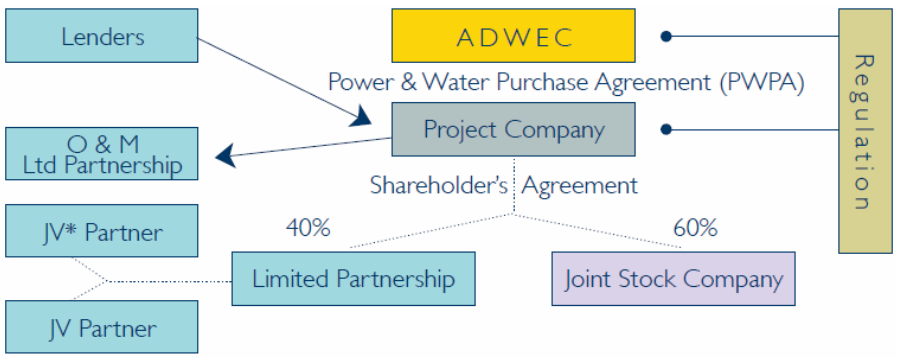

Figure 5.2: Power purchase agreement structure.[112]

It is important to note that while the generation of water and electricity remain non-monopoly activities, the transmission, purchase, sale, and distribution of these resources are conducted my monopolistic entities.[113] The monopolistic side of Abu Dhabi's power sector is the reason that the RSB exists, citing regulation to be the only real alternative to protect the rights of consumers from any potential abuses, be it in quality of service or price of product.[114]

Tariff and Pricing

One of the ways in which the RSB protects customers is by establishing the terms, conditions, and price of supply. Price controls limit the prices and revenues that network

[111]Ibid.
[112]"Abu Dhabi Water and Electricity Company (ADWEC): Role."
[113]*Electricity Tariffs for Large Users in the Emirate of Abu Dhabi* (Regulation & Supervision Bureau, November 2009).
[114]*Water and Electricity: Sector Overview, 2010 -2013*.

licensees and ADWEC can recover from customers, and employ a building block approach to determine regulated revenue; this maximum allowed revenue is composed of an estimate of operating costs, regulatory depreciation, and regulatory returns.[115] On the generation side, RSB stipulates that all sector costs pass through to the distribution companies. ADWEC uses the Bulk Supply Tariff (BST) - comprised of a demand charge and a system marginal price - to charge for the output of the generation companies.[116] The system marginal price accounts for higher electricity tariffs during peak hours, which are usually in the summer time between noon and midnight,[117] and apply only to large users whose daily consumption of electricity is in excess of 1 MW.[118] These costs, in addition to the transmission and distribution costs, comprise of the total *cost* of electricity generation and distribution. They are recovered using a combination of revenues generated by the sale of the electricity and significant government subsidies.[119]

The government subsidies are even greater for the standard tariff imposed on customers that consume less than 1 MW daily, because there is no semblance of a demand-oriented charge.[120] [121] UAE nationals pay as little as 3 fils per kWh (less than one US cent) because of these subsidies (Figure 5.3):

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[115]Ibid.
[116]*Electricity Tariffs for Large Users in the Emirate of Abu Dhabi*.
[117]Ibid.
[118]"Customer Tariffs & Charges," *Regulation & Supervision Bureau*, n.d., http://www.rsb.gov.ae/en/PrimaryMenu/index.aspx?LeftType=1&SubCatLeftMenu_Name=Customer%20Tariffs%20&%20Charges&SubCatLeftMenu_ID=152&SubCatMenu_Name=Tariffs%20&%20Charges&SubCatMenu_ID=151&CatMenu_ID=67&PriMenu_ID=177&CatMenu_Name=Tariffs&PriMenu_Name=Sector%20Structure.
[119]*Electricity Tariffs for Large Users in the Emirate of Abu Dhabi*.
[120]"Customer Tariffs & Charges."

