An Update on Georgia Tech's Energy Efficiency Study

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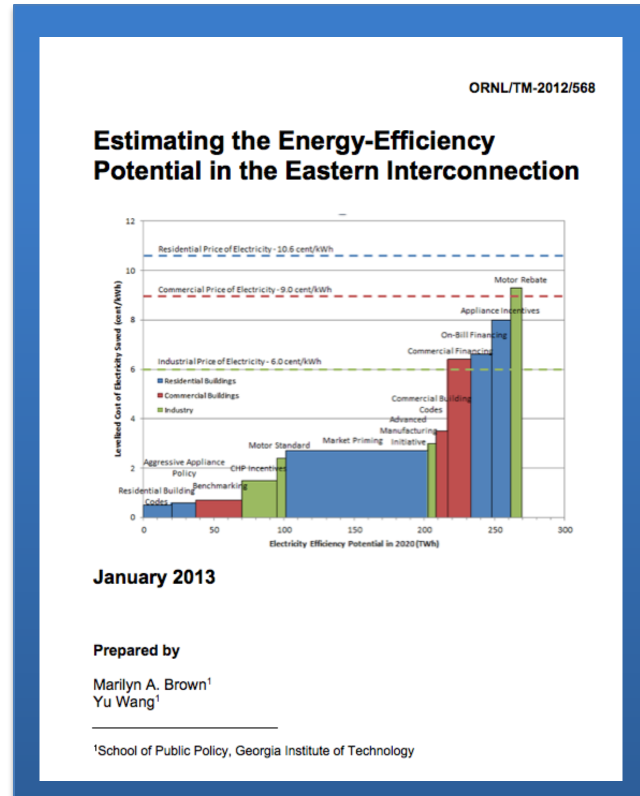
ORNL/TM-2012/568

Estimating the Energy-Efficiency Potential in the Eastern Interconnection

January 2013

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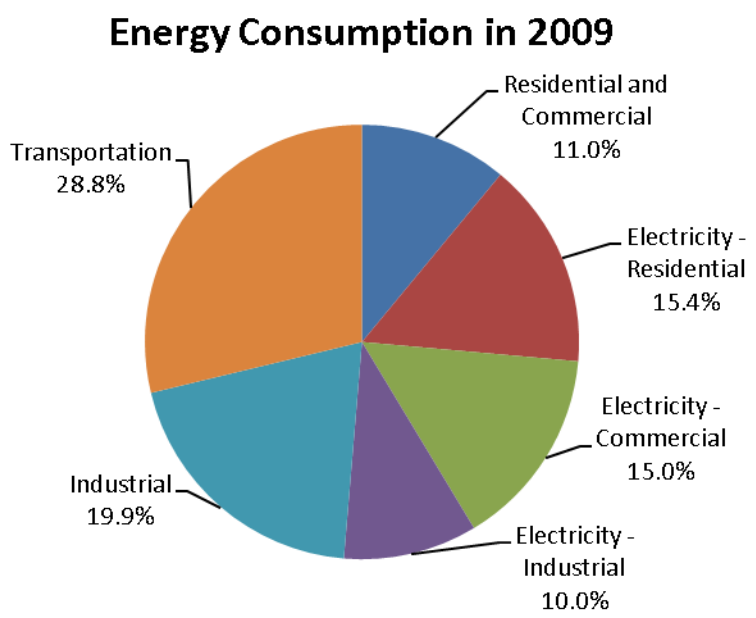
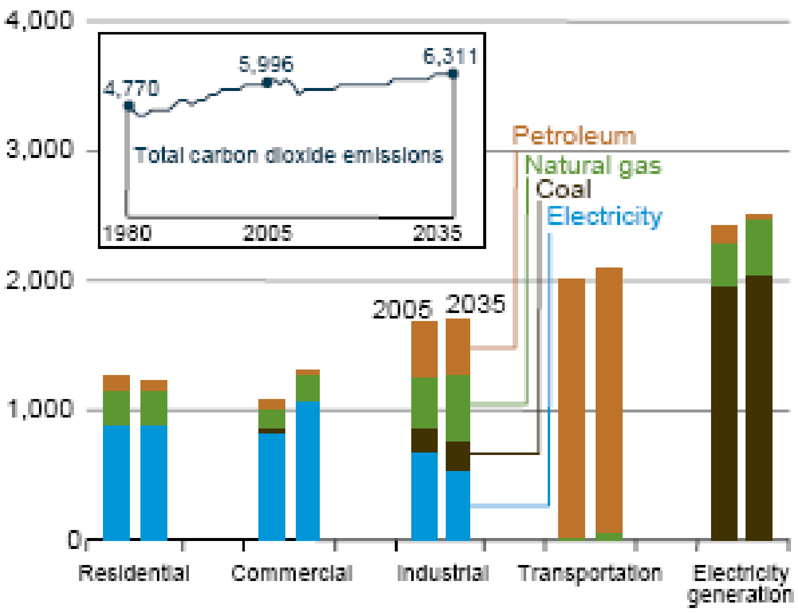
Contents

Electricity as the Main Player in Energy Use and Carbon Emission

- Electricity accounts for over 57% of total energy demand except for transportation
- Electricity is the main source of CO_2 emissions





Source: EIA, Annual Energy Outlook 2011

End-use efficiency as an important part of Integrated Resource Planning

Demand forecasting
- Trend forecasting
- Econometric forecasting
- End-use forecasting

Demand-side resource management
- End-use efficiency
- Demand response

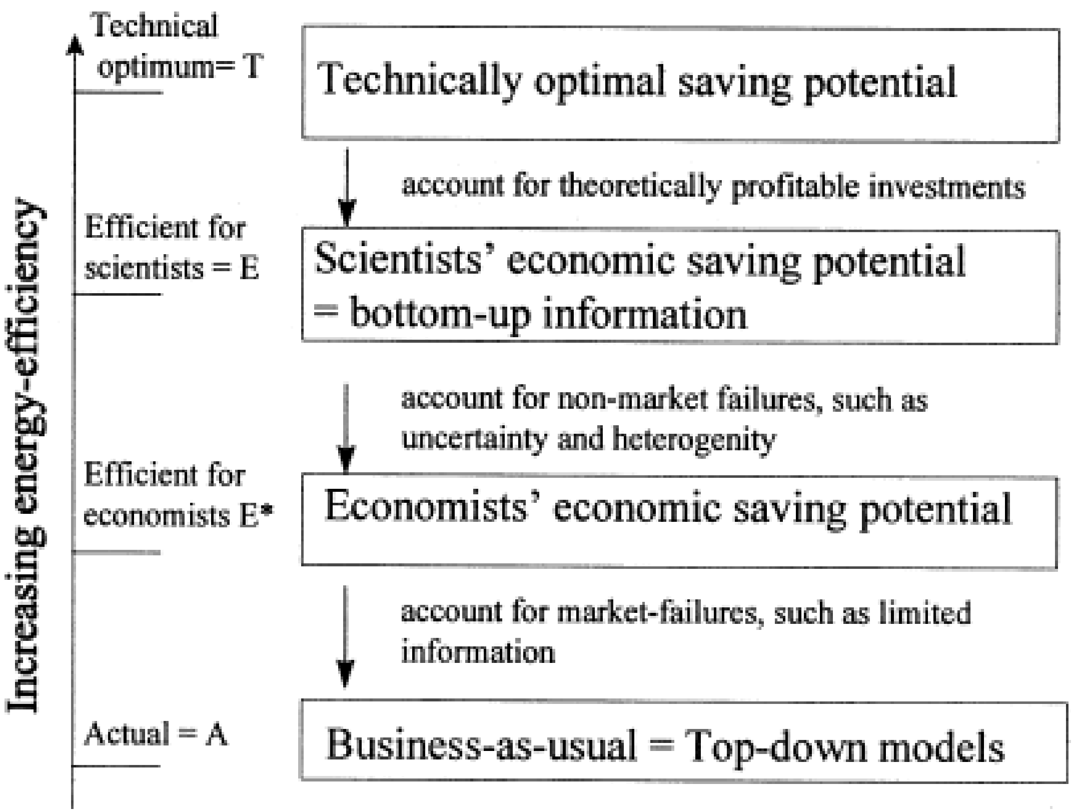
Supply-side resources
- Renewable energy
- Decentralized generation

→

- Reliability
- Security
- Profitability
- Sustainability

The Energy-Efficiency Gap

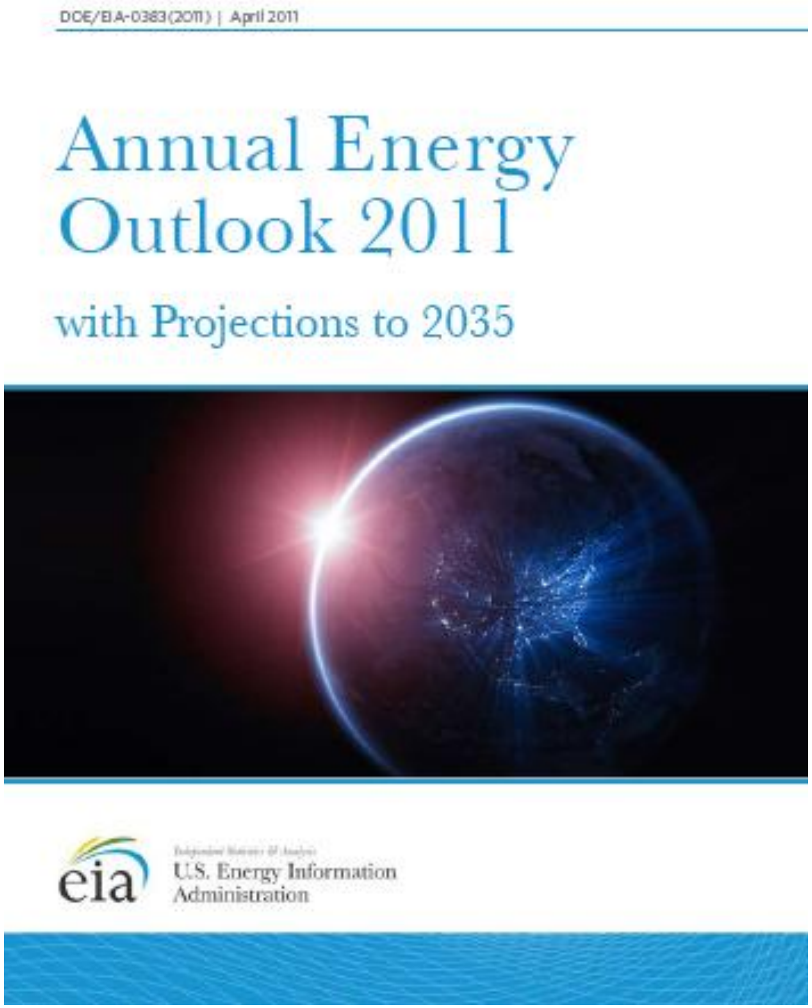
- There is a gap between real-world and cost-effective efficiency (Hirst and Brown, 1990)
- The gap is caused by various market and policy failures, including:
  - Lack of information
  - Policy uncertainties
  - Externalities
- This project focuses on the potential for cost-effective efficiency that can be achieved by policy efforts



Source: Koopmans, and Velde, 2001; Mims et al, 2009

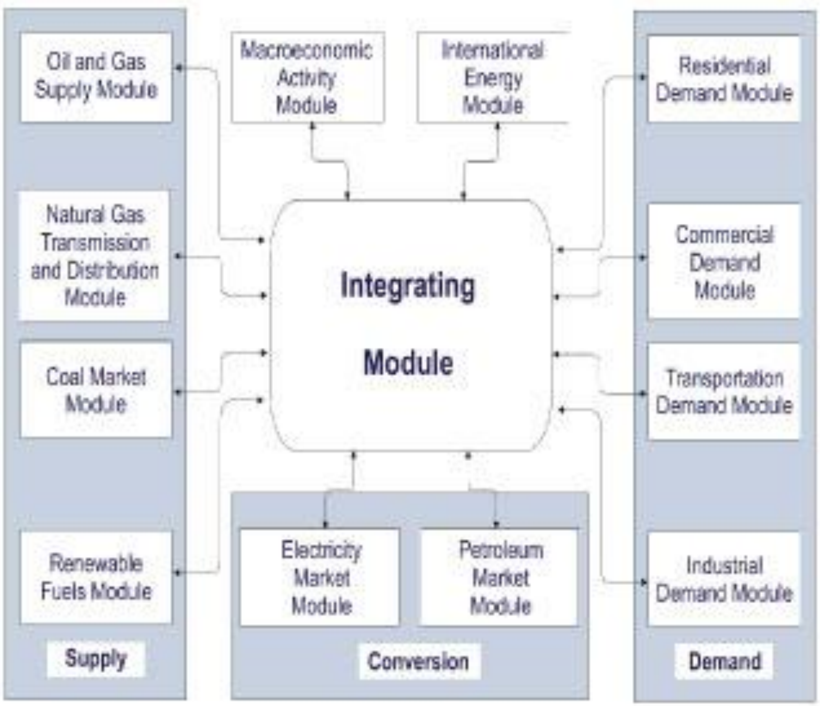
National Energy Modeling System (NEMS)

- Large, regional energy-economy model of the United States
- Detailed end-use technology characterizations
- Annual Projections to 2035:
  - Consumption by sector, fuel type, region, major end-uses
  - Production by fuel
  - Energy imports/exports
  - Prices
  - Technology trends
  - CO_2 emissions
  - Macroeconomic measures and energy market drivers



NEMS Introduction

- NEMS is a general equilibrium model that balances the supply and demand for each fuel and consuming sector.
- It accounts for the economic competition between fuels types, the cost and benefits of technologies, as well as behavioral aspects of consumer choice.
- Twelve modules represent supply, demand, energy conversion, and macroeconomic and international energy market factors. A thirteenth “integrating” module ensures that a general market equilibrium is achieved among the other modules.



