Informing federal energy policy decisions through analysis and research

Priya Sreedharan, PhD, PE
Senior Consultant, E3

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AAAS science and technology policy fellowship

- American Association for the Advancement of Science
- Places scientists and engineers across government to improve science policy decision making
- Motivations
  - Climate change activity moving to DC
  - Nexus of technology and policy

EPA placement

Climate Protection Partnerships Division, USEPA

- Clean energy voluntary programs
- My role:
  - Provide technical advice by conducting internal research and analysis of efficiency, renewables, and smart grid technologies
  - Worked within CPPD and closely with sister divisions and the Department of Energy (smart grid)

Prior to AAAS

Career theme: Systems-analysis and integrated design methods for energy & environmental systems

Highlights from the past:

- National Academy of Sciences researching environmental impacts of biofuels (post-doctoral fellowship)
- Real time sensor systems for detecting and characterizing toxic releases (PhD Research, UC Berkeley, with LBNL)
- Model-based diagnostics for reducing thermal equipment energy use (MS research, UC Berkeley, with LBNL)
- Sustainable commercial buildings and data centers, design and research (Rumsey Engineers)

Roadmap of presentation

1. Energy efficiency in a carbon constrained world
   - Energy efficiency potential
   - Highlights from Waxman Markey Analysis *
2. Smart grid and clean energy policy implications *

   * time permitting

Energy efficiency in a carbon constrained world

Context and objective

Context:

- Energy efficiency prominent in national legislation
  - American Recovery and Reinvestment Act
  - Waxman-Markey house bill
- EE is central to existing state and regional climate legislation (California, RGGI)

Review of national energy efficiency potential

1. Goal: Understand national-scale EE potential to inform internal policy efforts
   - How much energy efficiency potential?
   - What are the costs for achieving the potential?
2. Meta analysis of energy efficiency potentials
   - Used in internal governmental briefing
   - Presented at Stanford Energy Modeling Forum
   - Publication recently submitted to *Energy Policy*

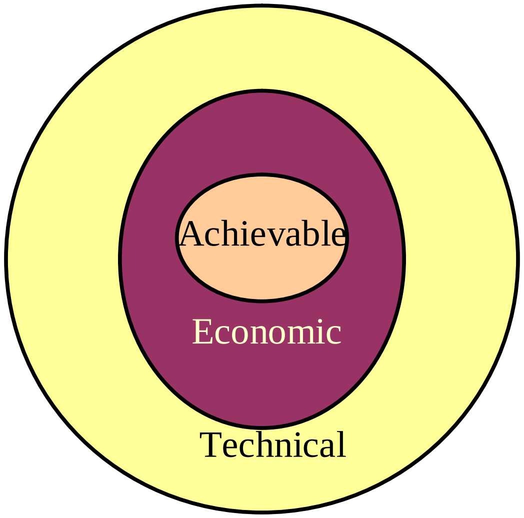
Energy efficiency potential

Each potential quantifies different levels of adoption of EE "measures"

- EE "measures":
  - Any action(s) that increases efficiency - equipment, controls, behavior
- Technical potential (TP):
  - Theoretical maximum amount of energy that could be displaced by EE
  - Independent of costs and barriers
- Economic potential (EP):
  - Cost-effective subset of TP, as compared to supply side resources or prices
- Maximum achievable potential (MAP):
  - Subset of EP achieved through aggressive efficiency program scenario
  - Considers extent to which market barriers can be cost-effectively addressed
  - Expert judgment applied towards market penetration

Source: National Action Plan for Energy Efficiency, 2007. Guide for conducting energy efficiency potential studies.

Venn Diagram of Efficiency Potentials



Source: Rufo and Coito, 2002

- "Bottom-up" analytical approach combines technology information & sector data
- Potentials are estimated independent of interactions with remainder of economy:
  - Energy prices are inputs
  - Technology cost profiles
- Life cycle/ levelized cost ($/kWh) calculation, especially discount rate (~6-8%), drives EP and MAP calculations

Scope of analysis & sources

Approach

- Compared national & state level EE potential studies
  - EE opportunities across industrial and building sectors
  - EE savings by year, sector, region, fuel and costs

Challenge:

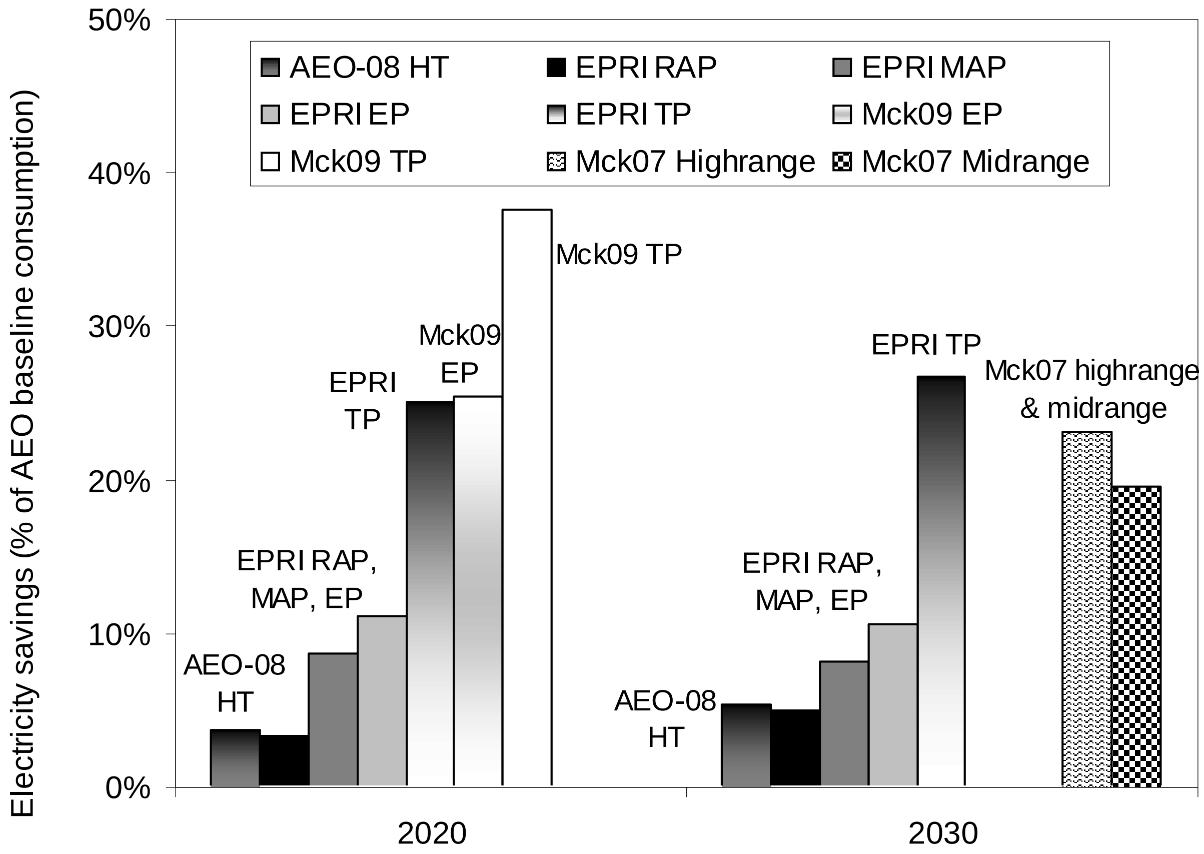
- EPRI and Mckinsey 09 are the only national potential studies

Source	Date	Title
EPRI	Jan, 2009	Assessment of achievable potential from energy efficiency and demand response programs in the U.S.
AEO 2008	Mar, 2008	Annual energy outlook, side scenarios: best available technology for buildings, high technology for industry
Mckinsey	Dec, 2007	Reducing U.S. Greenhouse Gas Emissions: How much and at what cost?
Mckinsey	July, 2009	Unlocking energy efficiency in the U.S. Economy
NAPEE (DOE/EPA)	Nov, 2007	Guide for conducting energy efficiency potential studies. A resource of the National Action Plan for Energy Efficiency

Comparing methods & data

- Modeling method
  - Generally “bottom-up” for buildings
  - “top-down” for industry
  - Studies use similar approaches but for AEO side scenarios
- Discount rates, measures considered, cost tests vary
- Baseline data
  - McK 09, EPRI, AEO side scenarios: AEO 2008
  - McK 07 uses AEO 2007
- Fuels considered: EPRI - electricity only; others broader
- State and regional studies may use more detailed and accurate data

Comparison of national studies : electricity EE savings



1. Overall, wide range
2. Significant variability in achievable potentials: 5%-20%, equivalent to 0.2-1%/yr
3. The Mckinsey 2007 study presents the most aggressive national level “achievable” scenario
4. Majority of 2030 savings achieved in 2020
5. Ratios of potentials (ach: econ, econ: tech) reflects market penetration & economic factors

   e.g. EPRI EP ~45% of TP, McK09 ~65% of TP

Impact on average annual growth

Scenario	Demand growth (TWh) [a]		Average annual growth (%)	
	2008-2020	2008-2030	2008-2020	2008-2030
Baseline (AEO 08)	490	930	1.0	1.0
EPRI TP	-585	-320	-1.4	-0.4
EPRI EP	15	430	0.0	0.5
EPRI MAP	115	550	0.3	0.6
EPRI RAP	345	695	0.7	0.8
McK09 TP	-1110	--	-2.5 [b]	--
McK09 EP	-595	--	-1.3 [b]	--
AEO-08 BT/HT	-55	130	-0.1	0.2
AEO-08 HT	330	680	0.7	0.8