Customer Category	Electricity Tariffs
UAE Nationals-Domestic (remote areas)	3 fils per kWh
UAE Nationals-Domestic (other areas)	5 fils per kWh
Non-UAE Nationals-Domestic	15 fils per kWh
Industrial/ Commercial	15 fils per kWh
Governmental & Schools	15 fils per kWh
Farms	3 fils per kWh

Figure 5.3: Typical electricity tariffs in the UAE. [122] **(1 US cent = 3.67 Emirati fils.)**

Telecommunications: Data Privacy Laws

Data privacy laws focus on the collection, storage, use, disclosure, and processing of personal data. In most legal systems, "personal data" refers to information relating to an identified or identifiable individual. The United Arab Emirates (UAE) does not have any specific federal laws on data privacy, but various pieces of legislation may have an impact on businesses that engage in data processing activities. These have been summarized below:[123]

- The UAE Constitution of 1971, which guarantees the right to secrecy of communications.
- Federal Law No. 5 of 1985 regarding Civil Transactions, which provides that a person is liable for acts causing harm generally. This could include

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[121]Jim Krane, "For Renewables to Work, First Cut Energy Subsidies," *The National*, January 19, 2012, http://www.thenational.ae/thenationalconversation/comment/for-renewables-to-work-first-cut-energy-subsidies.

[122]Ibid.

[123]Norton Rose Group, "Key Data Privacy and Intellectual Property Issues in the UAE," accessed November 11, 2012, http://www.nortonrose.com/knowledge/publications/54334/key-data-privacy-and-intellectual-property-issues-in-the-uae.

harm caused by unauthorized use or publication of the personal or private information of another.

- Federal Law No. 9 of 1987, as amended (Penal Code), which is the primary source of criminal law in the UAE. In articles 378 and 379, it sets out statutory offences and punishments for publication of private matters or the unauthorized disclosure of private information (although private information is not clearly defined).

The Telecommunications Regulatory Authority (TRA) for UAE derives its organizational objectives from the UAE Telecommunications Law, its Executive Order, and the UAE National Telecommunications Policy; one of its many functions is the management of "every aspect of the telecommunications and information technology industries" in the country.[124] The TRA hasn't shied away from flexing its authority as the regulator of sensitive consumer information; in 2010, Research in Motion (RIM, the company behind BlackBerry phones) were informed that they were in violation of the country's telecommunications laws because they chose to have data generated in the UAE to be stored and managed on foreign lands. According to the TRA, this was a national security issue because the encrypted servers located in North America would "inhibit local law enforcement's ability to monitor and access customer data."[125] The issue was eventually resolved, although the specific solution that was reached remains unclear: it is speculated

[124] "About TRA" UAE Telecommunications Regulation Authority, *About*, 2012, http://www.tra.gov.ae/about_tra.php.

[125] "BlackBerry Ban Averted as RIM, UAE Strike Deal on Encryption," August 10, 2010, http://www.eweek.com/c/a/Security/BlackBerry-Ban-Averted-as-RIM-UAE-Strike-Deal-on-Encryption-435456/.

that the data has either been routed through local servers, or that the RTA has obtained limited access to RIM's foreign encrypted servers.[126]

If the RTA and RIM hadn't been able to arrive at a compromise, up to 500,000 local users of BlackBerry devices would have seen a ban on the use of popular services such as BlackBerry Messenger, BlackBerry e-mail and BlackBerry Web-browsing. In the months succeeding the resolution of the matter, RIM has entered into partnerships with the RTA as well as local telecommunication companies Du and Etisalat to "foster mobile innovation" and promote the use of their devices across the Middle East, with Blackberry's enterprise services are now being encouraged in governmental and corporate work spaces.[127] Given the smart grid's reliance on consumer-sensitive information, navigating the TRA may prove to be challenging for foreign companies looking to invest in smart metering technologies in Abu Dhabi.

[126] Ibid.
[127] "UAE TRA, Research In Motion, Etisalat and Du Partner to Foster Mobile Innovation Across the Middle East | UAE TRA," *AMEinfo.com*, October 18, 2010, http://www.ameinfo.com/245621.html.

6. Considerations for Implementing Smart Grid in Abu Dhabi

This chapter focuses on developing an understanding of the factors that will affect the implementation and adoption of smart grid infrastructure in Abu Dhabi. The challenges and barriers described in previous chapters is synthesized, viewed, and analyzed through the lenses of the city's renewable energy goals and needs; regulatory structure of the power industry, including pricing models; and consumer involvement. The information is then presented in two sections highlighting the advantages and barriers for the adoption of smart grid technologies in Abu Dhabi.