Source: EIA, 2011. Assumptions to AEO2011

Methodology

- A portfolio of twelve energy-efficiency policies is modelled with the Georgia Tech–National Energy Modeling Systems (GT-NEMS)
  - Beginning with current resource supply, technology profile, and price data and making assumptions about future use patterns and technological development, NEMS carries through the market interactions represented by the thirteen modules and solves for the price and quantity of each energy type that balances supply and demand in each sector and region represented (EIA, 2009)
- This study used GT-NEMS to perform scenario analysis under a consistent modeling framework in order to compare policy options to the Reference case projections.
- A suite of twelve policies was selected to estimate the achievable potential for energy efficiency.

Selected Policies for Electric End-Use Efficiency

Sector	Type	Policy	Scenario Description
Residential	Financial	Appliance Incentives	Providing a 30% subsidy to cut down capital costs for the most efficient technologies
	Financial	On-Bill Financing	Offering zero-interest loans for the most efficient technologies
	Regulatory	Building Codes	Adding four new building codes to improve shell efficiency
	Regulatory	Aggressive Appliance Policy	Accelerateing market penetration for energy efficiency technologies by eliminating the least efficient ones from the market
	Information	Market Priming	Reduceing high discount rate (10-50%) to 7% for private investment in efficient technologies
Commercial	Financial	Financing	Offering flexible financing options to lower the up-front costs of highly energy-efficient equipment
	Regulatory	Building Codes	Higher building shell efficiency and more stringent standards on space heating and cooling equipment
	Information	Benchmarking	Requiring utilities to submit whole building energy consumption data to a uniform database accessible by building owners
Industrial	Financial	Motor Rebate	Providing a 30% subsidy for premium motors which satisfies the minimum efficiency requirement of EISA 2007
	Regulatory	Motor Standard	New motor standard requiring efficiency improvement and higher system savings
	Financial	CHP Incentives	Offering a 30% ITC for industrial CHP systems for 10 years
	Information	Advanced Manufacturing Initiative	Promoting plant utility upgrades by identifying efficiency opportunities with cost assessments and estimations of potential energy savings.

Calculation of Levelized Cost of Electricity

- The calculation of LCOE is based on the total resource cost test, where costs include the incremental private investment in energy-efficiency measures, program costs for providing incentives, information, technical and other assistances, and program administrative costs.

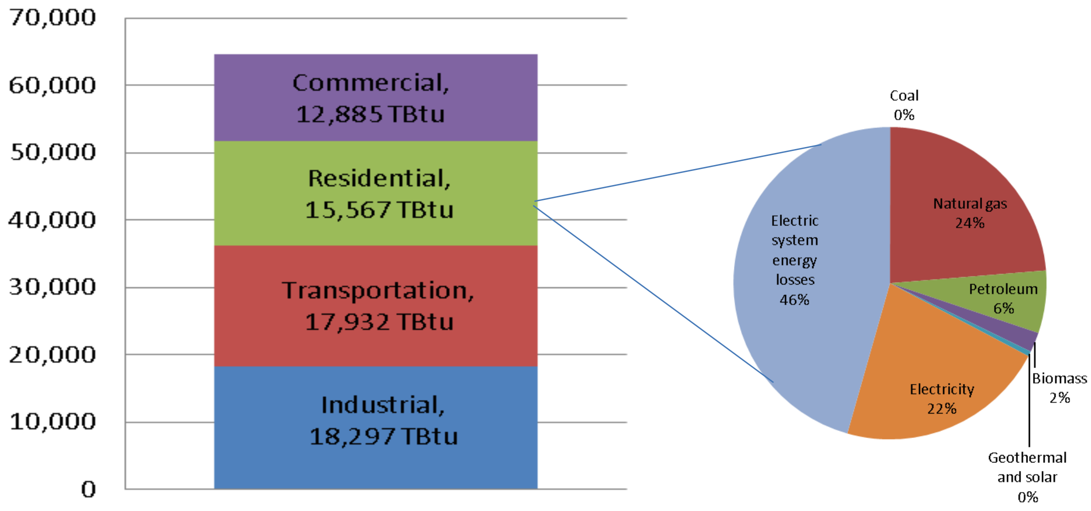
Policy	Private Cost	Public/Utility Cost
Appliance Incentives	incremental investment of home appliance and equipment	30% subsidy on equipment expenditure; program administrative cost
On-Bill Financing	Incremental cost of equipment expenditure	Loan seed money; program administrative cost
Residential Building Codes	Incremental cost of equipment expenditure; shell installation cost	Program administrative cost
Aggressive Appliance Policy	Incremental cost of equipment expenditure	Program administrative cost
Market Priming	Incremental cost of equipment expenditure	Program administrative cost
Commercial Financing	Incremental cost of equipment expenditure	Subsidy cost; program administrative cost
Commercial Building Codes	Incremental cost of equipment expenditure; shell improvement cost	Program administrative cost
Benchmarking	Incremental cost of equipment expenditure	Compliance cost
Motor Rebate	Incremental cost of equipment expenditure	Subsidy cost; program administrative cost
Motor Standard	Incremental cost of equipment expenditure	Program administrative cost
CHP Incentives	Incremental cost CHP equipment	Subsidy cost; program administrative cost
Advanced Manufacturing Initiative	Private investment for plant upgrade	Program administrative cost

General Assumptions of the LCOE Calculations

- Total cost associated with each policy was proportionate to the value of electricity versus natural gas savings.
- Avoided T&D losses are included as part of electricity savings. A multiplier of 1.07 was applied to electricity savings to account for the benefit of avoided electricity related losses.
- Program administrative costs are estimated to be $0.13/MMBtu energy saved, unless specified otherwise.
- We assume the twelve policies start from 2012 and end at 2035. Any costs stimulated from the policies occur through 2035. Private costs are discounted at 7%, while public costs are discounted at 3%.
- Electricity savings are then modeled to degrade at a rate of 5% after 2035, such that benefits from the policy have ended by 2055.

Energy Efficiency in Residential Buildings

- In 2010, the residential electricity consumption in the Eastern Interconnection Region was 1,069 TWh, which is 74.0% of national electricity consumption by the residential sector.
- The per capita residential energy consumption in the Eastern Interconnection Region was 21.7 MWh in 2009, which is slightly higher than the national level of 20.1 MWh.



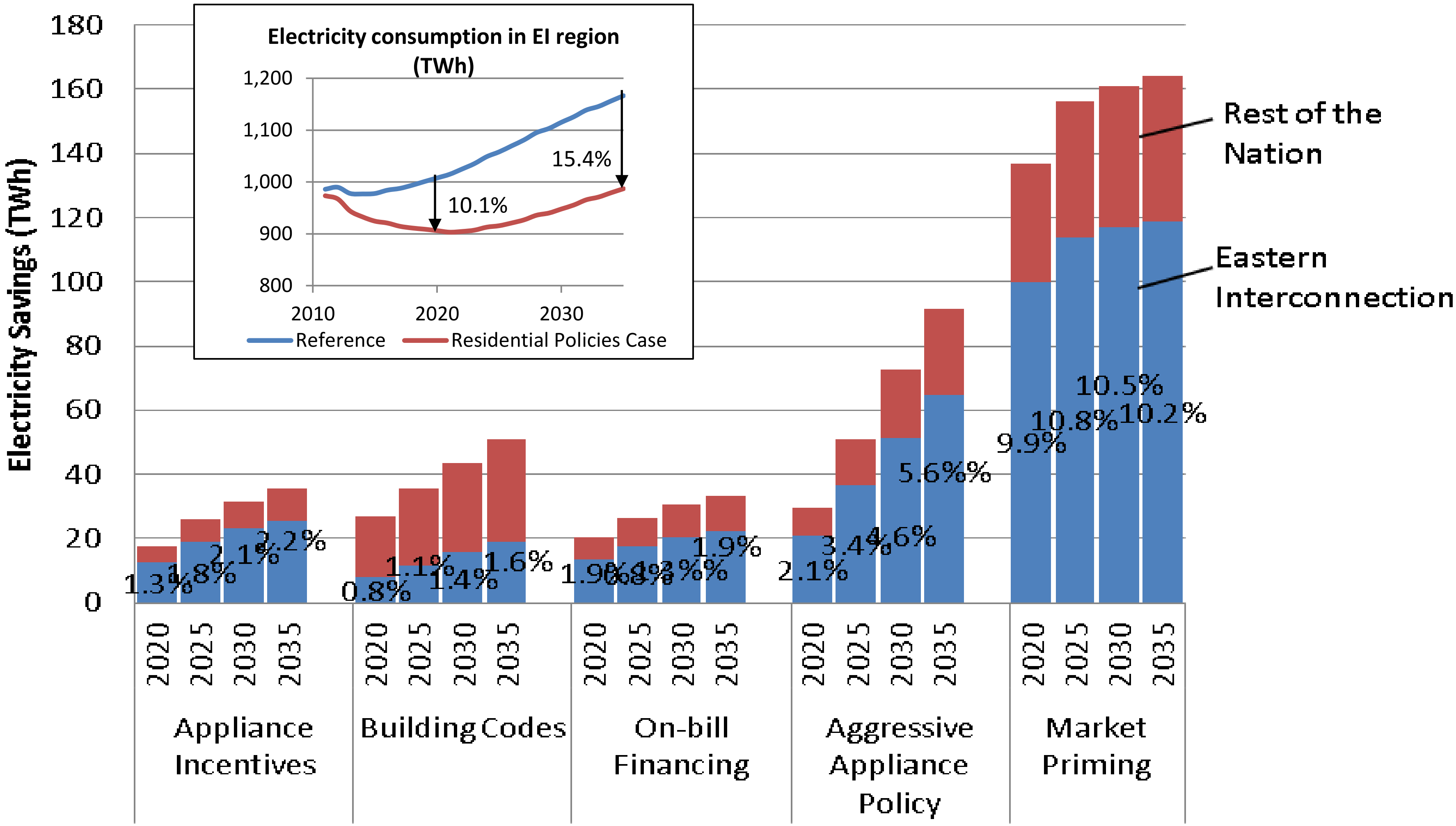
(Source: SEDS,2012)

Residential EE Policies

- **Appliance Incentives** decrease the up-front cost of efficient appliances and equipment
- **Aggressive Appliance Policy** accelerates market turnover rate for household appliances and HVAC equipment by aggressively eliminating the least efficient equipment from the market
- **On-bill Financing** accelerates the market penetration of new technologies
- **Building Codes** improve shell efficiency of building envelope
- **Market Priming** programs offer information and education to reduce consumers' perception of the uncertainty and investment risks associated with new and innovative technologies.