1. Range is from lowering from 1% to ~ 0.7% to negative load growth
2. McK 09 potentials and EPRI technical potentials result in negative load growth
3. EPRI RAP is Least aggressive case (slows down growth rates to 0.7% / yr)
4. AEO 08 high tech case roughly equivalent to EPRI RAP scenario

Comparison of state studies: electricity EE savings

Technical potentials

Reductions in end-use electricity consumption Technically achievable potential studies for states			
State	Total %	Years	Normalized savings (%/yr) *
California	19%	10	1.9%
New Brun	24%	17	1.4%
Conn	24%	10	2.4%
Georgia	29%	5	5.8%
NY	37%	10	3.7%
Ontario	33%	20	1.7%
Puget sound	33%	20	1.7%
Quebec	7%	8	0.9%
* Total % reduction divided by years		Average	2.4%
		Min	0.9%
		Max	5.8%

Source: National Action Plan for Energy Efficiency, "Guide for Conducting Energy Efficiency Potential Studies"

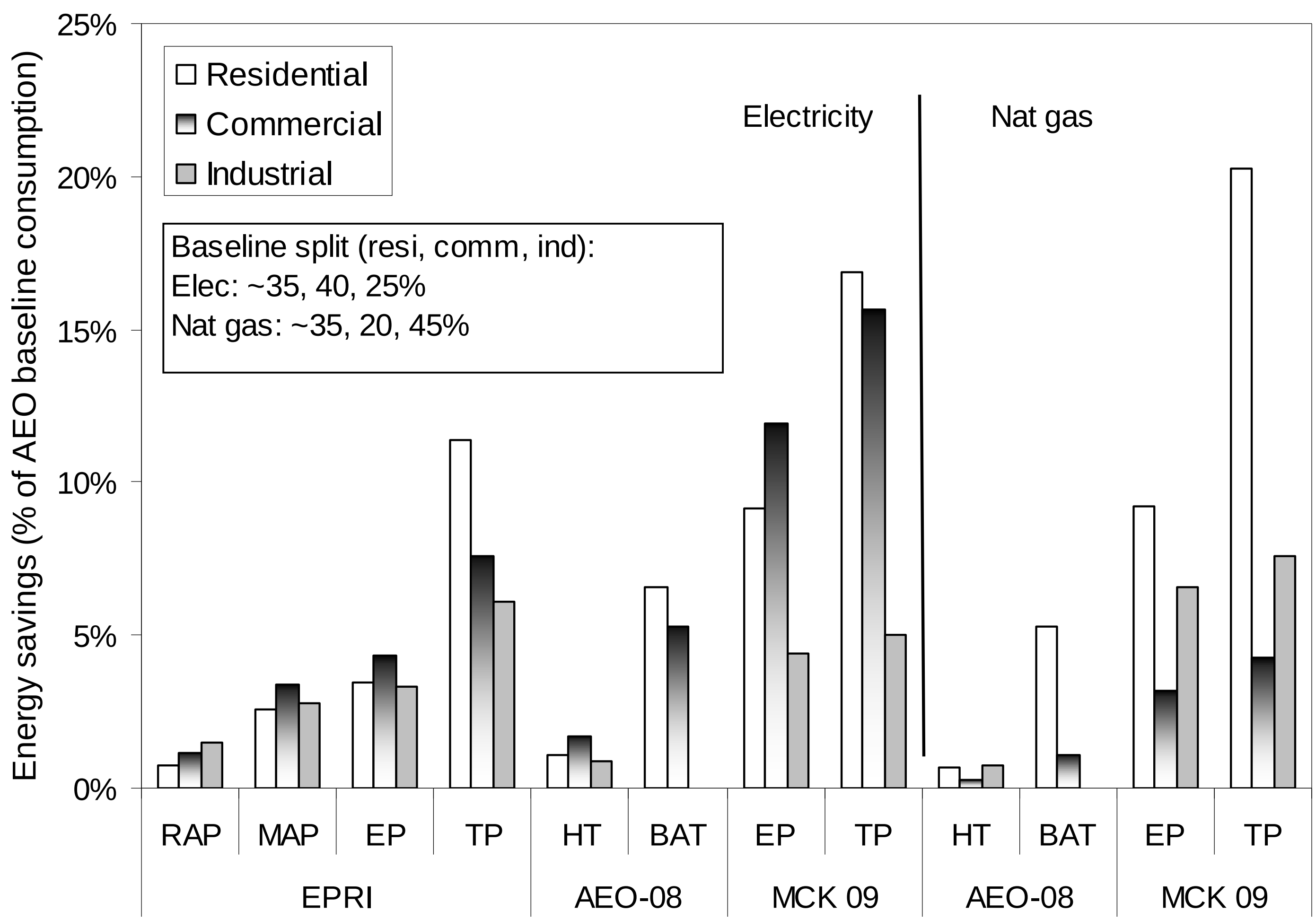
needs

