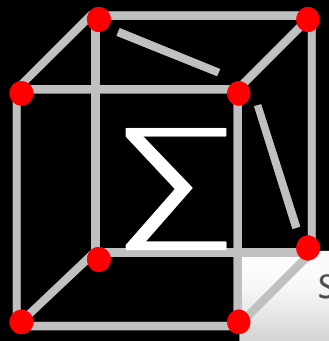


SEABORG – GRANGER DEDICATION

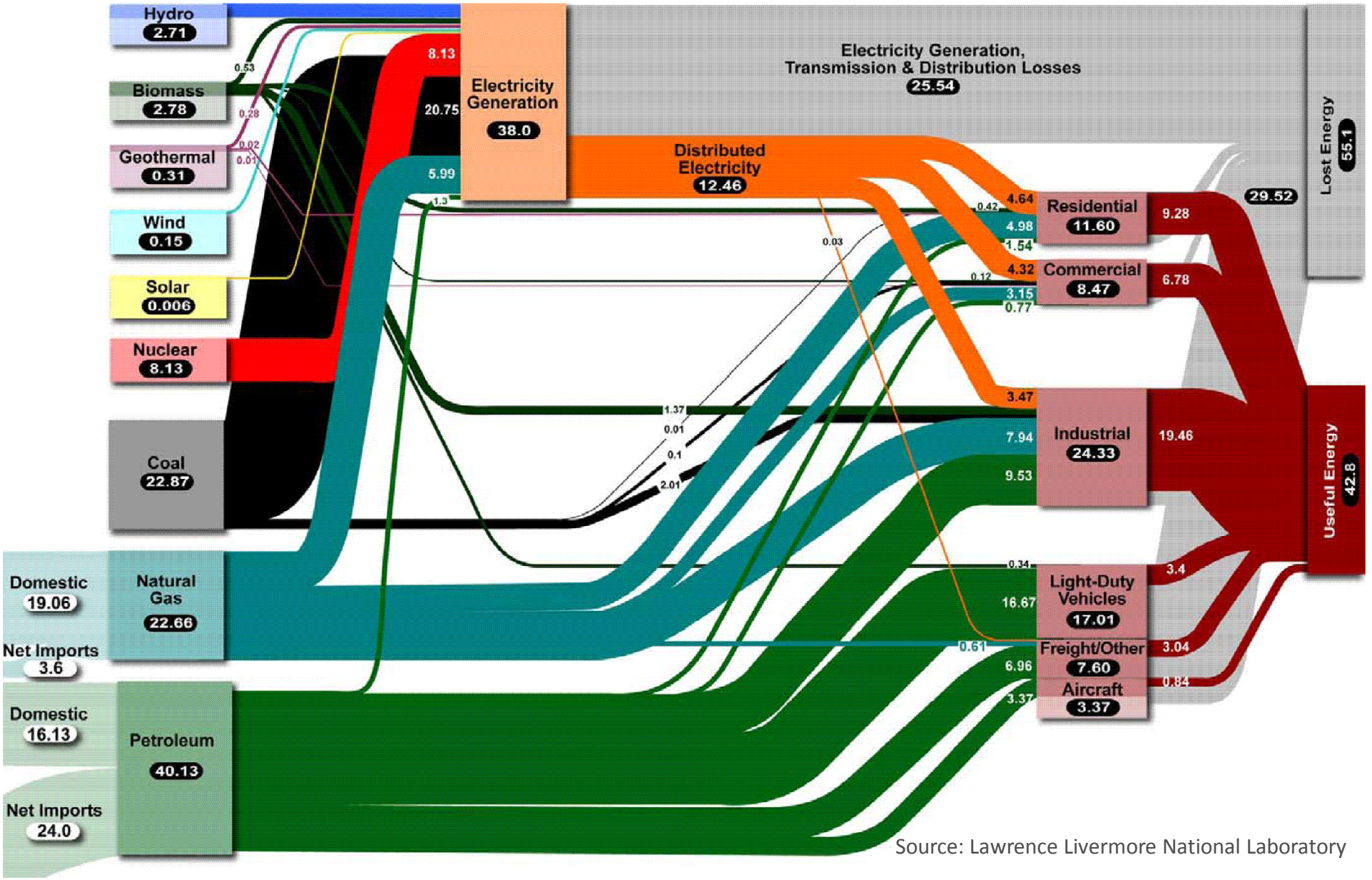
IS ENERGY EFFICIENCY NECESSARY?

Dr Shoumen Datta

School of Engineering

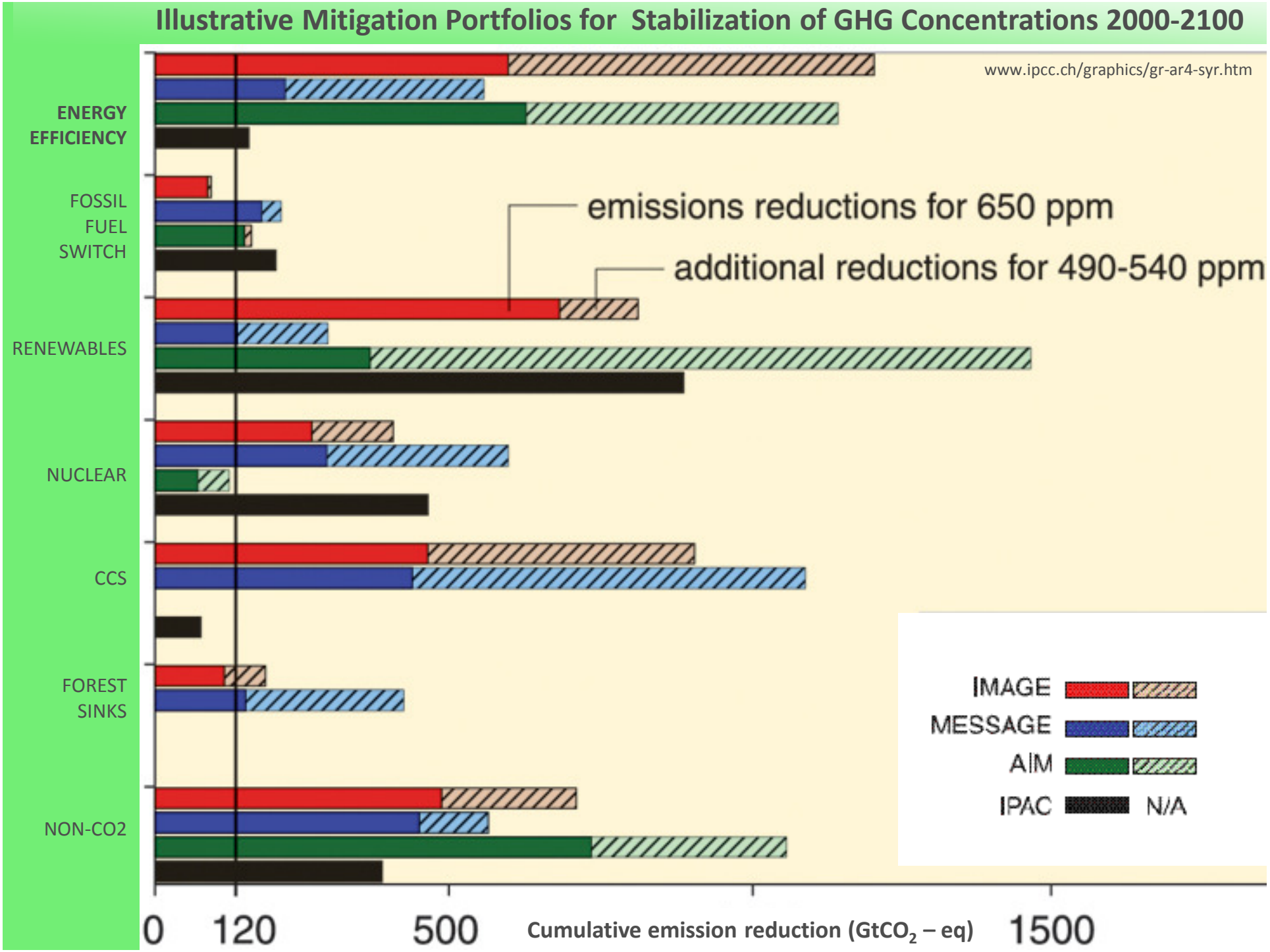
Massachusetts Institute of Technology

US Energy Flow about 100 Ej per year : Lost Energy is nearly 60%

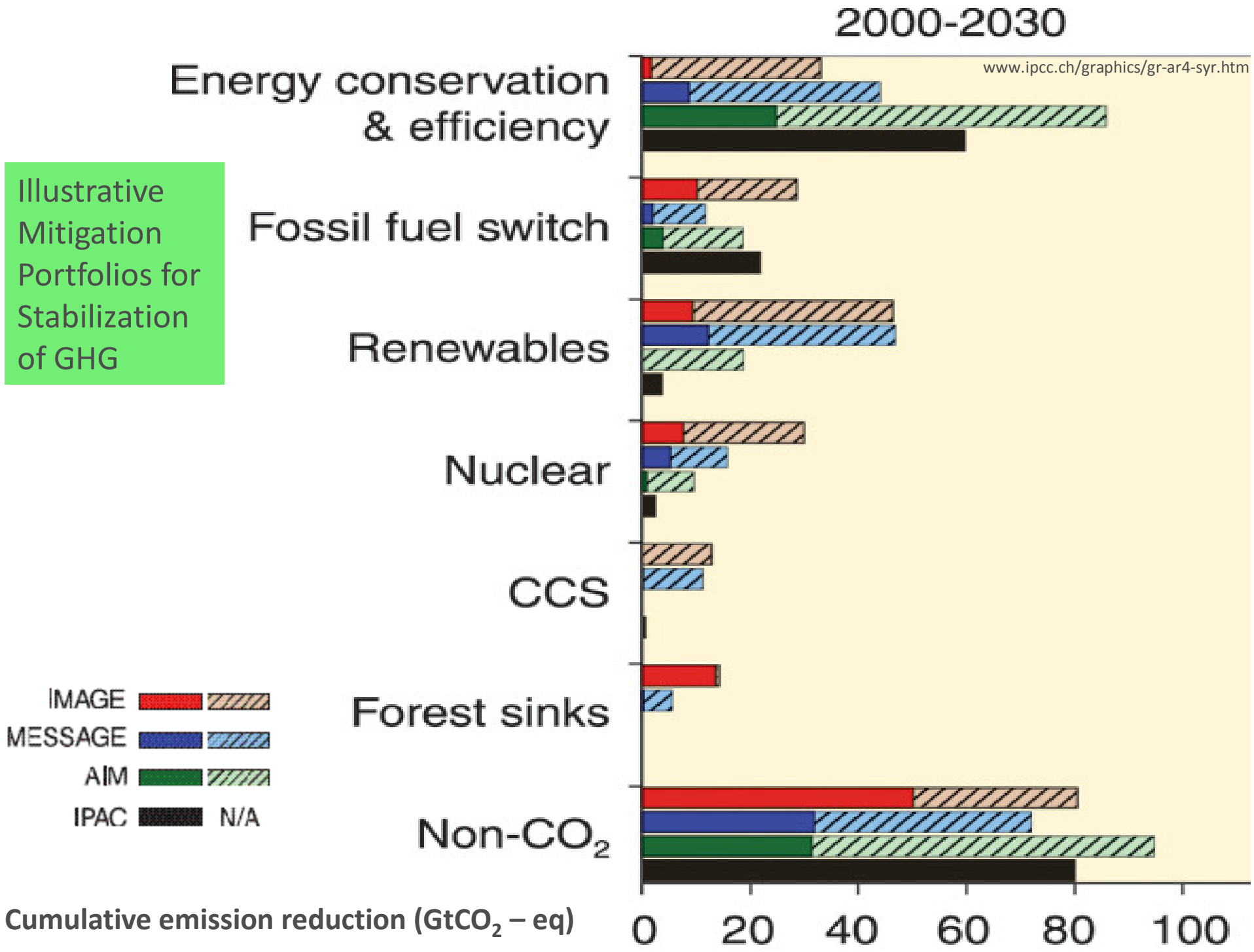


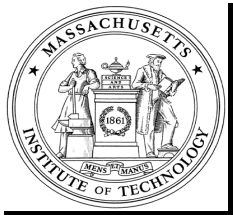
Source: Lawrence Livermore National Laboratory

Illustrative Mitigation Portfolios for Stabilization of GHG Concentrations 2000-2100

