Energy Efficient Infrastructure Development:
A case study analysis of cities' best practices

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Executive Summary

With the increasing economic, social, and political costs of producing energy, cities have started to focus on ways to decrease their energy usage while preparing for more frequent climate change-induced natural disasters. By investing in energy efficient infrastructure, a city can reduce the amount of electricity it needs to produce while improving its natural disaster resilience. One of the best ways a city can mitigate the costs of these infrastructure updates is to leverage support from the private sector in the form of public-private partnerships.

This paper will focus on three types of infrastructure updates that cities can implement: microgrids, smart meters, and building retrofits. Microgrids, a form of distributed energy generation, storage, and transmission, can increase electrical efficiency by decreasing the transmission distances between power generation sites and consumers. Smart meters are electrical meters that can record and transmit power usage in real time, and can be used in conjunction with demand response programs to encourage consumers to use electricity during off-peak hours. Building owners can make energy efficient retrofits to their buildings, drastically reducing the amount of electricity that they consume. Taken together, these three infrastructure updates can help keep consumers connected to the grid and make buildings more secure during natural disasters.

This paper focuses on three cases studies for each of these three forms of infrastructure updates, for a total of nine case studies. Each case study unpacks how a specific city leveraged public-private partnerships to install an infrastructure update that increased its energy efficiency while improving its natural disaster resilience.

The purpose of these case studies is to provide other cities with “best-practices,” giving city planners the information they need to implement similar successful strategies in their own regions.

Introduction

The year is 2050, and a typhoon with winds up to 130 km/hour heads directly towards the Okinawa prefecture of Japan. With ocean temperatures rising from the increased production of greenhouse gases, hurricane and tropical storms have become more intense in just a few short decades.[1] Like most typhoons, this one will most likely cause flooding, power outages, and structural damage to both buildings and infrastructure through high winds.

However, once this super-storm hits the main island of Okinawa, the damage, while intense due to the high winds, is less than a similar storm would have inflicted in prior decades. Microgrids throughout the capital city of Naha immediately turn on when sections of the city lose their connections to the main city power station. Connected to the main grid yet easily separated in case of emergency, these microgrids generate, store, and transmit power to localized sections of Naha, keeping critical city areas such as hospitals, storm shelters, and food stores supplied with full power throughout the duration of the storm.

Smart meters, connected to every residential home and business in Naha, immediately tell the local power company precisely where connectivity to the main grid has been lost, allowing them to dispatch crews more efficiently to repair the damaged energy infrastructure.

Finally, building retrofits made in the past few decades since the passing of updated building codes have ensured that most houses and businesses have sustained the high velocity winds and lashing rains without too much damage.

Microgrids, smart meters, and building retrofits have helped Naha emerge relatively unscathed from yet another high-intensity typhoon. However, these three types of infrastructure do more than just help during natural disasters, as they also significantly decrease the amount of energy Naha uses on a daily basis. Since the 2011 Fukushima disaster, the Okinawa Prefecture has shunned nuclear power plants, meaning that most of their power comes from imported fossil fuels, resulting in some of the highest electricity rates in Japan in the early 21st century.[2] However, with the implementation of smart meters, microgrids, and building retrofits, energy costs per resident decrease, as these infrastructure updates increase Naha's energy efficiency.

This futuristic vignette tells of a city that adhered to smart energy infrastructure updates that not only increase climate-change resiliency, but increase energy efficiency. However, Naha, and cities like it, can only become disaster-resilient and energy efficient in the future if they invest in energy infrastructure now.

This paper will look at ways that cities have successfully leveraged public-private partnerships to implement these energy infrastructure modernizations. By evaluating and highlighting the success stories found in multiple case studies, other cities can learn how they too can successfully install energy efficient infrastructure that also helps to protect them from the natural disasters of the future.

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[1] Thomas R. Knutson et al., "Tropical Cyclones and Climate Change," *Nature Geosci* 3, no. 3 (2010).

[2] "Okinawa's Nuclear-Free Power Attracts People, Companies", The Asahi Shimbun http://ajw.asahi.com/article/business/AJ201208010005 (2015).

Microgrids

Microgrids, or distributed power systems, are becoming more popular among cities that want to both cut energy costs while preparing for natural disasters. The Department of Energy defines a microgrid as:

> "A group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that act as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode."[3]

Microgrids have three main characteristics that impact host cities, each of which will be discussed in detail below:

1) Increased Energy Efficiency
2) Natural Disaster Resilience
3) Public-Private Partnerships

Microgrid Characteristic #1 - Increased Energy Efficiency

Throughout the past half-century, the dominant method of producing, storing, and transmitting electricity has been through the main grid, or the system of large power plants delivering electricity in a one-way route towards consumers. However, microgrids, by producing, storing, and transmitting energy at a local level, can vastly increase energy efficiency at the production, transmission, and consumption phases. The U.S. Energy Information Administration estimates that six percent of power is lost through long distance transmission lines running from large power plants towards consumers.[4] Microgrids can reduce the amount of energy lost through transmission by producing electricity in close proximity to consumers. For example, instead of one large power plant generating vast amounts of electricity for an urban center and its surrounding areas through long transmission lines, clusters of buildings could produce, store, and transmit their own electricity through their own localized microgrids.

Sources of main grid power typically include large coal, gas, and nuclear power plants, with only a few renewable energy resources available. For example, in the U.S, coal provides 39% of electrical generation, with renewable resources only providing a mere 13%.[5] However, with their distributed generation assets, microgrids can readily make use of renewable resources, especially photovoltaic sources (solar panels) and wind turbines. With their small size, solar panels and small wind turbines can be easily installed on surfaces in steady contact with the sun, such as rooftops, car parks, building sides, etc. By using these renewable resources, microgrids provide a viable way to provide lasting, clean energy to connected buildings and residences.

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[3] *Summary Report: 2012 Doe Microgrid Workshop* (Department of Energy Office of Electricity Delievery and Energy Reliability Smart Grid R&D Program, 2012). 1.
[4] "How Much Electricity Is Lost in Transmission and Distribution in the United States?", U.S. Energy Information Administration http://www.eia.gov/tools/faqs/faq.cfm?id=105&t=3 (2015).
[5] "What Is U.S. Electricity Generation by Energy Source?", U.S. Energy Information Administration http://www.eia.gov/tools/faqs/faq.cfm?id=427&t=3 (2015).

Microgrids can also help improve energy efficiency through their localized storage capacities. By storing excess electricity produced during off-peak hours, that stored energy can then be used during peak hours, thus lowering the necessary electrical generation capacity for energy production systems. Battery storage technology costs are falling fast, with predicted drops of up to seventy percent in the next five years.[6] Combined with the rising costs of non-renewable energy sources, microgrids that effectively use battery storage technology in concert with clean energy electricity generation make economic sense for cities looking to increase their energy efficiency.

Microgrid Characteristic #2 – Natural Disaster Resilience

From 2003-2012, the U.S. experienced 679 widespread power outages due to extreme weather. The economic annual cost estimates incurred from these power outages range from $18 billion to $33 billion, with some years costing significantly more due to superstorms such as Hurricane Ike (2008) and Hurricane Sandy (2012).[7]

Microgrids are a great way for areas to remain connected to electrical power even during a large storm. By switching into "island mode" and disconnecting from the main grid, a microgrid can continue to provide electricity to connected residences and businesses, even when the majority of consumers in the surrounding area have lost power through the main grid.[8] This improved reliability of electricity makes microgrids an attractive option for consumers in natural disaster-prone areas.