Catalysts for Smart Grid in Abu Dhabi

1. Motivations for renewable energy: Masdar

The city of Abu Dhabi has set itself a fairly lofty goal, with 7% of electricity generated in 2020 required to come from renewable sources. The Masdar Initiative is singlehandedly expected to carry the city in terms of renewable energy progress, and will be one of the most influential directives in catalyzing the implementation and adoption of smart grid infrastructure in Abu Dhabi. At the core of Masdar's objectives is to promote research, development, and implementation of renewable sources of energy, especially solar and wind. The very nature of these sources of generation entail that the transmission grid will need to be capable of ensuring the feasibility of using renewable energy as alternative energy sources. The scale and impact of such endeavors are factors that researchers in Masdar are well aware of:

> "Smart grids are a key national infrastructure whose benefits cannot be fully quantified in the short- or long-term. Investments into the smart grid in that regard is similar to investments into roads, bridges, water distribution and communications technology."[128]

Masdar is currently the city's only entity with the technology and know-how to incorporate renewable sources of energy into Abu Dhabi's future grid. With the strong backing of the local government, then, Masdar is well equipped to begin testing and implementation for smart grid.

2. Regulatory structure and the power industry

In addition to centralized policy decision-making, one of the advantages that Abu Dhabi affords in the implementation of smart grid hinges on the relationship between the utility companies and the regulatory structures that govern their operation. In the case of IOUs, there is definitely hesitancy in electric grid investments without a clear direction from the regulatory boards. Abu Dhabi's electrical market, however, affords a greater level of certainty to its electricity generation investors thanks to the 60:40 single buyer model. IPPs can make long term investments in upgrading their operational efficiency and infrastructure with the knowledge that the government already has a minimum 60% stake in the project, and is most likely not going to leave the private investors to fend for themselves. In fact, when IPPs were finding it hard to find capital to fund their operational expenses during the recent economic crisis, the government willingly stepped

[128] "Smart Grids to Achieve Abu Dhabi's Vision 2030 | ConstructionWeekOnline.com," October 29, 2012, http://www.constructionweekonline.com/article-19245-smart-grids-to-achieve-abu-dhabis-vision-2030/#.UJGkkBd2FBl.

in to keep things moving. This was demonstrated in the development of two waste water projects in Abu Dhabi, where projects were given time to acquire capital to cover the initial stages of investment. ADWEA assured them that if they failed to raise long-term finance options, it would take full ownership of the schemes.[129] The financial clout of the government, along with their vested interest in ensuring the success of the region's renewable energy vision, will definitely prove to be a significant factor in attracting private expertise to facilitate the build-out of the future electricity grid.

Barriers to Smart Grid Adoption and Sustainability Goals

1. The subsidy issue: impact on consumption

Perhaps the biggest barrier that exists in Abu Dhabi's case in the consideration of effective smart grid adoption is that of the government subsidy for electricity rates. While the presence of generous government investments will always be welcome in future capital assets relating to the electricity grid, the highly subsidized electricity rates for consumers will greatly influence the effectiveness of a comprehensive smart grid model in Abu Dhabi. A survey by the ACEEE summarizes the importance of the consumer's role in saving energy, drawing a direct relation between the amount of consumer feedback and the percentage of energy saved (Figure 6.1).

[129] "Policy reversal shows the way: Abu Dhabi, which once led the way with privatisation, could now lead the way on nationalisation," *MEED Middle East Economic Digest*, January 23, 2009.

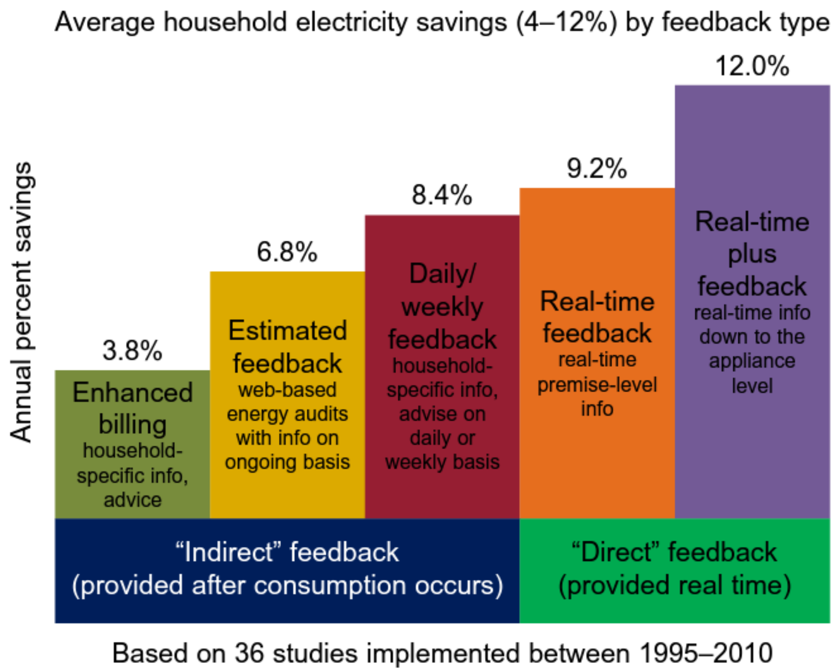

Figure 6.1: Energy savings from customer feedback programs. Source: Siohansi.[130]