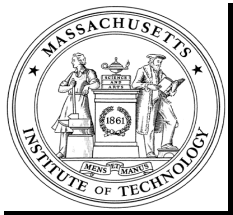


Illustrative Mitigation Portfolios for Stabilization of GHG

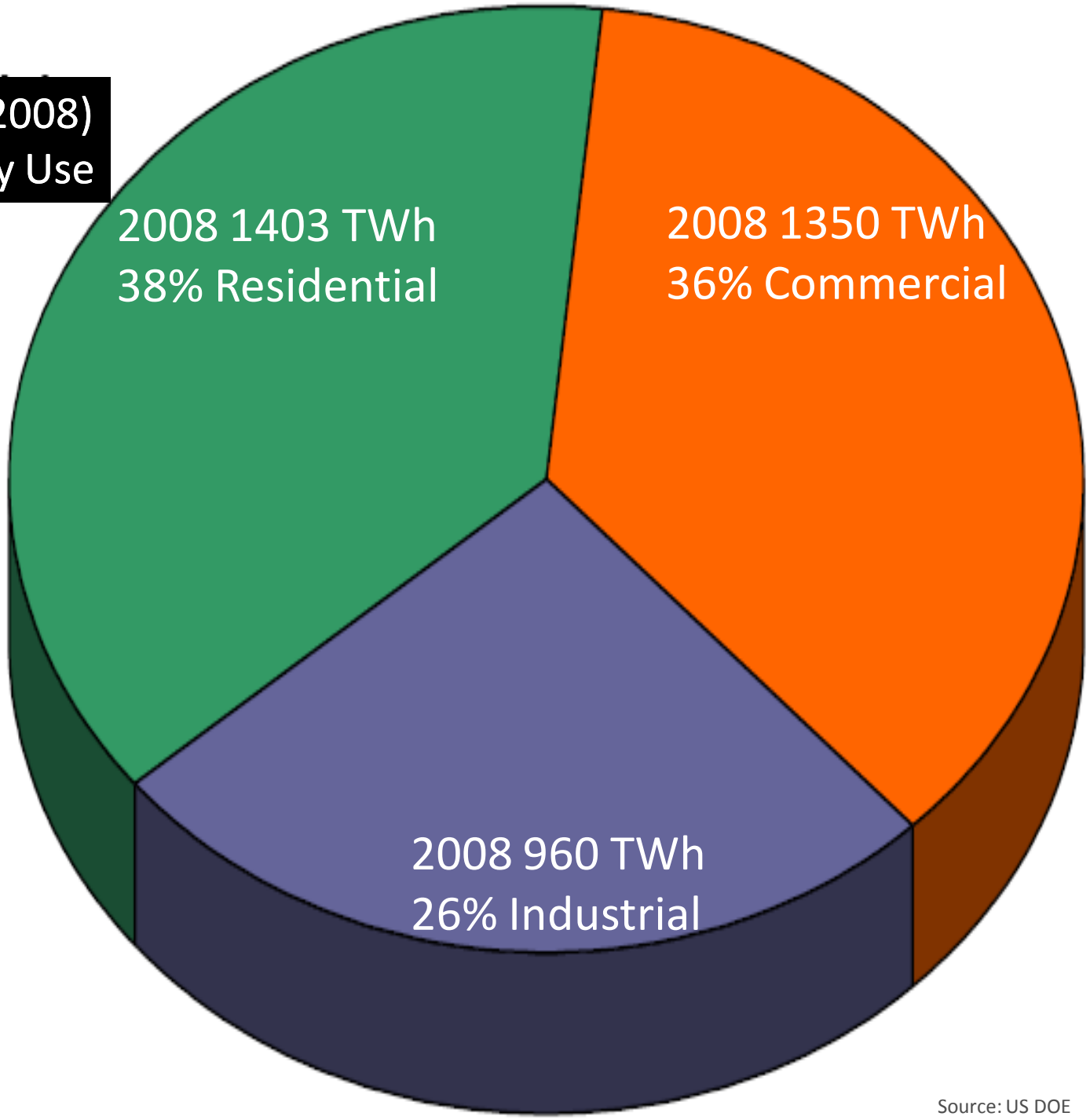




ENERGY CONSUMPTION ANALYSIS

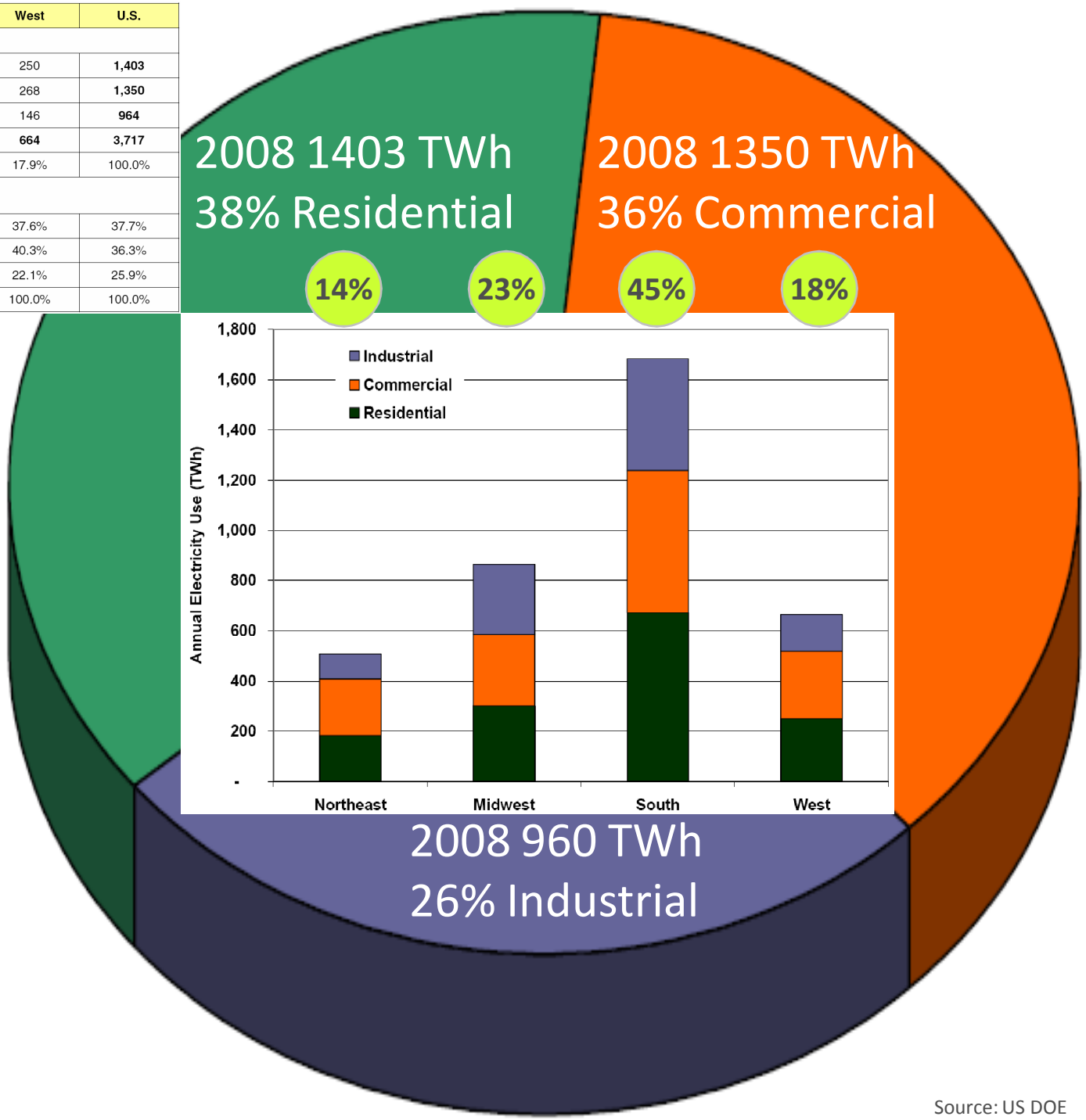


3717 TWh (2008) US Electricity Use



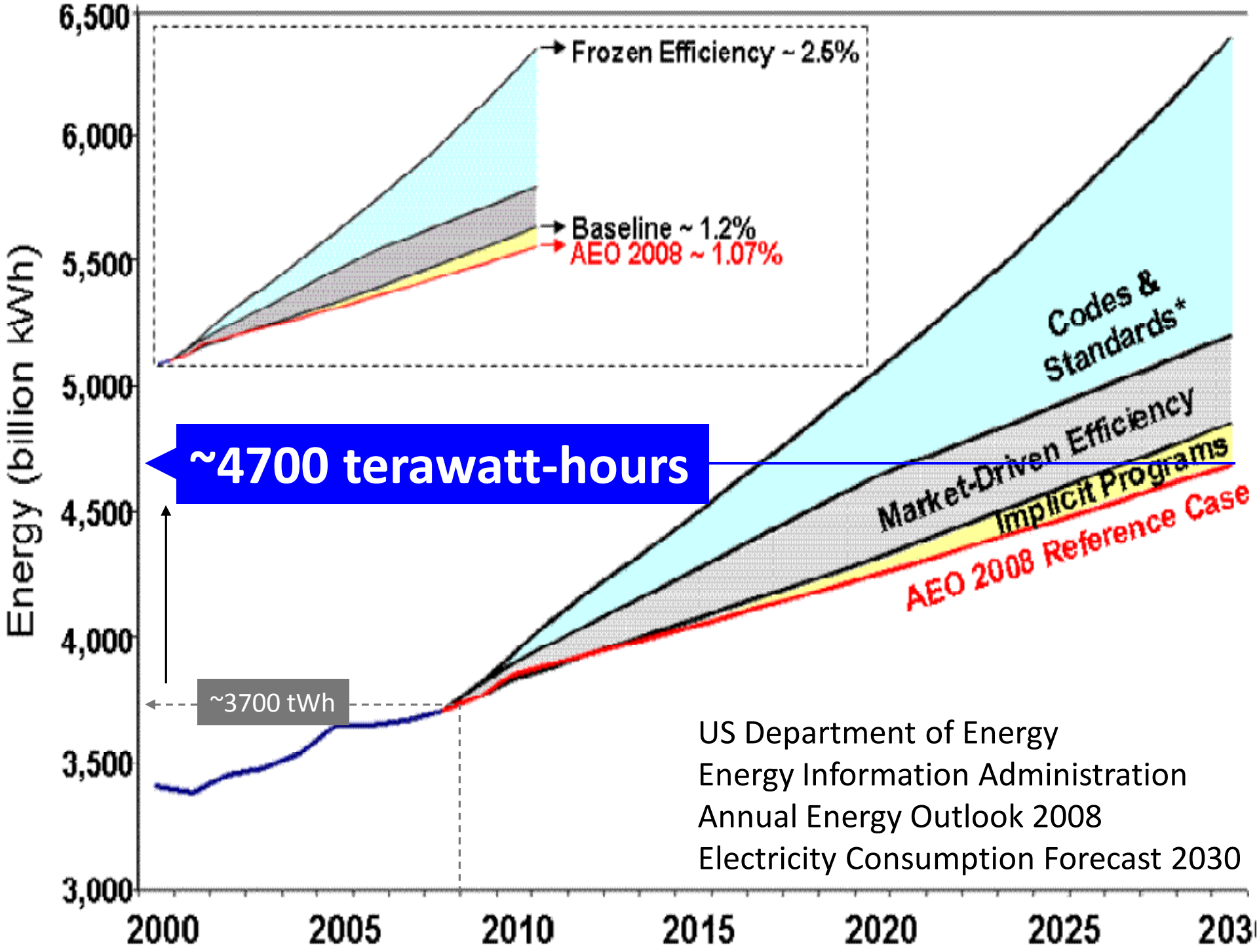
Source: US DOE

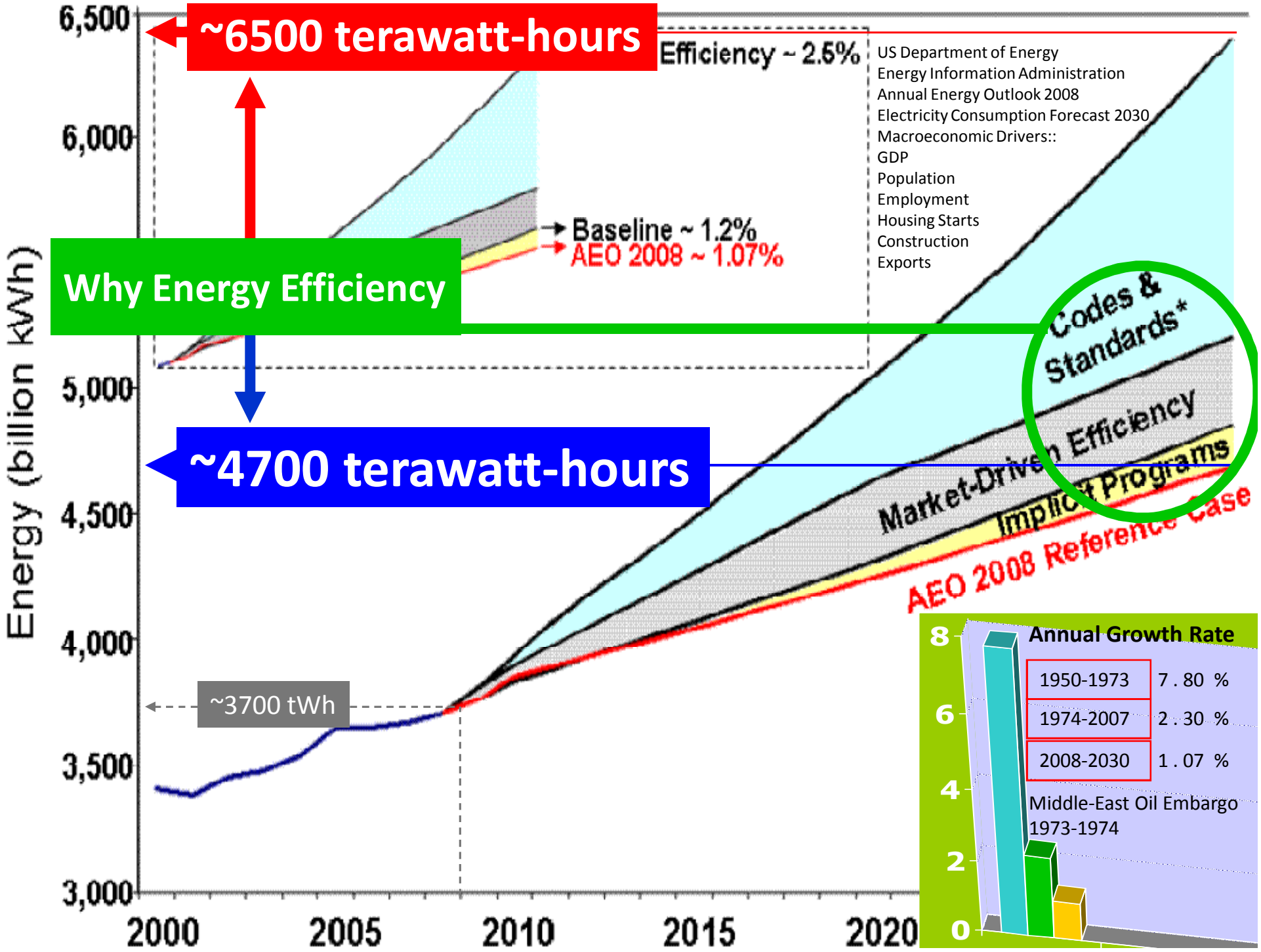
	Northeast	Midwest	South	West	U.S.
2008 TWh					
Residential	183	299	671	250	**1,403**
Commercial	227	287	568	268	**1,350**
Industrial	97	278	443	146	**964**
Total	**507**	**864**	**1,682**	**664**	**3,717**
% of U.S. Total	13.7%	23.2%	45.3%	17.9%	100.0%
Sector Share of Region					
Residential	36.1%	34.6%	39.9%	37.6%	37.7%
Commercial	44.8%	33.2%	33.8%	40.3%	36.3%
Industrial	19.1%	32.2%	26.3%	22.1%	25.9%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

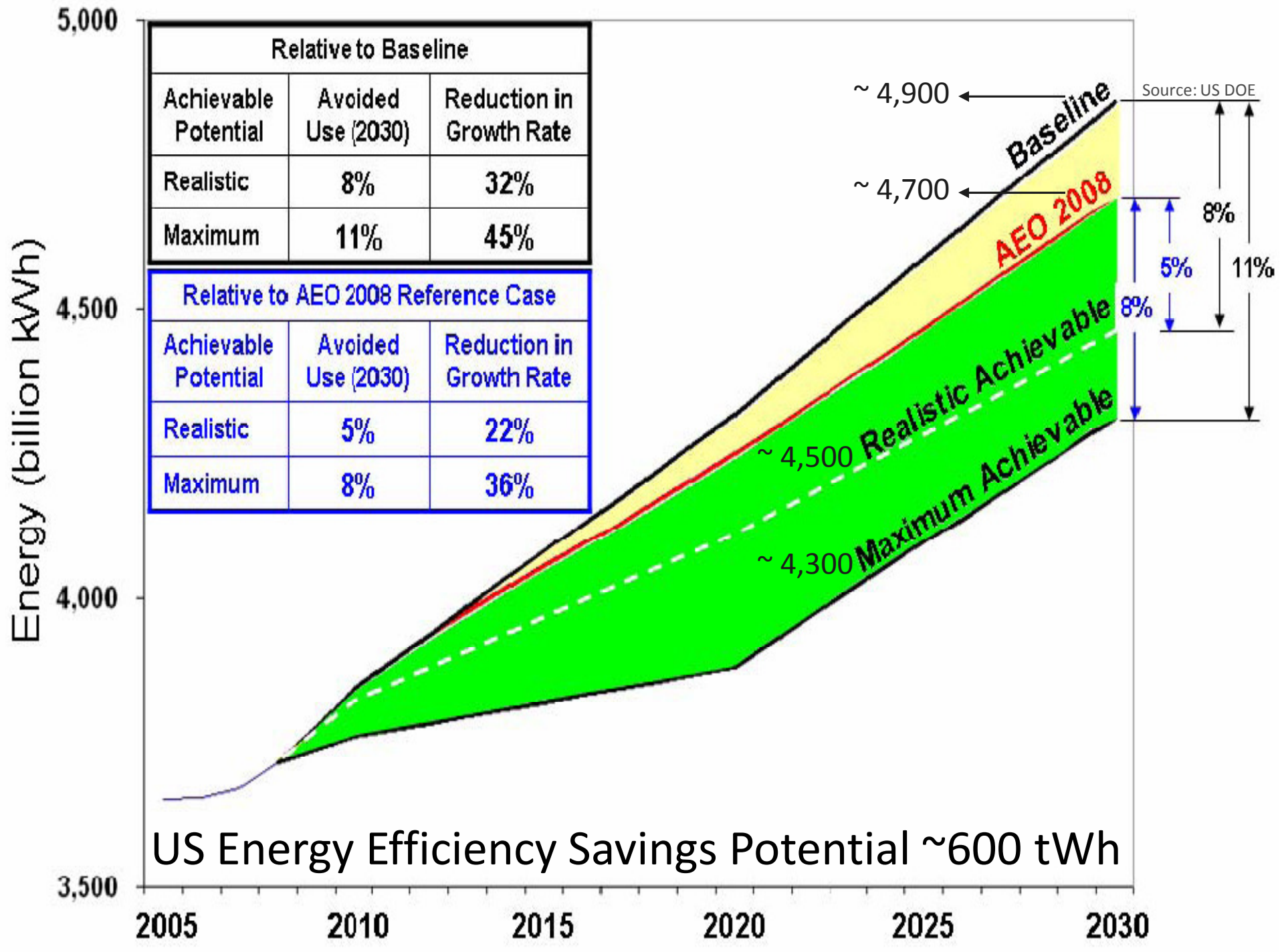


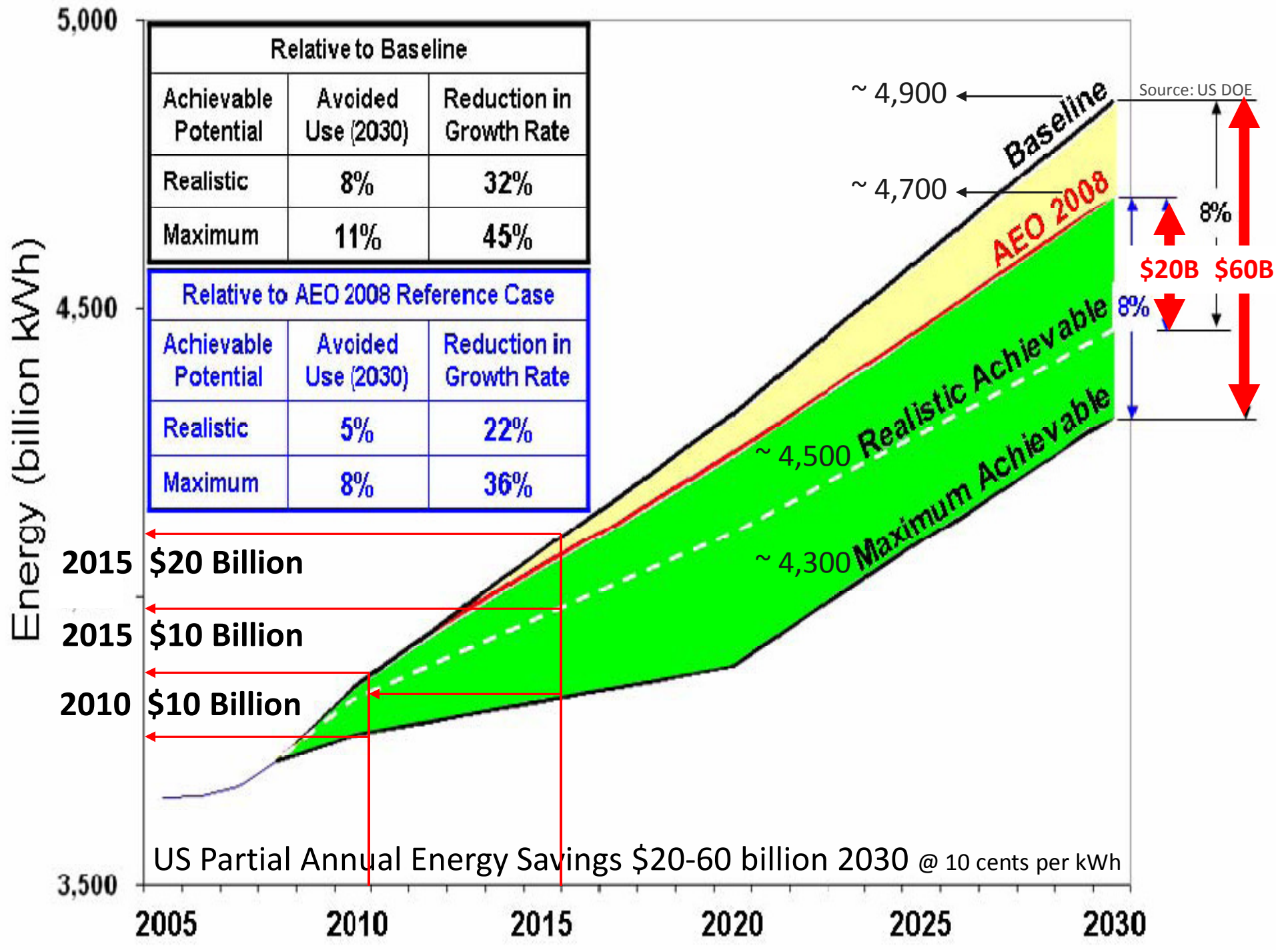
3,717 TWh (2008)
US Electricity Used

Source: US DOE


Energy (billion kWh)
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2000
2005
2010
2015
2020
2025
Frozen Efficiency ~ 2.5%
Baseline ~ 1.2%
AEO 2008 ~ 1.07%
Codes & Standards*
Market-Driven Efficiency
Implicit Programs
AEO 2008 Reference Case
~4700 terawatt-hours
~3700 tWh
US Department of Energy
Energy Information Administration
Annual Energy Outlook 2008
Electricity Consumption Forecast 2030

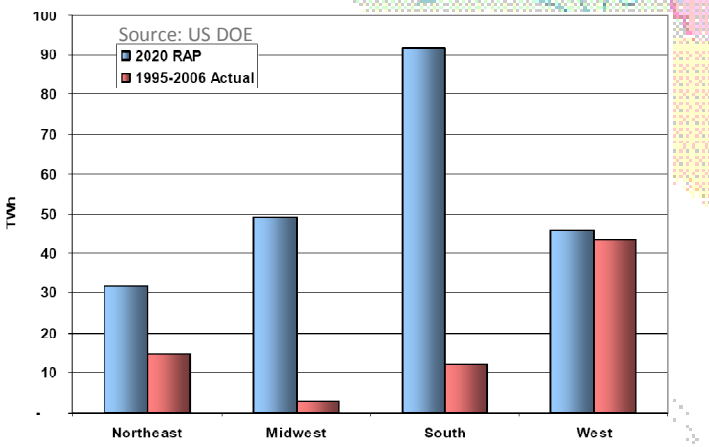

~6500 terawatt-hours
Efficiency ~ 2.5%
US Department of Energy
Energy Information Administration
Annual Energy Outlook 2008
Electricity Consumption Forecast 2030
Macroeconomic Drivers::
GDP
Population
Employment
Housing Starts
Construction
Exports
Baseline ~ 1.2%
AEO 2008 ~ 1.07%
Why Energy Efficiency
~4700 terawatt-hours
Codes & Standards*
Market-Driven Efficiency
Implicit Programs
AEO 2008 Reference Case
~3700 tWh
Energy (billion kWh)
6,500
6,000
5,000
4,500
4,000
3,500
3,000
2000
2005
2010
2015
2020
Annual Growth Rate
1950-1973 7 . 80 %
1974-2007 2 . 30 %
2008-2030 1 . 07 %
Middle-East Oil Embargo
1973-1974
8
6
4
2
0


Relative to Baseline
Achievable Potential | Avoided Use (2030) | Reduction in Growth Rate
Realistic | 8% | 32%
Maximum | 11% | 45%
Relative to AEO 2008 Reference Case
Achievable Potential | Avoided Use (2030) | Reduction in Growth Rate
Realistic | 5% | 22%
Maximum | 8% | 36%
Source: US DOE
~ 4,900
~ 4,700
~ 4,500
~ 4,300
Baseline
AEO 2008
Realistic Achievable
Maximum Achievable
8%
5%
11%
8%
Energy (billion kWh)
5,000
4,500
4,000
3,500
2005
2010
2015
2020
2025
2030
US Energy Efficiency Savings Potential ~600 tWh

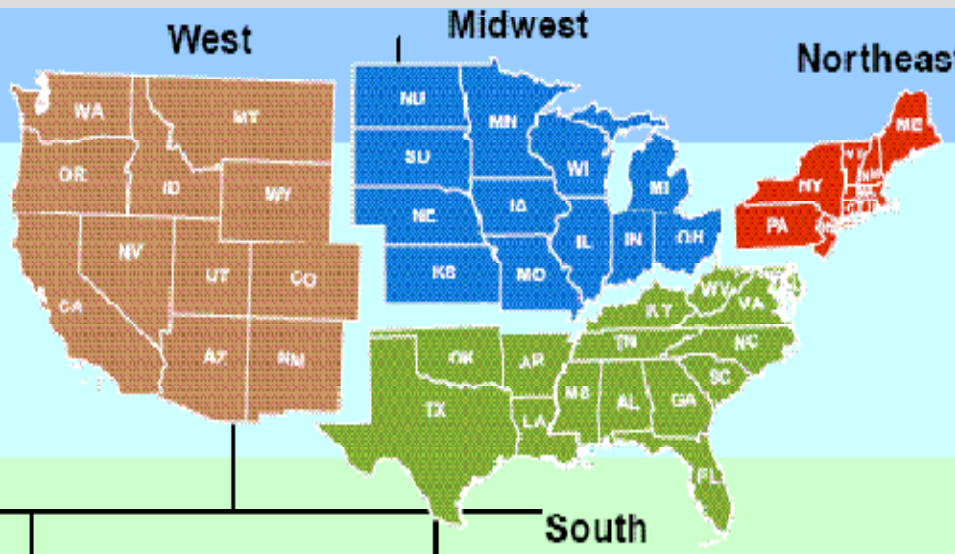

Relative to Baseline
Achievable Potential | Avoided Use (2030) | Reduction in Growth Rate
Realistic | 8% | 32%
Maximum | 11% | 45%
Relative to AEO 2008 Reference Case
Achievable Potential | Avoided Use (2030) | Reduction in Growth Rate
Realistic | 5% | 22%
Maximum | 8% | 36%
Source: US DOE
~ 4,900
~ 4,700
~ 4,500
~ 4,300
Baseline
AEO 2008
Realistic Achievable
Maximum Achievable
8%
8%
$20B
$60B
2015 $20 Billion
2015 $10 Billion
2010 $10 Billion
US Partial Annual Energy Savings $20-60 billion 2030 @ 10 cents per kWh
Energy (billion kWh)
5,000
4,500
3,500
2005
2010
2015
2020
2025
2030

The Business Case: Energy Efficiency Market

Electricity Grid



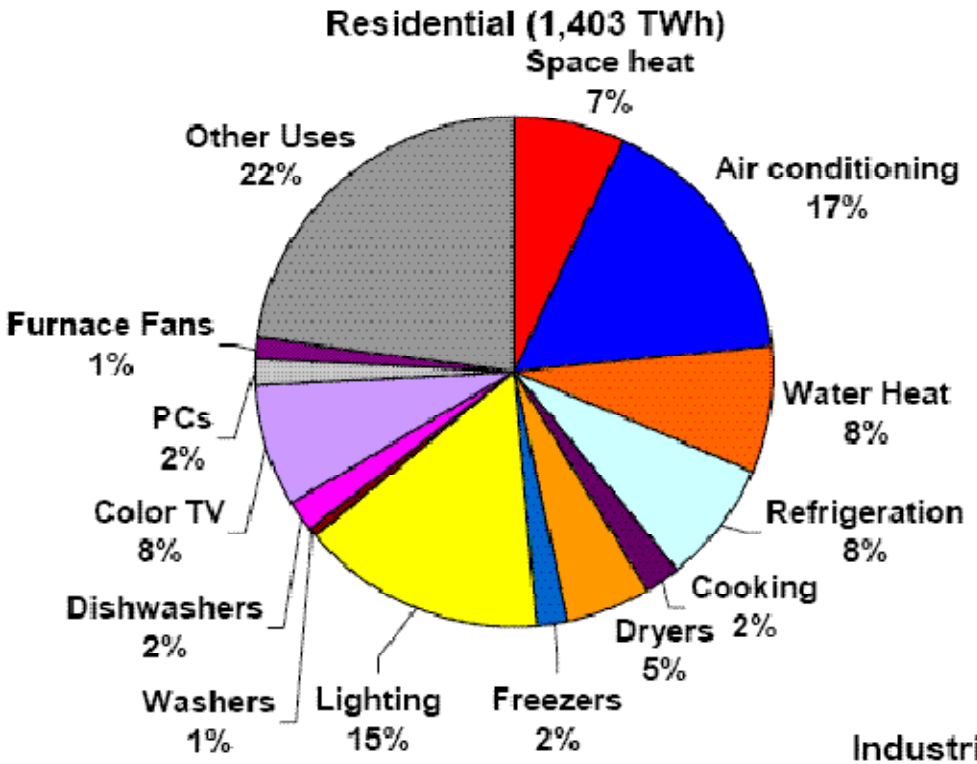
Data Granularity: Key to Energy Efficiency