Policy type	Policy	Scenario Description	NEMS Lever
Financial	Appliance Incentives	30% subsidy to reduce the capital costs for the most efficient equipment	Equipment cost in rtekty.txt
Regulatory	Aggressive Appliance Policy	Eliminating the least efficient equipment	Equipment available years in rtekty.txt
Regulatory	National Building Codes	Additional three rounds of improvement of building codes	Building shell profile: rtektyc.txt
Financial	On-bill Financing	Offering low interest loans for high efficient appliances through on-bill financing options	Source code + rtekty.txt
Information	Market Priming	7% hurdle rate for the most efficient equipment	Equipment choice parameters in rtekty.txt

Residential EE Policies would Cause Significant Reductions in Electricity Consumption



Electricity Savings Mainly Come from Space Cooling and Water Heating

Electricity Savings Potential by End-use in the US

End-use	Electricity Savings (TWh)			Cumulative Savings	
	2015	2025	2035	TWh	%
Space Heating	7.9	17.7	25.2	384.2	9%
Space Cooling	**38.7**	**92.5**	**119.3**	**1,923.2**	**46%**
Water Heating	**28.8**	**77.2**	**90.8**	**1,531.2**	**36%**
Refrigeration	2.3	3.3	3.2	71.5	2%
Dishwashers	2.1	9.2	12.0	176.8	4%
Other uses	1.7	5.4	9.2	118.9	3%

Technology Shifts Dramatically Among Equipment Types within the Same Class

Technology Demand Share Policies in EI

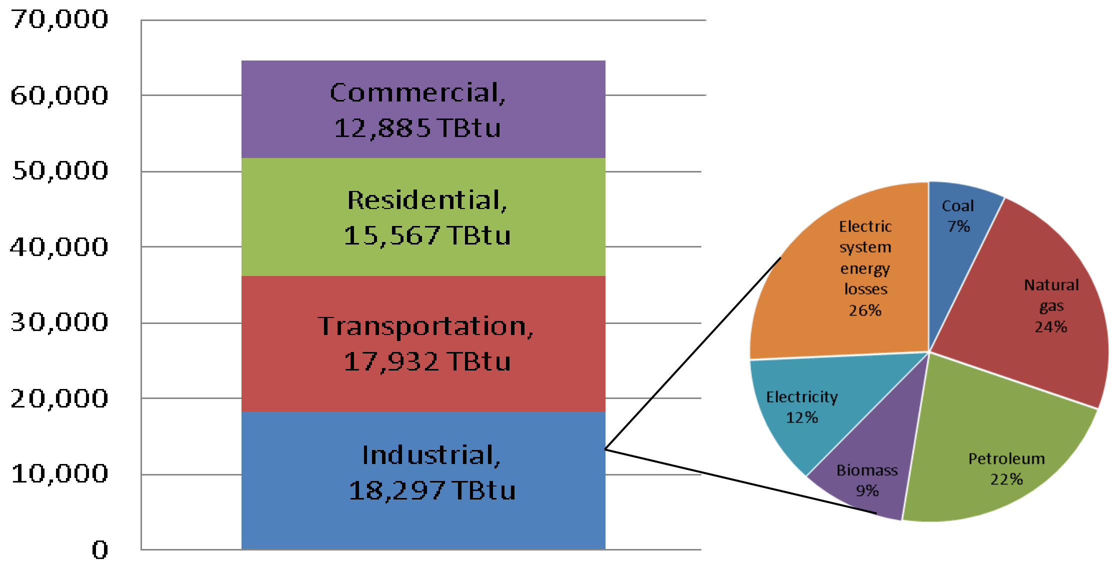
End-use	Equipment class	Reference			Policy		
		2015	2025	2035	2015	2025	2035
Space cooling	Central A/C	47%	50%	52%	47%	48%	51%
	Electric Heat Pump	11%	12%	13%	11%	13%	13%
	Geothermal Heat Pump	1%	1%	2%	1%	1%	2%
	Natural Gas Heat Pump	0%	0%	0%	0%	0%	0%
	Room A/C	41%	37%	33%	41%	37%	34%
Water heating	Distillate Fuel Oil Water Heater	3%	2%	2%	4%	3%	3%
	Electric Water Heater	47%	49%	50%	47%	49%	49%
	LPG Water Heater	2%	1%	1%	2%	2%	2%
	Natural Gas Water Heater	47%	47%	47%	47%	45%	46%
	Solar Water Heater	0%	0%	0%	0%	0%	0%

Demand Share of Electric Heat Pumps for Cooling in EI

	Efficiency	Reference			Policy		
		2015	2025	2035	2015	2025	2035
Type 1	2.26-2.40	67%	70%	69%	0%	5%	2%
Type 2	2.40-2.58	22%	20%	20%	1%	0%	0%
Type 3	2.75-2.80	9%	8%	9%	1%	0%	0%
Type 4	3.11-3.19	2%	2%	2%	98%	95%	97%

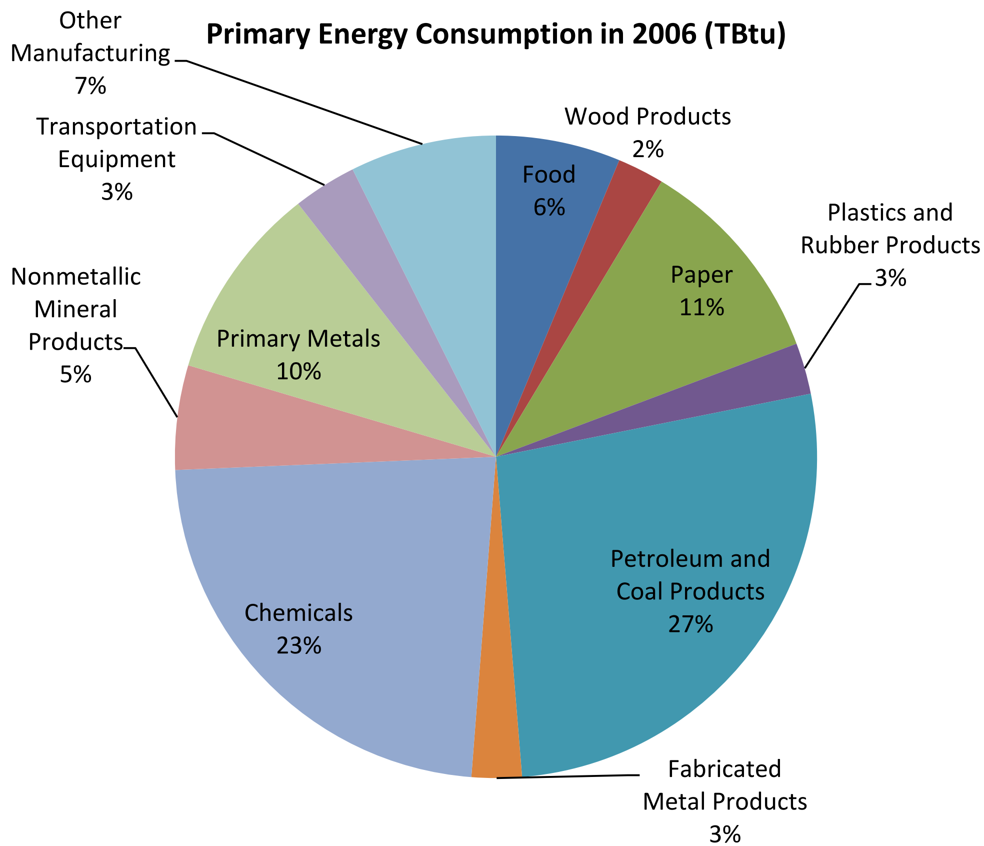
Energy-Efficiency Potential in Industrial Sector

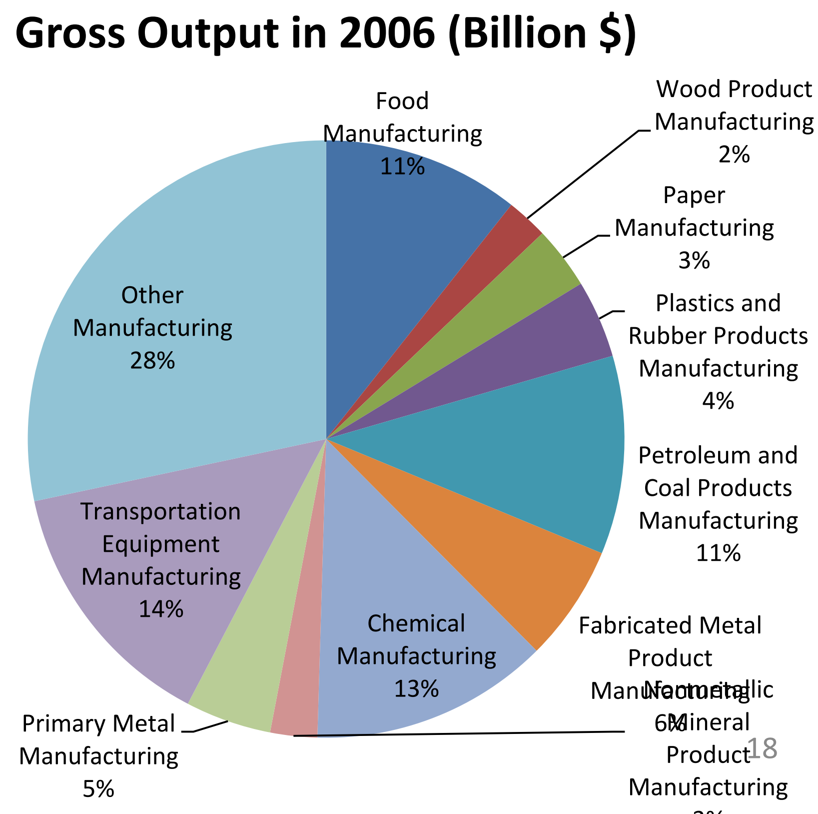
- Manufacturing industries in the EI region produce about 69% GDP of the nation.
- In 2010, the electricity consumption by the industrial sector in the Eastern Interconnection Region was 700 TWh, which was 72.1% of national consumption.



(Source: SEDS,2009; DOC Bureau of Economic Analysis, 2010)

Manufacturing Industries Are the Largest Energy Users (Nationwide)





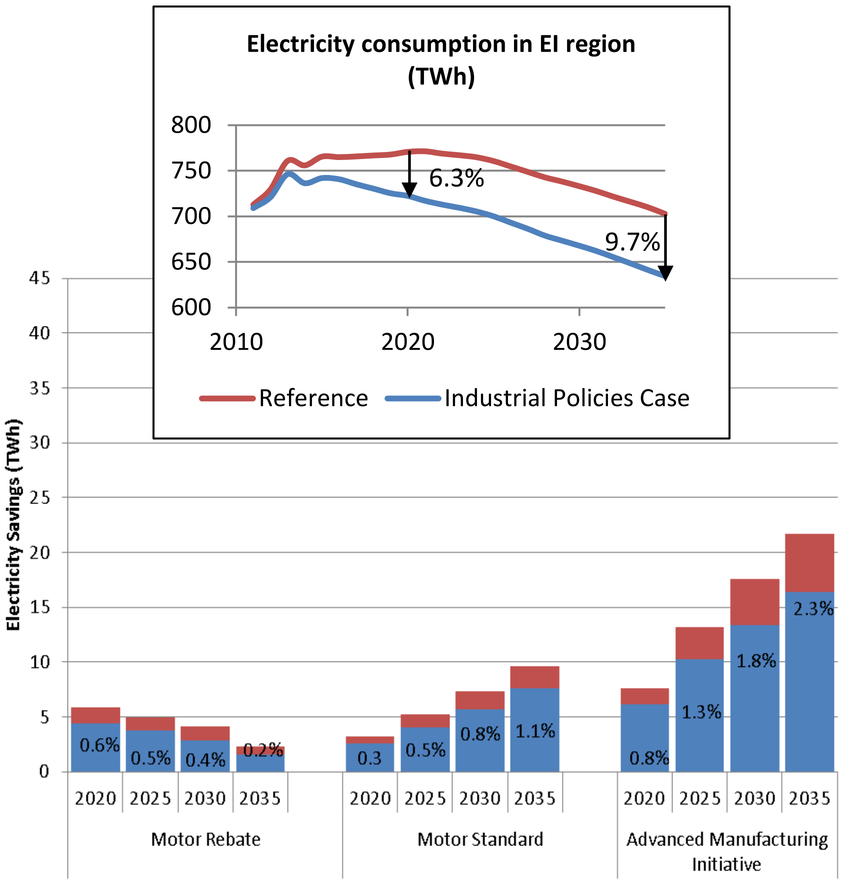
Sources: MECS, 2006; DOC, "Gross Domestic Product by Industry 1998-2007," 2009.