Microgrid Characteristic #3 - Public-Private Partnerships

While improved energy efficiency, lower energy costs, and higher electrical reliability during natural disasters make microgrids an attractive option, financing their initial costs can prove problematic. Public-private partnerships can help make these next-generation power distribution models a reality. Common public-private partnerships in the microgrid sector include traditional public contracting; operation, maintenance, and service contracts; and passive public investments. In traditional public contracting, the government provides the majority of funding while the private contractor provides the services to be delivered, in this case, microgrid development and operation. With operation, maintenance, and service contracts, the government retains ownership of the microgrids while paying private contractors to perform daily operations and maintenance. Passive public investments include grants given by government entities to private organizations to pursue microgrid investment.[9] As reviewed in the case studies below, cities use all three types of these public-private partnerships to install disaster-resilient and energy efficient microgrids.

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[6] John Addison, "Solar, Storage, and Smart Grid Transform Electric Utilities", Meeting of the Minds http://cityminded.org/solar-storage-smart-grid-distributech-2015-12473 (2015).

[7] *Economic Benefits of Increasing Electric Grid Resilience to Weather Outages* (Executive Office of the President, 2013).

[8] KEMA Laboratories, *Microgrids - Benefits, Models, Barriers and Suggested Policy Initiatives for the Commonwealth of Massachusetts* (KEMA, 2014). 4-4.

[9] "Public-Private Partnership Structures and Arrangements", ICMA International http://icma.org/en/international/resources/insights/Article/101962/PublicPrivate_Partnership_Structures_and_Arrangements (2015).

Case Studies

The following case studies include cities of different sizes, development levels, and locations:

1) Sendai, Japan
2) Borrego Springs, California, U.S.
3) Chhattisgarh, India

Each case study will be evaluated according to the microgrid characteristics listed above (where data is available) as well as a description of their electrical generation capacity. These characteristics will help to assess the impact of these microgrids on their participants and can help other cities learn from their examples.

Microgrid Case Study 1 – Sendai, Japan

Background

Sendai, Japan, the capital city of the Miyagi Prefecture in Japan, and the largest city in the Tohoku region, has a population of one million. Known for its prevalence of universities, Sendai is sometimes referred to as "Academic City" within Japan.[10] Sendai is also home to the Tohoku Electric Power Company, which supplies power to the rest of the remote Tohoku region. Largely rural, the Tohoku region is marked by its mountainous landscape, low population density, and heavy snow during the winter, making power distribution problematic.[11] Sendai itself is located on the Pacific coast 300km north of Tokyo, and just 80km north of Fukushima, the site of the 2011 nuclear disaster.[12] Due to its reputation as an academic city as well as headquartering the Tohoku Electric Power Company, Sendai was a perfect location to establish a demonstration microgrid, a system of power generation and distribution that could prove beneficial if installed in other parts of the rural Tohoku region.

Built in 2004 on Tohoku Fukushi University with public funds and managed by a private company, this demonstration microgrid proved instrumental in keeping power supplied to key areas such as hospitals during the Tohoku earthquake and ensuing tsunami that devastated the Fukushima nuclear reactors in 2011. By using distributed forms of energy generation and storage, it was able to sustain residents connected to the microgrid with electricity for three days while the rest of Sendai was disconnected from the main power supply.[13]

Electrical Generation Capacity: 1MW

The Sendai microgrid generation capacity comprises of two 350kW natural gas-fired microturbines, one 200kW phosphoric acid fuel-cell, and one 50kW array of solar panels.[14]

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[10] "Sendai Profile", City of Sendai http://www.city.sendai.jp/kikaku/kokusai/english/kankou.html (2015).
[11] "Tohoku Electric Power Company, Inc. - Company Profile", Reference for Business http://www.referenceforbusiness.com/history2/95/TOHOKU-ELECTRIC-POWER-COMPANY-INC.html (2015).
[12] "Distance Fukushima Nuclear Power Plant to Sendai" http://www.distance.to/Fukushima-Nuclear-Power-Plant/Sendai.
[13] Keiichi Hirose, *The Sendai Microgrid Experience in the Aftermath of the Tohoku Earthquake: A Case Study* (New Energy and Industrial Technology Development Organization, 2013). 1.
[14] Ibid. 1.

Natural Disaster Resilience:

The Sendai microgrid continued to supply electricity to key public areas during the earthquake and tsunami that destroyed the Fukushima reactors in 2011. As power started fluctuating in voltage, Sendai microgrid operators disconnected the microgrid from the main grid, effectively switching the microgrid into "island mode." While the surrounding area lost electricity for three days, residents connected to the Sendai microgrid continued using electricity due to the microgrid's diversified electrical generation and storage capacities. For example, this microgrid directly saved lives by supplying electricity to the local Tohoku Fukushi University hospital, allowing staff to continue their care for patients throughout the crisis.[15]

***Public-Private Partnerships:* Traditional Public Contracting**

The Sendai microgrid was originally built by a partnership between the New Energy and Technology Development Organization (NEDO) and NTT Facilities at Tohoku University.[16] NEDO is an Incorporated Administrative Agency, an organization unique to Japan, which combines private research with public funding to invest in high-risk research and development.[17] NTT Facilities, a private organization, managed and conducted the microgrid demonstration and continued management of the microgrid after the demonstration period ended in 2008. Public funds provided through NEDO paid NTT Facilities to build and manage this microgrid demonstration project for the benefit of a public university, Tohoku Fukushi University.[18]

Microgrid Case Study 2 – Borrego Springs, California, U.S.

Background

Borrego Springs, California, is a small city of 3,500 residents located in Southern California. Located in the desert, it is completely surrounded by the 600,000 acre Anza-Borrego Desert State Park.[19] A small town that caters to tourists visiting this remote desert, Borrego Springs is an ideal community to test microgrid technology due to its remote location and long distances from central power plants.

In 2012, San Diego Gas & Electric (SDG&E) received funding from the U.S. Department of Energy (DOE) and the California Energy Commission to build a demonstration microgrid serving 600 residents in the small community of Borrego Springs, California.[20] The microgrid proved especially useful to residents during a severe thunderstorm in 2013, as it continued to provide electricity to those 600 connected residents even while the rest of the city lost electricity for days.[21] The microgrid demonstration was so successful that the DOE extended its support in

[15] Ibid. 5.
[16] Ibid. 1.
[17] "Introduction to Incorporated Administrative Agencies" http://www.meti.go.jp/english/aboutmeti/data/aOrganizatione/keizai/dokuritugyousei/01.htm (2015).
[18] Hirose. 1.
[19] "Borrego Springs - California's Secret Desert", Borrego Springs Chamber of Commerce & Visitors' Bureau.
[20] Thomas Bialek, *Public Interest Energy Research (Pier) Program Final Project Report - Borrego Springs Microgrid Demonstration Project* (2013). 1-2.
[21] "Microgrid Powers Borrego During Emergency", UT San Diego http://www.utsandiego.com/sponsored/2013/nov/10/sgde-repair-crews-storm/ (2015).