Achievable potentials

Reductions in end-use electricity consumption Maximum achievable potential studies for states			
State	Total %	Years	Normalized savings (%/yr) *
California	10%	10	1.0%
Midwest	11%	20	0.6%
New Mex	8%	10	0.8%
Conn	13%	10	1.3%
Georgia	6%	5	1.1%
Iowa	5%	15	0.4%
Puget sound	6%	20	0.3%
Quebec	3%	8	0.4%
Texas	20%	15	1.3%
Utah	9%	6	1.5%
Vermont	23%	10	2.3%
AZ,CO,NV,NM,UT,WY	18%	8	2.3%
NY, NJ, PA	37%	14	2.6%
* Total % reduction divided by years		Average	1.2%
		Min	0.3%
		Max	2.6%

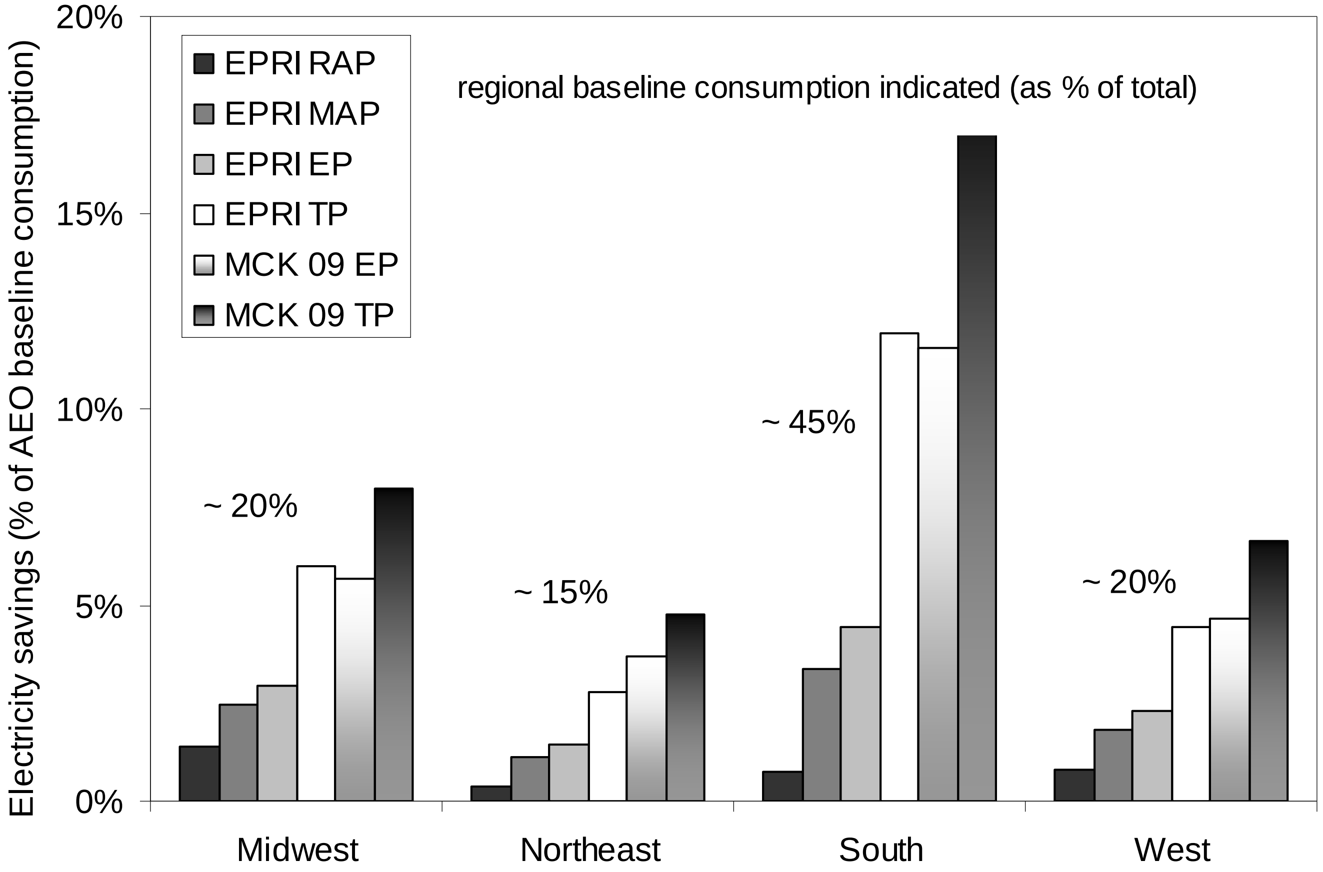
1. Significant variability across studies
2. Achievable potentials average at ~ 1+%/yr; comparable to the McK curves; But, variations in assumptions on baselines, measures, cost effectiveness challenge direct comparison
3. Technical potentials are roughly double the achievable potentials; state technical and achievable potentials generally more aggressive than national studies