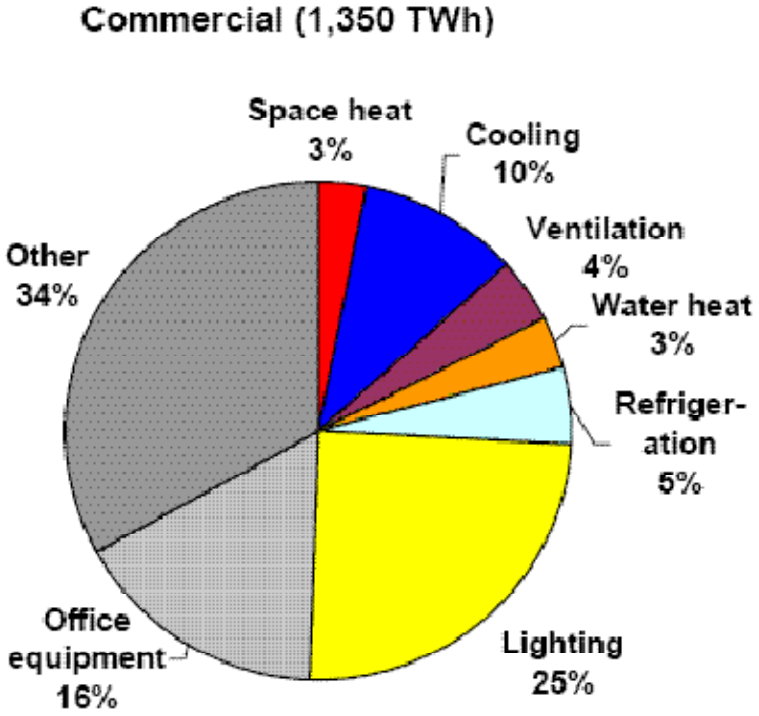


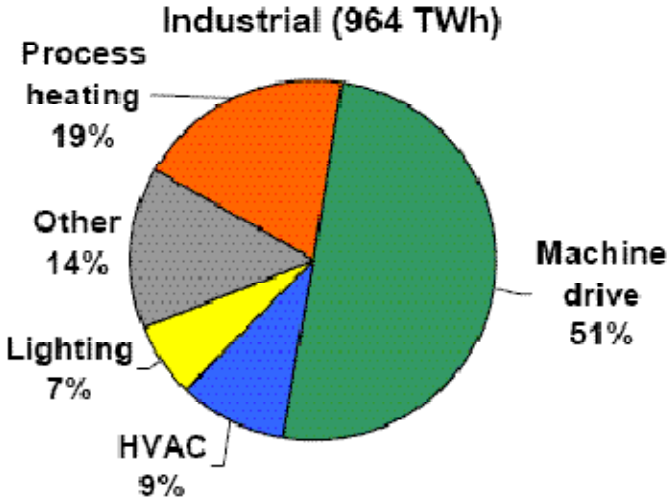
- Residential
- Commercial
  - Lighting
  - Space heating
  - Space cooling
    - Heat pump
    - Central A/C
    - Chiller
    - Other
  - Ventilation
  - Refrigeration
  - Others
- Industrial

Source: US DOE

Defining Energy Efficiency Target - Electricity Consumption 2008







US Department of Energy
Energy Information Administration

Energy Efficiency Measures: Realistic Achievable Potential Savings from Lighting and HVAC [2008 >150 tWh (~ $15 billion)]

Recommended Residential Measures

Efficient lighting and HVAC controls

Efficient space, water heating (heat pumps)
Efficient appliances (IT equipment, electronics, refrigerators, dishwashers, washer-dryer)
Duct repair, insulation, fans, faucet, showerheads
Reflective roof, storm doors, external shades
High-efficiency windows (self-cooling/self-heating)

Recommended Commercial - Industrial Measures

Efficient lighting and HVAC controls

Efficient space, water heating (heat pumps)
Efficient appliances (IT equipment, electronics)
Duct repair, insulation, fans, faucet
Reflective roof, storm doors, external shades
High-efficiency windows
High-efficiency motors and drives

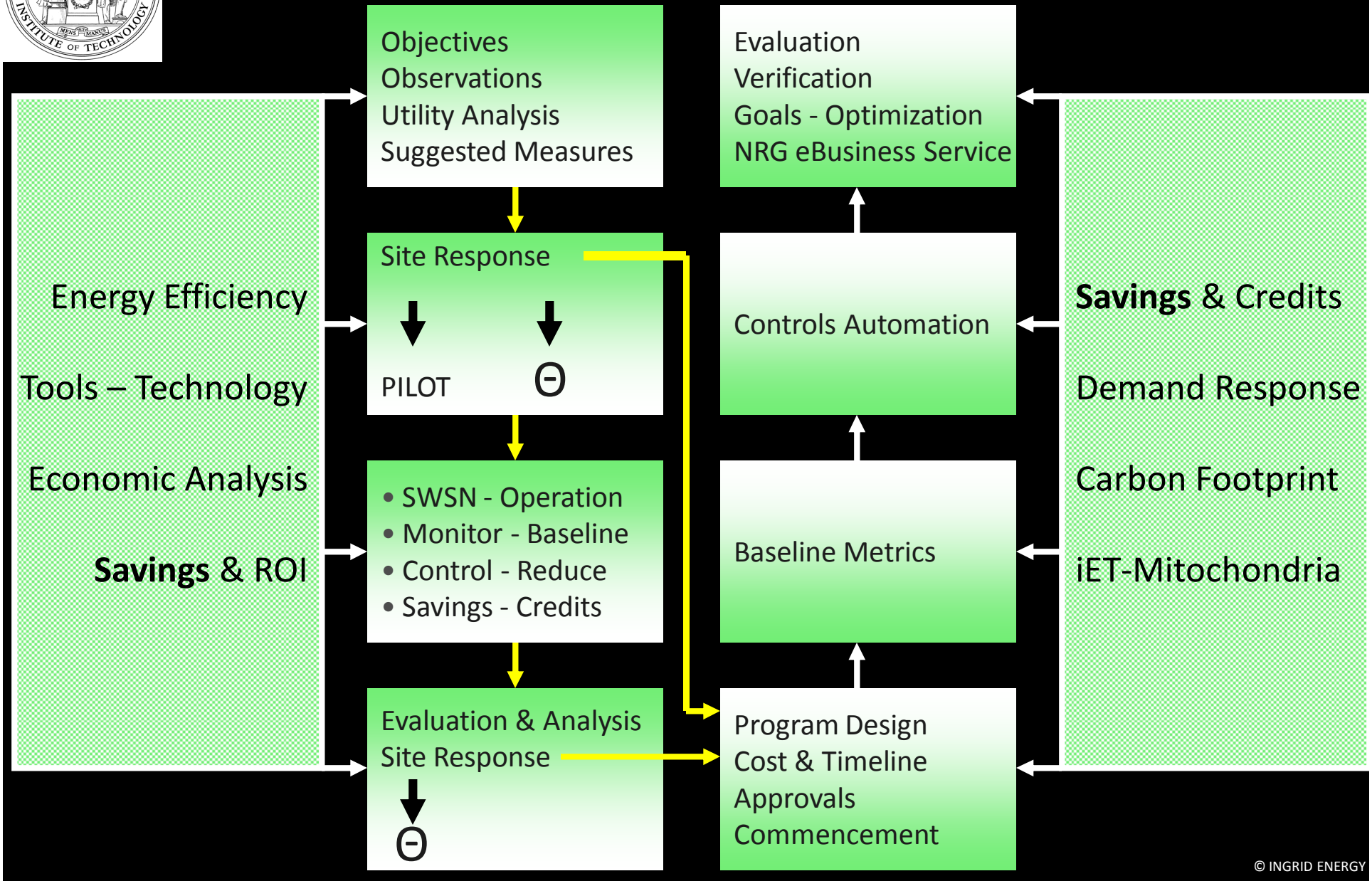
Residential Sector Measures
Efficient air conditioning (central, room, heat pump)
Efficient space heating (heat pumps)
Efficient water heating (e.g. heat pump water heaters & solar water heating)
Efficient appliances (refrigerators, freezers, dishwashers, clothes washers, clothes dryers)
Efficient lighting (CFL, LED, linear fluorescent)
Efficient power supplies for consumer electronics
Air conditioning maintenance
Heat pump maintenance
Duct repair and insulation Infiltration control
Whole-house and ceiling fans
Reflective roof, storm doors, external shades
Roof, wall and foundation insulation
High-efficiency windows
Faucet aerators and low-flow showerheads
Pipe insulation
Programmable thermostats
In-home energy displays

Commercial Sector Measures
Efficient cooling equipment (chillers, central AC)
Efficient space heating (heat pumps)
Efficient water heating equipment (heat pumps)
Efficient refrigeration equipment & controls (e.g. efficient compressors, floating head pressure controls, anti-sweat heater controls, etc.)
Efficient lighting (CFL, LED, linear fluorescent)
Efficient lighting (interior and exterior; LED exit signs, task lighting)
Efficient power supplies IT, electronics, office equipment
Lighting controls (occupancy sensors, daylighting)
AC maintenance
Water temperature reset
Efficient ventilation (air handling, pumps; variable air volume)
Economizers and energy management systems
Programmable thermostats
Duct insulation
Retro-commissioning
High efficiency motors and drives

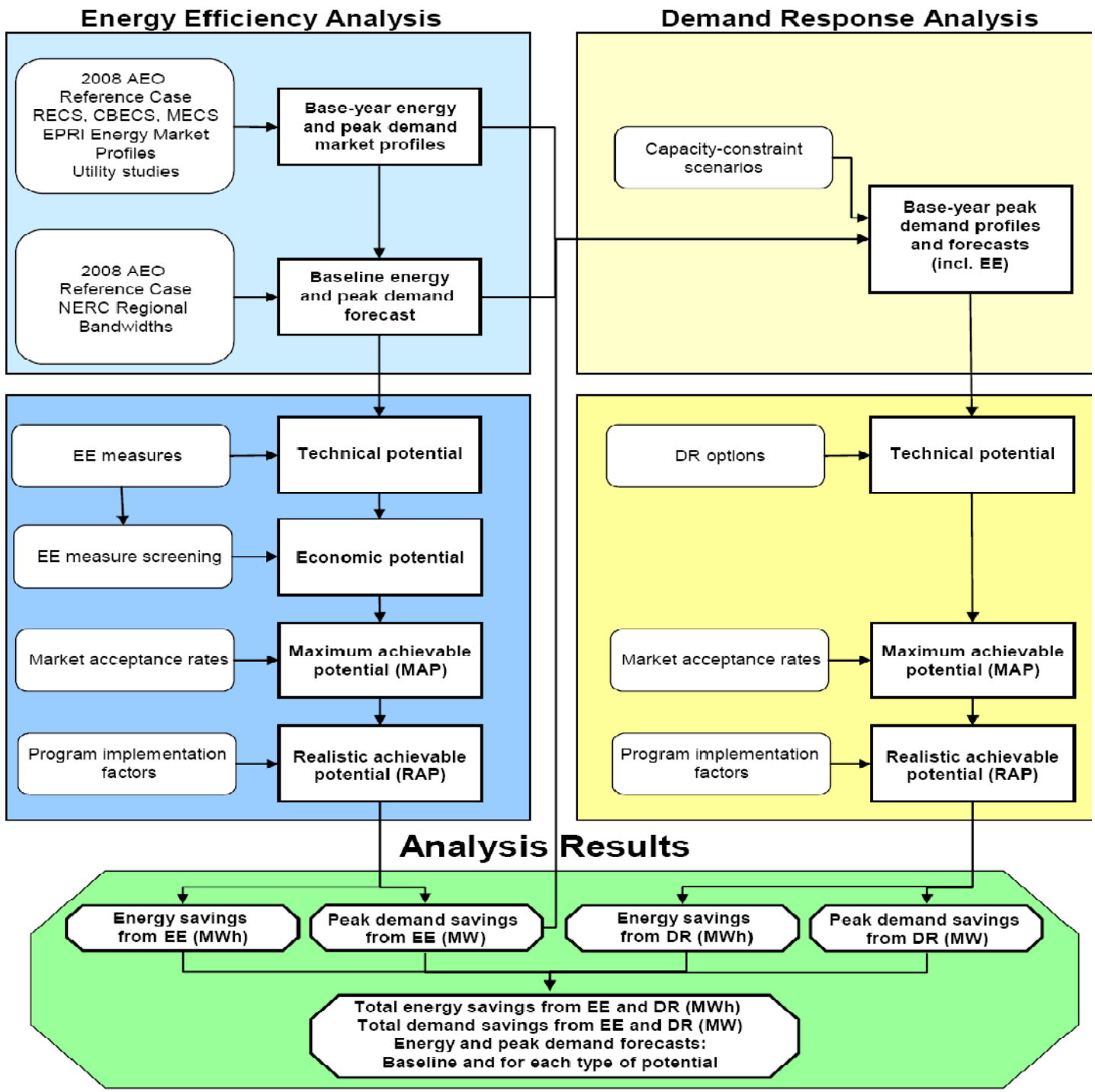
Dr Shoumen Palit Austin Datta < shoumen@mit.edu > MIT Forum for Supply Chain Innovation & MIT School of Engineering

Source: EPRI, DOE

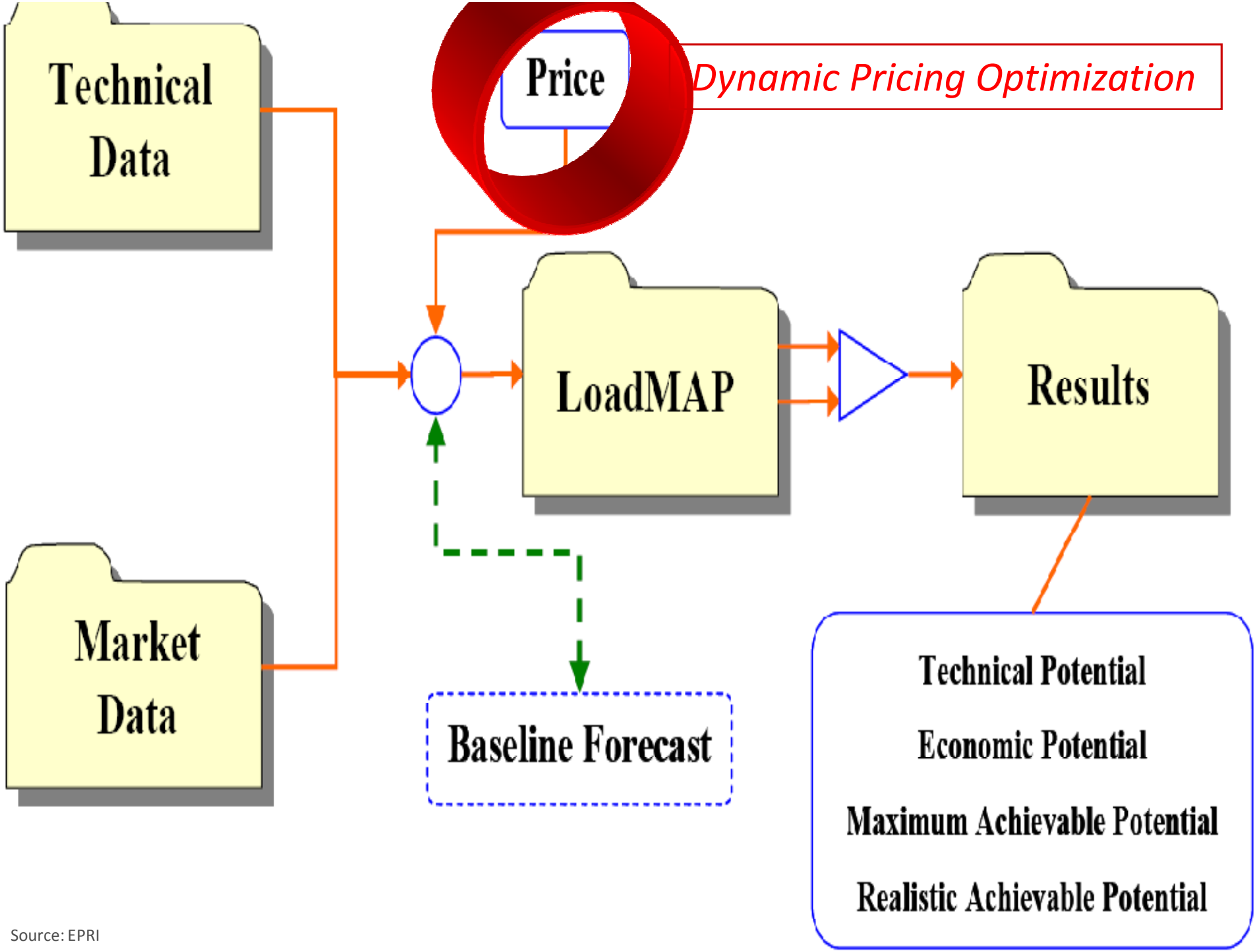
Energy Efficiency Framework for Savings



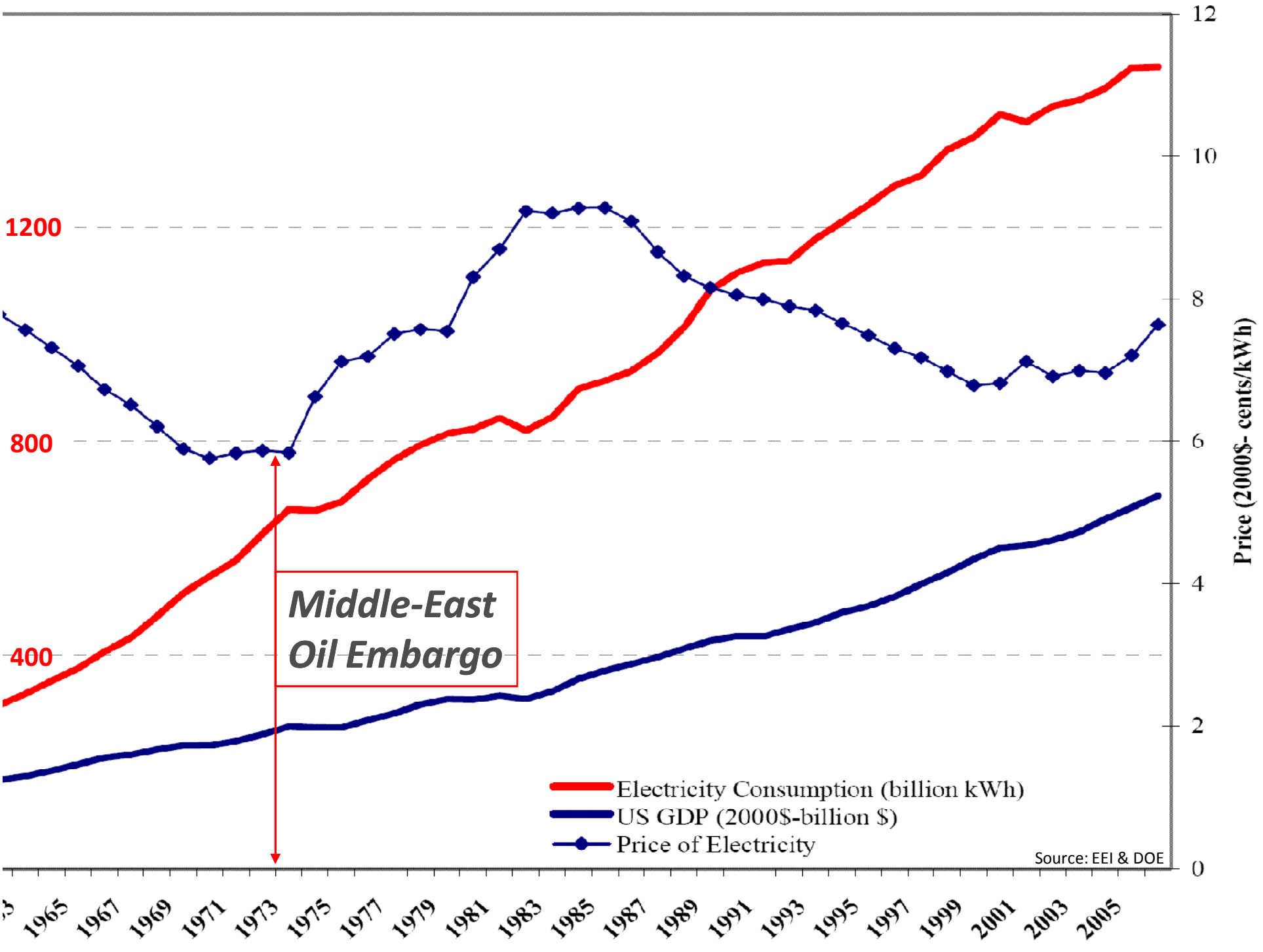
EPRI Framework



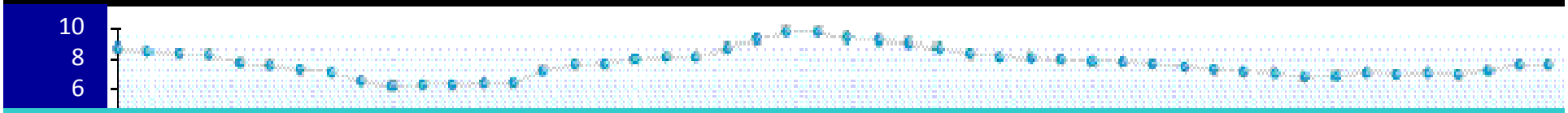
Dr Shoumen Palit Austin Datta


Technical Data
Price
Dynamic Pricing Optimization
LoadMAP
Results
Market Data
Baseline Forecast
Technical Potential
Economic Potential
Maximum Achievable Potential
Realistic Achievable Potential

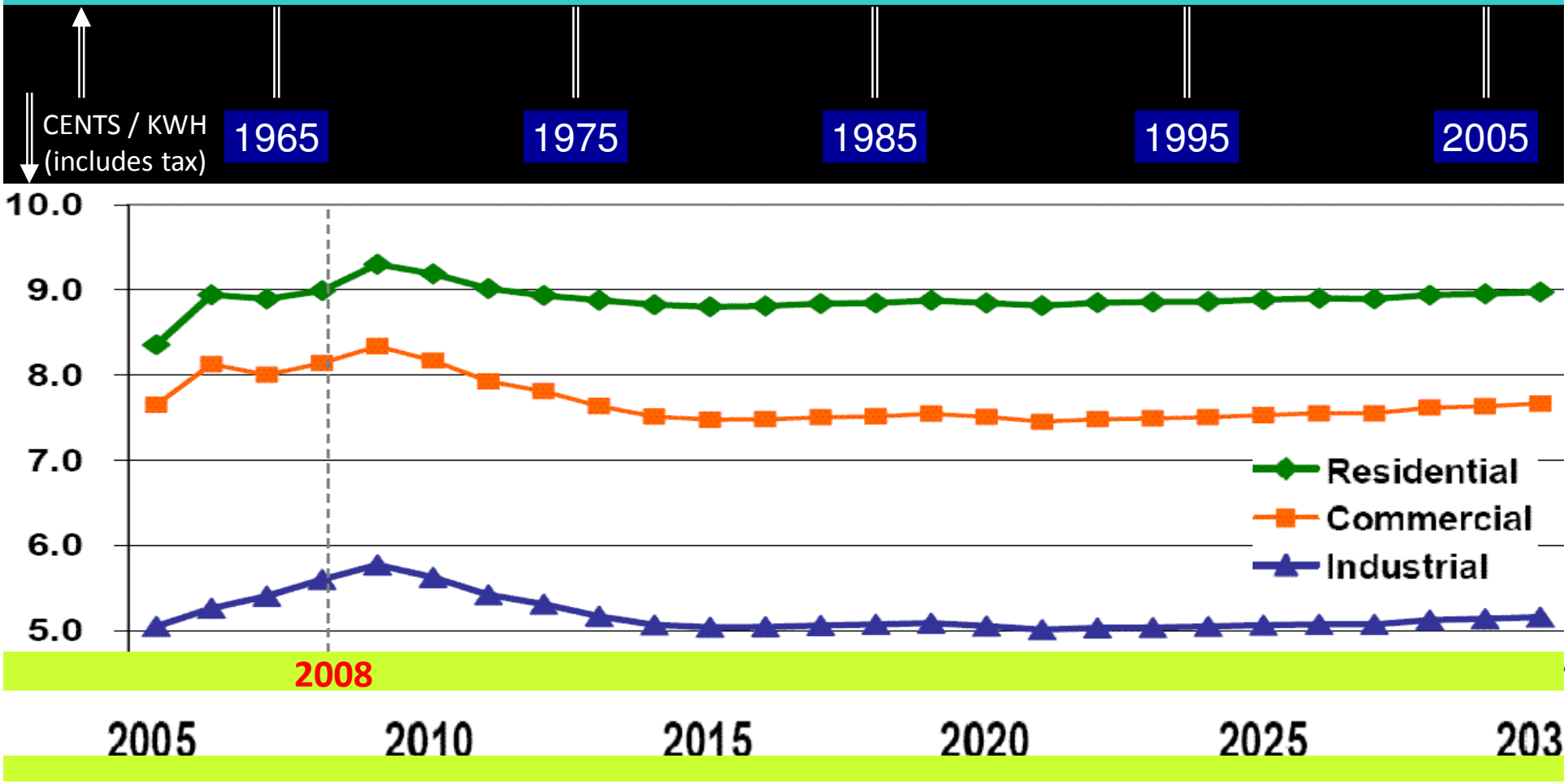
Source: EPRI

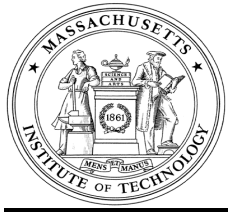

12
10
8
6
4
2
0
1200
800
400
Price (2000$- cents/kWh)
Middle-East
Oil Embargo
Electricity Consumption (billion kWh)
US GDP (2000$-billion $)
Price of Electricity
Source: EEI & DOE
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005

Law of Constant Pricing : Is it sustainable ?