2015 to provide SDG&E with the funds to expand the microgrid to service the entire population of Borrego Springs.[22]

Electrical Generation Capacity: **4 MW**

The microgrid that supports the community of Borrego Springs encompasses two 1.8MW diesel generators for the community and 125 households with solar panels.[23]

Increased Energy Efficiency: **15% Reduction in Peak Load**

Through the inherent increases in energy efficiency found in microgrids due to shortened transmission lines combined with demand response pricing (discussed in later case studies), residents and businesses connected to the Borrego Springs microgrid were able to reduce their peak demand for electricity by fifteen percent.[24]

Natural Disaster Resilience:

The Borrego Springs microgrid successfully switched over to island mode during intense thunderstorms, flooding, lightning, and high winds in September 2013. A lightning strike to transmission poles cut off electricity to the city, but within a few hours, those connected to the microgrid still had access to electricity. The microgrid supplied energy to key city areas such as schools, grocery stores, and gas stations, while also supplying power to designated "cool zones" so residents with medical conditions could take refuge from the ensuing heat wave the next day. The microgrid provided electricity for more than 24 hours while the power company repaired transmission lines from the main grid, successfully demonstrating the microgrid's usability during natural disasters.[25]

Public-Private Partnerships: **Passive Public Investment**

Combined with its own $4.1 million investment, the private company SDG&E received grants from both the U.S. DOE ($7.5 million) and the California Energy Commission ($2.8 million) to build, operate, and maintain the Borrego Springs microgrid. SDG&E also partnered with other private entities such as General Electric and Lockheed Martin, as these companies provided equipment, technical expertise, and funding ($0.8 million). SDG&E maintains ownership of the microgrid's distribution assets, while some of the generation assets, such as photovoltaic panels, are owned by private citizens.[26] Due to the microgrid's success, the DOE has awarded SDG&E with another $5 million grant to expand the Borrego Springs microgrid to service the entire community of 3,500 residents.[27]

[22] "Sdg&E Receives $5 Million Grant to Expand Borrego Springs Microgrid", PR Newswire http://www.prnewswire.com/news-releases/sdge-receives-5-million-grant-to-expand-borrego-springs-microgrid-300037273.html (2015).
[23] KEMA Laboratories. 6-3.
[24] Bialek. 2-3.
[25] "Microgrid Powers Borrego During Emergency".
[26] "Borrego Springs", Berkely Lab https://building-microgrid.lbl.gov/borrego-springs (2015).
[27] "Sdg&E Receives $5 Million Grant to Expand Borrego Springs Microgrid".

Microgrid Case Study 3 - Chhattisgarh, India

Background

Chhattisgarh is a state located in the central part of India. With its dense jungle terrain, more than 75% of Chhattisgarh's 25 million residents live in rural areas as either rice farmers or coal miners. The density of population per square kilometer of 191 makes Chhattisgarh one of the least densely populated states in India.[28] This low population density makes Chhattisgarh ideally suited for the installation of microgrid technology to supply power to its distributed populations.

Electrical Generation Capacity: 1-10kW

The Chhattisgarh Renewable Energy Development Agency (CREDA) owns approximately five hundred solar microgrids throughout the region, each varying in size from 1-10kW. These microgrids provide electric lighting for approximately 30,000 households across the region.[29]

Increased Energy Efficiency:

CREDA has only installed solar panels in rural areas, resulting in cheap electricity compared to that derived from the central grid. Payments come from an initial fixed household connection fee followed by a fixed household monthly fee. CREDA is able to ensure these low fees by requiring households to use only 0.22kW of electricity per day, just enough for each home to power a few light-bulbs or charge a small device.[30]

Public-Private Partnerships: Operation, Maintenance, and Service Contracts

CREDA is a state-run agency that hires private contractors to install and maintain solar microgrids throughout the region. The state issues a variety of different contracts, often paying one set of contractors to build the microgrids, then another to provide ongoing maintenance and operations. To help fray the costs of the microgrids' installation, operation, and maintenance, the state requires consumers to pay a small connection and monthly fee.[31] Unfortunately, CREDA cannot expand its market to commercial consumption, as the solar microgrids only provide enough electricity for homes to power a few light-bulbs and small electronic devices, such as cell phones. With this capacity shortcoming, consumers are starting to prefer to keep an additional connection to the main grid with no electrical limitations, even though the public subsidies for CREDA ensure the cheapest monthly consumer fees.[32]

Conclusion

Microgrids of various sizes can help communities generate, store, and transmit electricity at the local level, vastly increasing energy efficiency at all levels while reducing economic costs. Local governments can take specific actions to encourage microgrid development by providing

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[28] "Chhattisgarh Population Census Data 2011", Census 2011 http://www.census2011.co.in/census/state/chhattisgarh.html (2015).

[29] Daniel Schnitzer, *Microgrids for Rural Electrification: A Critical Review of Best Practices Based on Seven Case Studies* (United Nations Foundation, 2014). 51.

[30] Ibid. 51-53.

[31] Ibid. 35.

[32] Ibid. 35-36.

research and development grants to private companies that allow them to invest in microgrid technology. Other government-run programs, like the one in rural India, offset their costs of hiring private contractors to install and maintain solar microgrids by charging a small monthly connectivity fee to residents connected to the microgrids.

Most importantly, all three microgrids saved their respective cities valuable energy costs by using renewable resources to generate electricity in close proximity to consumers, thus decreasing transmission losses. With their distributed system of power generation, all three microgrids were able to rely heavily on solar panels installed at residences and businesses, resulting in less power that heavy-polluting power plants must produce for the main grid.

These microgrids also demonstrated increased reliability during storms and power outages. While residences and businesses connected to the main grid were left in the dark, those connected to the microgrids continued to use electricity unencumbered, demonstrating the microgrids' abilities to provide electricity even during the most strenuous natural disasters through their network of distributed energy generation, transmission, and storage assets.

Smart Meters

The installation of smart meters provides another way for cities to increase their energy efficiency while planning for natural disasters. Unlike a traditional electric meter installed at a residence or a business that requires someone from the power company to physically check how much energy has been used once a month, smart meters measure the amount of energy used at a location in real-time, and transmit that data to the electrical company up to a few times an hour.[33]

Smart meters have three main characteristics that impact host cities, each of which will be discussed in detail below:

1) Increased Energy Efficiency
2) Natural Disaster Resilience
3) Public-Private Partnerships

Smart Meter Characteristic #1 – Increased Energy Efficiency

With their real-time transmissions to the power company, smart meters allow a city to engage in real-time energy pricing schemes, called demand response programs, to encourage energy consumption during off-peak vice peak hours. By raising the price of electricity throughout the day based on electric demand, cities can effectively reduce the amount of peak energy that power stations must produce, as residences and businesses use less energy during these peak electricity demand hours in an effort to save money. This reduction in peak electrical capacity allows the energy company to save money by reducing the amount of electrical generation assets in which it must invest. These savings are in turn passed along to consumers, who pay significantly less for electricity during off-peak hours.

Smart meters are usually used in conjunction with two kinds of demand response pricing schemes: Time-of-Use (TOU) pricing and Critical Peak Pricing (CPP). TOU pricing occurs regularly with the energy company setting fixed rates for electricity that vary by time of day, with electricity costing significantly more during the day while people are consuming the most electricity by running appliances, air conditioning, heating, etc. CPP differs from TOU in that power companies announce special days and times during which extra-high rates are charged during peak hours.[34] Smart meters make these pricing schemes possible, with utilities able to track hourly usage by different residences and businesses. Figure 1 graphically displays the results of a CPP program in South Dakota after smart meters had been installed for three months. One group participated in the demand response CPP program (Opt-In), the other group opted out, but tried to decrease their energy consumption (Opt-Out), and the third group did not participate in the CPP program, but could monitor their energy output in real time via the internet (Tech Only). As seen from the data, in only three months, the group that participated in the CPP program realized the greatest energy reduction during peak periods.[35]

[33] *Smart Meters and Data Accuracy* (Washington, D.C., 2012).
[34] *Coordination of Energy Efficiency and Demand Response* (U.S. Department of Energy, 2010). 2-3.
[35] *Critical Peak Pricing Lowers Peak Demands and Electric Bills in South Dakota and Minnesota* (US Department of Energy, 2012). 2.