Sector breakdown



1. Opportunities across sectors
2. Electricity: larger TP in resi, then comm, then ind
3. Comm & ind more economic
4. Magnitude of ind EP and TP savings lower but more economical
5. Normalized sector TP to baseline energy → modeled sector efficiency

Regional breakdown



1. All studies point to the South
2. Consistent with recent studies (Chandler and Brown, 2009; Brown, 2010)
3. Larger baseline energy, lower levels of historically adopted EE, lower energy prices all factors

Comparison of national studies : natural gas EE savings

Reductions in end-use natural gas consumption in 2030 National studies of energy efficiency scenarios and potentials				
Study	% of 2030 consumption	Normalized Savings (%/yr)*	% of 2030 savings achieved by 2020	Impact on yearly avg growth (2008-30)**
AEO Best tech/High tech	10%	0.5%	66%	-0.2%
AEO High tech case	3%	0.1%	56%	0.2%
Mckinsey 07 Highrange +	~ 17%	0.8%	--	--
Mckinsey 07 Midrange +	~ 11%	0.5%	~ 70%	--
Mckinsey 09 Tech Pot'l ++	32%	1.6%	97%	~ -1.1%
Mckinsey 09 Econ Pot'l ++	21%	1.0%	91%	~ -0.6%

* Total % reduction divided by the number of years
** Average annual end-use natural gas growth for AEO 2008 reference is 0.4%/yr
+ Approximation based on published data; 70% per conversation w/ Mckinsey
++ Data shown with permission from Mckinsey & Co. Impact on yearly average growth is approximated from demand impacts in 2020 & 2030 (not year to year savings).

1. All Mckinsey potentials (2007 and 2009 reports) estimate potential savings that result in negative load growth.
2. Majority of savings are reached by 2020 in all scenarios.
3. Mckinsey 2007 “achievable” potential rivals the AEO “technical potential”
4. Negative load growth is “achievable” per Mckinsey 2007 midrange scenario

Comparison of state studies: natural gas EE savings

Technical potentials

Reductions in end-use natural gas consumption
Technically achievable potential studies for states

State	Total %	Years	Normalized savings (%/yr) *
California	35%	20	1.8%
Midwest (Quantec)	10%	20	0.5%
NY	47%	5	9.3%
Utah	38%	10	3.8%
* Total % reduction divided by years	Average		3.8%
	Min		0.5%
	Max		9.3%

Source: National Action Plan for Energy Efficiency, "Guide for Conducting Energy Efficiency Potential Studies"

Achievable potentials

Reductions in end-use natural gas consumption
Maximum achievable potential studies for states

State	Total %	Years	Normalized savings (%/yr) *
California	9%	20	0.5%
Georgia	4%	5	0.7%
Iowa	4%	15	0.2%
Midwest (ACEEE)	9%	20	0.5%
Midwest (Quantec)	25%	20	1.3%
NY	2%	5	0.3%
Utah	20%	10	2.0%
* Total % reduction divided by years	Average		0.8%
	Min		0.2%
	Max		2.0%

1. State achievable potentials average at 0.8 %/yr, more aggressive than AEO and Mckinsey "achievable" potentials (~ 0.5%/yr)
2. Ratio of technical to achievable potential for natural gas exceeds that for electricity
3. On both electricity and natural gas, state studies suggest higher savings achievable

Key points

- All studies identify significant potential
  - Technical opportunities: reverse load growth (currently ~ 1%/y)
  - Economic opportunities: results range from load growth reversal to cutting load in half
- “Achievable” potentials far lower than economic --> role for policy
- Reaching potentials require early investment