Real Retail Price for Electricity, US Annual Average (Source: US Department of Energy)





Devices to Monitor and Control with USWSN for Savings and Carbon Credits

Residential Use (kWh)	Northeast	Midwest	South	West	U.S.
Space Heat	538	784	1,163	616	845
Air Conditioning	753	1,425	3,617	1,184	2,064
Furnace Fans	251	316	84	97	170
Water Heating	476	743	1,631	574	988
Refrigerators	960	1,055	961	908	977
Freezers	138	279	221	181	211
Dishwashers	205	245	257	237	243
Cooking	180	260	365	209	274
Clothes Washers	79	95	92	81	88
Clothes Dryers	424	674	858	488	658
Lighting	1,708	1,936	1,980	1,802	1,895
Personal Computers	202	210	206	191	204
Color TV	932	1,003	990	888	966
Other Uses	1,947	2,902	3,677	1,997	2,823
Total (2008)	**8,793**	**11,927**	**16,101**	**9,454**	**12,407**

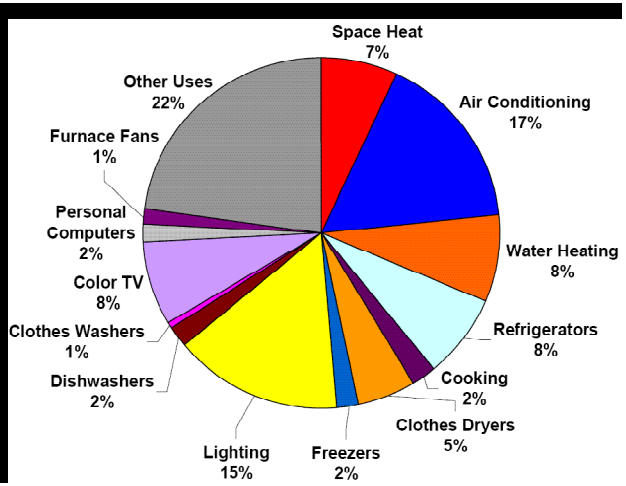
Source: US DOE

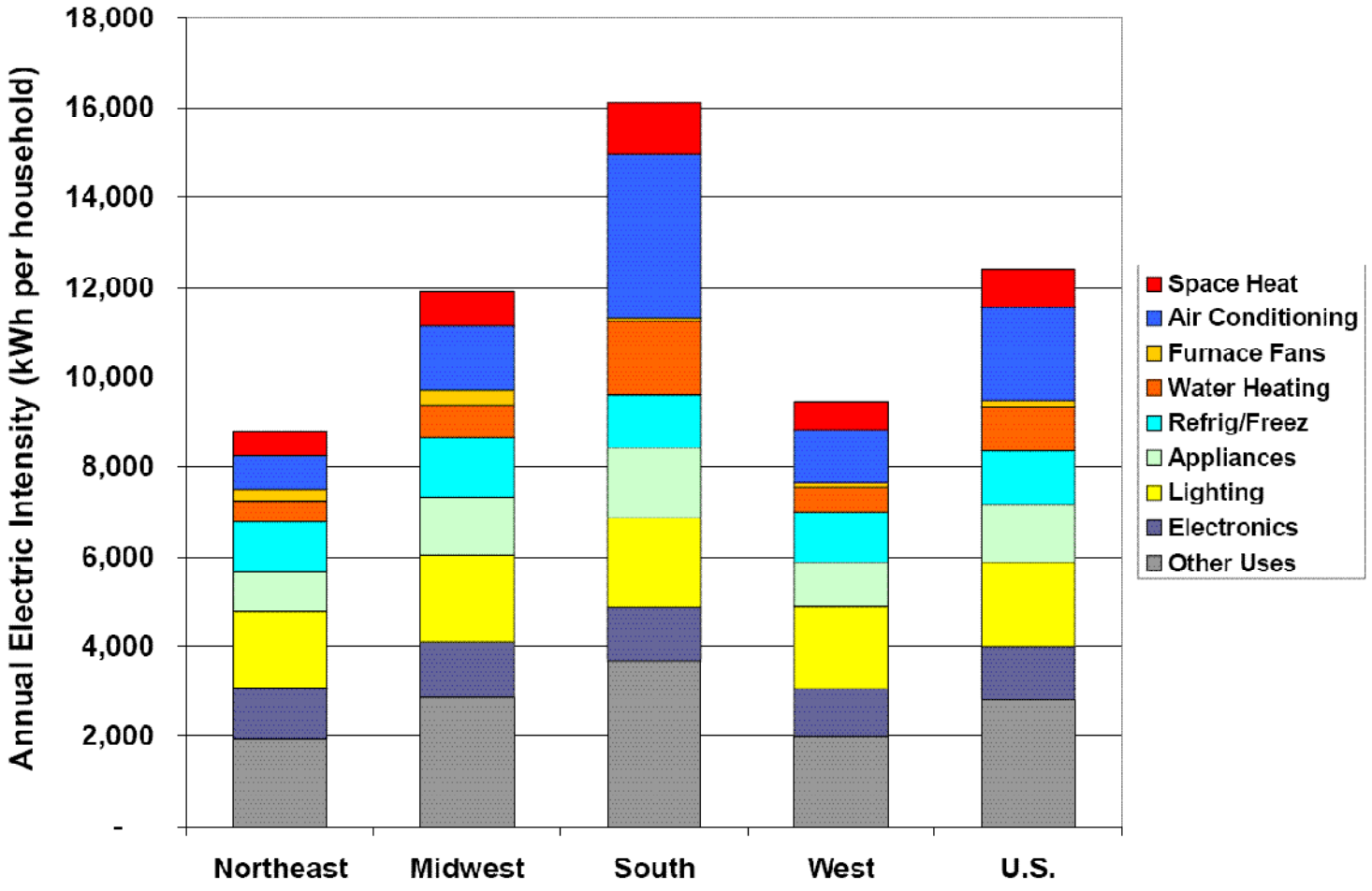
RESIDENTIAL

HVAC + LIGHTING = 47%

Green Card
Annual $10,000
HVACL 47%
Savings 10%
Actual $470

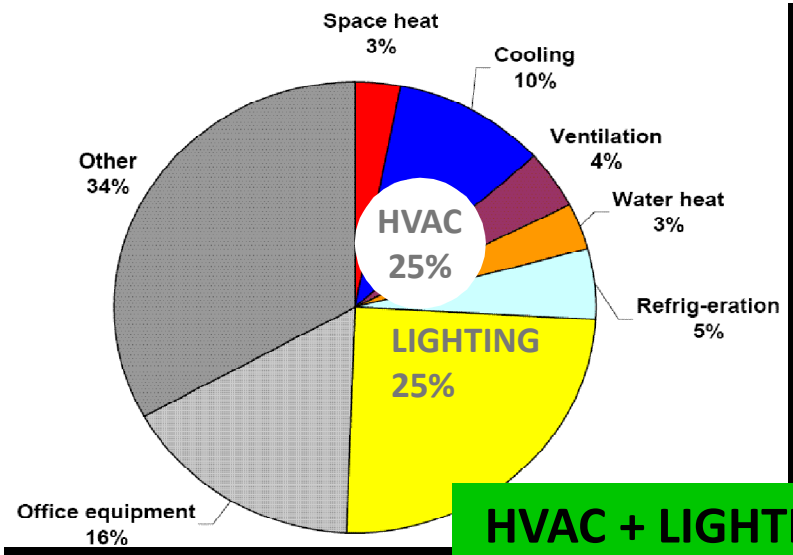
Target Devices to Monitor and Control with USWSN for Savings and Carbon Credits





Source: US DOE

Dr Shoumen Palit Austin Datta



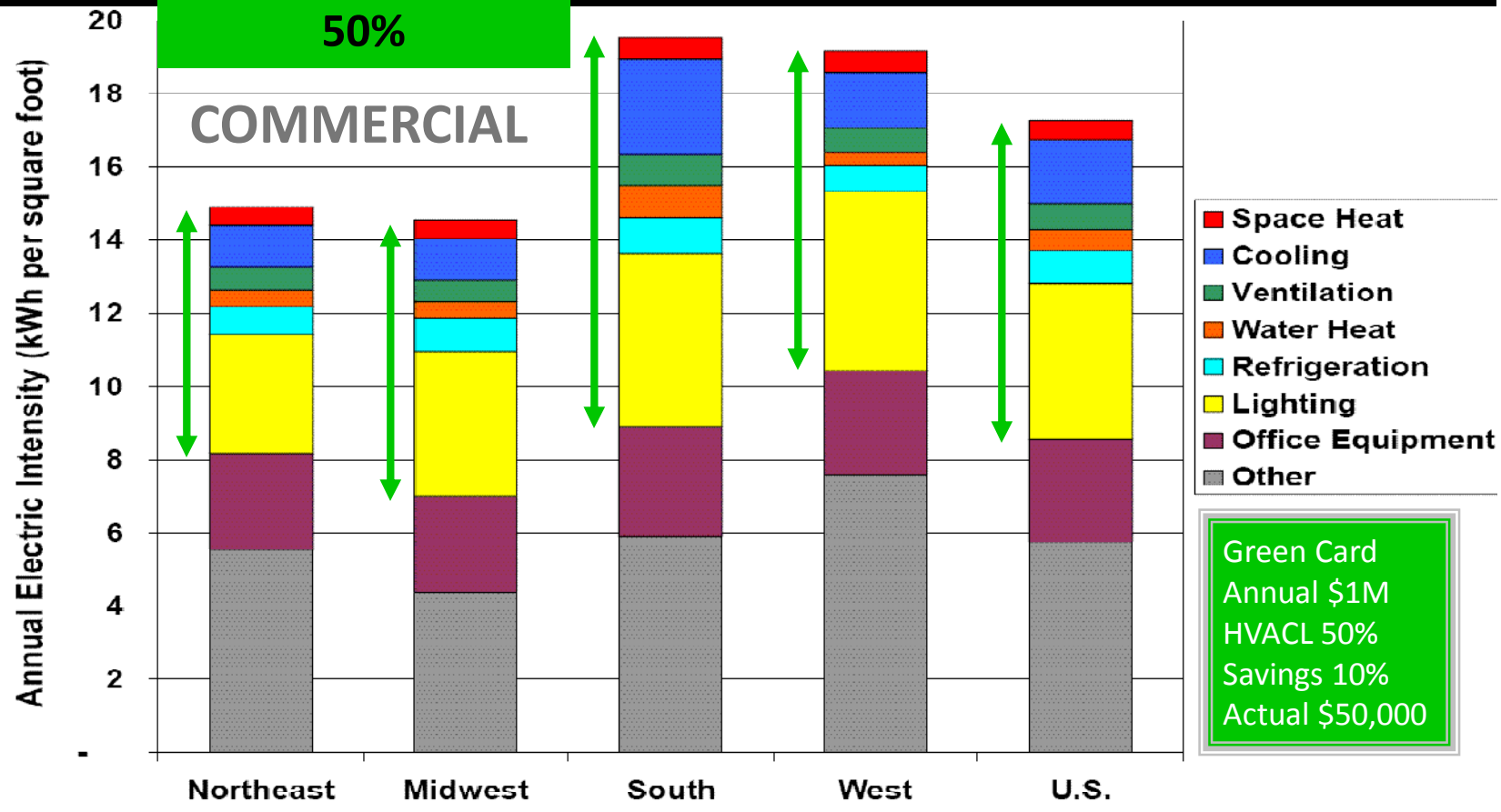
Commercial (kWh/sq ft)	Northeast	Midwest	South	West	U.S.
Space Heat	0.5	0.5	0.6	0.6	0.5
Cooling	1.1	1.1	2.6	1.5	1.8
Ventilation	0.6	0.6	0.9	0.7	0.7
Water Heat	0.5	0.4	0.9	0.4	0.6
Refrigeration	0.8	0.9	1.0	0.7	0.9
Lighting	3.2	4.0	4.7	4.9	4.3
Office Equipment	2.6	2.7	3.0	2.9	2.8
Other	5.6	4.4	5.9	7.6	5.7
(2008) TOTAL	**14.9**	**14.6**	**19.5**	**19.2**	**17.3**

HVAC + LIGHTING 50%

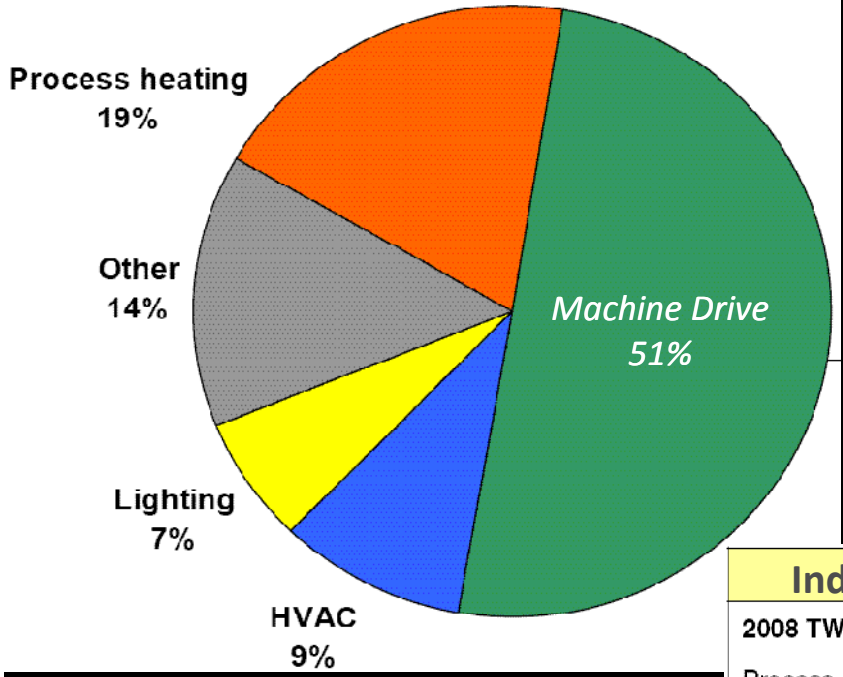
Target Devices to Monitor and Control with USWSN for Savings and Carbon Credits

Source: US DOE

Dr Shoumen Palit



Green Card
Annual $1M
HVACL 50%
Savings 10%
Actual $50,000



Industrial Energy Efficiency Market
Different Criteria for Optimization

Different Devices to Monitor and Control

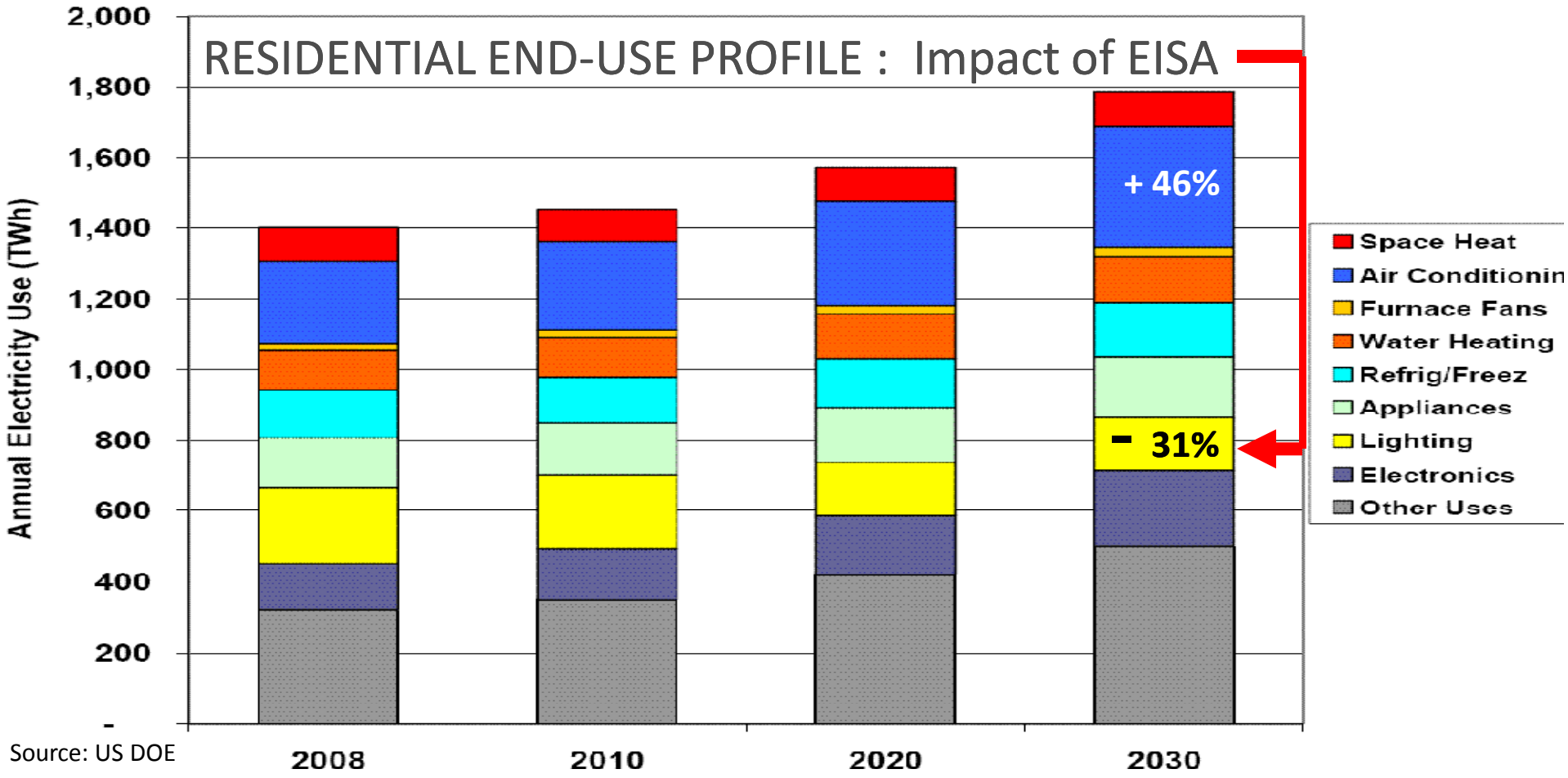
for Savings and Carbon Credits

HVAC + LIGHTING
16%

Industrial	Northeast	Midwest	South	West	U.S.
2008 TWh					
Process Heating	19	58	85	23	**185**
Machine Drive	45	139	228	74	**485**
HVAC	11	24	39	15	**89**
Lighting	9	21	26	10	**66**
Other	13	35	65	25	**138**
Total	**97**	**278**	**444**	**146**	**964**
% of U.S. Total	10%	29%	46%	15%	100%
End Use Share of Region					
Process Heating	20%	21%	19%	16%	19%
Machine Drive	46%	50%	51%	50%	50%
HVAC	12%	9%	9%	10%	9%
Lighting	9%	8%	6%	7%	7%
Other	14%	13%	15%	17%	14%
Total	100%	100%	100%	100%	100%

Dr Shoumen Palit Austin Datta < shoumen@mit.ed

Energy Efficiency Market – Projection through 2030	2008	2010	2020	2030	% Increase (2030/2008)	Average Growth Rate
Residential	1,403	1,454	1,574	1,787	27%	1.1%
Commercial	1,350	1,395	1,710	2,033	51%	1.9%
Industrial	964	992	1,035	1,038	8%	0.3%
Total	**3,717**	**3,841**	**4,319**	**4,858**	**31%**	**1.2%**