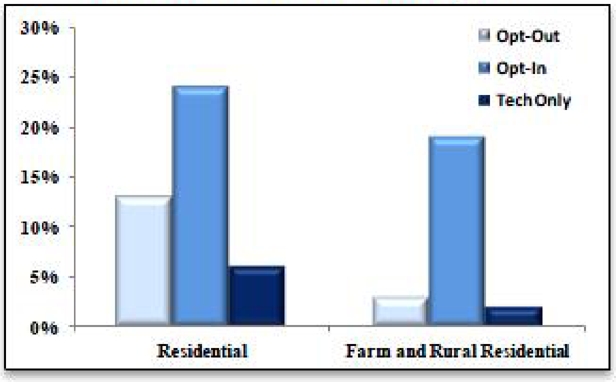

Figure 1 – Reductions in peak period consumption with CPP program[36]

Smart meters combined with TOU pricing schemes can also encourage the installation of private photovoltaic systems (solar panels). If electricity prices increase in the middle of the day, when solar panels would be the most useful, solar energy production becomes more valuable to consumers, incentivizing them to install solar systems to generate cheaper electricity from what they can buy off the main grid.[37] For example, Berkeley, California increased day-time electricity rates through a TOU pricing scheme, making solar energy a viable option for consumers wanting to reduce the economic costs of using energy during these times (see Figure 2).[38] This sort of smart demand response pricing combined with other incentives that encourage residents and businesses to invest in solar generation has resulted in the installation of over 400 private solar systems, accounting for 1.75MW in private solar generation capacity.[39]

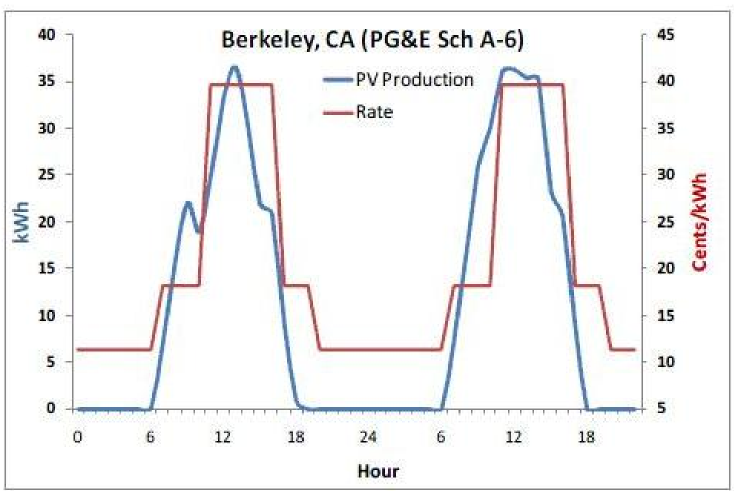

Figure 2 – TOU pricing scheme that correlates well with PV production[40]

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[36] Ibid. 2.
[37] Sean Ong, Paul Denholm, and Elizabeth Doris, *The Impacts of Commercial Electric Utility Rate Structure Elements on the Economics of Photovoltaic Systems* (National Renewable Energy Laboratory, 2010). 18.
[38] Ibid. 13.
[39] *Challenges and Successes on the Path toward a Solar-Powered Community: Solar in Action* (U.S. Department of Energy, 2011). 2.
[40] Ong et al. 13.

Smart Meter Characteristic #2 – Natural Disaster Resilience

Smart meters provide power companies with key information on where outages have occurred during a natural disaster. When smart meters are part of an Integrated Distribution Management System, power companies can automatically see where power has been disconnected from the power station control room, vice the traditional method of waiting for consumers to call the power company with outage information. With this increased flow of information, power companies can more quickly and effectively send out repair crews to the precise locations where power has been disrupted, helping to reduce the amount of time consumers find themselves disconnected. Alternatively, the power company can cut power remotely via smart meters to certain areas in cases of emergency to prevent further injuries or fires.[41]

Smart Meter Characteristic #3 – Public-Private Partnerships

Cities and states can encourage the installation and use of smart meters by private consumers through several methods. By implementing Energy Efficiency Resource Standards (EERS), the city can set energy-saving targets for private power companies, encouraging them to install smart meters and use CPP/TOU pricing schemes to reduce their peak loads.[42] In areas served by public power utilities, the public sphere installs smart meters, while the private consumers use the CPP/TOU pricing schemes, resulting in both public and private energy savings.

Case Studies

The following case studies include cities of different sizes, development levels, and locations:

1) Austin, Texas, U.S.
2) Beijing, China
3) Sacramento, California, U.S.

Each case study will be evaluated according to the smart meter characteristics listed above (where data is available) as well as their prevalence throughout the city. These characteristics will help to assess the impact of these smart meters on their respective cities and can help other cities learn from their examples.

Smart Meter Case Study 1 – Austin, Texas, U.S.

Background

Austin, the capital city of Texas, is known throughout the U.S. as a city that values sustainable energy production, increased energy efficiency, and good environmental stewardship. For example, Austin, with a population of one million, has become the first large U.S. city to power all of its city-owned buildings with renewable resources. Furthermore, the publically-

[41] *Storm Reconstruction: Rebuild Smart - Reduce Outages, Save Lives, Protect Property* (Rossyln, VA, 2013). 6-7.
[42] *State Energy Efficiency Resource Standards* (2014).

owned utility and department of the City of Austin, Austin Energy, has set a goal to increase its use of renewable energy resources from 27% of total production to 35% by 2020.[43]

Located directly between tornado alley, the region in the central to south-central U.S. that experiences a large frequency of annual tornadoes, and the Gulf of Mexico, a coastal region that can experience hurricanes and tropical storms, Austin can experience a variety of natural disasters, making it ideally suited for infrastructure development that focuses on natural disaster resiliency.[44] Austin's geography also plays a factor in how and when its residents use electricity. With average temperatures of well over 36°C during the summer months, Austin residents often rely on energy-intensive air-conditioning units to keep cool.[45]

Austin's lofty city goals combined with its high average temperatures make it an ideal place to implement aggressive and varied energy savings initiatives, starting with the installation of smart meters at every residence and building within the city limits. True to its reputation of pioneering clean and efficient energy programs, Austin has been one of the first cities in America to install smart meters and use CPP/TOU pricing schemes on a large scale.[46] Through the innovative use of smart meters combined with several demand response program options for consumers, Austin has effectively reduced the amount of peak electricity it must produce.