Methodology needs and opportunities

- Uncertainty analysis can provide context
- Greater transparency in studies is needed: methods, data
- Better integration of engineering and economic methods (rather than linear process TP -> EP -> MP)
- Greater consideration of integrated design techniques and "fall-through-cracks" technologies
  (e.g., solar hot water heating, combined heat and power)

Highlights from Waxman Markey Analysis

Comprehensive climate change legislation passed by the House of Representatives

Context: Prior, EPA had not looked at the impacts of energy efficiency in proposed climate legislation

- Typically, economy-wide climate models do not look at energy efficiency measures

1. Developed hybrid economic / engineering approach
   - Analyzed impacts of Waxman Markey bill
2. Worked across the Agency

Key efficiency related results

Analysis of Waxman Markey discussion draft

- Energy efficiency savings significant
  e.g., reach ~ 6% electricity sales, 7% of natural gas sales
- Economic impacts from climate policy dampened,
  e.g., energy prices, allowance prices lower, GDP higher
- Less reliance on less proven technologies (CCS)

Sreedharan et al, 2009, Proc of Third Annual Energy Sustainability Conference, American Society of Mechanical Engineers, San Francisco

Smart Grid technologies and clean energy implications

Context and role

<u>Context</u>

- Much federal attention and funding towards smart grid
- Clean energy and climate benefits often claimed

<u>My role</u>

- Understand the link between smart grid and clean energy
- Understand technical opportunities
- Identify policy and analytical needs
- Guide external research (through interagency taskforce)

Key environmental questions

- Can smart grid help mitigate greenhouse gas emissions (GHG)?
  - How, how much, & at what cost?
  - What are the barriers?
  - What policies are needed?
  - How should EPA/CPPD programs evolve?

Policy background

Federal

- Energy Independence and Security Act 2007 Title XIII
- American Recovery and Reinvestment Act: ~$4.5 Billion
- National Institutes of Standards (NIST): interoperability

State/ Utility

- Utilities invested(ing) $ billions
  - Advanced Metering Infrastructure
  - Less attention in transmission & distribution
  - Buildings focus has been in residential sector
- Some pilots and deployments moving beyond AMI

Smart grid infrastructure

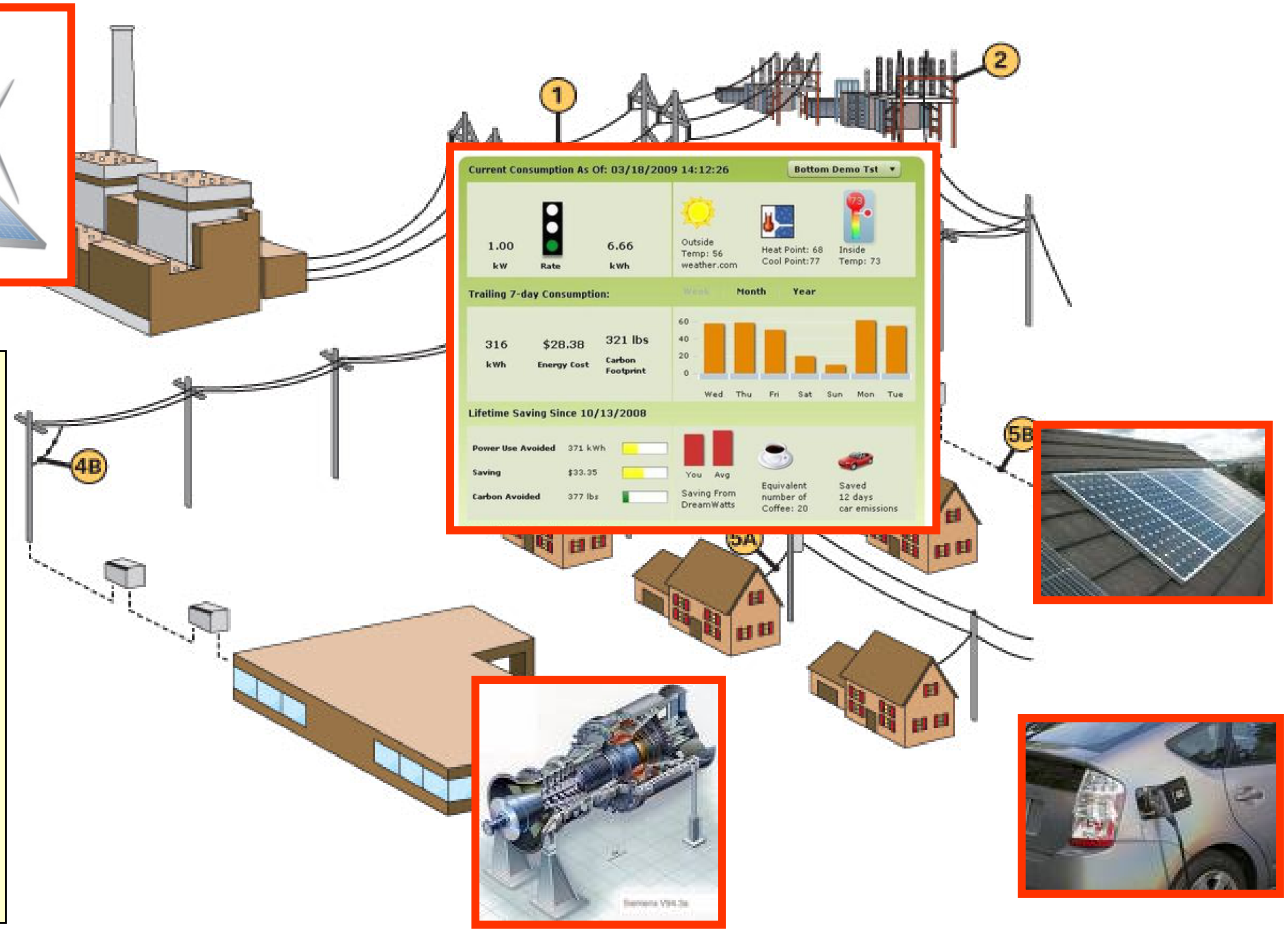
Power system that has an intelligent communications infrastructure enabling timely, secure and adaptable information flow to provide the right information to the right entity (e.g. end-use devices, T&D system controls, customers, etc.) at the right time to take the right action (*Electric Power Research Institute)*