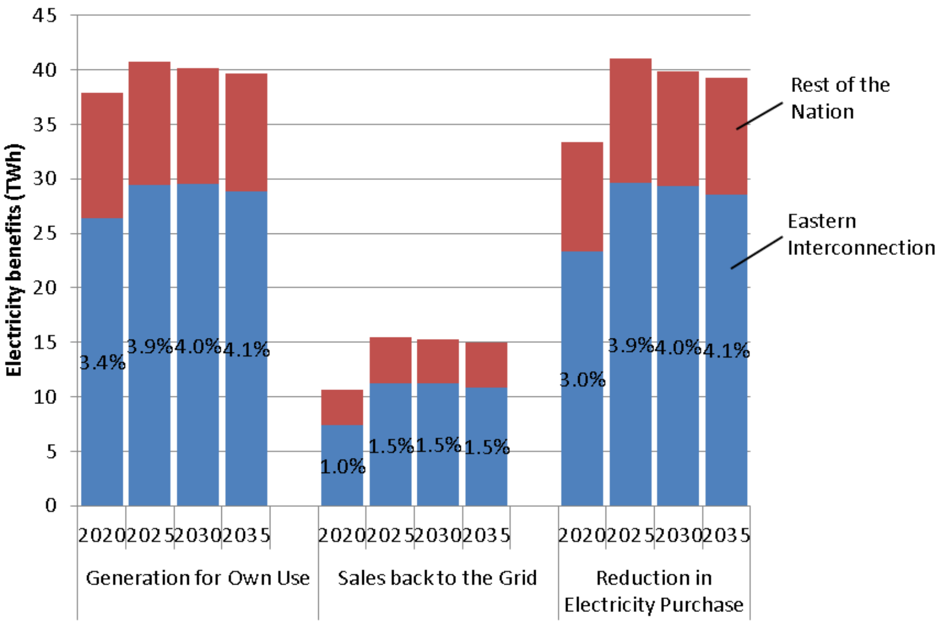
Industrial Sector EE Policy Options

- Industry EE policies tackle the electricity consumption by industrial activities
  - Industry CHP incentives the deployment of CHP systems by offering a 30% ITC for 10 years
  - Motor Rebate cuts down the capital cost for premium motors
  - Motor Standard requires efficiency improvement for motors and the systems which use motors
  - Advanced Manufacturing Initiative provides R&D and demonstration programs which boost plant utility upgrade for efficiency opportunities.

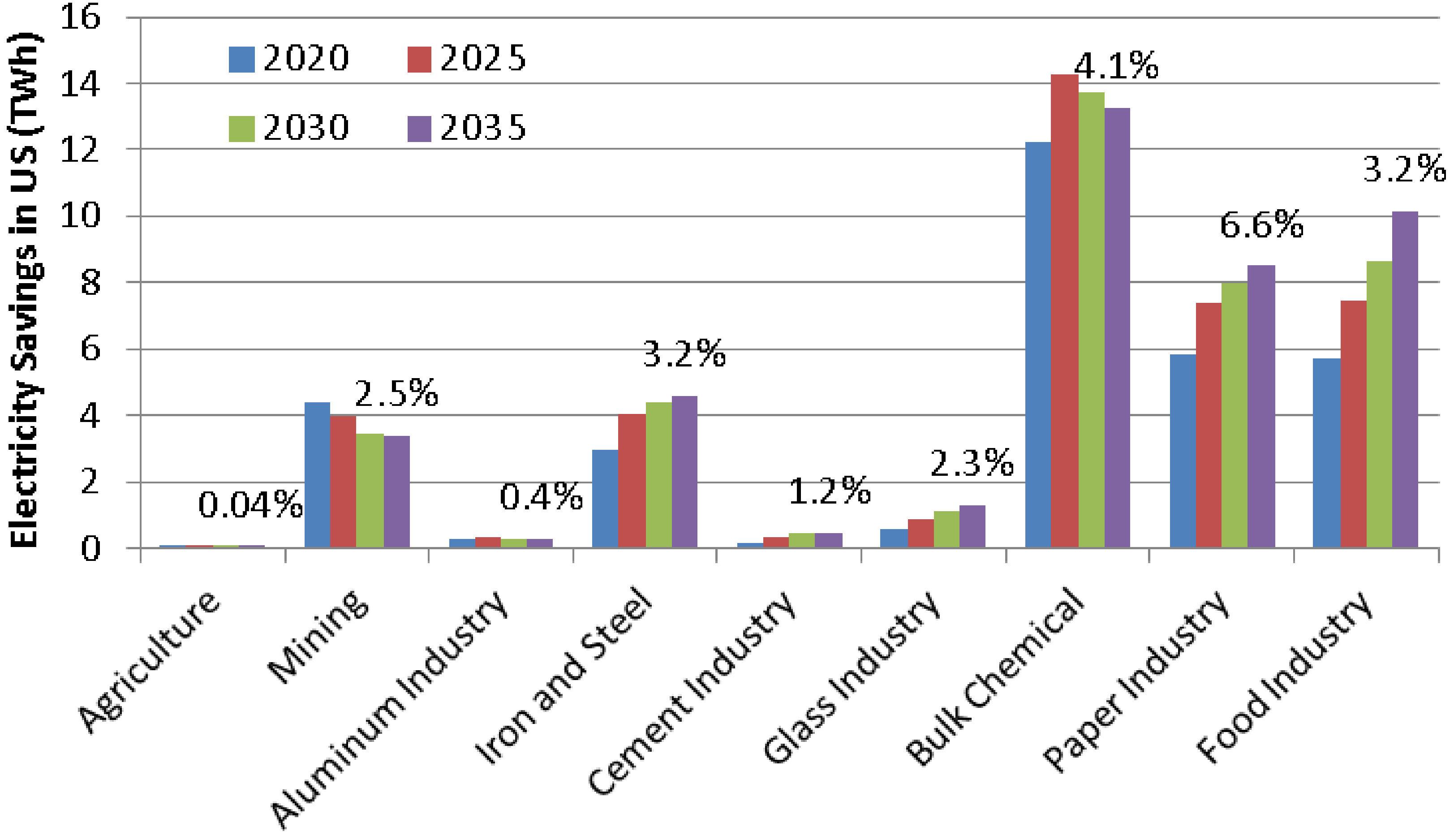
Policy type	Policy	Scenario Description	NEMS Lever
Financial	Industry CHP	A 30% ITC for industrial CHP for 10 years	indcogen.xml
Financial	Motor rebate	A 30% subsidy for premium motors which satisfies the minimum efficiency requirement of EISA 2007	Indmotor.xml
Regulatory	Motor standard	New motor standard at 2017 which has efficiency improvement for premium motor and system savings increase by 25%	Source code
R&D and Demonstration Program	Advanced Manufacturing Initiative	Assessments for Plant Utility Upgrades for efficiency opportunities. Energy savings potential are based on the assessment from Industrial Assessment Centers (IAC) dataset.	itech.txt

Industrial EE Policies would Cause Significant Electricity Savings



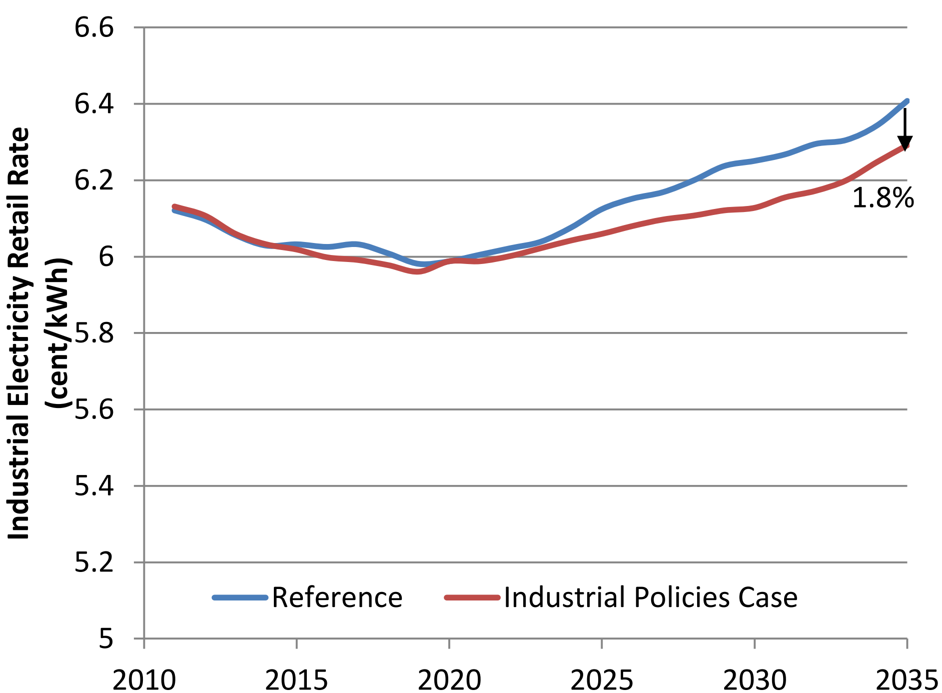


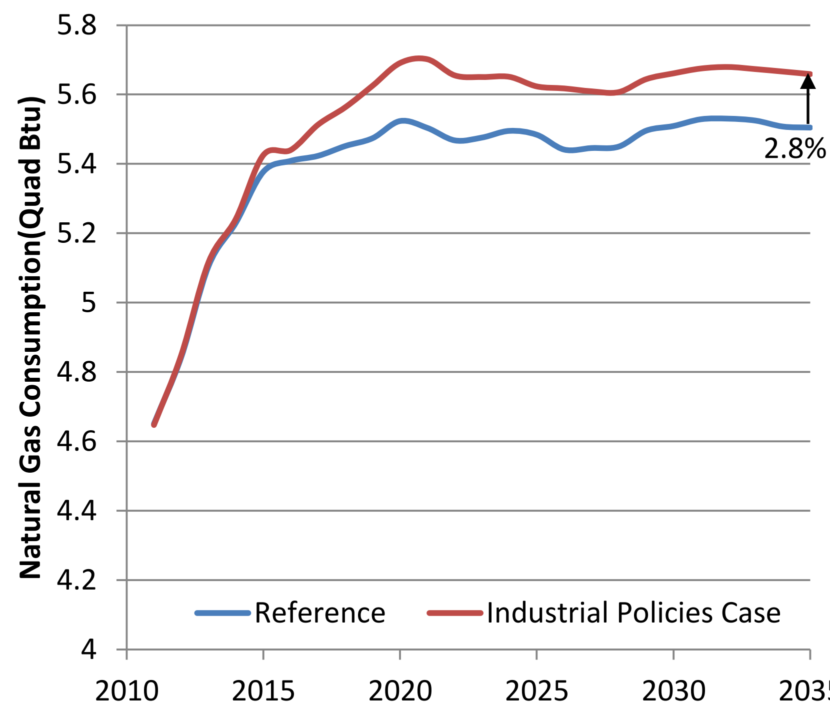
Electricity Savings by Industry Subsector



CHP Generation Drives Electricity Rates Down

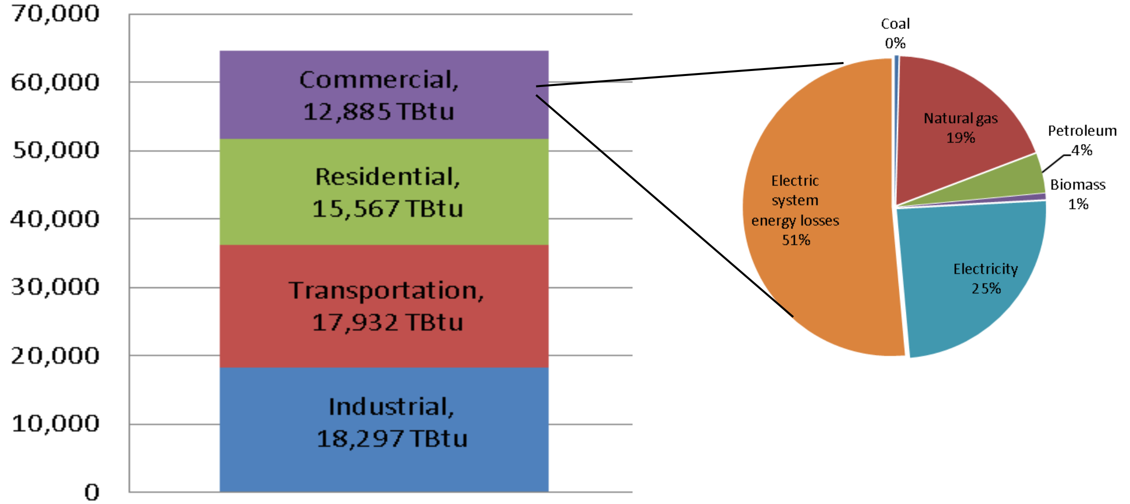
- In the policy case, installed capacity for industrial CHP would increase by 4.8 GW (15%) in 2020, and by 5.2 GW (10%) in 2035.
- Similarly, electricity generation from industrial CHP would increase by 35.2 TWh (18%) in 2020, and by 39.3 TWh (11%) in 2035.