***Prevalence of Smart Meters:* 410,000 Smart Meters**

At the end of 2009, Austin Energy had installed 410,000 smart meters, covering the city's electric footprint for over one million residents and 43,000 businesses.[47]

Increased Energy Efficiency:

With the installation of smart meters, Austin offers several demand response programs to encourage consumers to use less energy. One such example centers on TOU as the demand response pricing scheme. A voluntary program, consumers with smart meters agree to pay different electricity rates based on the time of day. Consumers pay up to twenty times as much for electricity during "on-peak" hours (2:00PM-8:00PM) as they do during "off-peak" hours.[48] Studies have shown that this widely varied pricing is the most effective way of implementing a TOU pricing scheme, as the high costs of using electricity during peak hours encourages users to change their consumption patterns.[49]

Another example of a program Austin has enacted centers on the use of thermostats. Located in a hot climate, many Austin residents run their air-conditioners to escape from the blistering Texas heat. Austin Energy has offered consumers an $85 cash rebate to install and use "smart-thermostats." Through the transmission and control capabilities inherent in smart meters, residents in this program allow Austin Energy to control their thermostats by a few degrees during the peak hours of the day, reducing the amount of electricity that they use. This

[43] "Sustainability Action Agenda: Austin Ahead of Pace for 35% Renewable Energy Goal", austintexas.gov https://austintexas.gov/blog/sustainability-action-agenda-austin-ahead-pace-35-renewable-energy-goal (2015).
[44] "Tornado Alley", National Oceanic and Atmospheric Administration National Climatic Data Center http://www.ncdc.noaa.gov/climate-information/extreme-events/us-tornado-climatology/tornado-alley (2015).
[45] "Climate Austin - Texas", U.S. Climate Data http://www.usclimatedata.com/climate/austin/texas/united-states/ustx2742 (2015).
[46] Andres Carvallo, "Lights On: Austin Energy Delivers First Smart Grid in the Us," *Electric Energy T&D Magazine*2009.
[47] Ibid.
[48] "City of Austin Electric Rate Schedules," (Austin Energy, 2015).
[49] Ahmad Faruqui et al., *Assessing Ontario's Regulated Price Plan: A White Paper* (2010). 3-5.

automatic thermostat control saves consumers money on their electricity bills while reducing the amount of peak electrical load that Austin Energy must produce.[50]

Through its programs such as linking smart thermostats and TOU pricing schemes with smart meters, Austin has reduced its electrical demand by 269MW from 2007-2011, which accounts for more than a third of its goal of offsetting peak electrical demand by 800MW by 2020.[51]

Natural Disaster Resilience:

Austin can experience intense thunderstorms and flooding that can produce power outages to many residents. On one such night in September 2014, almost 12,000 customers lost power due to an overnight thunderstorm and flash flood. By 10:00AM the next morning, Austin Energy had restored power to 11,000 of those customers, largely due to the effective deployment of repair crews to precise locations based on data received from smart meters.[52]

Austin can also increase its climate resistance through its automatic thermostat control program. With the increasing prevalence of extreme weather, this program will become even more crucial as Austin tries to save energy while coping with hotter summers and colder winters.

Public-Private Partnerships: **Passive Public Investment**

Austin gives each of its residents $85 to install and use automatic thermostats controlled through smart meters. Essentially "micro-grants" given to residences and businesses, these rebates are a cost-effective way for Austin to encourage residents to use less energy. In keeping with the idea that passive public investment is meant to foster the formation of private enterprise, these rebates have encouraged companies to invest in new technology such as smart thermostats. For example, only one company, Nest, had a smart thermostat on the market when Austin started its smart thermostat rebate program.[53] Now, thanks to rebate programs such as Austin's proliferating around the country, other manufacturers are designing and selling smart thermostats, including Google (which bought Nest in 2014) and Honeywell.[54] Consumers benefit from this expanded market and increased competition as their choices improve while prices for smart thermostats drop. Smart thermostat rebate and demand response programs such as Austin's spurred private corporations to invest in smart thermostat technology that could communicate with city-installed smart meters.

As the city provides specific energy efficiency goals and direction, energy utilities can work towards achieving measurable impacts. This partnership of the city setting goals and the utility working towards implementing them has truly resulted in a "win-win-win" scenario, as private consumers have lowered their electricity demand and bills by changing their consumption habits, Austin Energy has saved money by not having to invest in new electrical generators, as they have reduced the amount of electricity they must produce at any given time, while the City of Austin has made measurable progress towards achieving its energy efficiency goals.

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[50] "Save More Energy. And Get Paid $85.", Nest https://nest.com/energy-partners/austin-energy/ (2015).

[51] *Austin Energy Dsm Market Potential Assessment* (Oakland, California: Austin Energy, 2012). 2-2.

[52] Nicole Chavez, Ciara O'Rourke, and Roberto Villalpando, "Flood Warning Expires in Hays; 31 Low Water Crossings Remain Closed", Statesman http://www.statesman.com/news/news/flash-flood-warning-for-travis-hays-counties/nhPqW/ (2015).

[53] "Nest", Nest Labs https://nest.com/about/ (2015).

[54] Nathan Ingraham, "The Heat Is On: Honeywell Is Finally Challenging the Nest Thermostat", The Verge http://www.theverge.com/2014/6/10/5793536/the-heat-is-on-honeywell-is-finally-ready-to-challenge-nest (2015).

Smart Meter Case Study 2 – Beijing, China

Background:

Known for its pollution and rapid economic growth, China is in dire need of effective energy efficiency strategies. As China's capital and second most populous city after Shanghai, Beijing has a responsibility to take the lead on urban energy policy. With over 18 million people living and working within the city, any city-wide policy that helps individuals reduce their energy consumption would have a large effect on increasing the city's energy efficiency as a whole. [55]

Within the past few years, Beijing has taken important first steps towards responsible energy policy by installing city-wide smart meters at every residence and business, making it one of the world's largest cities that has installed universal smart meters. The city's success with mandatory CPP/TOU pricing schemes for businesses to increase energy efficiency has become a model for the rest of China, as central leaders now want to take the Beijing model to the rest of China and install smart meters in every home and business by 2017.[56]

***Prevalence of Smart Meters:* 5.7 million**

At the end of 2014, Beijing had 78% smart meter coverage (5.7 million connected homes and businesses). It expects to increase this coverage to 100% by the end of 2015.[57]

Increased Energy Efficiency:

Studies of Chinese electrical consumption patterns indicate that residences and businesses in China are very sensitive to price fluctuations, making the argument for the future success of CPP/TOU pricing schemes.[58] Beijing separates its electricity charges for heavy industry, ordinary industry, non-industrial, commercial, non-residential, agricultural, and residential. For all sectors except for residential, Beijing has enacted a TOU pricing scheme in an attempt to encourage businesses to change their electrical consumption patterns. Prices during peak hours are almost twice of those at non-peak hours. Although the price of electricity varies significantly less than the previous case study of Austin, Texas, Beijing's TOU pricing for businesses are mandatory, resulting in their widespread use and increased energy savings.[59] As for residences, Beijing is slow to enact mandatory TOU pricing, as they do not want to overly burden the poor with high electricity prices. Instead, Beijing has enacted a tiered system, with residents consuming less than 240kWh/month paying less than those consuming 241-400kWH/month. Meanwhile, those residences that consume more than 400kWh/month will experience price

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[55] "The Most Populated Cities in China", Nations Online http://www.nationsonline.org/oneworld/china_cities.htm (2015).

[56] Jeff John, "China Wants Time-of-Use Pricing by 2015, One Meter Per Home by 2017", GreenTechMedia http://www.greentechmedia.com/articles/read/china-wants-time-of-use-pricing-by-2015-one-meter-per-home-by-2017 (2015).

[57] Metering International, "Smart Meters China: Beijing to Hit 100% Residential Coverage by Year End" http://www.metering.com/smart-meters-china-beijing-to-hit-100-residential-coverage-by-year-end/ (2015).

[58] G. Shi, X. Zheng, and F. Song, "Estimating Elasticity for Residential Electricity Demand in China," *The Scientific World Journal* 2012, (2012).

[59] Beijing International, "Guide to Heating, Electricity, Water, and Gas - Policies and Procedures", Beijing International http://www.ebeijing.gov.cn/feature_2/GuideToHeatingElectricityWaterAndGas/PriceGuide/t1107813.htm (2015).

increases for every extra 1000 kWH/month that they use.[60] While this tiered-level pricing scheme does not mirror a true TOU/CPP program, it still attempts to reduce the amount of electricity that residents use. Beijing lacks comprehensive data on how these pricing schemes have affected the city's energy consumption, but overall GDP per unit of energy use in China as a whole has started to level off after rising significantly for several years (see Figure 3), presumably spurred along in no small part by Beijing's aggressive energy efficiency policies as China's second-largest city.[61] Even a leveling-off of GDP per unit of energy use can be counted as a success, as China's meteoric economic growth in the last few decades, like many fast-developing countries, has largely been spurred by heavy carbon dioxide emissions.