The challenge that is raised in terms of consumer participation in Abu Dhabi has a lot to do with whether or not the residents consider rising electricity prices as a cause for concern in the first place. Government subsidies create a very artificial electricity market, which demonstrates a huge gap in the cost of electricity production (24.9 fils per kWh)[131] and the price that customers pay (between 3 fils to 15 fils per kWh). With electricity and water costs forming a relatively lower percentage of residents' overall expenses, they are less likely to be worried about issues relating to energy conservation.[132] It is not surprising that this attitude is corroborated by the actual consumption data; the RSB revealed that for the year 2006, Abu Dhabi's residential customers consumed an average

[130]Sioshansi, *Smart grid: integrating renewable, distributed & efficient energy*, 357.
[131]Mezher, Dawelbait, and Abbas, "Renewable Energy Policy Options for Abu Dhabi."
[132]Krane, "For Renewables to Work, First Cut Energy Subsidies."

of 41,000 kWh of electricity, which was *more than triple* the average American home's consumption in 2010 of 11,500 kWh.[133]

2. The ability of renewable capacity to keep up

Exorbitant consumption predictably leads to a very high rate of demand, as forecasted by ADWEC. While the emirate's total installed capacity (12,222 MW as of 2010) may be enough for today's needs, it will most definitely not be enough to cover the future peak demand levels which are expected to group annually at a rate of 16.7% until 2015.[134] The increasing growth rate of demand also strains the ability of the emirate to meet its renewable energy goals. While Masdar has shown an unequivocal desire to explore all potential renewable generation options within its technological test bed, the majority of the projects still remain in experimental stages, unable to step up and shoulder the emirate's generation capacity burden. This is demonstrated with Abu Dhabi's focus on solar generation; Krane explains that the typical summer electricity demand curve for the region reveals two daily peaks; one in midday, when the sun is overhead, and one after sundown, when the humidity effects are at their most intense.[135] Solar radiance, however, is only well matched to the first peak. This implies that Abu Dhabi faces a challenge relying on solar power capacity to replace conventional generation, potentially rendering the benefits of forgoing the cost of building, operating, and maintaining a conventional power plant unfeasible. Indeed, TRANSCO's seven year statement already has plans for transmission from new conventional generation sources, whereas renewable generation

[133] Krane, *An Expensive Diversion*, 7.
[134] Miller, "ADWEC Winter 2011/2012 Electricity & Water Demand Forecasts."
[135] Krane, *An Expensive Diversion*, 14.

projects are referred to as "opportunities", perhaps reflecting the lack of confidence in these sources.[136]

3. Network challenges

Since smart grid has been a fairly new consideration for Abu Dhabi, it is understandable that there hasn't been a concerted effort in discussing the kind of network standards that will allow a new information economy to flourish. The TRA has shown that it is a key entity in enforcing its interpretations of the country's information, telecommunication, and privacy laws. However, the sort of reaction that was seen in the RIM case may dissuade private capital from getting involved in Abu Dhabi's smart grid market. The TRA needs to collaborate with private investors, researchers at Masdar, and ADWEA to ensure the development of robust network standards that delineate a clear vision for how smart grid infrastructure will develop in Abu Dhabi.

Current Steps

Given the circumstances, Abu Dhabi seriously risks the development of a smart grid that is primarily utility-centric, focusing on priorities such as operational efficiencies and cost reductions which are focused on dealing with the immense growth in electricity demand. The government has already identified consumer attitudes and opinions of the smart grid as one of the biggest challenges to implementing demand response programs, and has

[136] *2011 Seven Year Electricity Planning Statement (2012-2018)* (Abu Dhabi: TRANSCO, November 2011), http://www.transco.ae/media/pdf/Seven%20Year%20Electricity%20Planning%20Statement-Main-report.pdf.

earmarked Masdar City as an experimental ground for carefully testing consumer response.[137]