Energy Efficiency Potential in Commercial Sector

- GDP from commercial businesses and activities in the EI region represent 68.6% of the national total.
- In 2010, the electricity consumption by commercial buildings in the Eastern Interconnection was 945 TWh, which was 71.1% of national consumption.



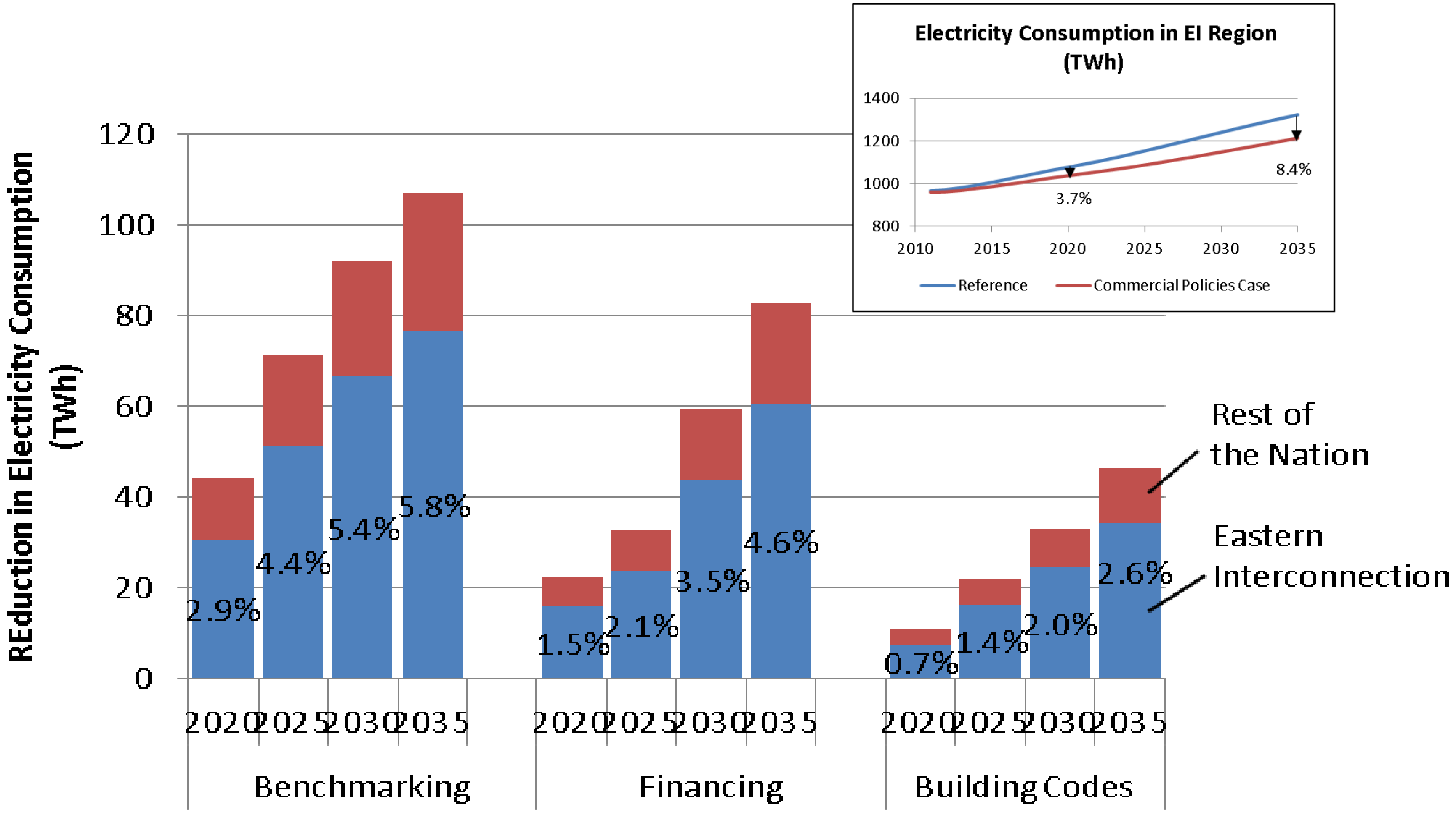
(Source: SEDS,2012)

Commercial EE Policies

- Commercial EE policies tackle electricity use in commercial buildings
  - Building Codes improve shell efficiency and take out the inefficient HVAC equipment from the market for new and existing buildings
  - Benchmarking program provides information about building stock and energy use, which lowers the discount rate for efficiency investment
  - Financing programs offer building owners and tenants loan options for the purchase of efficient equipment

Policy type	Policy	Scenario description	NEMS Lever
Regulatory	**Building codes**	Revised factor of efficiency improvement in 2035 for new buildings	KSHEFF.txt Ktek.xml
Financial	**Financing**	An 30% subsidy was applied to the capital costs of the winning technologies under Carbon Tax	Ktek.xml
Information	**Benchmarking**	Lower the time preference premium for commercial technologies	Kprem.txt

Commercial EE Policies would Produce Significant Electricity Savings

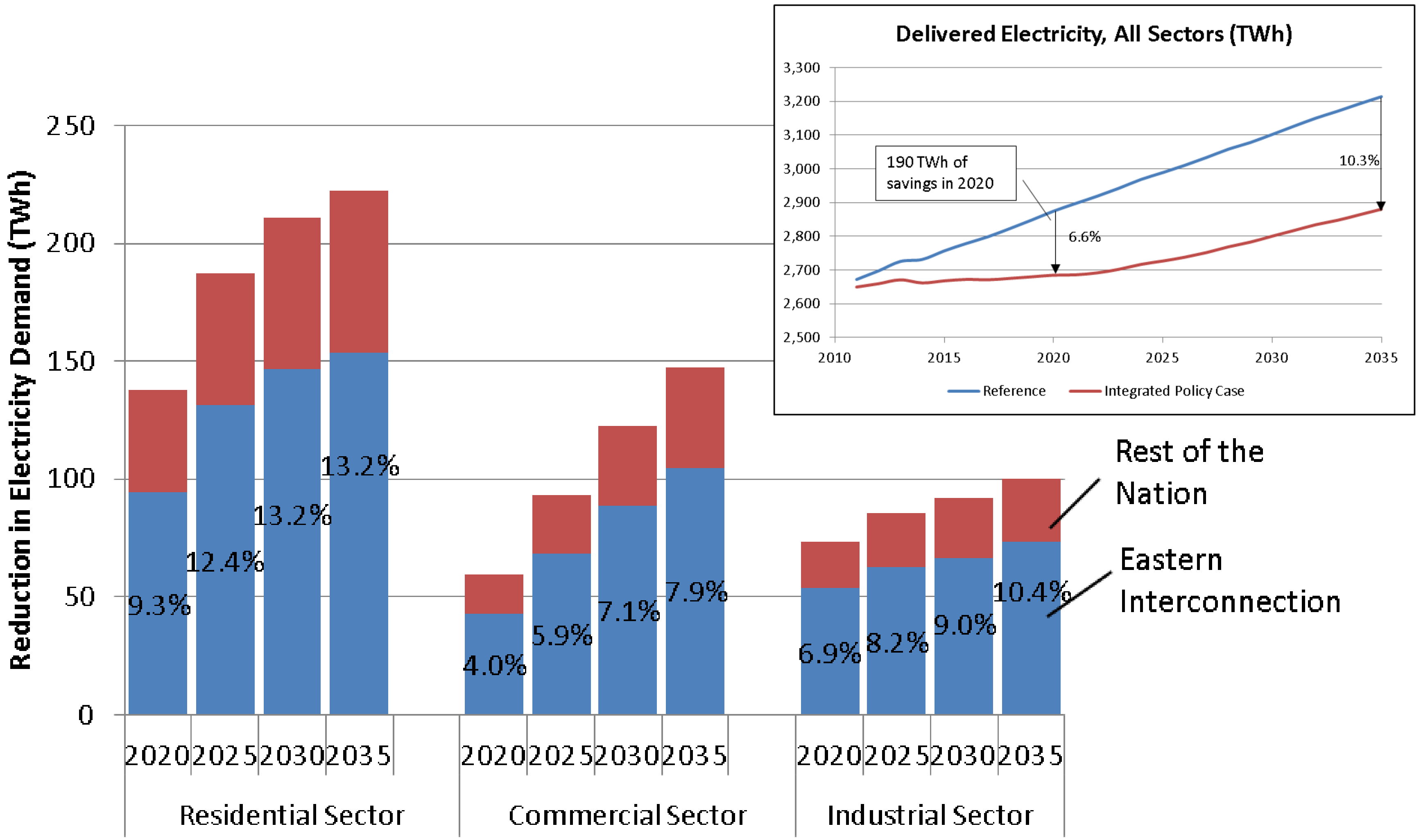


Electricity Consumption by Commercial Buildings End-use

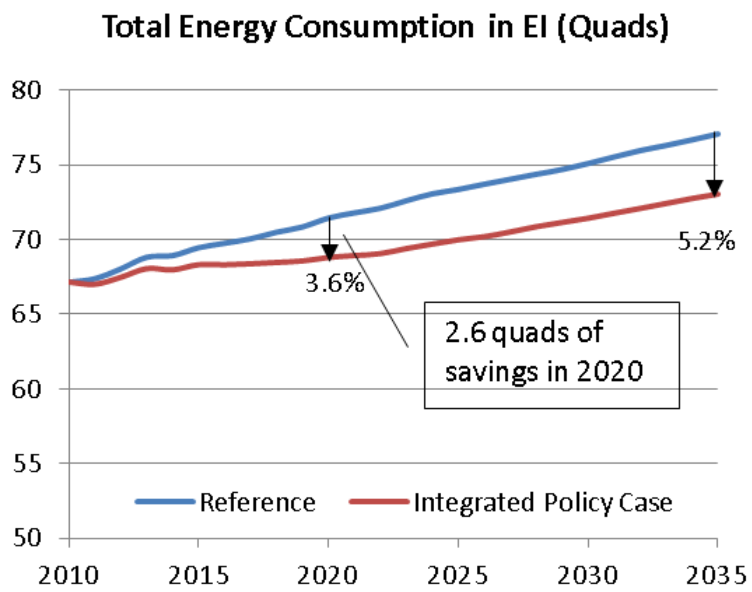
- Electricity consumption by space cooling and heating, and ventilation has reduced significantly in the Commercial Policies Case
- However, electricity consumption by “other” end-use services has increased in the Commercial Policies Case

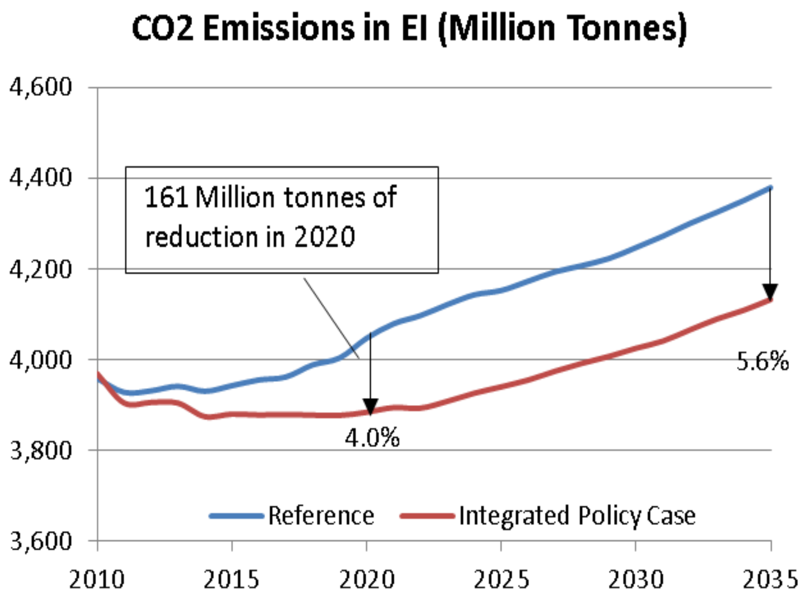
End Use	2010	2020			2035		
	Reference	Reference	Commercial Policies	Percent Change	Reference	Commercial Policies	Percent Change
Space Heating	**51**	**50**	**43**	**-15%**	**52**	**42**	**-18%**
Space Cooling	**170**	**160**	**137**	**-14%**	**180**	**141**	**-22%**
Water Heating	27	28	27	-4%	28	25	-10%
Ventilation	**150**	**176**	**102**	**-42%**	**209**	**107**	**-49%**
Lighting	300	321	311	-3%	365	303	-17%
Refrigeration	115	105	100	-5%	114	105	-8%
Personal Computer	62	56	56	0%	62	62	0%
Other Office Equipment	77	108	108	0%	137	137	0%
Other Uses	***391***	***518***	***578***	***11%***	***730***	***802***	***10%***