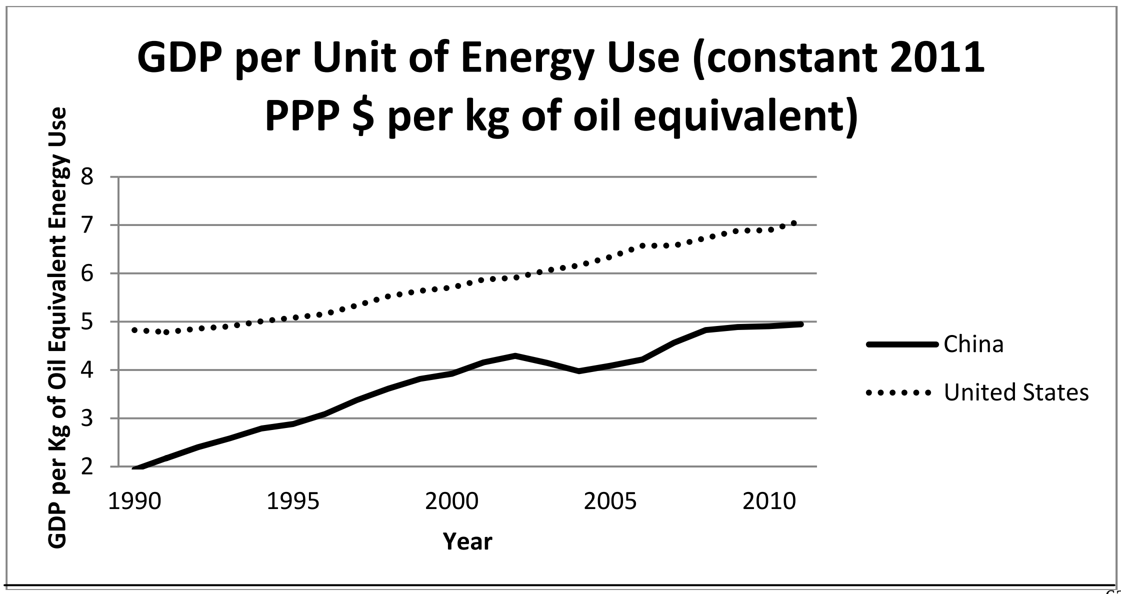

Figure 3 – GDP per Unit of Energy Use (constant 2011 PPP $ per kg of oil equivalent)[62]

Public-Private Partnerships:

Beijing's central government controls the utility company and sets its electricity prices, thus exerting a large amount of control on smart meter installation and pricing schemes. Unlike the previous case study of another publically-owned utility, Austin Energy, Beijing requires its businesses to take part in the TOU pricing scheme and its residents to comply with the tiered-pricing levels.[63] While this requirement generates greater energy savings for all private participants if they change their consumption patterns, it does significantly reduce the amount of consumer choice when it comes to when consumers can use electricity. The public sphere, Beijing, sets energy prices for private citizens and businesses, resulting in reduced energy costs for both private electricity consumers and public electricity generators alike.

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[60] "China Changes Residential Electricity Pricing", China Daily http://www.chinadaily.com.cn/bizchina/2012-06/12/content_15495789.htm (2015).
[61] "Gdp Per Unit of Energy Use (Constant 2011 Ppp $ Per Kg of Oil Equivalent)," ed. The World Bank (2015).
[62] Ibid.
[63] John.

Case Study 3 – Sacramento, California, U.S.

Background:

Sacramento, the capital of California with a population of 2.5 million, boasts sunny California skies, and is even known as one of America's sunniest major cities, with an average of 78% sunny days throughout the year.[64] With all that sun, Sacramento has installed more than 1000 solar energy projects, combined for a total of 16MW peak power capacity.[65] With the growing prevalence of clean, renewable energy installed throughout the city, Sacramento has also focused on using this energy efficiently, and has recently made additional strides towards reducing its carbon footprint through the installation of smart meters and its use of demand response pricing programs.

Many energy efficiency programs such as the one reviewed in Austin, Texas are targeted at residential consumers. However, Sacramento designs some smart meter and demand response programs specifically for small businesses. In 2008, the Sacramento Municipal Utility District (SMUD), a publically owned utility company, ran a pilot program that offered small businesses free energy efficiency audits through on-site evaluations in trade for their participation in a demand response thermostat program.[66]

Prevalence of Smart Meters: **604,000 Smart Meters**

As of 2012, Sacramento had installed 604,000 smart meters, with plans to install up to 618,000.[67] In 2008, SMUD conducted a pilot program for 78 small businesses with installed smart meters to help increase their energy efficiencies.[68] The results of this pilot program will be discussed below.

Increased Energy Efficiency: **20% Energy Savings**

SMUD sent a team of energy efficiency experts to small businesses that took part in the program. These teams performed an energy audit on each small business, giving business owners customized and actionable advice on how they could reduce their electrical consumption. Program participants also allowed SMUD to control their thermostats by a few degrees during days when temperatures reached over 90°F, as well as agreeing to participate in a TOU pricing scheme. This combination of thermostat control, TOU pricing, and energy efficiency advice resulted in the small businesses using twenty percent less electricity throughout the test period, and a five percent decrease in their electricity bills.[69] By agreeing to the TOU pricing scheme, business owners paid more for electricity during the peak electricity demand times (usually during the day) than they did during off-peak hours (generally at night). Therefore, the decrease in the amount of electricity consumed did not necessarily decrease at the same rate as the electric bill, as the price of electricity varied depending on what time of day the small businesses used it.

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[64] "Ranking of Cities Based on % Annual Possible Sunshine in Descending Order from Most to Least Average Possible Sunshine," ed. National Oceanic and Atmoshperic Administration (2004).

[65] Benjamin Davis, Travis Madsen, and Michelle Kinman, *California's Solar Cities 2012* (2012). 5.

[66] *Coordination of Energy Efficiency and Demand Response*. 3-4.

[67] *Utility-Scale Smart Meter Deployments, Plans, & Proposals* (Washington, D.C.: The Edison Foundation, 2012). 9.

[68] Karen Herter, Seth Wayland, and Josh Rasin, *A Succesful Case Study of Small Business Energy Efficiency and Demand Response with Communicating Thermostats* (2009). 1.

[69] Ibid. 1.

Public-Private Partnerships:

SMUD, a publically-owned utility, partnered with private small businesses to teach them how to reduce their electrical consumption, which not only helped these small businesses reduce their monthly electrical bills, but reduced the amount of energy that the city of Sacramento had to produce. Funded partly by city funds and partly by the electrical bills of the private small businesses, these installed smart meters and ensuing small changes in consumption patterns helped both entities achieve their electrical and economic goals. The success of this partnership led to the wide-scale implementation of this pilot program to the community of Sacramento.[70]

Conclusion

These three case studies all have one essential infrastructure component in common: smart meters. Without smart meters, demand response programs are impossible to enact, as power companies need to fluctuate their charges based on peak demand times for electricity. Smart meters allow the basic principles of supply and demand infiltrate the electricity market, benefitting producers and consumers alike. Besides enabling significant power savings, smart meters can help power companies more efficiently dispatch repair crews in cases of power outages, a vital resource when recovering from a natural disaster. Public-private partnerships are easy to use to fund the installation of these smart meters, as they help not only public utilities, but private consumers, a true win-win for all participants.