- Devices (e.g., AMI, sensors for power monitoring)
- 2-way communications (e.g., networking systems)
- Advanced control and data management systems

"The Electricity Economy: New Opportunities from the Transformation of the Electric Power Sector", Global Environment Fund and Global Smart Energy - 2009

Using Smart Grid infrastructure effectively may get you to the next slide

Next generation electric grid



- 2-way flow of power and information
- Renewable energy and distributed generation
- Information to consumers

Source: DTE Energy (http://my.dteenergy.com/products/electricity/images/electricFlow.jpg)

Mechanisms for reducing GHG emissions

- Smart grid applications across the grid
- Example mechanisms
  - Consumer behavior change from energy information
  - Optimized voltage control
  - Dynamic line ratings allowing wind energy
- Most reductions are from applications, not from the smart grid infrastructure (indirect reductions, not direct)
- How the smart grid infrastructure is used is critical

Quantifying GHG reductions

- GHG reduction mechanisms are indirect (through applications)
  - Home energy savings stimulated by energy information
  - Greater wind energy enabled by dynamic line ratings
- Indirect reductions depend on several factors (e.g., persistence of behavioral change)
- Quantifying possible GHG impacts is challenging
  - Additionality/ incremental benefit from smart grid
  - Uncertainty and variability
  - No consensus definition of smart grid
- Two national studies give early 1st-order estimates
  - PNNL, 2010 & EPRI, 2008

Savings from end-use measures

Potential U.S. electricity and CO_2 reductions in 2030 [1]

	EPRI		PNNL
Measure	**Low (%)**	**High (%)**	**(%)**
Diagnostics / commissioning	<0.1	0.2	3
Behavior change from energy information	0.7	2	3
Impacts on EE programs	0.2	0.8	1
End-use efficiency total	1	3	7

[1] Normalized to the Annual Energy Outlook 2008 baseline for 2030

1. End-use measures represent roughly ½ of CO2 reductions
2. Additional CO2 reductions from PHEVs & renewable integration, peak load management
3. EPRI is an “achievable” scenario; PNNL “technical” scenario
4. For perspective, EPRI estimates cost effective GHG reductions from energy efficiency of ~ 30% in 2030

Policy considerations and gaps

- Business case / consumer perspective
  - What are the societal benefits? How certain are these?
- What/ where are low-hanging smart grid fruit?
  - Transmission & distribution; commercial & industrial?
- Traditional barriers to “clean” energy remain
- Multiple barriers (financial, technical, social) to GHG reduction mechanisms occuring
- Evaluating performance and benefits of smart grid investments

Relationship to known energy efficiency barriers

- Recognized market barriers to energy efficiency
  - Split incentives/ principal agent
  - Financial
  - Institutional & behavioral
  - Lack of information
- Smart grid may address some informational barriers (combined ENERGY STAR and smart grid opportunities)
- Key barriers to energy efficiency need addressing
  - utility financial incentives
  - misaligned incentives among owners, architects, engineers

