Supplementary information

A Smarter Grid for Renewable Energy: Different States of Action

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Appendix 1. Additional State Policy Detail for Smart Grid Investment, Net Metering and Interconnection for Renewables Policies

This section provides detail about state-level energy use and relevant smart grid policies. All data on electricity generation comes from U.S. Energy Information Administration State Electricity Profiles 2010 [1]. RPS, net metering and interconnection statuses come from dsireusa.org, and installed wind from the U.S. Department of Energy and the National Renewable Energy Laboratory [2,3]. Information for smart meters comes from U.S. Energy Information Administration Form 861, file 8 and the Edison Foundation [4,5]. More detailed information on net metering policies and interconnection standards is presented in Tables A1 and A2.

2.1. California

California uses 260 TWh of electricity per year, while generating a total of 204 TWh with 60 TWh produced from renewable sources. California's electricity market has suspended deregulation following the Western U.S. Energy Crisis of 2000 and 2001 [6]. California's in-state electricity generation is relatively low carbon and depends largely on natural gas. California has already installed 5.5 GW of wind. California enacted net metering in 1996, which is available for systems less than one MW or five MW for government or university institutions. An examination of smart grid projects in California emphasized their strong commitment to grid modernization; Advanced Metering Infrastructure (AMI) projects had received over $400 million in investment by 2011, and over 10 million two-way advanced smart meters had been installed [4]. California projects have also seen significant investment in storage technologies at $400 million, as well as general smart grid funding at $200 million.

2.2. Illinois

Illinois generates 200 TWh with five TWh coming from renewable sources, and consumes 145 TWh annually. The state has been restructuring its electricity market since the late 1990s [7]. Illinois has an RPS goal of 25 percent generation by 2025, which applies to investor-owned utilities (IOUs) and retail suppliers, as well as distributed generators, and has 3.5 GW of installed wind. Net metering was introduced in the state in 2008 and requires all IOUs and alternative retail energy suppliers to offer net metering. Interconnection standards were also introduced in 2008 and set standards for renewable energy facilities and distributed generation facilities with 10 MW capacity or less. They were modified in 2010 to include all facilities with more than 10 MW of capacity. Illinois smart meter projects have been supported with over $600 million in investments, with other significant smart grid investments in transmission and distribution technologies at $62 million and supervisory control and data acquisition (SCADA) at $32 million.

2.3. Massachusetts

Massachusetts generates 43 TWh with three TWh coming from renewable sources, and consumes 57 TWh annually. Massachusetts initiated electricity market restructuring in the late 1990s [8]. The state's RPS, adopted in 2003, requires every retail supplier to provide a minimum of one percent of kilowatt-hours sales to end-use customers from new renewable energy-generating sources. The RPS was set to increase by 50% percent every year until 2009, when it was scheduled to increase by one percent per year. Currently, the RPS calls for 15 percent of all electric sales by 2020 to be generated by renewable resources and continues the goal of one percent per year thereafter, yet the state only has 100 MW of installed wind. Net metering is mandated in Massachusetts for investor-owned utilities, and municipal utilities may opt in if they wish. Interconnection standards are still evolving in the state; legislation enacted in 2012 mandates that the Massachusetts Department of Public Utilities set an enforceable interconnection timeline by November 2013. Massachusetts's Model Interconnection Tariff specifies levels of interconnection and associated protocol. Massachusetts smart meter & AMI projects have seen $120 million in investments, but smart meter penetration is low at 46 thousand end users, and penetration is not expected to exceed 50 percent of end users by 2015. Transmission and distribution technologies and SCADA have also seen significant investment at $110 million and $32 million, respectively.

2.4. Minnesota

Minnesota generates 54 TWh with 8 TWh coming from renewables, and consumes 68 TWh annually. The electricity market in Minnesota remains traditionally-regulated and neither time-of-day pricing nor third-party demand response aggregators are legal. In 2007, Minnesota introduced an RPS that requires that renewable electricity account for 25% of utilities' retail electricity sales by 2025, with Xcel mandated to provide 30% of sales. The state currently has 2.9 GW of installed wind and just passed a policy to promote solar PV. Net metering policies in Minnesota are applied across a variety of technologies and are applicable to the industrial, residential, and commercial sectors and all utilities for any system capacity less than or equal to one MW. Minnesota's interconnection standards are well-developed and are applicable to numerous distributed generation technologies across all utilities. Minnesota has only six AMI projects with a total funding of $30 million, and has 170 thousand smart meters deployed with no plans to reach 50 percent end user deployment [4]. Minnesota also has one transmission and distribution project with a budget of $35 million.