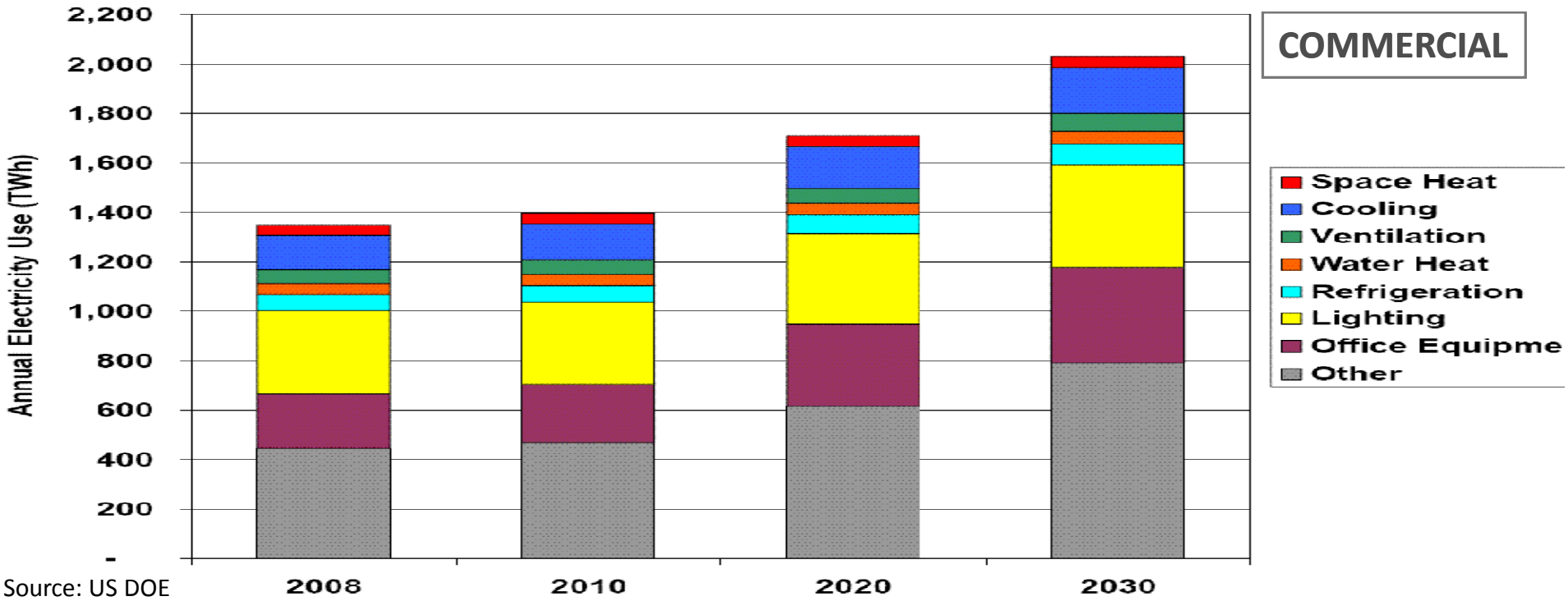


Source: US DOE

Energy Efficiency Market – Projection through 2030

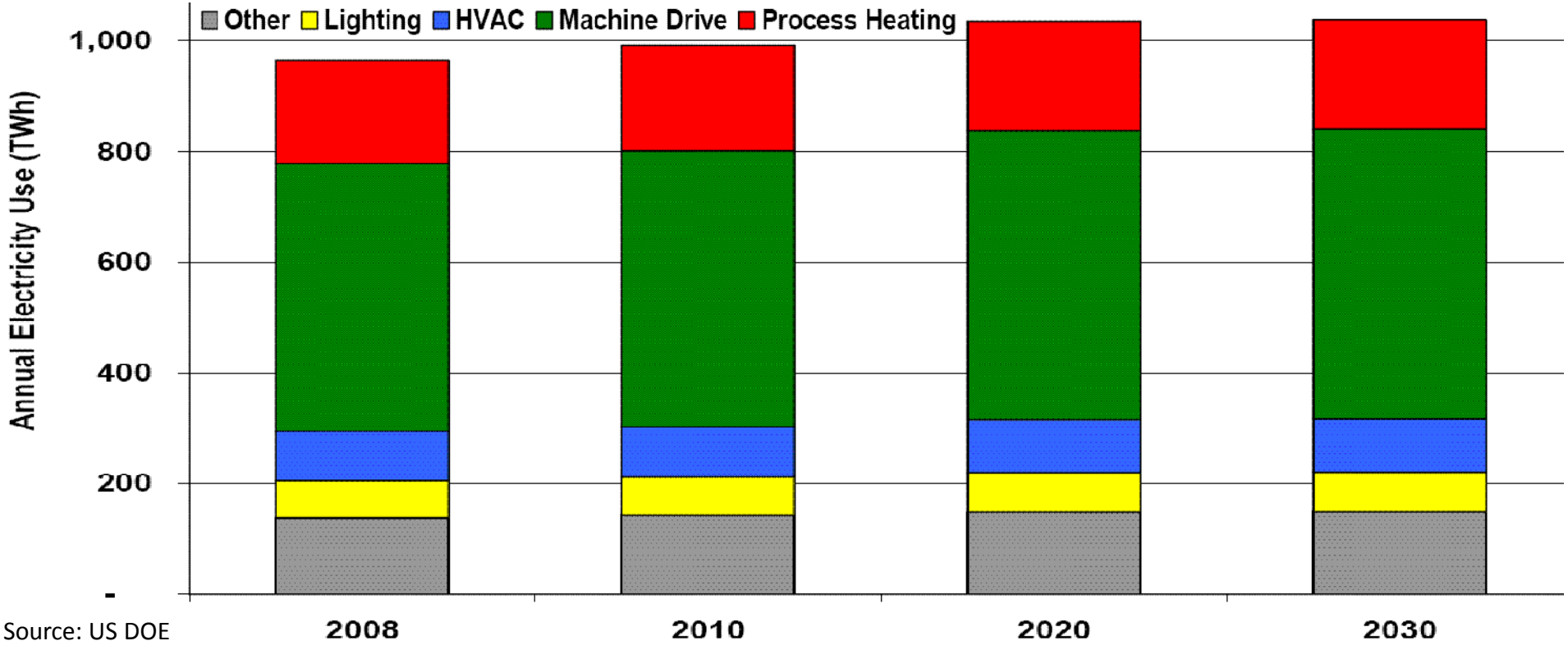
COMMERCIAL	2008	2010	2020	2030	% Increase (2030/2008)	Average Growth Rate
Space Heat	42,451	40,671	43,203	45,528	7%	0.3%
Cooling	137,182	146,578	165,069	187,822	37%	1.4%
Ventilation	55,426	55,992	63,071	70,981	28%	1.1%
Water Heat	45,725	45,201	48,352	49,677	9%	0.4%
Refrigeration	68,086	68,965	76,176	85,823	26%	1.1%
Lighting	333,500	330,590	367,265	412,710	24%	1.0%
Office Equipment	220,305	237,646	329,328	389,320	77%	2.6%
Other	447,709	469,759	617,659	791,100	77%	2.6%
Total (GWH)	**1,350,385**	**1,395,401**	**1,710,122**	**2,032,961**	**51%**	**1.9%**

HVAC+L



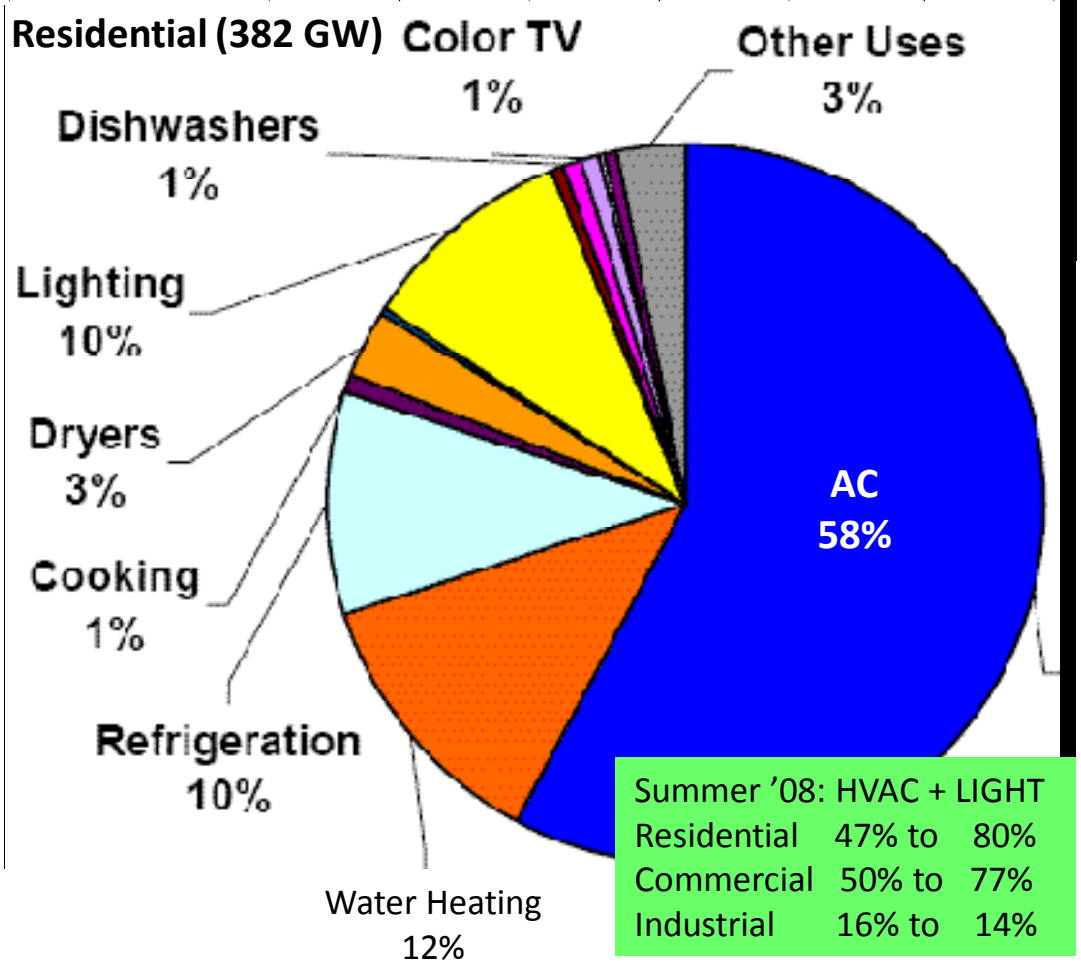
Source: US DOE

US Industrial Sector Electricity Forecast	2008	2010	2020	2030	% Increase (2030/2008)	Average Growth Rate
Process Heating	185,139	190,376	198,226	198,229	7%	0.3%
Machine Drive	485,302	499,350	521,709	523,702	8%	0.3%
HVAC	89,056	91,610	95,578	95,792	8%	0.3%
Lighting	66,201	68,036	70,632	70,390	6%	0.3%
Other	138,330	142,402	149,147	150,130	9%	0.4%
Total (GWH)	**964,028**	**991,774**	**1,035,292**	**1,038,243**	**8%**	**0.3%**



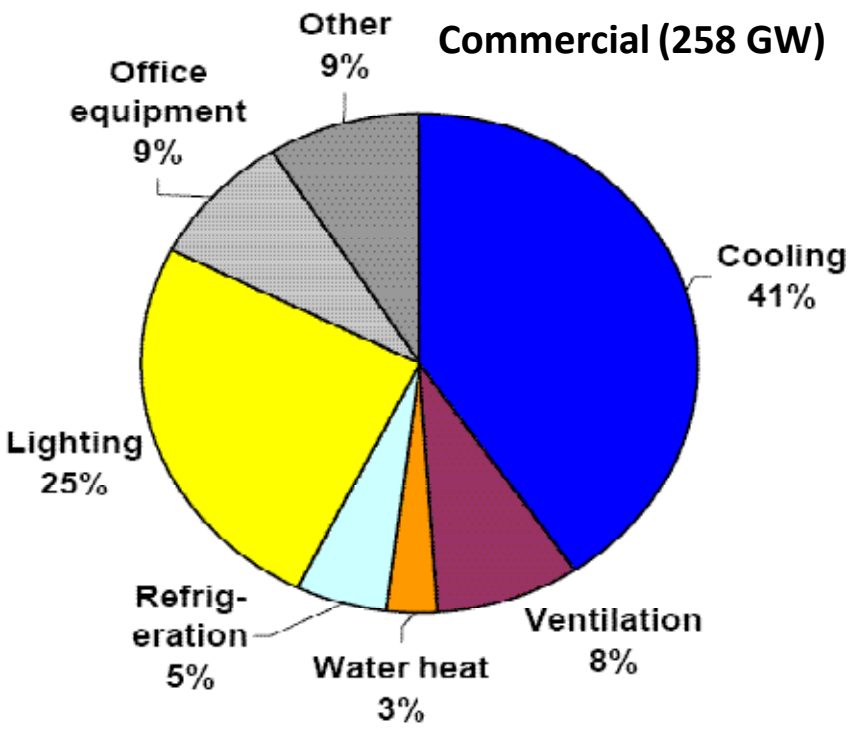
Source: US DOE

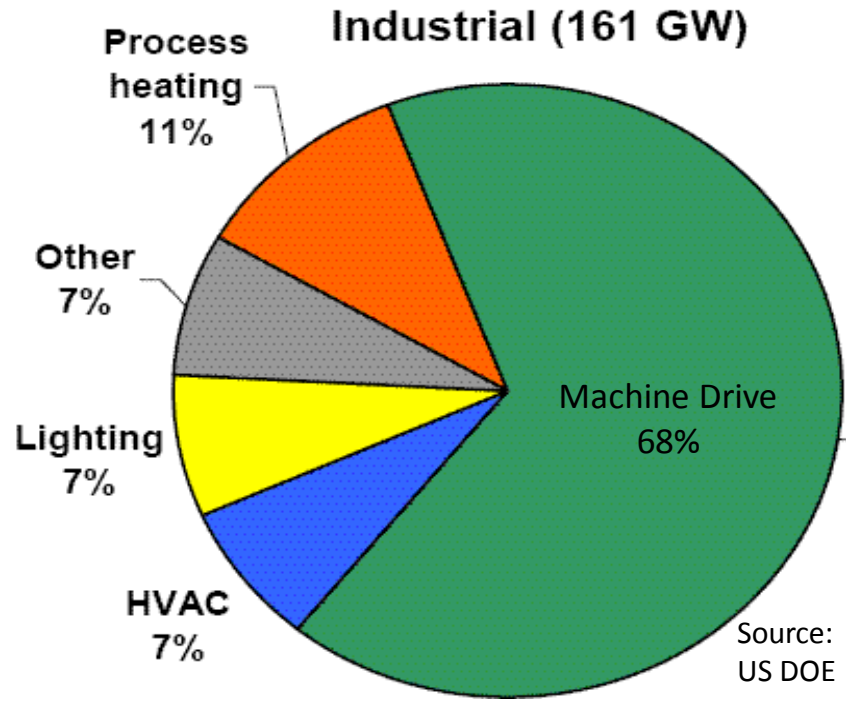
Summer Opportunity: More Savings from Efficiency Summer: HVACL		GW 2008	GW 2010	GW 2020	GW 2030	% Increase (2030/2008)	Average Growth Rate
Residential	80%	382	394	462	536	40%	1.54%
Commercial	77%	258	266	310	359	39%	1.50%
Industrial	14%	161	166	192	222	38%	1.48%
Total		**801**	**826**	**964**	**1,117**	**39%**	**1.51%**