Integration of Twelve Energy Efficiency Policies



Total Energy Savings and CO_2 Emission Reductions





	Savings in Total Energy Consumption (Quads)			
	2020	2025	2030	2035
EI	2.6	3.3	3.6	4.0
US	3.5	4.7	5.3	5.6

	Reduction in CO_2 Emissions (Million Tonnes)			
	2020	2025	2030	2035
EI	161	211	221	246
US	211	270	291	317

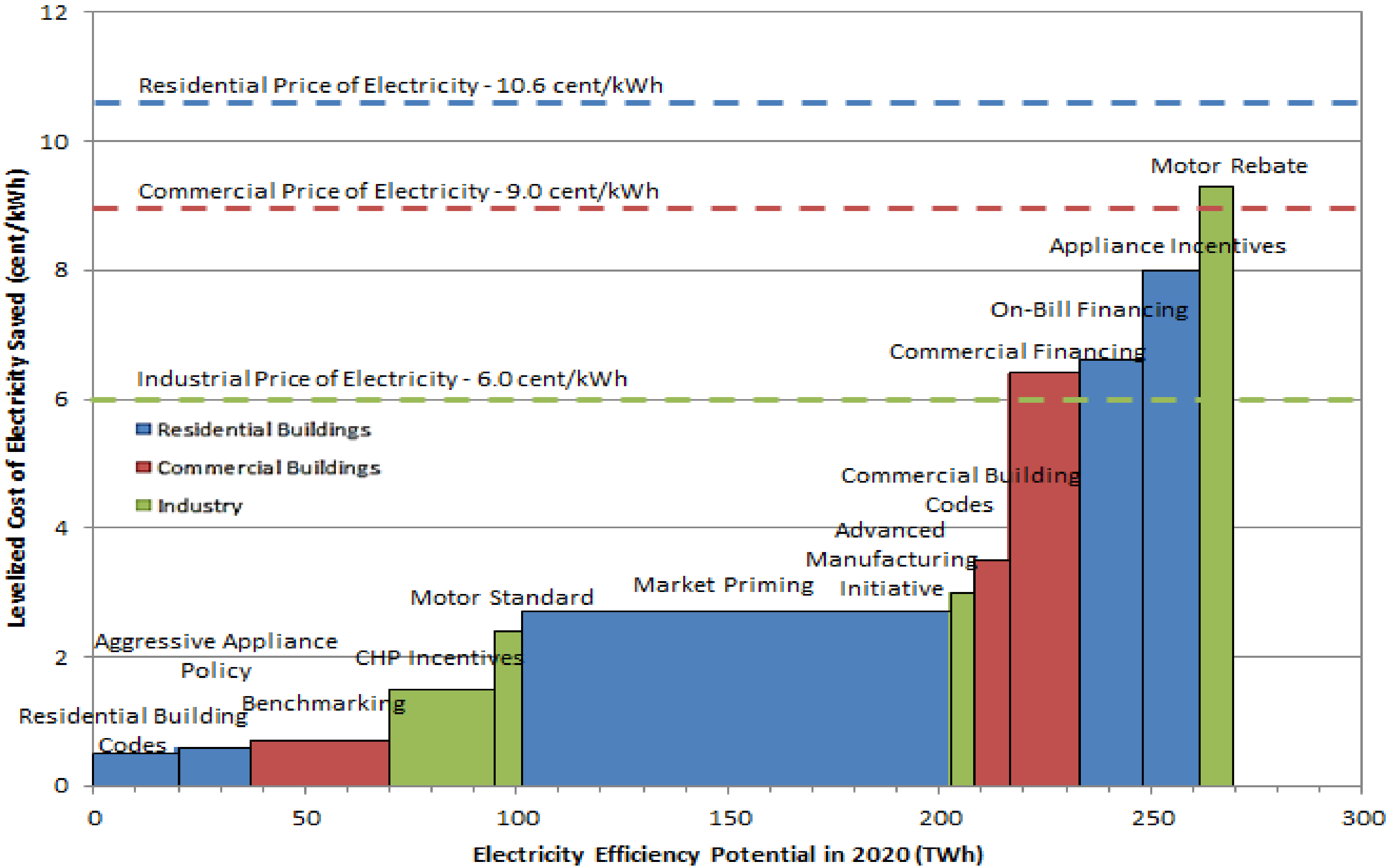
The Estimated Levelized Cost of Electricity Efficiency Averages 3.0-3.6 cents/kWh in the Eastern Interconnection

Type of Energy-Efficiency Policy	LCOE in cents/kWh (Lower bound)*		LCOE in cents/kWh (Upper bound)**	
	EI	US	EI	US
Information Policies	2.1	2.1	2.9	2.9
Regulations	2.8	3.4	3.5	4.1
Financing Policies	4.6	4.8	4.7	5.0
Information Policies	3.0	3.3	3.6	3.9

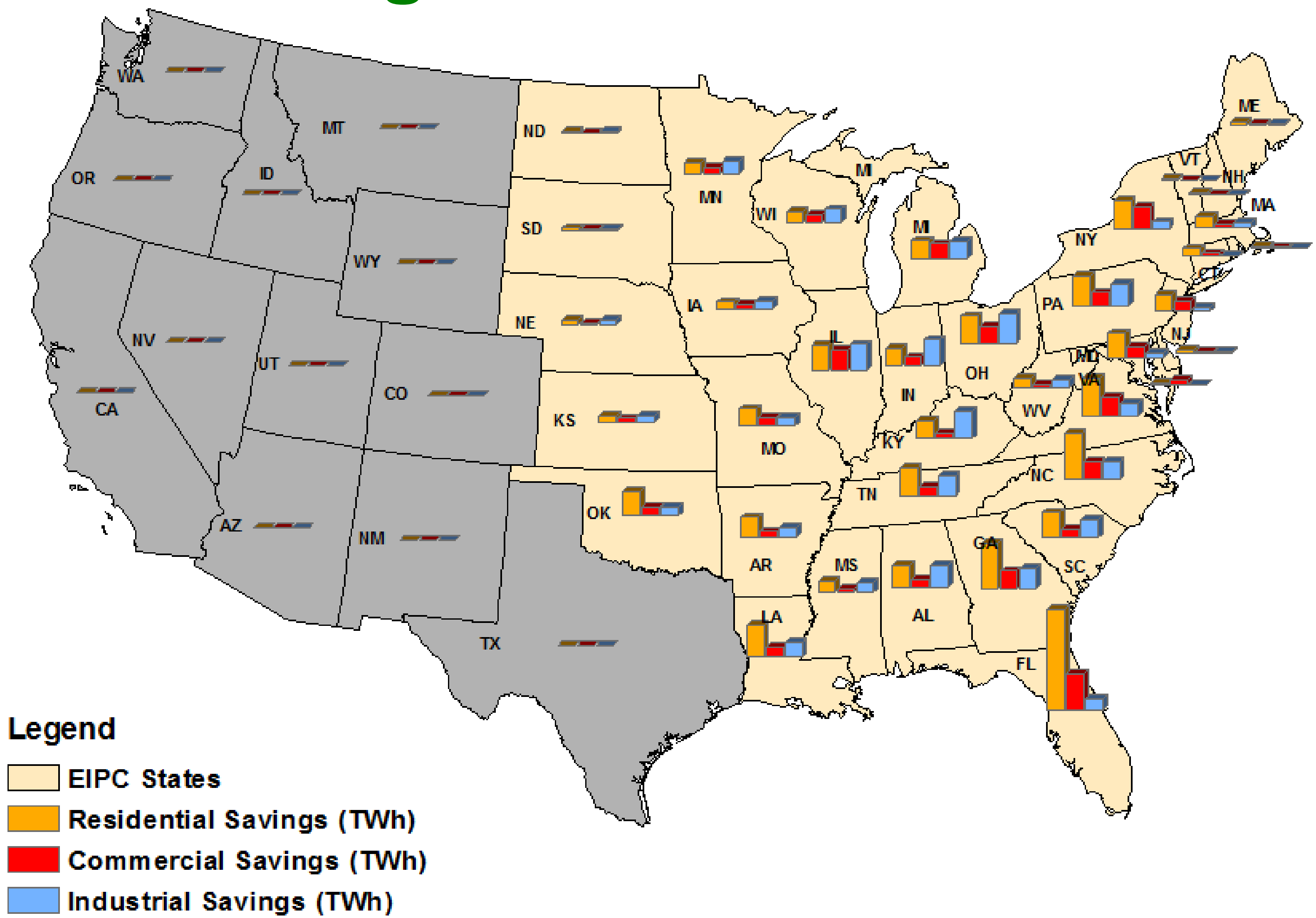
*3% discount rate for public and private costs.

**7% discount rate for private costs and 3% discount rate for public costs.

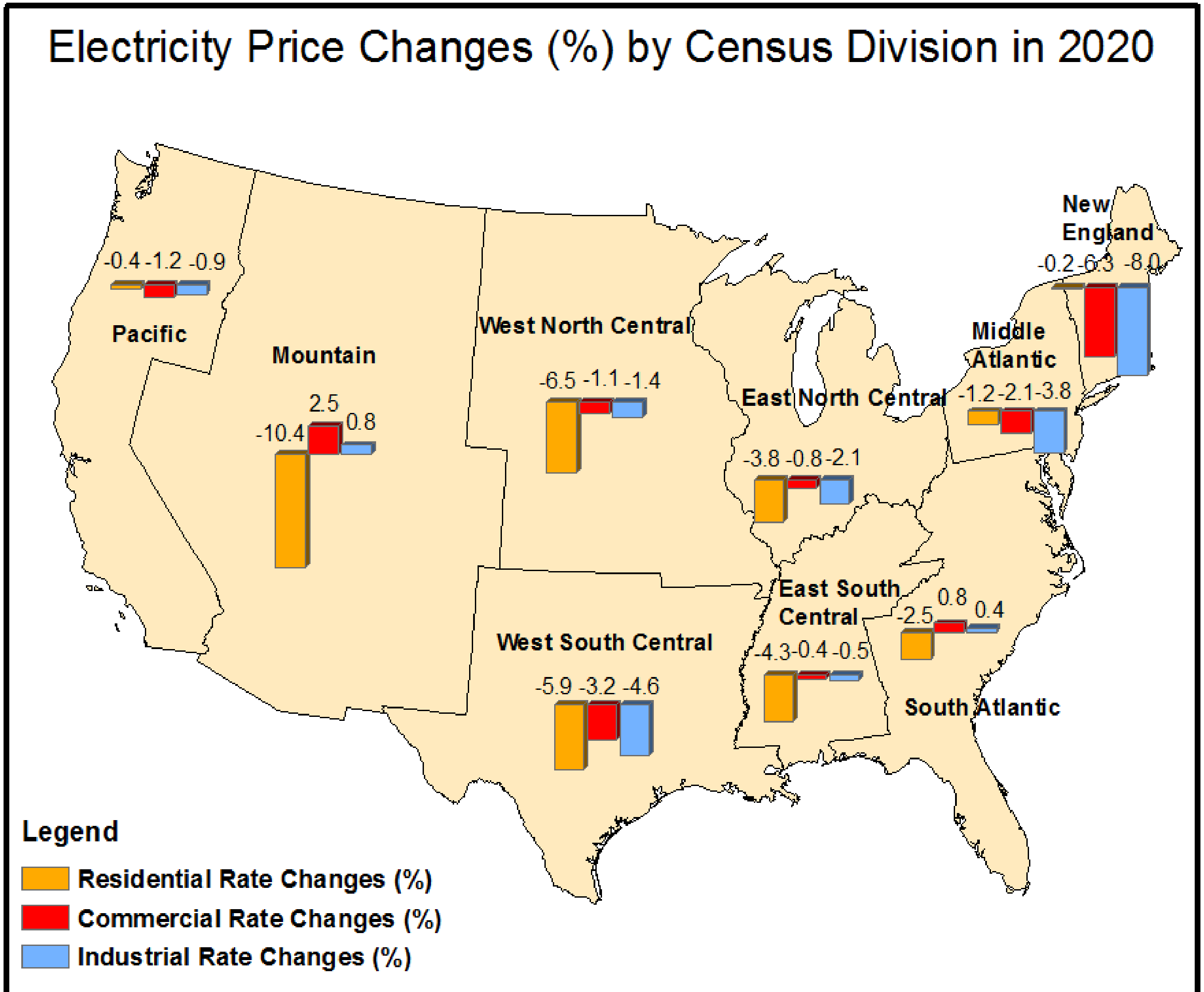
Electricity-Efficiency Policy Supply curve



The Central and Southern Regions have the Highest per Capita Electricity-Savings Potential in 2020



Expanded Energy Efficiency would Decrease Electricity Rates in almost Every Census Division in 2020 (in all by 2035)



Energy-efficiency Policies have No Significant Impact on GDP

- The national GDP is estimated to grow $16 billion less in the policy case in 2020, which is equivalent to only 7 hours of delay in GDP growth.
- This estimation of GDP impact is smaller than some estimations from studies on energy consumption-GDP nexus (Narayan and Smyth, 2009; Mishra et al., 2009; Ozturk, 2010).