2.5. New York

New York generates 137 TWh with 31 TWh coming from renewables, and consumes 144 TWh annually. The electricity market was restructured in the late 90s [9]. New York's RPS was enacted in 2004 and has a goal of 29 percent renewable generation by 2015, with 1.6 GW of installed wind. Net metering was enacted much earlier, in 1997, and originally applied to only residential photovoltaic systems. Since then, the program has expanded and net metering is now available to all utilities on a first-come, first-served basis. Interconnection in New York applies to all IOUs and has a system capacity limit of two MW. New York was the second state to adopt uniform interconnection standards for distributed generation systems. In terms of smart meter deployments, New York had only 19 thousand meters installed in 2011, and $51 million in investment. The state also has significant investment in storage projects at $125 million.

2.6. Texas

Texas generates 410 TWh with 29 TWh of generation coming from renewables, and consumes 360 TWh annually. In 2002, Texas restructured both wholesale and retail electricity markets. In 1999, Texas adopted renewable energy mandates, but wind installation has already surpassed the largest goal of 10,000 MW, with 12.2 GW of wind installed. Texas has no statewide net metering law, but electricity providers can choose to compensate consumers for distributed renewable energy they may be generating and exporting back to the grid. The 1999 Texas Public Utility Regulatory Act brought interconnection standards to the state [2]. Texas currently has over $800 million invested in 11 smart meter & AMI projects and approximately 5.9 million smart meters have been installed in the ERCOT region of the state, connecting over 50 percent of end users. Texas also has significant investments over four projects involving transmission and distribution technologies ($126 million). They also have smart grid projects involving SCADA technologies.

2.7. Vermont

Vermont generates 6.6 TWh with 1.8 TWh coming from renewables, and consumes 6 TWh annually. The electricity market in Vermont is traditionally-regulated. The state has initiated an RPS goal of 20 percent renewable generation by 2017 and 119 MW of installed wind capacity. Vermont has had a net metering system in place since 1998. While the state has articulated a goal of full AMI penetration (300 thousand meters, covering 85 percent of customers) by 2015, and had installed over 70 thousand advanced one-way meters, two-way AMI penetration remained low in 2011 [10]. However, Vermont has three active AMI projects with a combined budget of $170 million. Vermont has also initiated a large SCADA project with a budget of $140 million and a smaller transmission and distribution project of $18 million. Vermont also currently has an active eEnergy Vermont smart grid initiative and received a $138 million Smart Grid Investment Grant.

Table A1. Net Metering Policies.

State	Eligible Technologies	System Capacity Limit	Cumulative Generating Capacity (% of Utility's Aggregate Peak Demand	Buy-Back Rate
CA	Solar Thermal Electric, PV, Landfill Gas, Wind, Biomass, Geothermal Electric, Fuel Cells, Municipal Solid Waste, Biogas, Anaerobic Digestion, Small Hydroelectric, Tidal Energy, Wave Energy, Ocean Thermal, Fuel Cells using Renewable Fuels	1 MW	5%	Retail price

