Smart Grid Economics & Policy

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Smart Grid and Climate Change

- Electricity production and transportation are dominant sources of GHG emissions
- Addressing Climate Change
  - Switch to cleaner and renewable power sources: Solar, Wind, Geothermal (remote & distributed)
  - Reduce wastage and improve efficiency
  - Switch to cleaner vehicles (Electric, hybrid, plug-in-hybrid)
- A grid connects sources to users
  - New distributed sources, new demands, efficiency and reliability ---- SMART GRID
POTENTIAL SOLUTIONS

- **Existing Power Stations**
  - **Upgrade**
- **New Development**
  - **Alternative Energy Sources**
  - **New Transmission Grid**
- **Existing Transmission Grid**
  - **Upgrade**
- **New Development**
- **Distribution Grid**
- **Information System**
  - **Upgrade**
- **Consumer - Homes, Business and Industry**
  - **Upgrade**
UPGRADING INITIATIVES

- The Federal Government has set aside $54 billion to upgrade the national grid
- In Oct. 2009, the largest single electric grid modernization investment in U.S. history involving $8 b was announced.
- It funded 100 major smart grid projects with $3.4b in DOE $’s and $4.7b in private $’s
- In Nov. 2009, another $620m, matched with $1b in private $’s were announced for 32 demonstration projects on new upgrading technologies
FEDERAL FUNDING EXAMPLES

- **Potomac Electric Power Co. ($209m)**
  - Smart meters with network interface
  - Distribution automation & communication technology

- **Idaho Power Co. ($94m)**
  - Transmission & distribution infrastructure modernization
  - Smart meters
  - Outage management
  - Irrigation load control

- **Detroit Edison ($5M)**
  - energy storage projects
VC Funding

Figure 3.7. Venture-Capital Funding of Smart-Grid Startups (2002-2007)
Venture Capital Investments

- Optimal Technologies International, Inc. received $25 million towards the development of software for managing electrical grids.
- SmartSynch, Inc. secured $20 million to develop wirelessly communicating meters.
- Trilliant Incorporated secured $40 million toward the development of intelligent networks powering smart grid related functions.
- Tendril Networks received $12 million to develop smart grid networking products.
- Fat Spaniel Technologies received $18 million toward the development of an energy intelligence platform.
- GridPoint, Inc. received $15 million for their management of distributed storage, renewable generation, and load, bringing the firm’s total funding to over $100 million.
- eMeter Corporation secured $12.5 million to support development of advanced metering technologies.
What is SMART in Smart grids?

Technologically

- Digital communication overlay and integration into the electric power network.
- This communication technology includes
  - Digital switching networks
  - Remote sensing and monitoring in wires and in transformers
  - Fault detection
  - Devices for automated fault repair
  - Intelligent end-use devices in homes, stores, office buildings, garages, and factories.
Functional Smartness

- Transactive coordination of the system
- Distributed resource interconnection, including renewable generation
- The ability of a resource/agent to be either a producer or consumer of electricity, or both
- Demand response to dynamic pricing
- The ability of an agent to program end-use devices to respond autonomously to price signals
- Distribution system automation by the wires company, leading to better service reliability
Improving reliability

- Risk reduction and management
  - Reducing outages
  - Reducing vulnerabilities to deliberate attacks
  - Improving emergency management

*RISE OF CYBER ATTACKS from 1995 to 2003*

An escalating problem. Cyber attacks continue to proliferate against energy and power companies in the United States.

*POWER SYSTEM FACT*

<table>
<thead>
<tr>
<th>INDUSTRY</th>
<th>AMOUNT</th>
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<tbody>
<tr>
<td>Cellular communications</td>
<td>$41,000</td>
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<tr>
<td>Telephone ticket sales</td>
<td>$72,000</td>
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<tr>
<td>Airline reservation system</td>
<td>$90,000</td>
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<tr>
<td>Semiconductor manufacturer</td>
<td>$2,000,000</td>
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<tr>
<td>Credit card operation</td>
<td>$2,580,000</td>
</tr>
<tr>
<td>Brokerage operation</td>
<td>$6,480,000</td>
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Value Propositions of Smart Grid

Demand side Management (DSM)

- Dynamic pricing induces consumers to shift consumption away from expensive peak hours, which leads to a reduced need for expensive infrastructure investment that is built to meet peaks and then mostly sits idle. Avoiding that investment saves costs and saves resources.