[70] "Small Commercial Deep Energy Retrofit Demonstration Program", Sacramento Municipal Utility District https://www.smud.org/en/business/save-energy/rebates-incentives-financing/small-commercial-DER.htm (2015).

Building Retrofits

As new energy-saving technology becomes available, large building owners can make both minor and major structural adjustments to reduce their energy consumption.

Building retrofits have three main characteristics that impact host cities, each of which will be discussed in detail below:

1) Increased Energy Efficiency
2) Natural Disaster Resilience
3) Public-Private Partnerships

Building Retrofit Characteristic #1 – Increased Energy Efficiency

Building owners can take a variety of steps towards increasing their buildings' energy efficiency, and thus reducing their electric bills. Measures could include upgrades to the central heating/cooling systems, improvements to the building's insulation features by keeping air from leaking through windows and walls, air flow system upgrades, hot water heater upgrades, etc. Large buildings in particular warrant increased energy efficiency measures, as their size causes them to use more energy than their smaller counterparts. For example, in New York City, a mere two percent of the properties (usually large apartment buildings) account for 48% of the city's energy use.[71] By focusing energy efficient upgrades on these larger buildings, a city can drastically reduce its overall energy consumption.

Building Retrofit Characteristic #2 – Natural Disaster Resilience

Disaster resilient buildings and energy efficient buildings share many common infrastructure components. For example, double-paned windows and sealing off openings to the exterior both improve a building's disaster resilience while reducing the amount of energy it consumes. Furthermore, most energy efficient upgrades focus on the same components of a building that improve disaster resilience, such as roofs, doorways, and windows.[72] Instead of choosing either energy efficiency or disaster resilience, building owners can invest in both at the same time, ensuring that their buildings not only decrease their energy usage, but are also built to withstand the damages of natural disasters in the long-run.

Building Retrofit Characteristic #3 – Public-Private Partnerships

The upfront costs of these building retrofits, especially to older buildings, can be prohibitively expensive, even if they result in long-term economic savings. Cities can use a variety of different financing options and regulations to encourage private owners of both new

[71] Henry Grabar, "The Closest Look yet at the Relative Energy Efficiency of Big Buildings", The Atlantic http://www.citylab.com/tech/2013/09/closest-look-yet-relative-energy-efficiency-big-buildings/7033/ (2015).
[72] *Linking Efforts to Improve Disaster Resistance and Energy Efficiency of Homes* (Center for Housing Policy).

and old buildings to upgrade their infrastructures. These public-private partnerships, especially when focused on large building owners, can really make an impact as to how much electricity a city needs to produce. "On-bill financing" is one such popular financial strategy that cities use to encourage building owners to make energy efficient upgrades. With an initial loan provided by the city or the service company installing the energy efficient upgrades, owners can finance the retrofit of their buildings to reduce their energy consumption. Owners pay back the loan with the money they save on their monthly electric bill. This sort of financing has been adopted by cities and utilities in 23 states, with many of those using legislation to further encourage on-bill-financing.[73] Figure 4 gives an example of how on-bill financing would work for a large building owner taking out a loan from an energy service company to make energy efficient upgrades. The owner does not see a change in the electric bill for the loan repayment period (twelve years in this case); as the energy savings gleaned from the new energy efficiency measures undertaken go directly to paying off the initial loan. After the loan has been paid off, the building owner starts to realize the economic savings from the energy efficient upgrades, resulting in a drastically-lowered electric bill.

Average Yearly Electricy Bill Before Loan: $9000 Amount of Loan to be Repaid: $48,000 Repayment Period: 12 Years				
	Total Electric Bill	**Energy Costs (Paid to electric company)**	**Energy Savings (Paid to service company)**	**Amount of loan remaining**
Year 1	9000	5000	4000	44,000
Year 2	9000	5000	4000	40,000
Year 3	9000	5000	4000	36,000
Year 4	9000	5000	4000	32,000
Year 5	9000	5000	4000	28,000
Year 6	9000	5000	4000	24,000
Year 7	9000	5000	4000	20,000
Year 8	9000	5000	4000	16,000
Year 9	9000	5000	4000	12,000
Year 10	9000	5000	4000	8,000
Year 11	9000	5000	4000	4,000
Year 12	9000	5000	4000	0
Year 13	5000	5000	0	0
Year 14	5000	5000	0	0
Year 15	5000	5000	0	0

Figure 4 - On-bill financing example for large building owner

[73] *On-Bill Financing for Energy Efficiency Improvements* (American Council for an Energy-Efficient Economy, 2012). 1.

Case Studies

The following case studies include cities of different sizes, development levels, and locations:

1) Greensburg, Kansas, U.S.
2) Tianjin, China
3) Berlin, Germany

Each case study will be evaluated according to the building retrofit characteristics listed above (where data is available). These characteristics will help to assess the impact of these building retrofits on their respective cities and can help other cities learn from their examples.

Building Retrofit Case Study 1 – Greensburg, Kansas, United States

Background:

The city of Greensburg, Kansas, is a town located directly in tornado alley in the U.S. A small town of only 1000 and composed of an economically declining farming community, Greensburg's population prior to 2007 desperately needed an economic boost.

In 2007, an EF-5 tornado, the highest possible on the meteorological scale, ripped through Greensburg, Kansas, and destroyed 90% of the city's commercial and residential areas. Confronted with a "clean slate," the city decided to rebuild focusing not only on energy efficiency, but on disaster resilience. By partnering with the U.S. Department of Energy (DOE) and the National Renewable Energy Laboratory, Greensburg, Kansas attempted to rebuild in the form of a community powered entirely through renewable energy. To achieve this goal, they needed to significantly reduce the amount of electricity they consumed. Greensburg worked extensively with the DOE as well as private partners to design and rebuild their town with the most energy efficient materials available. Greensburg proved that a small town could not only become natural disaster resilient, but could dramatically reduce its energy consumption.[74]

***Increased Energy Efficiency:* 59% Energy Savings**

Both commercial and city buildings participated in Greensburg's energy efficiency initiatives. From the data provided by thirteen commercial or civic buildings three years after the tornado, redesigned buildings achieved an average of 59% energy savings as compared to other buildings of their types in America.[75] Meanwhile, more than half the private homes have achieved 40% energy savings as compared to other buildings of their same type.[76]

Natural Disaster Resilience:

All of the redesigning in Greensburg focused not only on energy efficiency but disaster resilience as well. Residential homes in particular were rebuilt with these two principles in

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[74] *Rebuilding It Better: Greensburg, Kansas - High Performance Buildings Meeting Energy Savings Goals* (U.S. Department of Energy, 2012). 1.

[75] Ibid. 3.