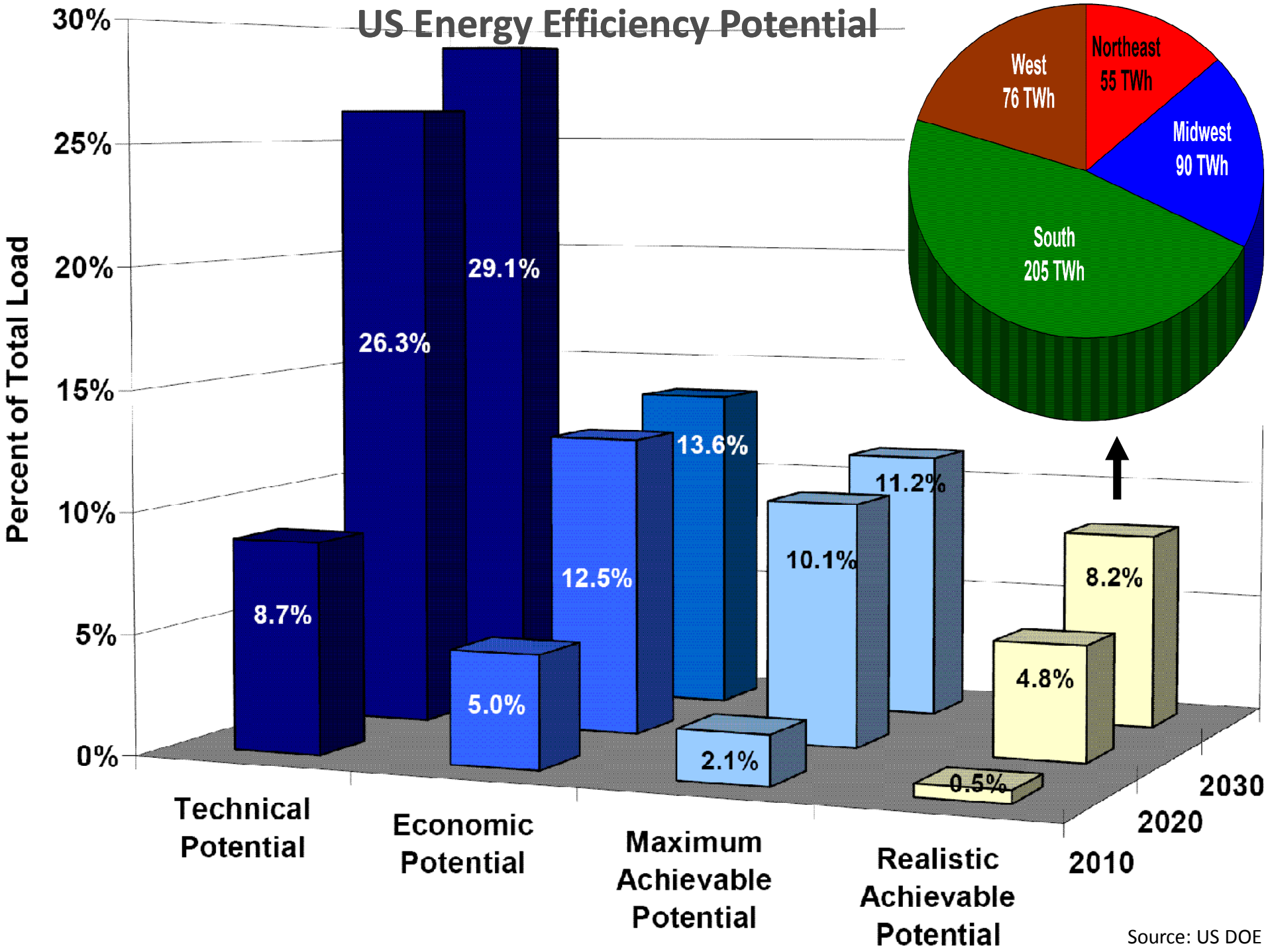
Summer '08: HVAC + LIGHT

Residential	47% to	80%
Commercial	50% to	77%
Industrial	16% to	14%

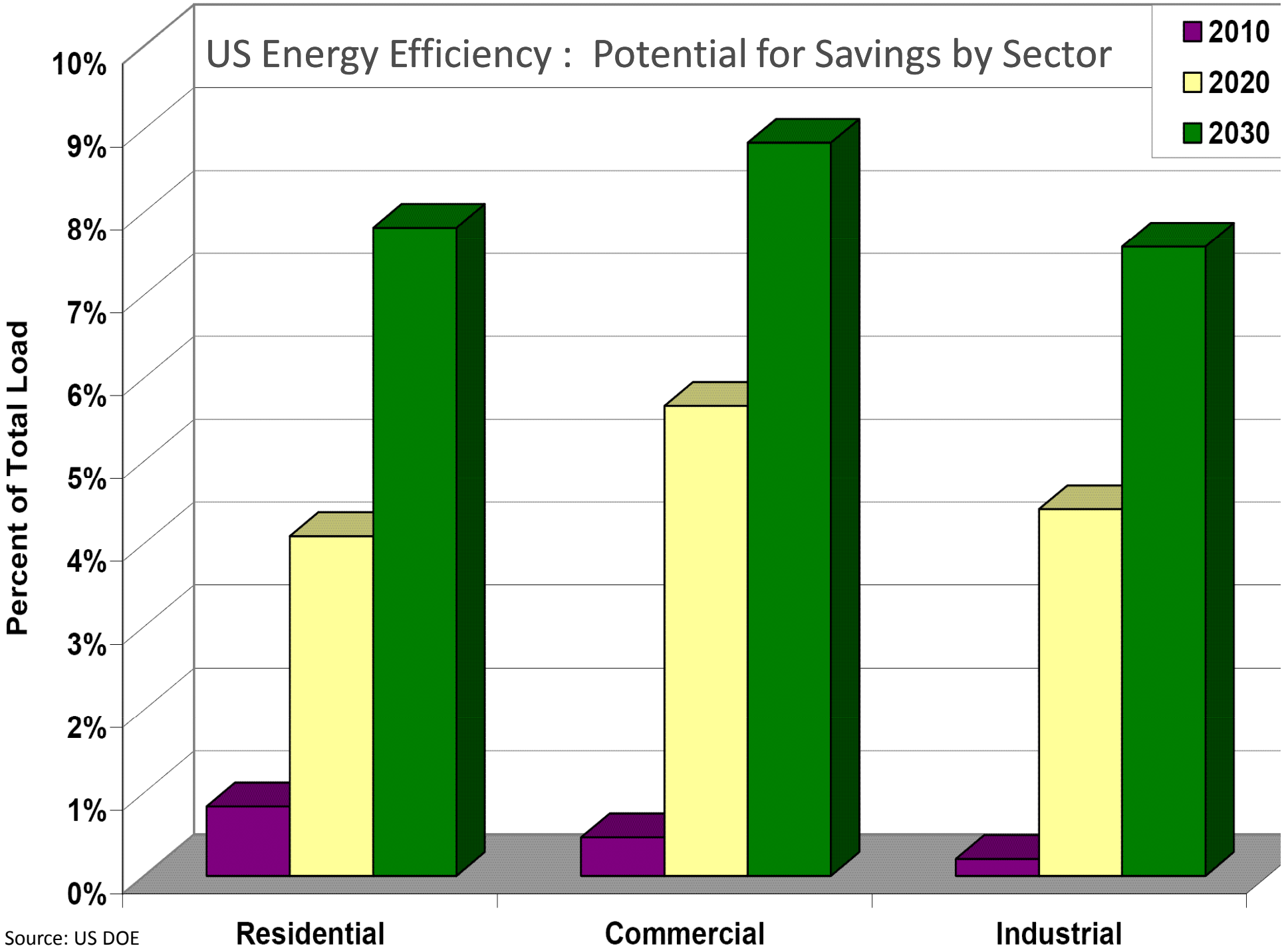




Source: US DOE

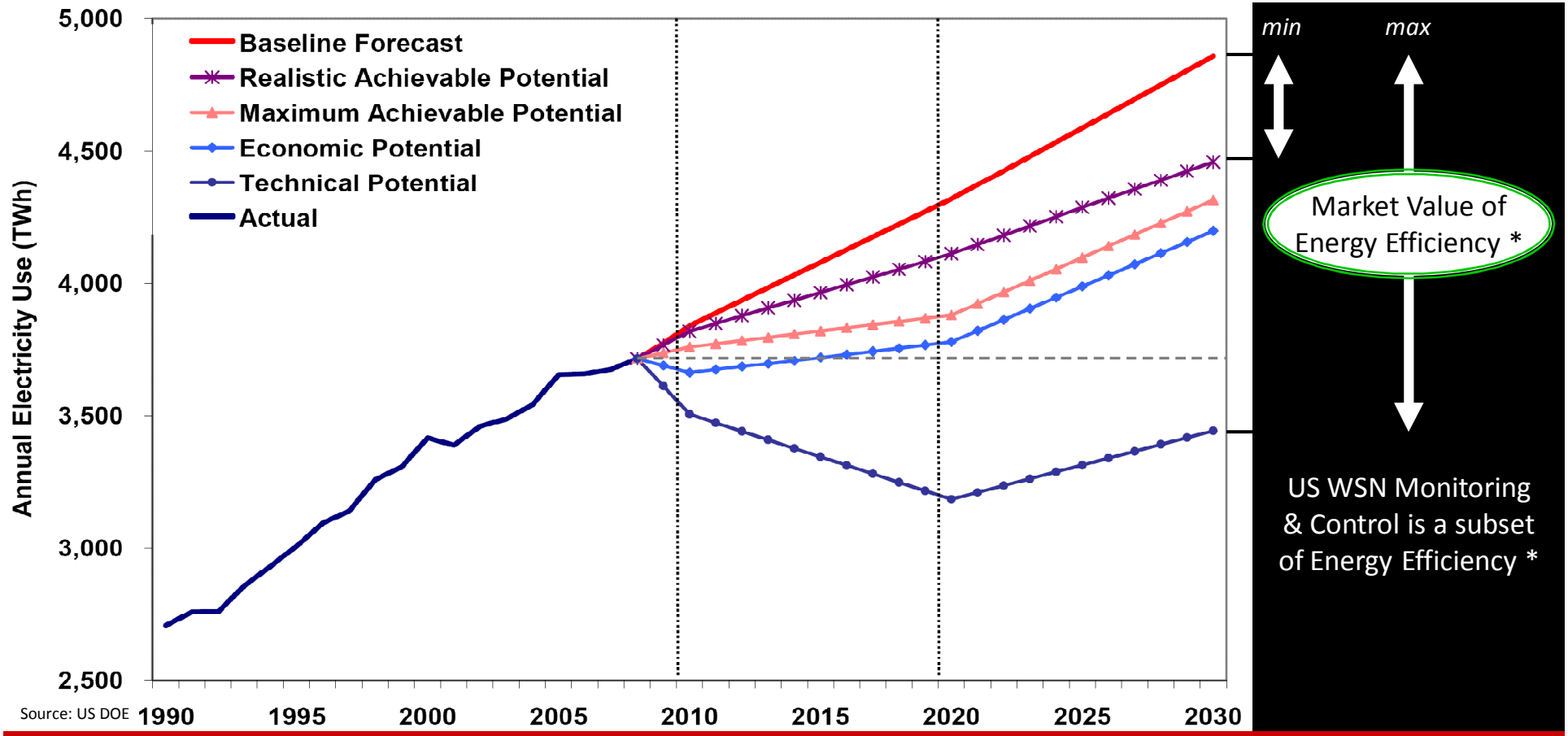


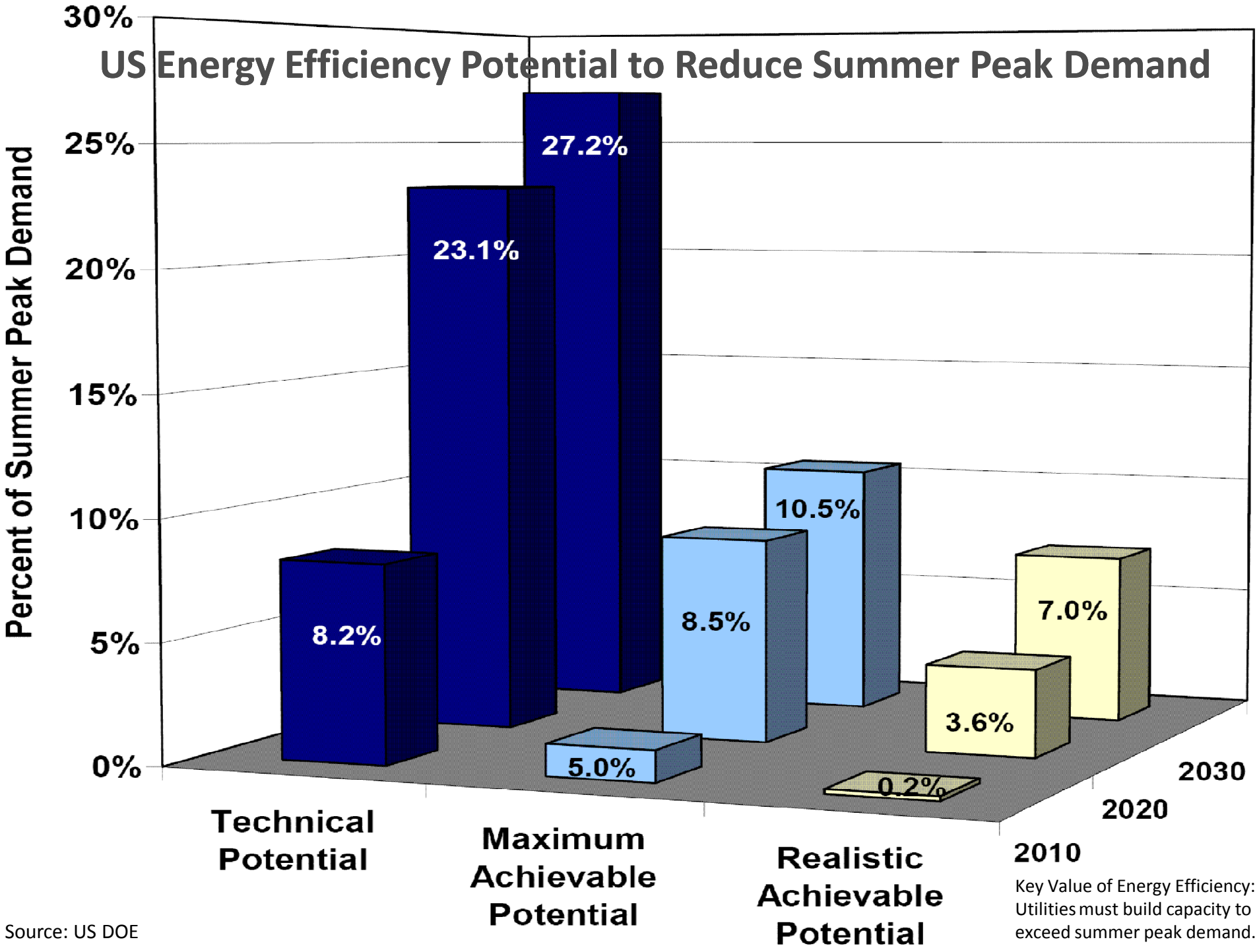
Source: US DOE



Source: US DOE

Realistic Achievable Potential for Savings from Energy Efficiency	2010 (GWh)	2020 (GWh)	2030 (GWh
Residential	12,127	64,374	139,637
Commercial	6,455	96,878	179,632
Industrial	2,027	45,696	78,736
Total	**20,609**	**206,947**	**398,005**



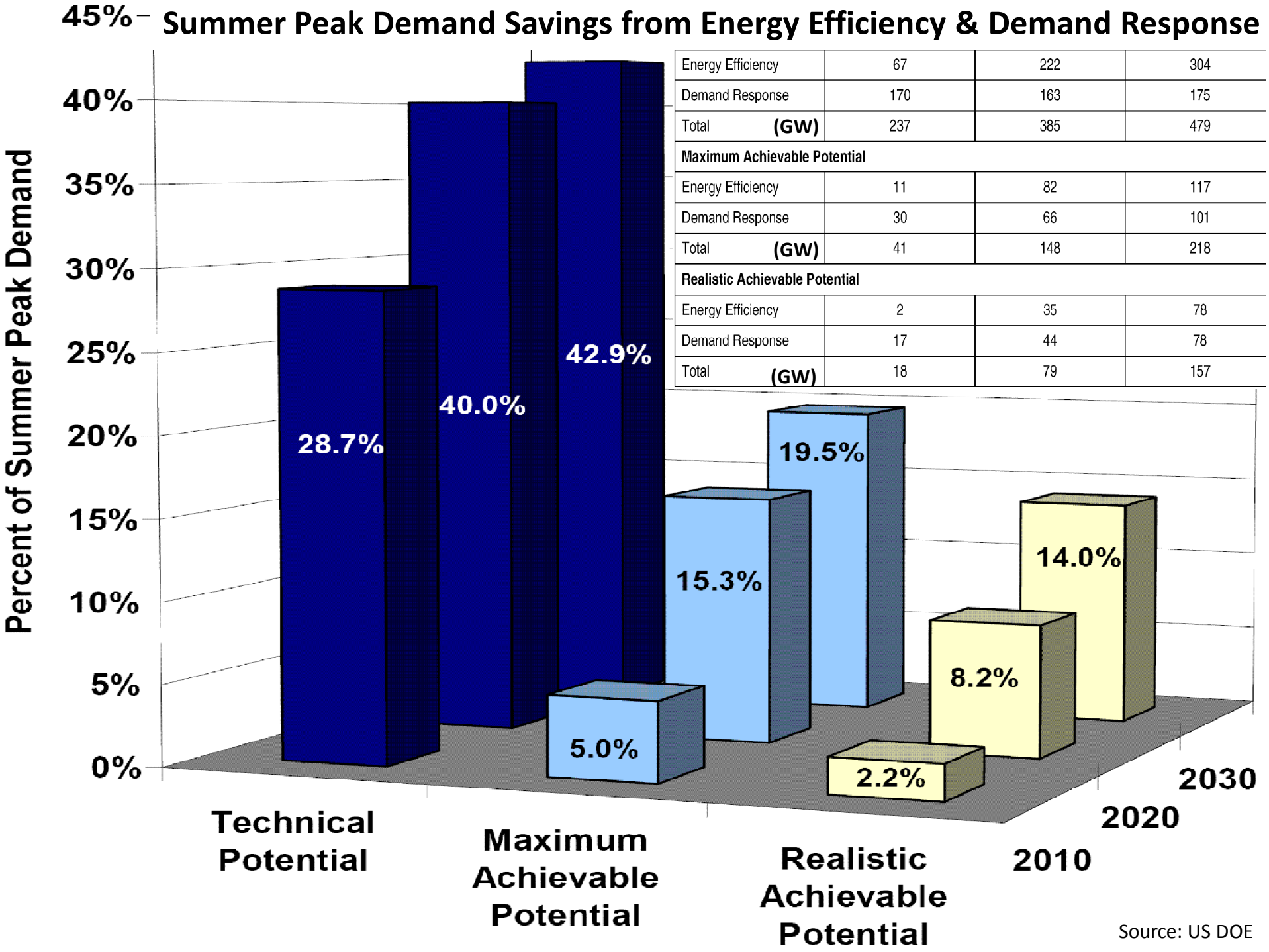


Source: US DOE

Key Value of Energy Efficiency: Utilities must build capacity to exceed summer peak demand.

Summer Peak Demand Savings from Energy Efficiency & Demand Response

Energy Efficiency	67	222	304
Demand Response	170	163	175
Total (GW)	237	385	479
Maximum Achievable Potential			
Energy Efficiency	11	82	117
Demand Response	30	66	101
Total (GW)	41	148	218
Realistic Achievable Potential			
Energy Efficiency	2	35	78
Demand Response	17	44	78
Total (GW)	18	79	157



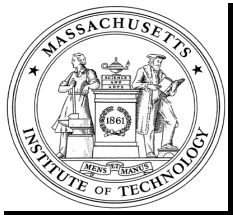
Source: US DOE

Market Acceptance Ratios

Measure Residential Efficiency	2010	2015	2020	2025	2030
Central AC	25%	50%	75%	75%	75%
Room AC	50%	75%	90%	90%	90%
Space Heat - Heat Pumps	25%	50%	75%	75%	75%
Lighting (CFL)	50%	63%	75%	75%	75%
Lighting (Linear Fluorescent)	100%	100%	100%	100%	100%
Refrigerators	100%	100%	100%	100%	100%
Freezers	100%	100%	100%	100%	100%
Water Heating	33%	66%	80%	80%	80%
Clothes Washers	25%	35%	45%	50%	50%
Clothes Dryers	50%	75%	90%	90%	90%
Dishwashers	50%	75%	90%	90%	90%
Color TVs	50%	63%	75%	75%	75%
PCs	50%	63%	75%	75%	75%
Ceiling Fan	25%	50%	75%	75%	75%
Whole-House Fan	25%	50%	75%	75%	75%
Duct Insulation	25%	33%	50%	65%	75%
Programmable Thermostat	33%	50%	75%	100%	100%
Storm Doors	25%	33%	50%	65%	75%
External Shades	25%	33%	50%	65%	75%
Ceiling Insulation	33%	50%	70%	80%	90%
Foundation Insulation	33%	50%	70%	80%	90%
Wall Insulation	33%	50%	70%	80%	90%
Reflective Roof	33%	50%	70%	80%	90%
Windows	25%	33%	50%	65%	75%
Faucet Aerators	50%	75%	75%	75%	75%
Pipe Insulation	50%	75%	75%	75%	75%
Low-Flow Showerheads	50%	75%	75%	75%	75%
AC Maintenance	25%	33%	50%	65%	75%
HP Maintenance	25%	33%	50%	65%	75%
Duct Repair	25%	33%	50%	65%	75%
Infiltration Control	25%	33%	50%	65%	75%

Source: US DOE

Dr Shoumen Palit Austin Datta < shoumen@



Market Acceptance Ratios

Measure Commercial Efficiency	2010	2015	2020	2025	2030
Cooling - Central AC	25%	50%	75%	75%	75%
Cooling - Chiller	30%	60%	85%	85%	85%
Cooling – Chiller Water Temperature Reset	30%	60%	85%	85%	85%
Cooling – Chiller VSD on Pump	25%	50%	75%	75%	75%
Cooling – Economizer	25%	50%	75%	75%	75%
Cooling – Central, Duct Insulation	30%	60%	85%	85%	85%
Cooling – Energy Management System	25%	50%	75%	75%	75%
Cooling – Programmable Thermostat	25%	50%	75%	75%	75%
Cooling – Fans, Energy-Efficient Motors	25%	50%	75%	75%	75%
Cooling – Fans, Variable Speed Control	25%	50%	75%	75%	75%
Cooling – Chiller: Duct Testing and Sealing	30%	60%	85%	85%	85%
Cooling – Cool Roof	30%	60%	85%	85%	85%
Cooling – Roof Insulation	30%	60%	85%	85%	85%
Cooling – Efficient Windows	30%	60%	85%	85%	85%
Cooling – HVAC Retrocommissioning	30%	60%	85%	85%	85%
Heating – Heat Pump	25%	50%	75%	75%	75%
Heating – Economizer	25%	50%	75%	75%	75%
Heating – Heat Pump, Duct Insulation	30%	60%	85%	85%	85%
Heating – Energy Management System	25%	50%	75%	75%	75%
Heating – Programmable Thermostat	25%	50%	75%	75%	75%
Heating – Roof Insulation	30%	60%	85%	85%	85%
Heating – Efficient Windows	30%	60%	85%	85%	85%
Heating –HVAC Retrocommissioning	30%	60%	85%	85%	85%
Ventilation – Variable Air Volume System	25%	50%	75%	75%	75%
Ventilation – Fans, Energy-Efficient Motors	25%	50%	75%	75%	75%
Ventilation – Fans, Variable Speed Control	25%	50%	75%	75%	75%
Lighting	50%	70%	85%	85%	85%
Lighting – LED Exit Lighting	50%	75%	95%	95%	95%
Lighting – Occupancy Sensors	50%	65%	75%	75%	75%
Lighting – Task Lighting	50%	65%	75%	75%	75%
Lighting – Outdoor	30%	65%	75%	75%	75%
Lighting – Daylighting Controls, Outdoors	50%	65%	75%	75%	75%
Lighting Retrocommissioning	30%	60%	85%	85%	85%
Water Heater	25%	55%	80%	80%	80%
Refrigeration – Compressor, High-Efficiency	30%	60%	85%	85%	85%
Refrigeration – Controls, Anti-Sweat Heater	30%	60%	85%	85%	85%
Refrigeration – Controls, Floating Head Pressure	30%	60%	85%	85%	85%
Refrigeration – Glass Doors, Installation	30%	65%	75%	75%	75%
Refrigeration – Icemakers	30%	60%	85%	85%	85%
Refrigeration – Reach-in Coolers and Freezers	30%	60%	85%	85%	85%
Personal Computers	50%	70%	85%	85%	85%
Servers	50%	70%	85%	85%	85%
Monitors	50%	70%	85%	85%	85%
Copiers, Printers and Other Electronics	50%	70%	85%	85%	85%
Vending Machine, High Efficiency	25%	50%	75%	75%	75%

Source: US DOE

Dr Shoumen Palit Austin Datta < shoum

Market Acceptance Ratios

Measure Industrial Efficiency	2010	2015	2020	2025	2030
Process Heating – Electric resistance	25%	35%	50%	50%	50%
Process Heating – Radio Frequency	25%	35%	50%	50%	50%
1-5 hp motors	50%	75%	95%	95%	95%
5-20 hp motors	50%	75%	95%	95%	95%
20-50 hp motors	50%	75%	95%	95%	95%
50-100 hp motors	50%	75%	95%	95%	95%
100-200 hp motors	50%	75%	95%	95%	95%
200-500 hp motors	50%	75%	95%	95%	95%
500-1,000 hp motors	50%	75%	95%	95%	95%
1,000-2,500 hp motors	50%	75%	95%	95%	95%
>2,500 hp motors	50%	75%	95%	95%	95%
HVAC	30%	60%	85%	85%	85%
Lighting – Fluorescent	50%	65%	85%	85%	85%
Lighting – HID	50%	65%	85%	85%	85%
Other	25%	35%	50%	50%	50%

Source: US DOE

Program Implementation Factors

Residential Measure	2010	2015	2020	2025	2030
Cooling – Central AC	30%	40%	50%	60%	70%
Cooling –Room AC	50%	60%	70%	80%	90%
Space Heat – Heat Pumps	30%	40%	50%	60%	70%
Lighting (CFL)	60%	70%	80%	90%	100%
Lighting (LF)	45%	55%	65%	75%	85%
Refrigerators	50%	60%	70%	80%	90%
Freezers	30%	38%	45%	53%	60%
Water Heating	30%	35%	40%	45%	50%
Clothes Washers	50%	60%	70%	80%	90%
Clothes Dryers	30%	35%	40%	45%	50%
Dishwashers	50%	60%	70%	80%	90%
Cooking	20%	26%	32%	39%	45%
Color TV	25%	36%	48%	59%	70%
Personal Computers	25%	39%	52%	66%	80%
Furnace Fans	25%	31%	38%	44%	50%
Miscellaneous	0%	0%	0%	0%	0%
Ceiling Fan	10%	18%	25%	33%	40%
Whole-House Fan	20%	28%	35%	43%	50%
Duct Insulation	5%	11%	18%	24%	30%
Programmable Thermostat	20%	34%	48%	61%	75%
Storm Doors	5%	10%	15%	20%	25%
External Shades	5%	11%	18%	24%	30%
Ceiling Insulation	5%	11%	18%	24%	30%
Foundation Insulation	5%	11%	18%	24%	30%
Wall Insulation	5%	11%	18%	24%	30%
Reflective Roof	10%	20%	30%	40%	50%
Windows	15%	26%	38%	49%	60%
Faucet Aerators	5%	11%	18%	24%	30%
Pipe Insulation	5%	11%	18%	24%	30%
Low-Flow Showerheads	5%	11%	18%	24%	30%
AC Maintenance	5%	9%	13%	16%	20%
HP Maintenance	5%	9%	13%	16%	20%
Duct Repair	5%	11%	18%	24%	30%
Infiltration Control	5%	11%	18%	24%	30%
Dehumidifier	1%	2%	3%	4%	5%
Combined Washer/Dryer	1%	4%	8%	12%	15%
Reduce Standby Wattage	15%	27%	40%	52%	65%
In-home Feedback Monitor	2%	16%	31%	45%	60%

Source: US DOE

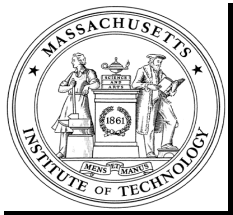
Dr Shoumen Palit Austin Datta < shoumen@