- The national average load factor (the degree to which physical facilities are being utilized) is about 46.5%.

- Current idle capacity can meet 73% of national transport energy if PHEVs are charged off peak (+ V2G distributed generation and storage options)
FIGURE 18: DEMAND RESPONSE – ACHIEVABLE ENERGY SAVINGS

REALISTIC ACHIEVABLE ENERGY SAVINGS POTENTIAL
(percent of total load by sector)

Residential: 0.8% (2010), 4.1% (2020), 7.8% (2030)
Commercial: 0.5% (2010), 5.7% (2020), 8.8% (2030)
Industrial: 0.2% (2010), 4.4% (2020), 7.6% (2030)


Source: Electric Power Research Institute
Transactive efficiency

A smart grid is a transactive grid

- High transaction costs have contributed to the vertically-integrated firms that have been the producers in this industry.
- Low transaction costs (thru communication, control technologies and intelligent devices) enable significantly more mutually beneficial transactions across a variety of agents, resulting in efficiency gains.
  - Within facility, local microgrids and macrogrid transactions, generation, storage.
Renewables Integration

- Environmental benefits,
- But transaction costs have been high
  - Smaller scale
  - Geographically distributed
  - Less controllable
  - Mismatch between demand and supply
  - Intermittent
  - Less dispatchable
  - Need plug and play interconnection, two-way transmission and storage
- Location of large scale renewable sources far from current grid infrastructure (traditional grid investments) is a different but relevant issue
Renewables and Grid

Power lines where renewable energy isn’t

Today’s high voltage transmission lines do not connect to the regions where wind power, solar power, and geothermal power are most abundant.

The potential of renewable wind power

Linking our national electricity grid to the best sources of renewable wind power could result in 20 percent of our domestic energy coming from wind farms.
Figure 1: NREL/AWS Truewind 2004 Wind Resource Map for Michigan

The annual wind power estimates for this map were produced by TrueWind Solutions using their Mesosmap system and historical weather data. It has been validated with available surface data by NREL and wind energy meteorological consultants.

Wind Power Classification

- Poor: 6 - 700 W/m², 0.6 - 5.6 m/s, 0.0 - 12.5 m/s
- Marginal: 100 - 300 W/m², 3.6 - 6.4 m/s, 12.5 - 14.3 m/s
- Fair: 200 - 300 W/m², 4.5 - 6.8 m/s, 14.3 - 16.7 m/s
- Good: 400 - 500 W/m², 7.0 - 7.5 m/s, 15.7 - 18.8 m/s
- Excellent: 500 - 600 W/m², 7.5 - 8.0 m/s, 16.8 - 17.9 m/s
- Outstanding: 600 - 800 W/m², 8.0 - 8.8 m/s, 17.8 - 19.7 m/s
- Super: > 800 W/m², 8.8 > 9.7 m/s

*Wind speeds are based on a Weibull k of 2.0.
Policy

- Transactive efficiency is a major value driver
- Technology development important but institutional development and changes are critical
  - Without dynamic pricing and consumer choice, AMI will fail to create value
  - Without appropriate pricing, renewables will not be integrated
  - Utilities incentives for promoting conservation (decoupling!)
- Current institutional structure (historical legacy) is geared toward local, monopoly regulation (fragmented state-by-state, utility-by-utility).
- Smart grids need more transactive flexibility without endangering reliability and price stability
Supporting Organizations
- Product and service suppliers
- Policymakers and regulators
- Policy advocates
- Standards organizations
- Financial community

Operational Stakeholders
- Gen/Load Wholesalers
- Wholesale Market Operators
- Transmission Providers
- Reliability Coordinators
- Balancing Authorities
- Energy Service Retailers
- Distribution Providers