[76] Shanti Pless, Lynn Billman, and Daniel Wallach, "From Tragedy to Triumph: Rebuilding Greensburg, Kansas, to Be a 100% Renewable Energy City," in *ACEEE Summer Study* (Pacific Grove, CA: National Renewable Energy Laboratory, 2010). 2.

mind. For example, homes incorporated the use of energy efficient and disaster resilient walls, helping to increase insulation while simultaneously resisting the forces of strong storm winds.[77] Other buildings incorporated insulated windows, doors, and roofs that could also resist high velocity winds.[78]

Public-Private Partnerships: **Passive Public Investment**

Without the support of private enterprises, none of this reconstruction would have been possible. As the Mayor of Greensburg, Bob Dixson, stated in an interview, "LEED-certified energy efficient buildings are great, but you need people to inhabit those buildings for a vibrant economy. And for that to happen, we must involve private enterprise in the process."[79] Part of the purpose for reconstruction was to re-energize a stagnant economy, focusing on attracting investors interested in energy efficient communities and commercial enterprises. Through its partnership with the U.S. Department of Energy, the city received funding from many multinational corporations for its rebuilding. For example, General Motors and John Deere both helped their local dealerships rebuild using energy efficient and disaster resilient technology.[80]

Building Retrofit Case Study 2 – Tianjin, China

Background:

Tianjin, China, the sixth most populous city in China with a population of over 10 million, also has some of the most energy efficient buildings. A leader when it comes to increasing energy efficiency in both commercial and residential buildings, Tianjin has adopted strict Building Energy Efficiency Codes (BEECs) for both new and old buildings. While other Chinese cities have similar energy efficient building codes by law, they rarely enforce them. Compared to the rest of China, Tianjin has had exceptionally high compliance rates because:[81]

i) Standardized procedures for BEEC enforcement
ii) Ability of construction companies to meet BEECs through better skill-sets, greater availability of needed parts

To help enforce BEECs, Tianjin has worked with the World Bank extensively on improving their buildings' energy efficiencies, with the last project ending in 2013. These projects provide Tianjin with technical expertise on BEEC compliance strategies, giving Tianjin the knowledge to draft continually updated energy efficient building standards.[82] Third-party private architects in charge of the building process are responsible when designing buildings with these BEECs in mind. The onus lies upon the architect, not the building owner, to ensure that their plans comply with the current BEECs, otherwise their architectural licenses will be

[77] *Linking Efforts to Improve Disaster Resistance and Energy Efficiency of Homes*. 2.
[78] *Rebuilding It Better: Greensburg, Kansas - High Performance Buildings Meeting Energy Savings Goals*. 5-8.
[79] Bob Dixson, "Greensburg Builds Back Better," ed. PwC (PwC, 2013). 1.
[80] Ibid. 2.
[81] *Good Practices in City Energy Efficiency* (Energy Sector Management Assistance Program, 2011). 1-2.
[82] *Implementation Completion and Results Report on a Global Environment Facility (Gef) Grant in the Amount of Us$18 Million to the People's Republic of China for a Heat Reform and Building Energy Efficiency Project* (The World Bank, 2014), ICR00003153. vii-viii.

revoked by the city. By embedding this responsibility with a private third-party, with city oversight, Tianjin has found a solution to typically low Chinese BEEC compliance rates.[83]

Increased Energy Efficiency:

Chinese leadership has set national BEEC standards for both new and old buildings throughout China. However, Tianjin is one of few cities to not only enforce, but exceed the national standard. Specifically, a recent study found that Tianjin has close to 100% compliance rates, compared to a national average of 80%. Furthermore, in terms of building thermal integrity, the Tianjin BEECs are 30% more stringent than the national BEECs.[84] With the successful implementation of these BEECs, Tianjin residential buildings have decreased their energy demand by 65% as of 2004 from the base year of 1980.[85]

Building Retrofit Case Study 3 – Berlin, Germany

Background:

Since the fall of the Berlin Wall in 1989, Berlin has continually updated its infrastructure to integrate East and West Berlin into one community. With over 3.5 million people calling Berlin home, Berlin is another city that can realize substantial energy savings by focusing on the energy efficient retrofit of large buildings.

Berlin has established itself as a leader when it comes to energy efficient building retrofits. Through the 1996 establishment of the Energy Saving Partnership (ESP), a private-public partnership between the City of Berlin, the Berlin Energy Agency, and private building owners, Berlin has significantly reduced building carbon outputs while simultaneously saving building owners money on their electrical bills. Berlin has shared its knowledge with other cities, leading others to copy its successful ESP program in seven countries and twenty cities around the world.[86]

***Increased Energy Efficiency:* 25%**

Since 1990 levels, Berlin has managed to reduce its annual carbon dioxide emissions by 25%. This 25% reduction aligns itself with the increased energy efficiency of Berlin's large buildings, as measured by the ESP.[87] ESP projects have been responsible for retrofitting 1500 buildings as of 2012, accounting for a reduction of approximately 70,000 metric tons per year in carbon dioxide emissions. These energy efficient retrofits have led to a yearly savings of 14.3 million USD, or 26% on average per electricity bill.[88]

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[83] *Good Practices in City Energy Efficiency*. 5-7.
[84] Ibid. 1.
[85] Jihong Ling et al., "Statistical Analysis of Residential Building Energy Consumption in Tianjin," *Frontiers in Energy* 8, no. 4 (2014). 513.
[86] *Berlin Energy Saving Partnership for Energy Efficiency in Buildings* (Washington, DC: Center for Clean Air Policy, 2012). 4.
[87] "Berlin: Energy Saving Partnerships", City Climate Leadership Awards http://cityclimateleadershipawards.com/berlin-energy-saving-partnerships/ (2015).
[88] *Berlin Energy Saving Partnership for Energy Efficiency in Buildings*. 3.

Public-Private Partnerships:

Berlin utilizes a unique on-bill-financing scheme to help private building owners surmount the high economic costs of installing energy efficient upgrades to their buildings, which often include new lighting throughout the buildings, insulation upgrades, retrofitting old water heaters, etc. To install energy efficient upgrades, building owners apply for an Energy Performance Contract, essentially a loan, with private energy system companies. These private energy system companies (such as Honeywell, Siemens, etc.) guarantee certain energy savings thresholds through the installation of their equipment. These private energy system companies cover the costs of the building retrofits with the loan, and building owners continue to pay the same monthly electricity bill that they always have, with the economic savings from the energy efficient upgrades going directly to paying off the loan. Once the contract expires and the loan is paid off, typically in 8-12 years, the building owner begins to see the economic savings of the building retrofit with a significantly reduced electricity bill.[89]

The Berlin Energy Agency acts as the mediator between the private energy system companies and the private building owners. It facilitates the loan process by connecting these two entities through the Energy Savings Program, and acts as the project manager during the physical building upgrade portion of the contract.[90]

Conclusion

These three case studies demonstrate that building retrofits can significantly reduce the amount of electricity a city consumes. When combined with disaster resilient upgrades, these retrofits can prepare a city for climate change while increasing its energy efficiency. Through the use of on-bill-financing and the enforcement of Building Energy Efficiency Codes (BEECs) outlined in city legislature, cities can adopt creative solutions that ensure that buildings account for less carbon emissions, saving money for not only the city with its reduced energy generation costs, but for private building owners as well as they realize lower monthly electricity bills.

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[89] Ibid. 2.

[90] "Energy Saving Partnership Berlin (Esp) - an Effective and Innovative Model to Reduce Co2 and Energy Costs without Expenses for Building Owners", C40Cities http://www.c40.org/case_studies/energy-saving-partnership-berlin-esp-%E2%80%94-an-effective-and-innovative-model-to-reduce-co2-and-energy-costs-without-expenses-for-building-owners (2015).

Conclusion

Microgrids, smart meters, and building retrofits are all excellent solutions in their own right towards making a city both climate-change resilient and energy efficient. However, they are the most effective when they work concurrently towards achieving those goals. For example, a microgrid would be remiss if it did not include smart meters as integral pieces in controlling the flow and pricing of its clean energy resources. Likewise, a building retrofit would not achieve its full potential in energy savings without installing a smart meter or connecting to a microgrid that supplied renewable energy.

By reading through these case studies, city planners can get a sense of what techniques work in reducing the amount of energy their cities consume. Only by analyzing past case studies, implementing creative solutions, and sharing information between cities of similar size and development levels can city planners hope to increase their cities' long-term energy efficiency.

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