Program Implementation Factors

Measure Commercial	2010	2015	2020	2025	2030
Cooling					
Central AC	30%	41%	52%	64%	75%
Chiller	25%	34%	42%	51%	60%
Chiller Water Temperature Reset	20%	30%	40%	50%	60%
Chiller, VSD on Pump	20%	30%	40%	50%	60%
Economizer	15%	24%	33%	41%	50%
EMS	20%	28%	35%	43%	50%
Programmable Thermostat	20%	28%	35%	43%	50%
Fans, Variable Speed Control	25%	38%	50%	63%	75%
Fans, Energy-Efficient Motors	25%	38%	50%	63%	75%
Duct Testing and Sealing	15%	21%	27%	34%	40%
Cool Roof	10%	18%	25%	33%	40%
Roof Insulation	15%	21%	27%	34%	40%
HVAC Retrocommissioning	10%	20%	30%	40%	50%
Efficient Windows	15%	21%	27%	34%	40%
Heating					
Heat pump	30%	41%	52%	64%	75%
Economizer	15%	24%	33%	41%	50%
Duct Insulation	15%	21%	27%	34%	40%
EMS	20%	28%	35%	43%	50%
Programmable Thermostat	20%	28%	35%	43%	50%
Roof Insulation	15%	21%	27%	34%	40%
Efficient Windows	15%	21%	27%	34%	40%
HVAC Retrocommissioning	10%	20%	30%	40%	50%
Ventilation					
Fans	10%	26%	42%	59%	75%
Variable Air Volume System	10%	18%	25%	33%	40%
Fans, Energy-Efficient Motors	25%	38%	50%	63%	75%
Fans, Variable Speed Control	25%	38%	50%	63%	75%

Source: US DOE

Dr Shoumen Palit Austin Datta < shoumen@mit



Program Implementation Factors

Measure Commercial	2010	2015	2020	2025	2030
Lighting					
Lighting	50%	63%	75%	88%	100%
Daylighting Controls, Outdoors	5%	11%	18%	24%	30%
LED Exit Lighting	50%	63%	75%	88%	100%
Occupancy Sensors	20%	28%	35%	43%	50%
Task Lighting	5%	11%	18%	24%	30%
Outdoor Lighting	25%	38%	50%	63%	75%
Lighting Retrocommissioning	10%	20%	30%	40%	50%
Water Heater	40%	52%	65%	77%	90%
Refrigeration					
Refrigeration, High-Efficiency	25%	31%	38%	44%	50%
Compressor, High-Efficiency	15%	21%	27%	34%	40%
Controls, Anti-Sweat Heater	15%	21%	27%	34%	40%
Controls, Floating Head Pressure	15%	21%	27%	34%	40%
Glass Doors, Installation	15%	21%	27%	34%	40%
Icemakers	5%	16%	27%	39%	50%
Reach-in Coolers and Freezers	10%	20%	30%	40%	50%
Electronics and Other					
Personal Computers	25%	38%	50%	63%	75%
Servers	25%	38%	50%	63%	75%
Monitors	20%	34%	48%	61%	75%
Copiers Printers	20%	34%	48%	61%	75%
Other Electronics	20%	34%	48%	61%	75%
Vending Machine, High Efficiency	15%	21%	27%	34%	40%

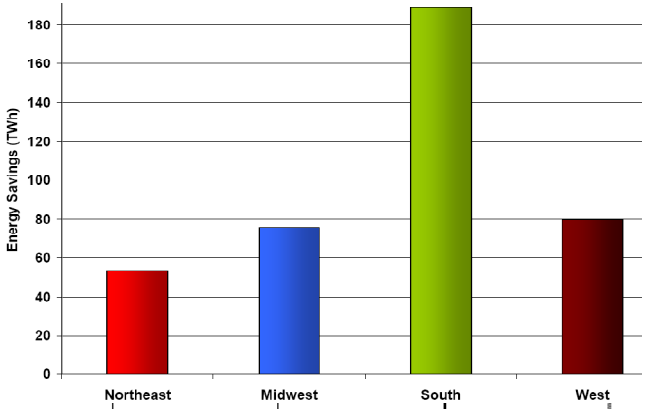
Source: US DOE

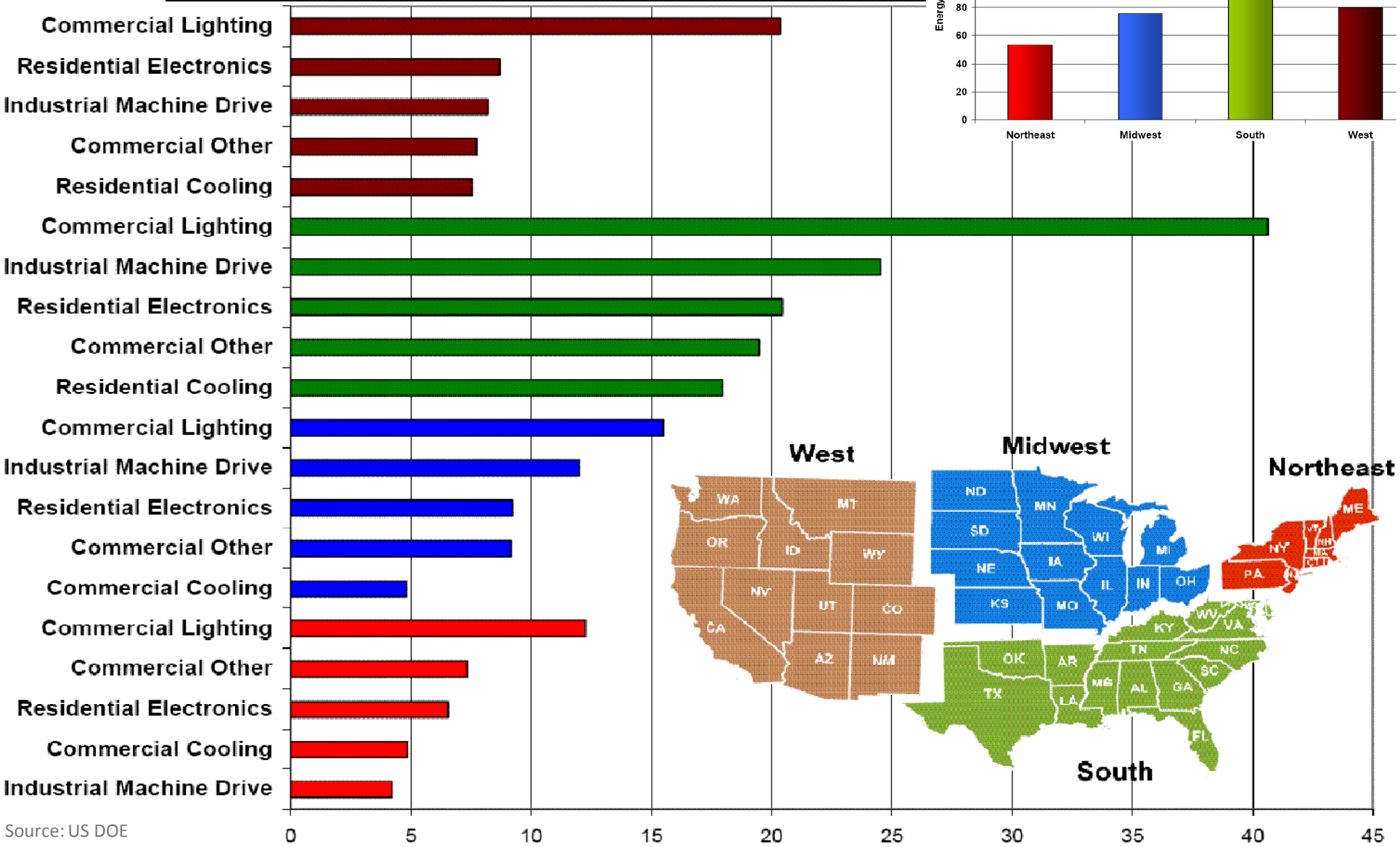
Program Implementation Factors

Measure Industrial	2010	2015	2020	2025	2030
Electric resistance	2%	6%	11%	15%	20%
Radio frequency	2%	6%	11%	15%	20%
1-5 hp motors	15%	21%	27%	34%	40%
5-20 hp motors	15%	21%	27%	34%	40%
20-50 hp motors	10%	18%	25%	33%	40%
50-100 hp motors	10%	18%	25%	33%	40%
100-200 hp motors	10%	18%	25%	33%	40%
200-500 hp motors	10%	18%	25%	33%	40%
500-1,000 hp motors	10%	18%	25%	33%	40%
1,000-2,500 hp motors	10%	18%	25%	33%	40%
>2,500 hp motors	10%	18%	25%	33%	40%
HVAC	10%	20%	30%	40%	50%
Lighting – Fluorescent	20%	30%	40%	50%	60%
Lighting – HID	20%	30%	40%	50%	60%
Other	2%	6%	11%	15%	20%

Source: US DOE

Energy Efficiency 2030
Realistic Achievable Potential

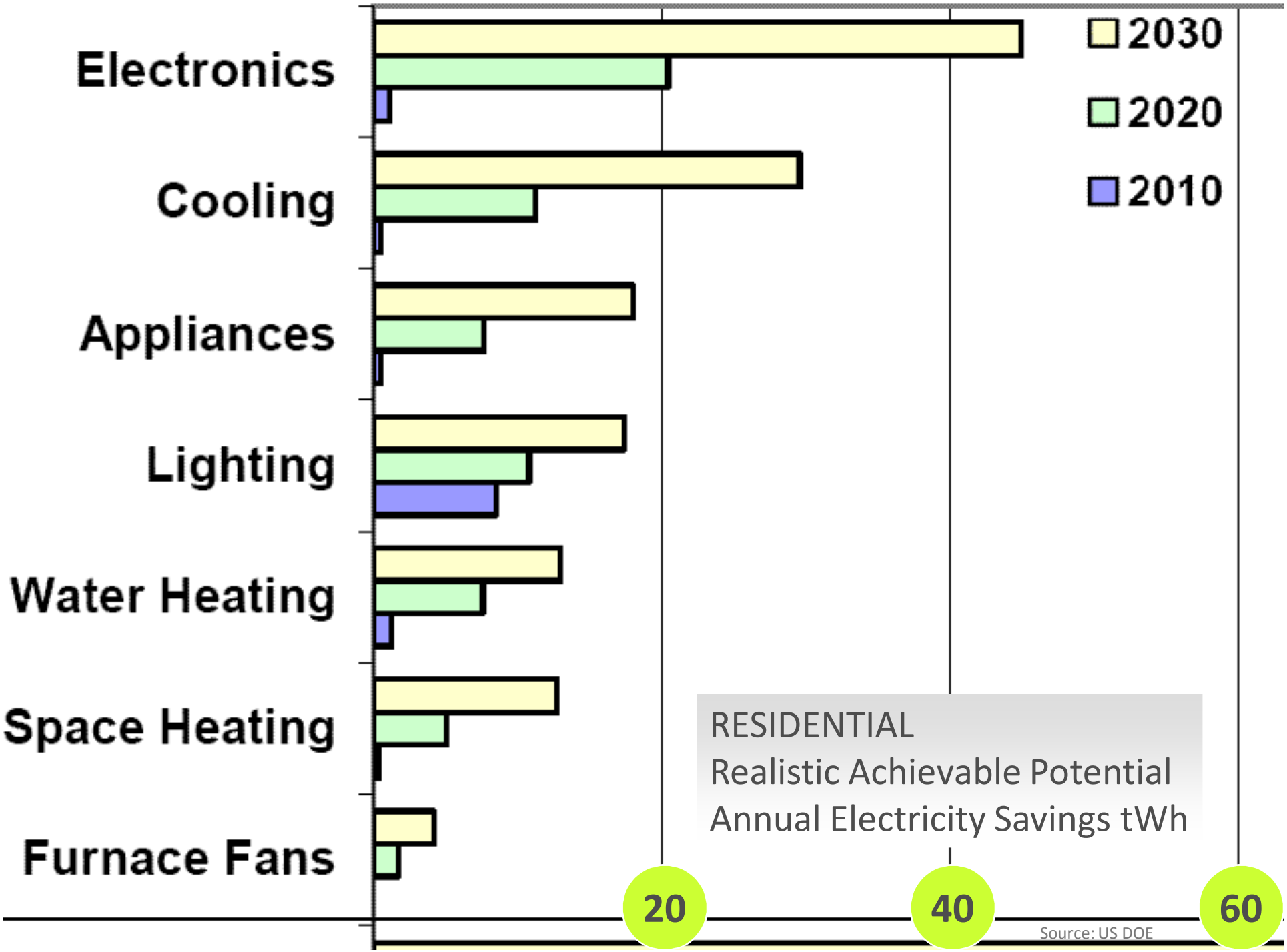


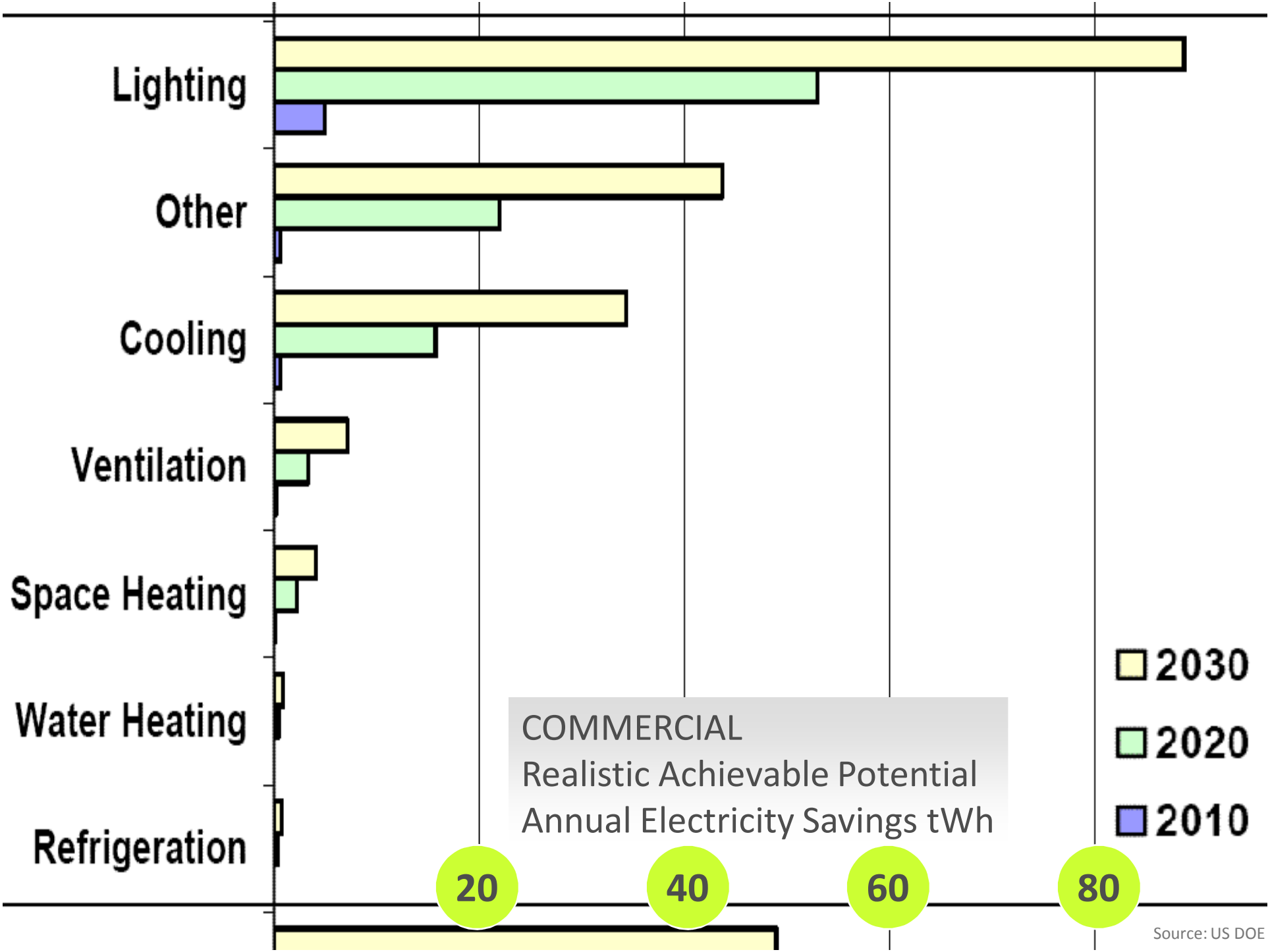


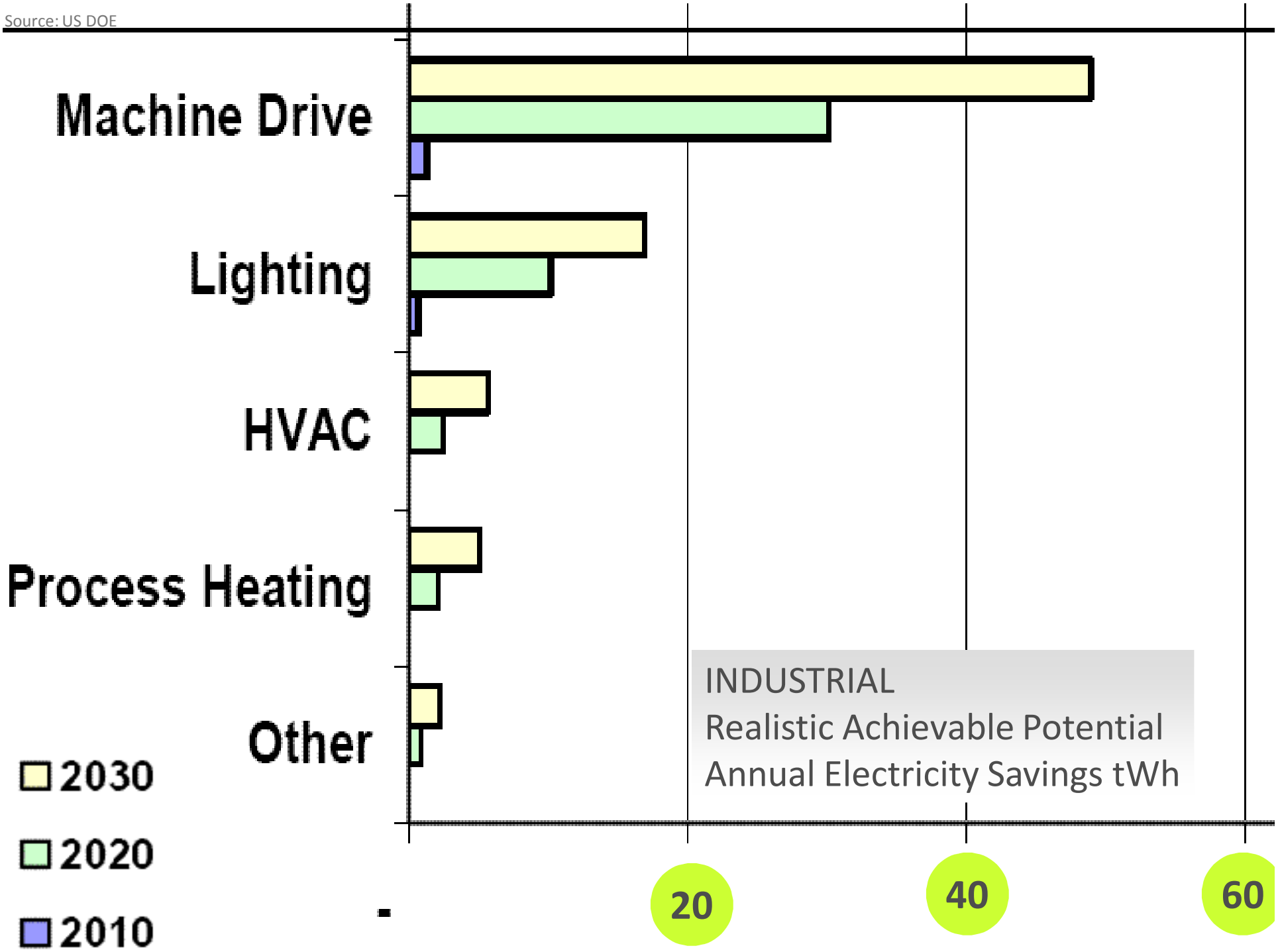
Source: US DOE

Dr Shoumen Palit Austin Datta < shoumen@mit.edu

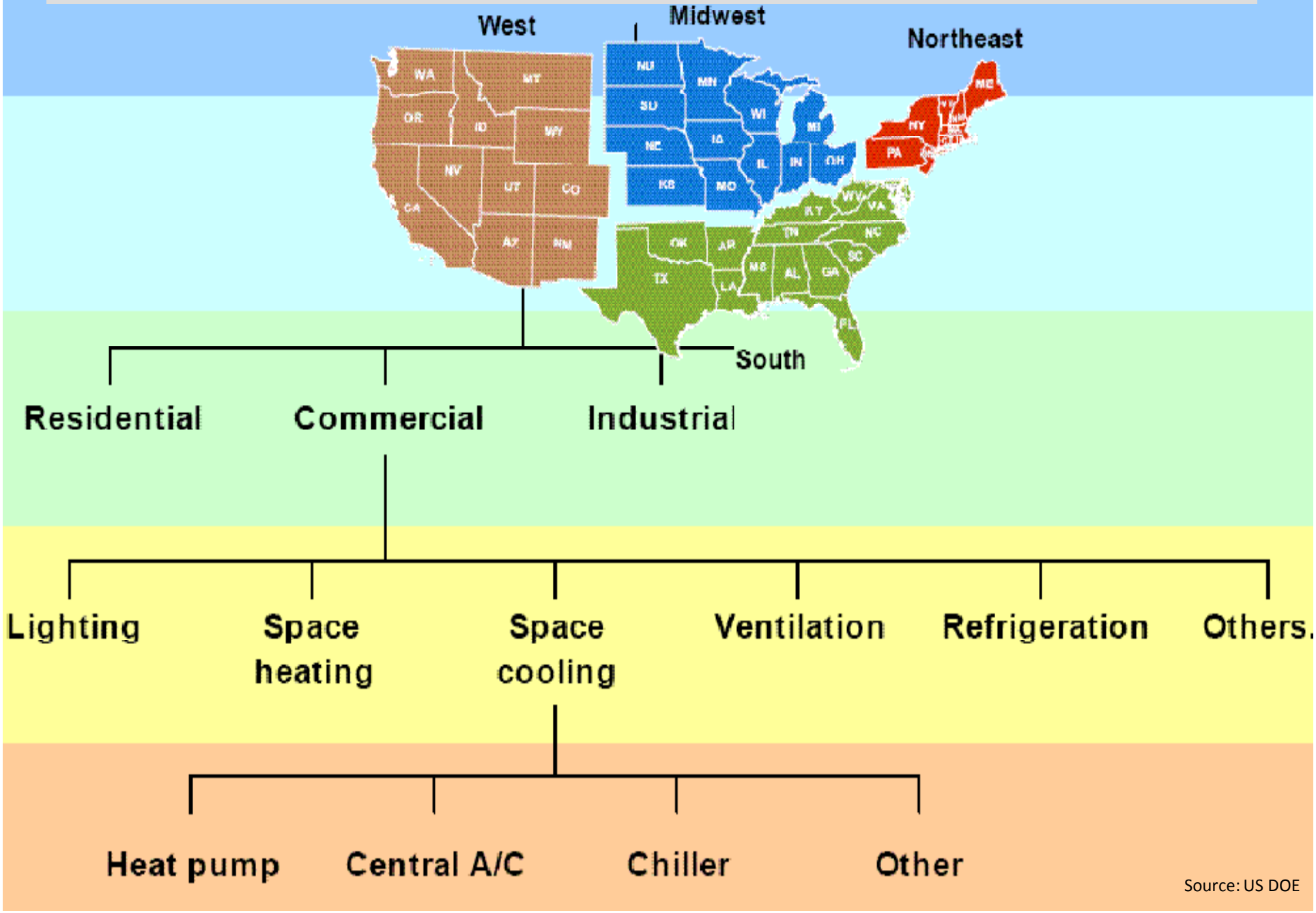
Annual Electricity Savings Relative to Baseline (TWh)