The regulatory board has also thrown its full support behind testing the effectiveness of demand-side programs. As recently as the summer of 2012, RSB initiated a program in conjunction with ADDC (the distribution company) called 'Powerwise', which introduced time-of-day pricing trials to a group of 400 volunteer homes.[138] In addition to maintaining current electricity tariffs as off-peak rates, the program introduces a *theoretical* peak demand rate increase during the hours of 2:00pm to 8:00pm. The participants will still pay the standard rates through the period of the trial, but will receive periodical information on how their consumption habits would have affected their utility bill had the theoretical peak demand rates been in use. Similarly, the RSB has also released a new utility bill layout that highlights to consumers the actual cost of the electricity they consumed, along with how much of it was paid for by government subsidies.[139]

Implementation of programs such as Powerwise represents positive steps by the leadership of the city to better understand the nuances of their local consumers. The RSB will need to further collaborate with ADDC and ADWEA to continue the dissemination of information regarding future demand-based pricing programs. Similar efforts will need

[137]Christopher Stanton, "Masdar a Testing Bed for Grid of the Future," *The National*, accessed November 11, 2012, http://www.thenational.ae/business/energy/masdar-a-testing-bed-for-grid-of-the-future.
[138]"Powerwise: Time-of-day Trial," *Abu Dhabi Regulation & Supervision Bureau*, 2012, http://www.rsb.gov.ae/en/PrimaryMenu/index.aspx?LeftType=1&SubCatLeftMenu_Name=FAQ&SubCatLeftMenu_ID=228&SubCatMenu_Name=Time-of-day%20trial&SubCatMenu_ID=226&CatMenu_ID=100&PriMenu_ID=202&CatMenu_Name=&PriMenu_Name=Powerwise.
[139] "To Spur Conservation, Power Bills Highlight Subsidies - The National," accessed November 29, 2012, http://www.thenational.ae/business/energy/to-spur-conservation-power-bills-highlight-subsidies.

to be taken to ensure that consumers are familiar with the environmental impacts of their consumption, and how using smarter appliances in their homes can contribute to an information database that can effectively reduce both their energy consumption and utility bills.

7. Recommendations & Conclusion

Given the rising demand in electricity consumption both locally and in the region, Abu Dhabi is planning for unprecedented levels of generation capacity over the next few decades. While the extent to which renewable sources of generation can shoulder the demand burden is debatable, it doesn't change the fact that investments in these sources will see an increase, as costs come down and innovations are made in energy storage. The Masdar initiative will play a significant role in any sort of investments relating to renewable energy generation technology. In this scenario, investing in a smarter grid is beneficial; in addition to providing operational efficiencies and reducing transmission and distribution losses, a smarter grid will provide the flexibility that is required facilitate the integration of renewable sources of energy.

Unfortunately for Abu Dhabi, this is where the benefits of a smart grid will end, unless something is done about the significant government subsidy for electricity rates. The negative impacts of the subsidy on electricity consumption levels and consequent climate effects like GHG emissions cannot be understated. A comprehensive smart grid system is shown to be most effective at reducing peak demand when consumers are aware of the financial and environmental impacts of their consumption levels, and have the tools to make informed decisions on how to modify their behavior progressively. The presence of a government subsidy that covers the majority of the electricity cost burden will do little to promote such behavior.

1. Phase out the subsidies

The government and leadership of the Emirate therefore need to make a decision on what they value to be more important: honoring an historical social entitlement that their residents have had for cheap water and electricity; or helping their residents become aware of the true costs of electricity generation, and encouraging sustainable consumption through participation. The Powerwise trials and the new utility bill layouts are acceptable first steps to generate awareness; however, the Emirate needs to move to gradually phase out the electricity subsidies in order to truly involve consumers with how they use energy.

There are examples of governments that have successfully phased out subsidies for electricity. In 2011, Iran was able to roll back about $60 billion in energy subsidies with very few complaints from consumers. The program adopted an innovative strategy which provided $40 monthly dividends in an account opened for each Iranian family, with a view of offsetting the new increased prices.[140] The intent of this program was not to demonstrate that the government was cash-strapped, and needed the revenue; instead, it was to give consumers the option to reduce their electricity consumption so that they could use the "subsidy" in their account however they pleased. Consumers were now obligated to choose whether to spend the subsidy money on electricity, or to curb consumption and spend the money on other needs. In this way, sustainable consumption was being promoted while still sharing the nation's wealth with its residents. It is not

[140] Krane, "For Renewables to Work, First Cut Energy Subsidies."

unreasonable to expect a similar reaction from residents in Abu Dhabi, and should therefore be one of the emirate's top priorities.