Table A1. *Cont.*

State	Eligible Technologies	System Capacity Limit	Cumulative Generating Capacity (% of Utility's Aggregate Peak Demand	Buy-Back Rate
IL	PV, Wind, Biomass, Hydroelectric, Anaerobic Digestion, Small Hydroelectric, Fuel Cells using Renewable Fuels, Microturbines	2 MW	5% of utility's peak demand in previous year	Retail price for non-hourly customers, credit based on hourly rate for hourly customers
MA	Solar Thermal Electric, PV, Wind, Biomass, Hydroelectric, Geothermal Electric, Fuel Cells, Municipal Solid Waste, CHP, Anaerobic Digestion, Small Hydroelectric, Fuel Cells using Renewable Fuels	10 MW for government entities, 60 kW–2 MW for private entities	3%	Predetermined rate, slightly less than retail price
MN	PV, Landfill Gas, Wind, Biomass, Hydroelectric, Municipal Solid Waste, CHP, Anaerobic Digestion, Small Hydroelectric, Other Distributed Generation Technologies	40 kW	None	Retail price
NY	PV, Wind, Biomass, Fuel Cells, CHP, Anaerobic Digestion, Small Hydroelectric, Fuel Cells using Renewable Fuels, Microturbines	10 kW–2 MW, varying by scale and technology	1% for most technologies	Retail price and avoided cost rate (for CHP, fuel cells, and small wind, PV, biogas)
TX	Varies by utility	50 kW *	None	Credit for avoided cost
VT	Solar Thermal Electric, PV, Landfill Gas, Wind, Biomass, Hydroelectric, CHP, Anaerobic Digestion, Small Hydroelectric, Fuel Cells using Renewable Fuels	500 kW (except for military systems and micro CHP)	4% of utility's 1996 peak demand or peak demand during recent year (whichever is greater)	Retail price

Table A2. Interconnection Standards and Rules.

	Main Provisions	Targeted Systems
CA	• Standard interconnection, operating, and metering requirements • Application and evaluation procedures, fees, and costs	Facilities to be connected to utility distribution systems
IL	• Four tiers of review for interconnection process • A project must meet all requirements of a classification	Tier 1: Facilities with capacity ≤ 10 kW Tier 2: Facilities ≤ 2 MW Tier 3: Facilities with capacity ≤ 50 kW Tier 4: Facilities with capacity ≤ 10 MW
MA	• Simplified, expedited, and standard processes for interconnection • Standard process with application procedure and fees	Facilities connected to utility distributed systems and distributed generation

Table A2. *Cont.*

	Main Provisions	Targeted Systems
MN	• Standards for interconnection and operating procedures • Application procedures and application fees for safety, economic, and reliability issues	Facilities with capacity ≤ 10 kW
NY	• Standard interconnection procedures • Requirement of a web-based system for customers • Expedited six-step interconnection process or basic 11-step interconnection process	Systems ≤ 50 kW eligible for expedited process Systems >50 kW and ≤ 300 kW use basic process
TX	• Requirements for generators and network interconnection of distributed generation • Requirements for control, protection, and safety equipment	Facilities with capacity ≤ 10 MW and connection voltage ≤ 60 kV
VT	• Special safety, power quality, and interconnection requirements for net metered systems • Standard process with application procedure and fees	Net metered systems ≤ 150 kW Distributed generation systems with capacity ≤ 50 MW

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Appendix 3. Additional Detail on Social Context Coding Frame

Table A3 Examples of specific focal areas for thematic-qualitative analysis focused on the social context within which smart grid systems are developing, adapted from Luhmann's social function systems theory for analysis of the socio-political context of state-level energy deployment [11,13,14].

Social Context	Examples
Technical	Smart grid technologies would improve the infrastructure Smart grid allows utility or consumer to better use the electricity The technologies will allow the creation of a more reliable electric grid Developing smart grid technologies present engineering challenges Integrating smart grid technologies will allow the electric system to function more efficiently
Political	Smart grid deployment may allow other political goals to be met Public frustration with smart grid could have political ramifications for officials Smart grid deployment lacks/enjoys strong political support The legal and regulatory process is difficult to navigate New laws and policies are needed to deploy smart grid technologies

Table A3. *Cont.*

Social Context	Examples
Political	New standards are needed for developing smart grid
Economic	Developing smart grid costs too much Smart grid will save money by avoiding the need of new facilities Smart grid technologies will allow the system to be used more efficiently Smart grid will cost consumers more but only benefit the electric utilities
Cultural and Aesthetic	Smart grid deployment presents privacy concerns Smart grid is necessary for progress Positive or negative about technology Utility industry culture and innovation
Environmental	Smart grid deployment will allow better integration of variable renewable resources Smart grid technologies could improve environmental and human health Smart grid could allow for reduced air pollution, additional low-carbon technologies and demand-side management
Health and Safety	Smart grid, particularly smart meters, represent a health risk to consumers Smart grid systems represent cybersecurity threats to critical infrastructure Smart grid will make the U.S. grid more vulnerable and susceptible to hostile attacks

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