End Users:
- Industrial
- Commercial
- Residential

Figure 1.2. Stakeholder Landscape
<table>
<thead>
<tr>
<th>State</th>
<th>Amount</th>
<th>Year</th>
<th>Organization Administering RPS</th>
</tr>
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<tbody>
<tr>
<td>Arizona</td>
<td>15%</td>
<td>2025</td>
<td>Arizona Corporation Commission</td>
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<tr>
<td>California</td>
<td>33%</td>
<td>2030</td>
<td>California Energy Commission</td>
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<tr>
<td>Colorado</td>
<td>20%</td>
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<td>Colorado Public Utilities Commission</td>
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<tr>
<td>Connecticut</td>
<td>23%</td>
<td>2020</td>
<td>Department of Public Utility Control</td>
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<td>District of Columbia</td>
<td>20%</td>
<td>2020</td>
<td>DC Public Service Commission</td>
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<tr>
<td>Delaware</td>
<td>20%</td>
<td>2019</td>
<td>Delaware Energy Office</td>
</tr>
<tr>
<td>Hawaii</td>
<td>20%</td>
<td>2020</td>
<td>Hawaii Strategic Industries Division</td>
</tr>
<tr>
<td>Iowa</td>
<td>105 MW</td>
<td>0000</td>
<td>Iowa Utilities Board</td>
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<tr>
<td>Illinois</td>
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<td>2025</td>
<td>Illinois Department of Commerce</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>15%</td>
<td>2020</td>
<td>Massachusetts Division of Energy Resources</td>
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<tr>
<td>Maryland</td>
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<tr>
<td>Michigan</td>
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<td>2015</td>
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<tr>
<td>Minnesota</td>
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<td>Minnesota Department of Commerce</td>
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<tr>
<td>Missouri</td>
<td>15%</td>
<td>2021</td>
<td>Missouri Public Service Commission</td>
</tr>
<tr>
<td>Montana</td>
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<td>2015</td>
<td>Montana Public Service Commission</td>
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<td>New Hampshire</td>
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<td>New Jersey</td>
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<td>New Mexico</td>
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<td>Nevada</td>
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<td>New York</td>
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<td>North Carolina</td>
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<td>North Dakota*</td>
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<tr>
<td>Rhode Island</td>
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<td>2019</td>
<td>Rhode Island Public Utilities Commission</td>
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**Figure 3.5. State Interconnection Standards (EPA 2008b)**

- **Favorable Interconnection Standards:** CA, CT, DE, IN, MA, MI, NH, NJ, NY, NV, OH, OR, PA, VT, WA
- **Unfavorable Interconnection Standards:** AR, FL, GA, KY, LA
- **Neutral Interconnection Standards:** AZ, CO, HI, MN, MO, NC, SC, TX, UT, VA, WI, WY
- **No policy in place:** AL, AK, DC, ID, IA, IL, KS, ME, MD, MS, MT, NE, NM, ND, OK, RI, SD, TN, WV

**Figure 3.6. Favorability of State Interconnection Standards (EPA 2008b)**
Real Time Pricing
(“Day ahead” or “Hour ahead” pricing)

- Allows consumers to vary their demand and usage in response to such price signals, and manage their energy costs by shifting usage to a lower cost period, or reducing consumption overall.

V/S

- Pacific Gas & Electric (PCG) has "paused" installing smart meters in the Bakersfield area because of complaints from residents that their new Pacific Gas & Electric smart meters are overcharging them. PG&E denies the allegations, noting that the rise in electricity bills some customers have seen come from other factors, such as regulator-approved rate hikes and air conditioning spikes during heat waves. Complaints for power have now taken the form of a lawsuit.

V/S

- Equity issues: poor, technically unsophisticated consumers will be worst off.

V/S

- Speculative volatility [ENRON]
Business Models

- Utility makes all smart grid investments, includes in the rate base, makes centralized optimization decisions, captures value, passes on savings through averaged consumer prices (*control & privacy*)
- Consumer/end user makes investments in user end smart equipment, locally optimizes based on price signals, and captures value (*effectiveness, discount rates*)
- Third parties make investments, partly control decisions, and collect a share of the value generated.
MSU’s Potential Role

- Microgrid and CHP
- An Experimental Lab
  - Technology development
  - Technology testing
  - Steam along with electricity
  - Access to ‘digital natives’ and advanced communication network
- Dynamic Pricing and consumer response modeling and testing
  - Time of use, Critical peak price, Real time pricing
  - Green power attribute choice modeling
  - Privacy and security concerns
  - Education and training effectiveness
- Renewables integration (small scale)
- PHEV Fleet acquisition and asset optimization
- Institutional and Policy Analysis
- Smart grid education and workforce training