Barriers to smart grid generating energy savings

- Technical
  - Interoperability, data management challenges
- Financial
  - Bells and whistles — like home energy monitors — cost $
- Consumer behavior
  - Uncertainty on consumer reactions – persistence, magnitude
- Regulatory/ institutional
  - Data access by outside entities may limit savings
  - Stovepiping limit optimal “system” solutions

Potential policy steps

- Careful analysis of costs and benefits
- Target both smart grid and clean energy barriers
- Federal level
  - Integrating elements into ENERGY STAR (commenced)
  - Share information on lessons and best practices
- Utility, state and local
  - Couple smart grid rollouts with efficiency programs
  - Address persistent barriers to efficiency and renewables

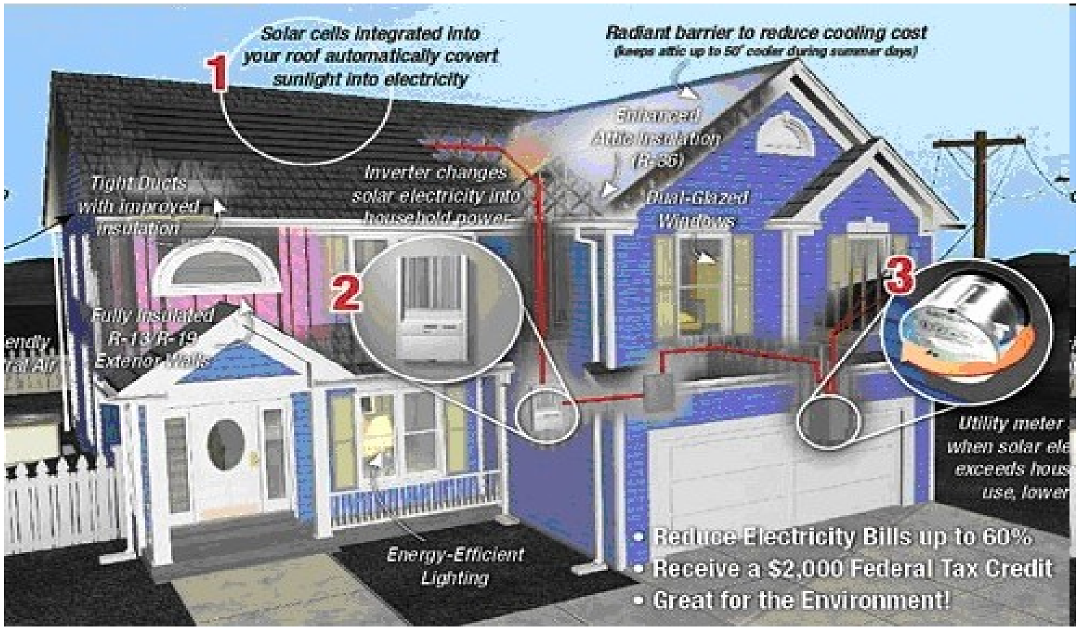
Possible new opportunities

- Programs and policies
  - Target clean energy technologies synergistically
- Ubiquitous energy data
  - Building diagnostics
  - EM&V for energy programs
- Future climate and/or aggressive energy legislation
  - Will require all flavors of clean energy

A systems perspective moving forward

- Smart grid links supply and demand
- Longer term, systems thinking
  - Engineering (systems design & operation)
  - Programs and policies (consider multiple clean energy options)
  - Economics (considering grid-level impacts)

Can Smart Grid influence the design, operations & evaluation of clean energy through systems thinking and using information systems?



Summary messages

- Smart grid is an enabling infrastructure only , and GHG reductions depend on how it's used
- With proper planning & policies, smart grid may
  - facilitate clean energy deployment
  - change how we think about clean energy
- Keep smart grid in perspective
  - Still need good "low-tech" design, complementary policies
  - Energy savings enabled by smart grid less than those estimated from efficiency
- Additional research and analysis is needed to clarify links

Friedman and Sreedharan, Proceedings of the ACEEE 2010 summer study

Broad observations

- Insights as a AAAS fellow:
  - System analysis and thinking imperative for solving real world sustainability problems
  - Cross-cutting issues – like smart grid - require an interdisciplinary and collaborative approach
  - Opportunities for scientists and engineers who can cross boundaries and fields
  - Such skills are becoming increasingly valued by federal agencies
- Influence happens in many directions (up, down, across, out)
- Politics and policy mix - 10,000 Pages Kerry-Boxer

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Contact information:

Priya Sreedharan, Ph.D., P.E.
Senior consultant, E3
415-391-5100
priya@ethree.com