2. Scale up dynamic pricing programs

Once residents are more aware of the true costs of electricity in both financial and environmental terms, Abu Dhabi can count on a more well-informed and proactive base of consumers as a test bed for dynamic pricing programs. The Powerwise trial lacks in this regard because it merely proposes a hypothetical rate change while hiding the true cost of electricity, and even offers a rebate to their customers if they were able to save electricity through the proposed rate. The experiments cited by Faruqui and Sergici demonstrate the various types of pricing programs that ADWEA and RSB ought to attempt, like TOU and CPP. Results from consequent trials should be used to delineate the type of pricing model that will most effectively help consumers take control of their peak demand usage.

It is also clear that enabling technologies like smart thermostats and other smart appliances have a significant positive impact on the amount of peak demand reduction. These could very well be classified as sustainable building design features, and could provide the Urban Planning Council with an opportunity to promote the use of such technologies by revising the Estidama development code rating system to reflect additional credits for implementation.

3. Explore innovative revenue models like decoupling

While Abu Dhabi does take a majority stake in all of its private-public generation projects, the revenue structure for the generation companies are still traditional. A rate case is decided after assessing the company's expenditures and forecasting sales. The challenge with such a system in terms of energy conservation is that utilities are obliged to sell more electricity to guarantee revenue. Decoupling is a rate adjustment mechanism that attempts to solve this issue by breaking the link between the amount of energy a utility sells and the revenue it collects to recover the fixed costs of providing service to customers.[141] Strategies for implementing decoupling could include full, partial, or limited mechanisms, varying in the amount of revenue that is allowed to be recovered. This is potentially an area that Abu Dhabi can explore further, ensuring that they take into account issues like whether and how frequently to adjust revenue requirements in light of changes in weather, customer base, and other relevant factors.[142]

4. Establish policy, regulations, and network standards

In concurrence with research in smart grid technology and programs, the modernization of Abu Dhabi's electric grid will sincerely begin with a detailed policy initiative that outlines the emirate's intent to create a smart transmission and distribution system. In a collaborative effort with the various agencies involved in Abu Dhabi's electricity market, guidelines must be developed in a framework that is based on a clear and consistent vision. The role of each participating organization in promoting the framework must also

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[141] *Decoupling Policies: Options to Encourage Energy Efficiency Policies for Utilities* (National Renewable Energy Laboratory, December 2009), http://www.nrel.gov/docs/fy10osti/46606.pdf.
[142] Timothy J. Brennan, "Decoupling in Electric Utilities," *Journal of Regulatory Economics* 38, no. 1 (August 1, 2010): 54, doi:10.1007/s11149-010-9120-5.

be delineated. The National Science and Technology Council of the U.S. created a comprehensive policy framework to address the country's approach to smart grid;[143] Abu Dhabi could very well use this framework as a model to develop their own.

Similarly, the RSB and ADWEA should collaborate with Masdar to develop an additional framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems. In addition to increasing the reliability of the grid, an interoperability standard framework should also aim to improve the security of the grid by introducing conformity to development. Rules and regulations for information management and control should also be clearly defined so that prospective entrants know in certain terms how budding markets like information management will be regulated.

Conclusion

This report attempts to make a case for why investments in smart grid will catalyze the adoption of renewable sources of generation in Abu Dhabi and vindicate the emirate's decision to invest in renewable energy generation. The benefits of a smart grid infrastructure, especially in terms of dealing with renewable sources of energy and reducing peak demand loads, could be crucial to ensuring the success of Abu Dhabi's future energy goals. There are many challenges that lie ahead; Abu Dhabi has yet to begin discussions of adopting interoperability standards and explicitly defining the regulatory framework within which the information generated through smart grid operations will be subject to. The significant amount of government subsidies for

[143] *A Policy Framework for The 21st Century Grid: Enabling Our Secure Energy Future*.

electricity will surely need to decrease to facilitate higher rates of consumer interest in conservation. Notable steps have been taken by both Masdar and ADWEC to run consumer response trials to smart meters, but a significant collaborative effort will be required to educate the local population about their energy habits in general, and how a smarter electrical grid can help them reduce their impact on the environment. With significant resource backing from the government, Abu Dhabi is perfectly poised to develop a flexible and reliable electricity infrastructure to serve the needs of the future.

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