Scenario	GDP (billion 2009$)	2020	2025	2030	2035
Reference	GDP	19,168	22,021	25,000	28,260
Integrated Policy Case	GDP	19,152	22,009	24,974	28,213
	Change	-0.08%	-0.05%	-0.10%	-0.17%
	Delay (hour)	7	7	15	25

*Numbers are percentage change relative to the Reference case
** "Delay" in GDP growth is defined as the number of days in a year required to make up the difference between GDP in the Reference case versus GDP in the Integrated Policy scenario.

Acknowledgement

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- Bob Pauley of Eastern Interconnection States Planning Council (EISPC) contributed meaningfully to communications with EISPC members and the Navigant team regarding the completion of this study. Valuable comments were received from Youngson Baek and Stanton Hadley (Oak Ridge National Laboratory).

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- The authors are grateful for the willingness of these individuals to engage in a dialogue about the potential to expand energy-efficiency resources.

- Any remaining errors are the sole responsibility of the authors.

Additional Slides

Conclusion and Discussion

- With energy-efficiency policies, we estimate that the United States could cost-effectively achieve significant savings in electricity consumption by 2035.
  - Regulatory, financial and information policies are able to generate significant electricity savings
  - Policy supply curve suggests that regulatory and information policies are generally more cost-effective in promoting energy efficiency
- The electricity savings benefit of energy-efficiency policies is accompanied by other benefits, including natural gas savings, savings in other fuel types, and reduced carbon emissions.
- In addition, the twelve energy-efficiency policies are able to drive electricity retail prices down in many regions and produce large energy bill savings for consumers.
- The electric power sector is also affected by these policies, in that generation growth is slowed in the Integrated Policy case, reducing the need for capital-intensive new generation.
- Overall, these policies are able to decrease the energy and carbon intensity with no significant impact on GDP growth.

The Central and Southern Regions have the Highest per Capita Electricity-Savings Potential

Census Division	Per Capita Delivered Electricity Savings (kWh/capita)			
	Residential Sector	Commercial Sector	Industrial Sector	Total
New England	248	99	87	430
Middle Atlantic	230	139	100	467
E.N. Central	286	195	309	788
W.N. Central	309	166	269	749
South Atlantic	576	230	181	985
E.S. Central	530	173	527	1,229
W.S. Central	686	226	273	1,204
Mountain	387	197	228	868
Pacific	246	86	118	470
U.S. Total	402	173	215	788

Savings Potential and Levelized Cost of Electric End-Use Efficiency

Sector	Policy	Electricity Efficiency Potential (TWh) in 2020	Electricity Efficiency Potential (TWh) in 2035	Levelized Cost of Electric End-Use Efficiency (cent/kWh)
Residential	Appliance Incentives	13	26	6.7-8.0
	On-Bill Financing	13	22	6.6-7.4
	Building Codes	8	19	0.5-0.8
	Aggressive Appliance Policy	16	40	0.6-0.7
	Market Priming	100	119	2.7-3.6
Commercial	Financing	31	77	6.4-6.6
	Building Codes	8	34	3.5-4.6
	Benchmarking	16	61	0.7-1.2
Industrial	Motor Rebate	4	2	9.3-11.5
	Motor Standard	3	8	2.4-3.9
	Advanced Manufacturing Initiative	6	16	3.0-4.8
	CHP Incentives	23	29	1.5-2.3

Expanded Energy Efficiency would Decrease Electricity Rates in 2020

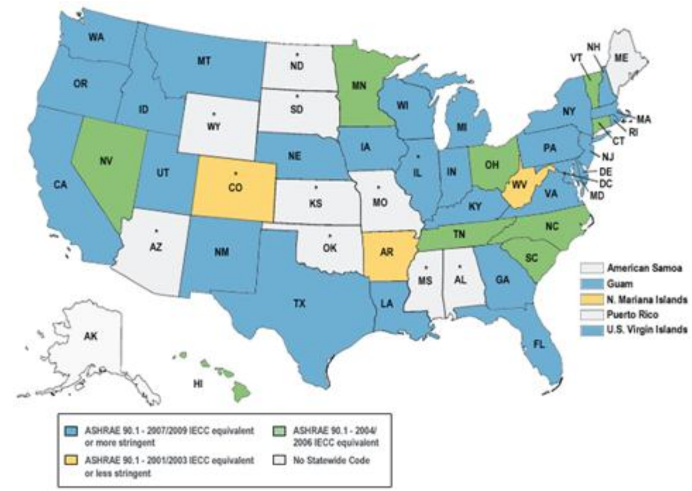
Census Division	Scenario	Residential Retail Rate (cent/kWh)	Commercial Retail Rate (cent/kWh)	Industrial Retail Rate (cent/kWh)
New England	Reference	17.7	12.0	7.8
	Integrated Policy Case	17.6	11.3	7.2
	Percent Change	-0.2%	**-6.3%**	**-8.0%**
Middle Atlantic	Reference	14.6	11.2	6.3
	Integrated Policy Case	14.4	11.0	6.0
	Percent Change	-1.2%	-2.1%	-3.8%
East North Central	Reference	10.0	8.4	5.9
	Integrated Policy Case	9.6	8.3	5.8
	Percent Change	-3.8%	-0.8%	-2.1%
West North Central	Reference	8.5	7.1	5.3
	Integrated Policy Case	7.9	7.0	5.2
	Percent Change	**-6.5%**	-1.1%	-1.4%
South Atlantic	Reference	10.8	9.0	6.5
	Integrated Policy Case	10.5	9.1	6.5
	Percent Change	-2.5%	***0.8%***	***0.4%***
East South Central	Reference	8.3	7.9	5.2
	Integrated Policy Case	7.9	7.9	5.2
	Percent Change	-4.3%	-0.4%	-0.5%
West South Central	Reference	9.7	7.2	5.4
	Integrated Policy Case	9.2	7.0	5.2
	Percent Change	**-5.9%**	-3.2%	-4.6%

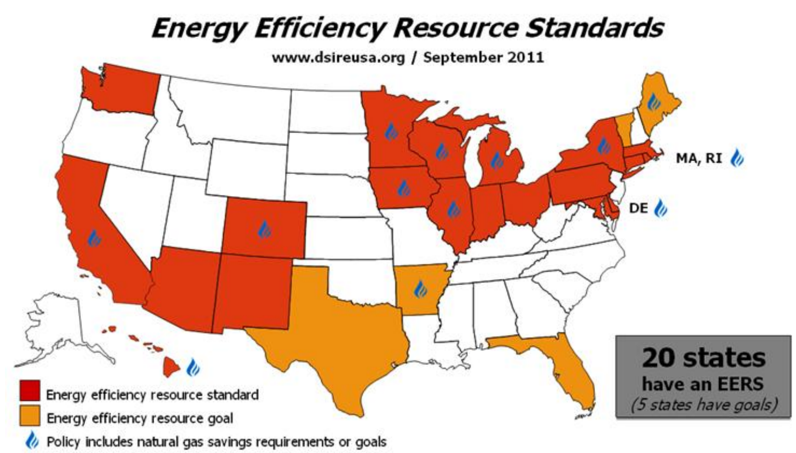
Efficiency gains from better policies (Illustrative Literature)

- Policy instruments (subsidies, income tax, carbon tax) pushes efficiency retrofitting profitable (Amstalden, et al, 2007).
- Energy labeling can help improve efficiency in household energy use (Feng, 2010).
- Energy savings from Energy Policy Act of 2005 leads to new energy policies (Dixon, 2010).
- Recent assessments for energy efficiency potential due to policy changes:
  - Energy Efficiency in the South (Brown et al, 2010)
  - Making Homes Part of the Climate Solution (Brown et al, 2009)

Current Policies on Energy Efficiency Vary Across States and Localities

- Federal, state & local codes and standards:
  - Building energy codes
  - Appliance / equipment standards
  - Energy standard for public buildings
- Financial incentives (Federal, state, & local – e.g., PACE):
  - Rebates
  - Tax credits
  - Grants
  - Loans

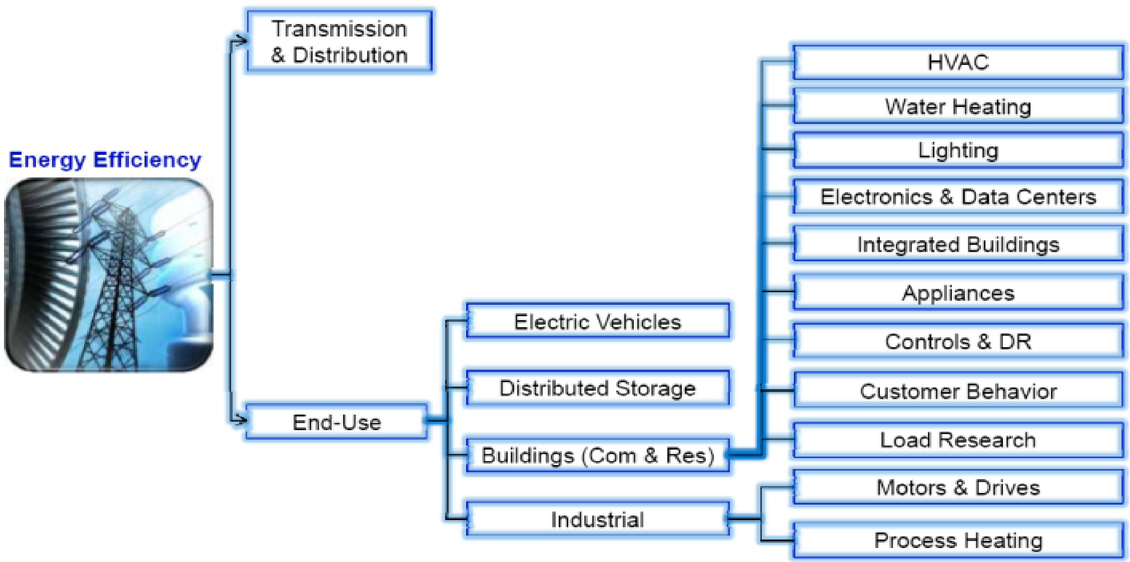




Source: DOE, Building Energy Code Program, 2011;
DSIR, Summary Map for Energy efficiency Resource Standard

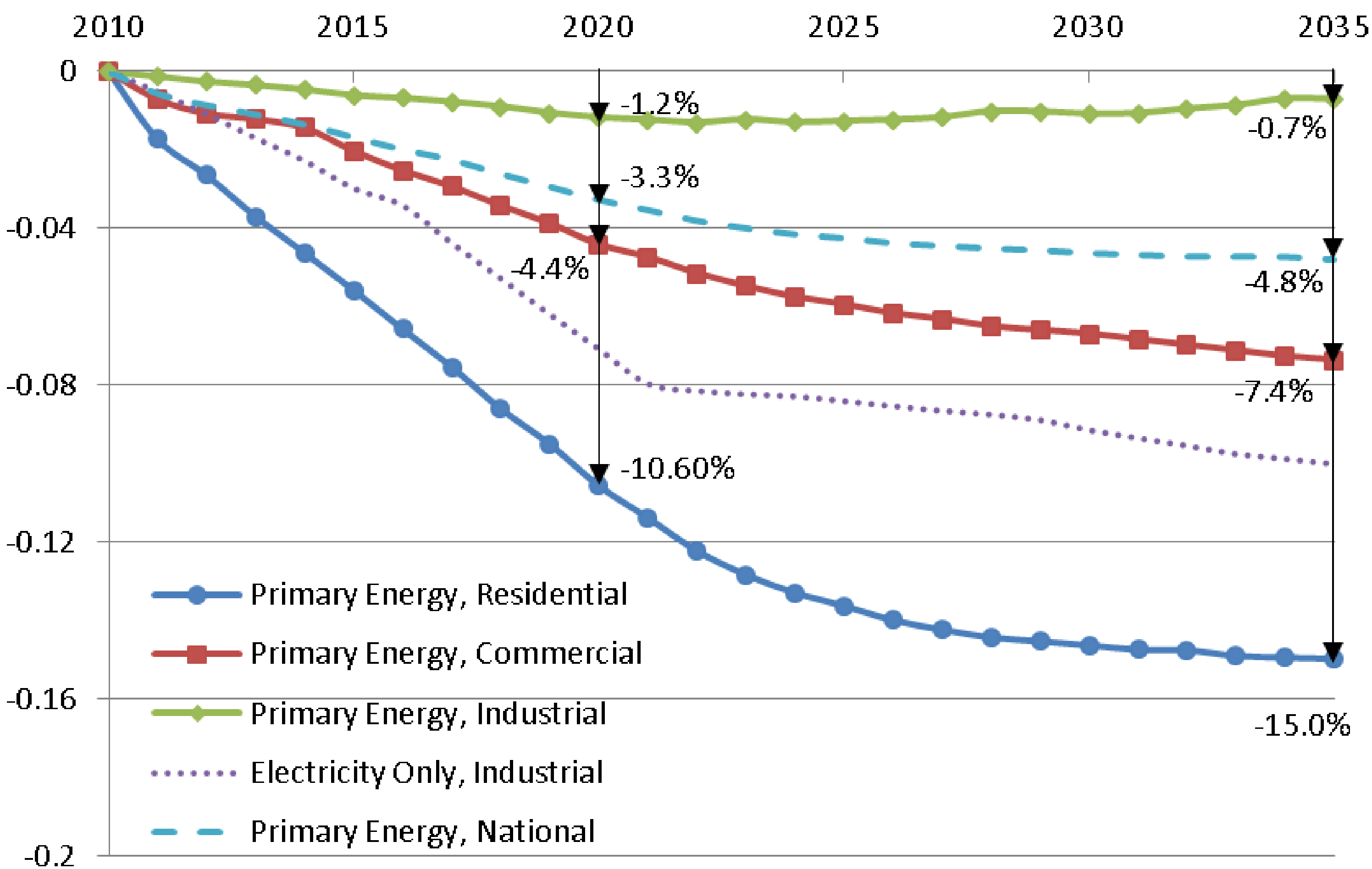
End-use Efficiency Potentials

- Efficiency gains from better technologies and operations
  - Energy efficiency in commercial buildings can be improved by adding technologies for remote control, data measurement, and monitoring (Guillermo, 2011).
  - Energy efficiency is associated with emerging technologies and innovations (Courtright, et al. 2011)
- Efficiency gains from behavioral changes
  - Occupant behavior is the most significant influencer for cooling energy consumption in households (Yun and Steemers, 2011).



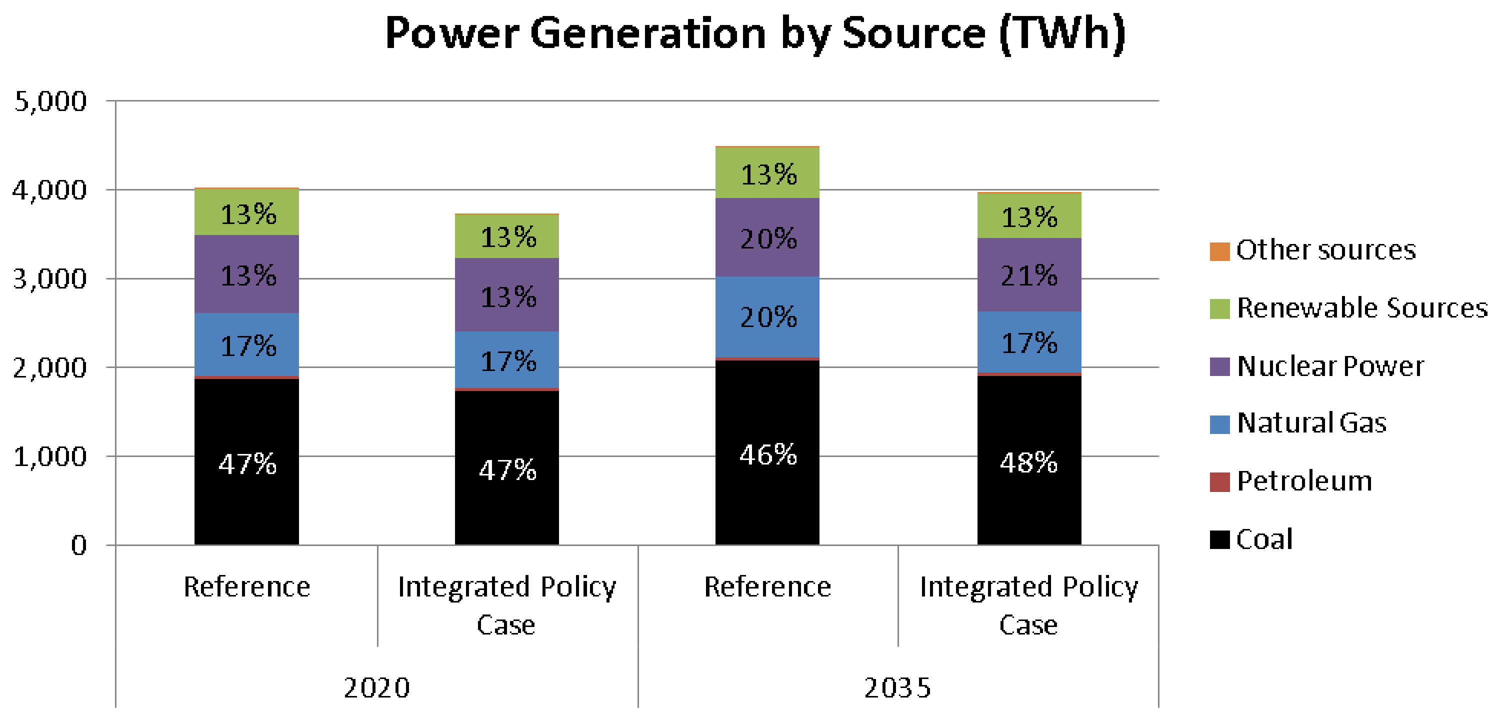
Source: Courtright, et al. 2011

Policy Impacts on Energy Intensity



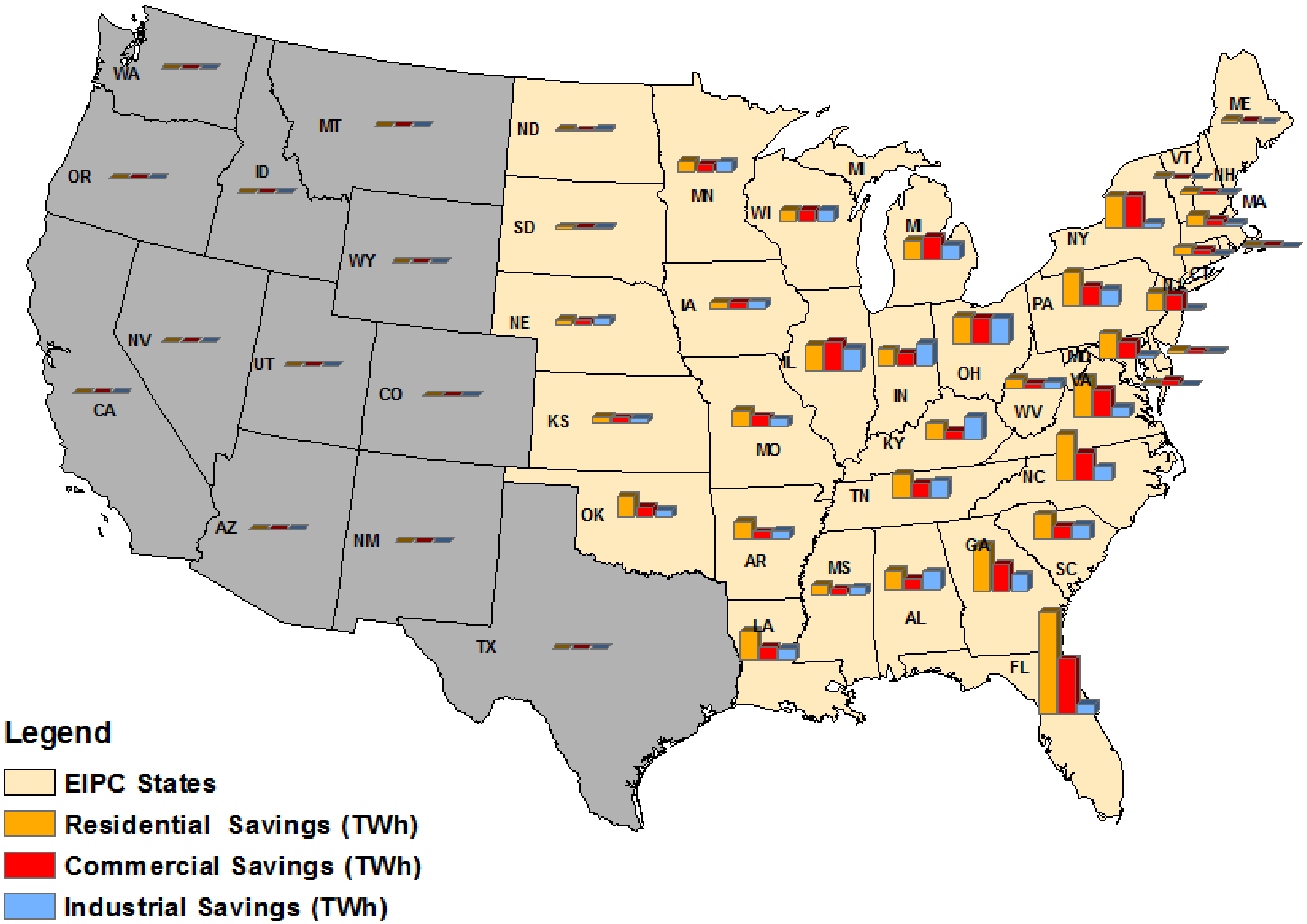
Energy intensity for residential and commercial buildings are measured by primary energy by floor space (MBtu/ft^2); energy intensity in the industrial sector is measured by primary energy (or electricity only) per values of shipment (Thousand Btu/2005$) ; energy intensity of the economy at large is measured by primary energy per GDP (MBtu/2005$) .

Impacts on the Power Sector



Fuel Type	2010	2020			2035		
	Reference	Reference	Integrated Policy Case	Percent Change	Reference	Integrated Policy Case	Percent Change
Coal	1812	1879	1738	-7.5%	2082	1912	-8.2%
Petroleum	39.45	39.02	36.84	-5.6%	41.32	39.41	-4.6%
Natural Gas	**779.1**	**696.4**	**632.7**	**-9.1%**	**914.1**	**683.6**	**-25.2%**
Nuclear Power	802.9	877.3	823.6	-6.1%	874.4	821.3	-6.1%
Renewables	371	519.3	494.6	-4.8%	567.3	512.9	-9.6%
Total	3804	4013	3726	-7.2%	4483	3972	-11.4%

Electricity Savings by State in 2035



Electricity Price Changes (%) by Census Division in 2035