Electronics
Cooling
Appliances
Lighting
Water Heating
Space Heating
Furnace Fans
2030
2020
2010
RESIDENTIAL
Realistic Achievable Potential
Annual Electricity Savings tWh
20
40
60
Source: US DOE

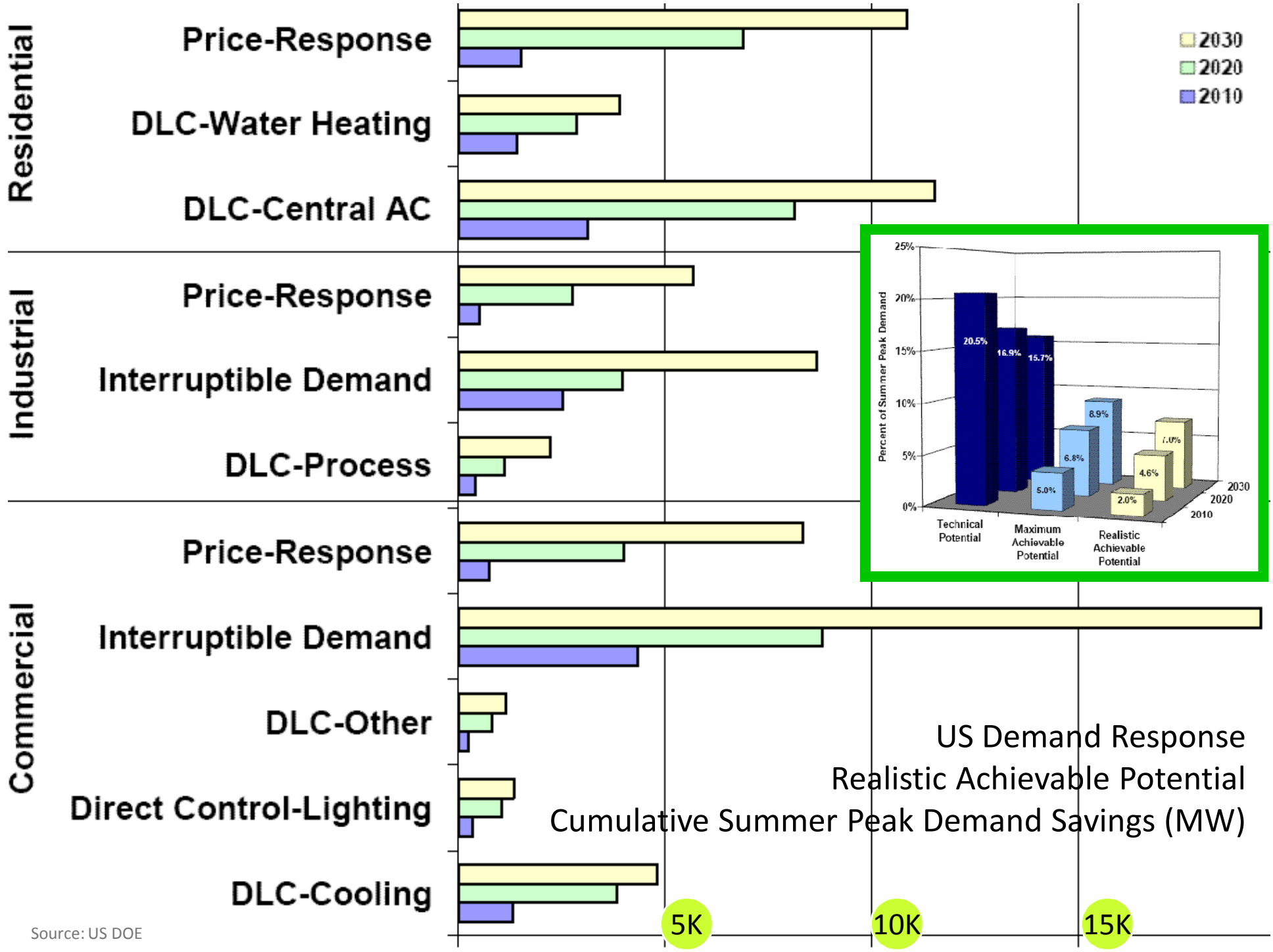

Lighting
Other
Cooling
Ventilation
Space Heating
Water Heating
Refrigeration
COMMERCIAL
Realistic Achievable Potential
Annual Electricity Savings tWh
20
40
60
80
2030
2020
2010
Source: US DOE


Source: US DOE
Machine Drive
Lighting
HVAC
Process Heating
Other
2030
2020
2010
-
20
40
60
INDUSTRIAL
Realistic Achievable Potential
Annual Electricity Savings tWh

Data Granularity: Key to Energy Efficiency from Demand Response

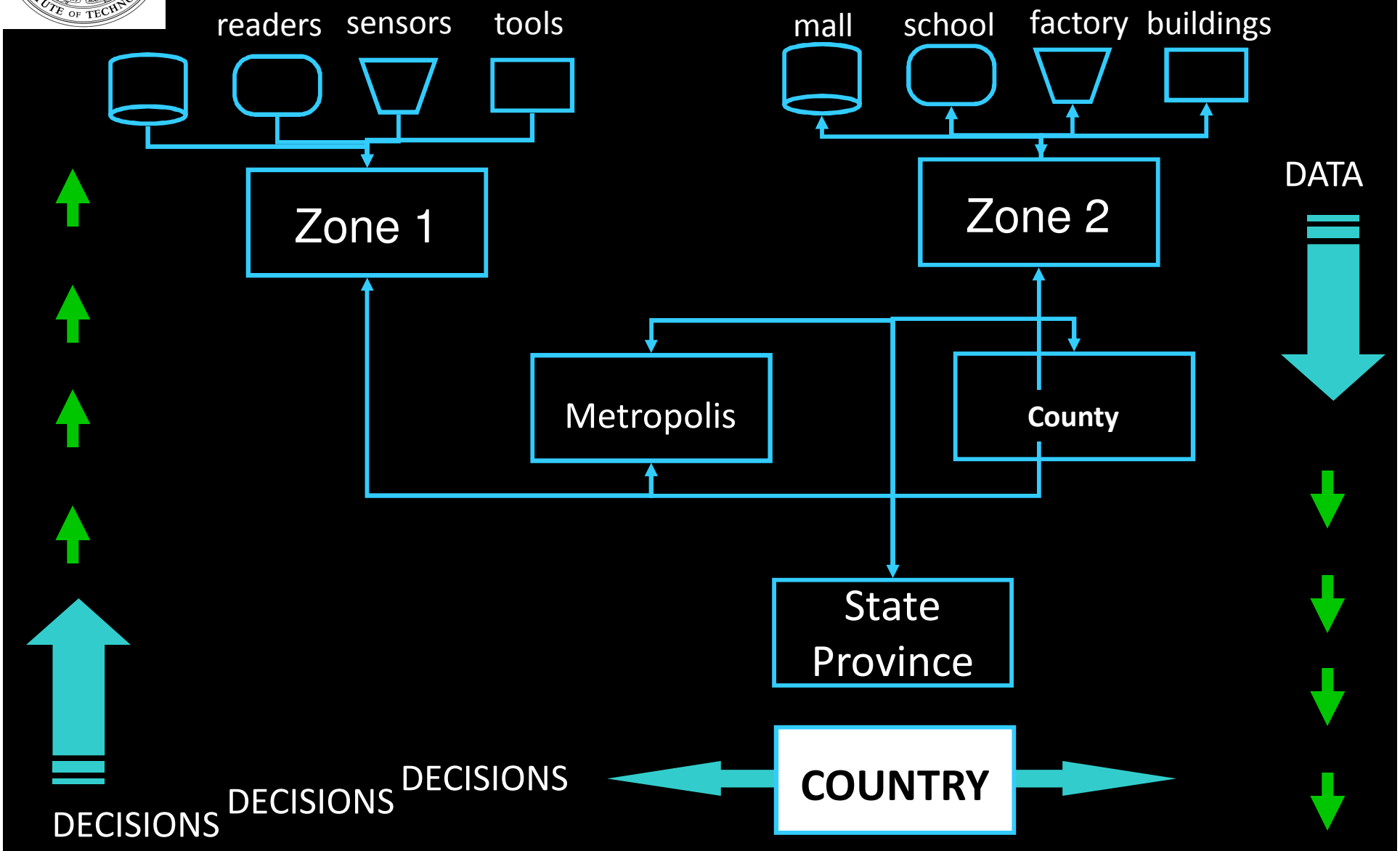


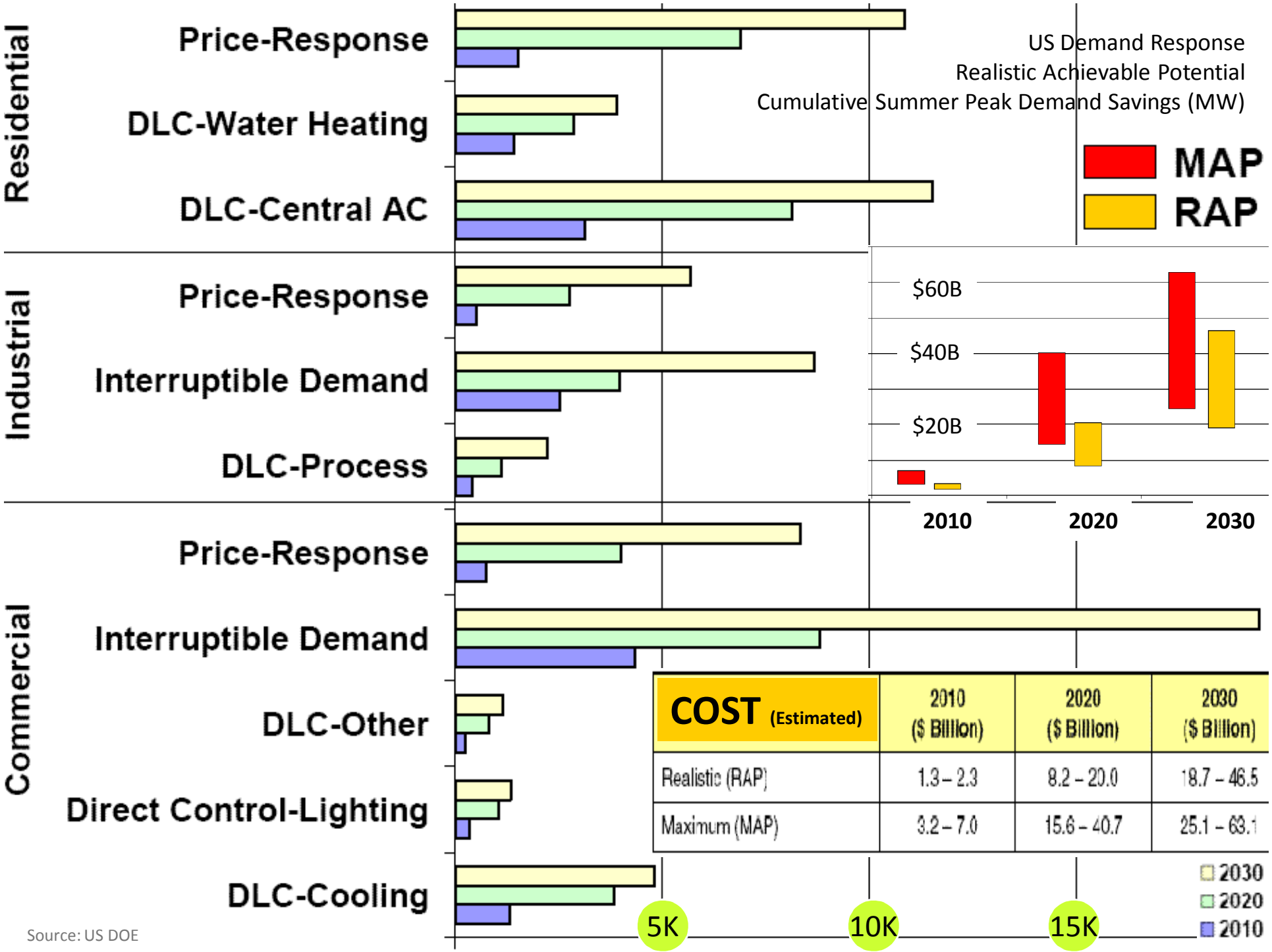
Source: US DOE



Source: US DOE

USWSN ENERGY TRANSPARENCY : DEMAND-RESPONSE





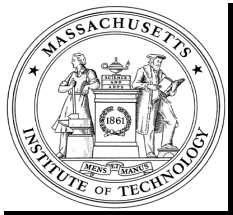
Source: US DOE

Source: US DOE

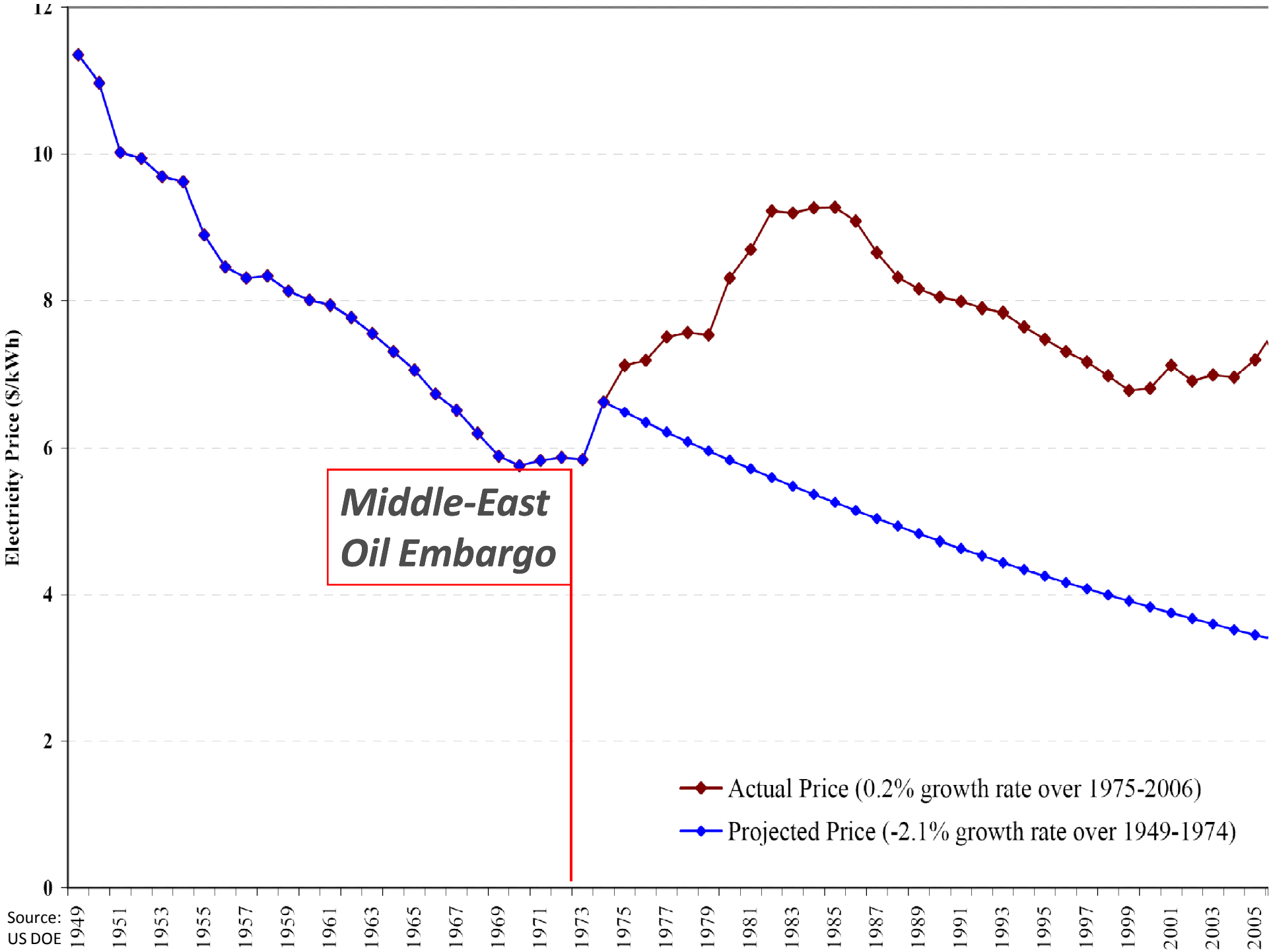
Year	Energy Efficiency Measures (Billion $)	Demand Response Measures (Billion $)	Total Cost (Billion $)
2010	$0.46 to $1.44	$0.84	$1.30 to $2.29
2020	$5.47 to $17.33	$2.74	$8.21 to $20.07
2030	$12.81 to $40.61	$5.91	$18.72 to $46.52

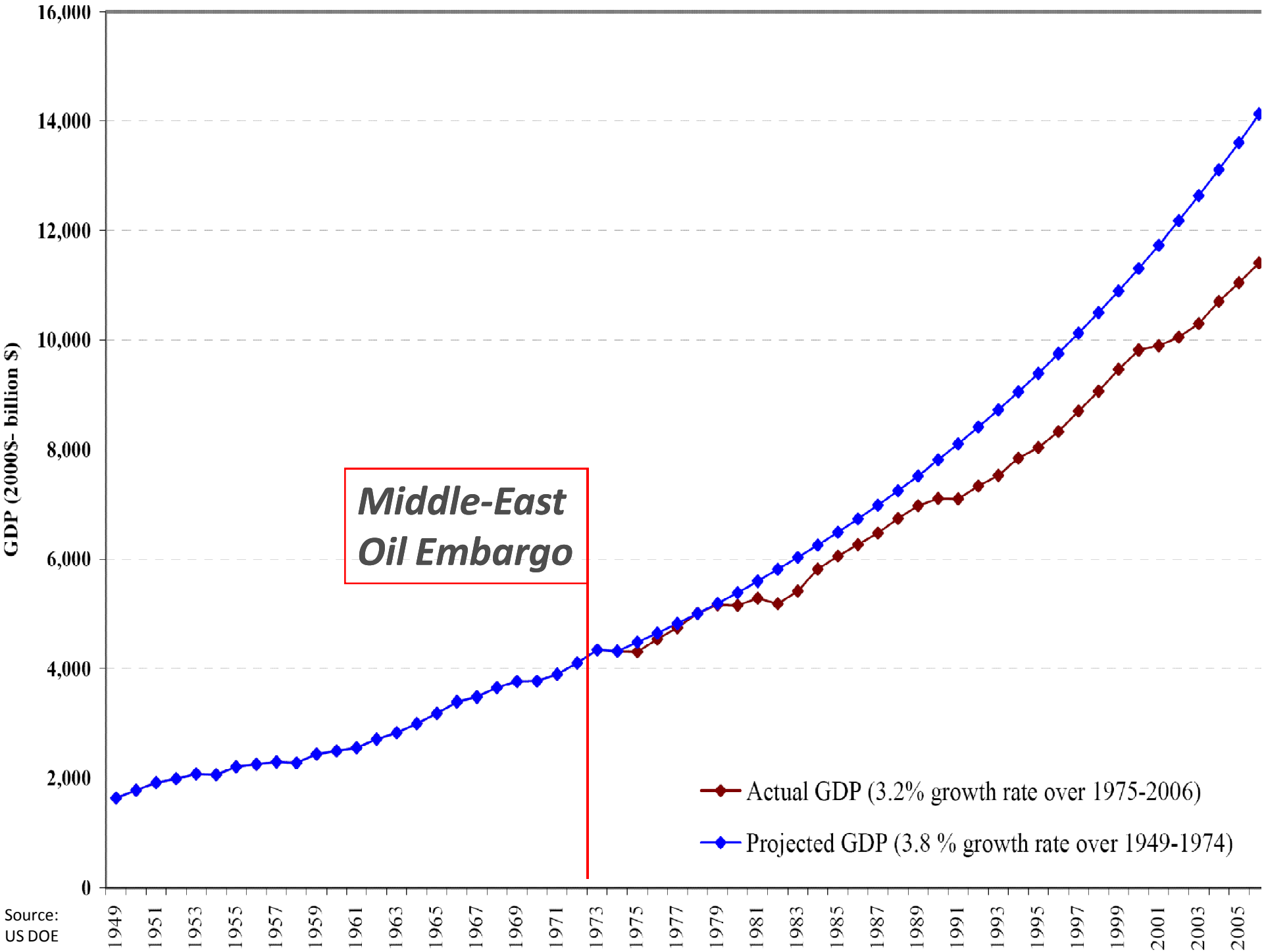
Do we expect customers to respond to: **Intelligent Energy Transparency (iET)** **Savings from Monitor and Control** **Carbon Credits**	Energy Savings (in Quads)	% of Total **1,219 TWh**
Appliance Standards	1.2	29%
Financial Incentives	0.62	15%
Information and Voluntary Programs	2.27	55%
Management of Government Energy Use	0.07	2%
Total	**4.16**	**100%**

Source: Gillingham, K., Newell, R. and Palmer, K. (2006) Energy Efficiency Policies: A Retrospective Examination. Ann Rev of Environ & Resources 31 161–192

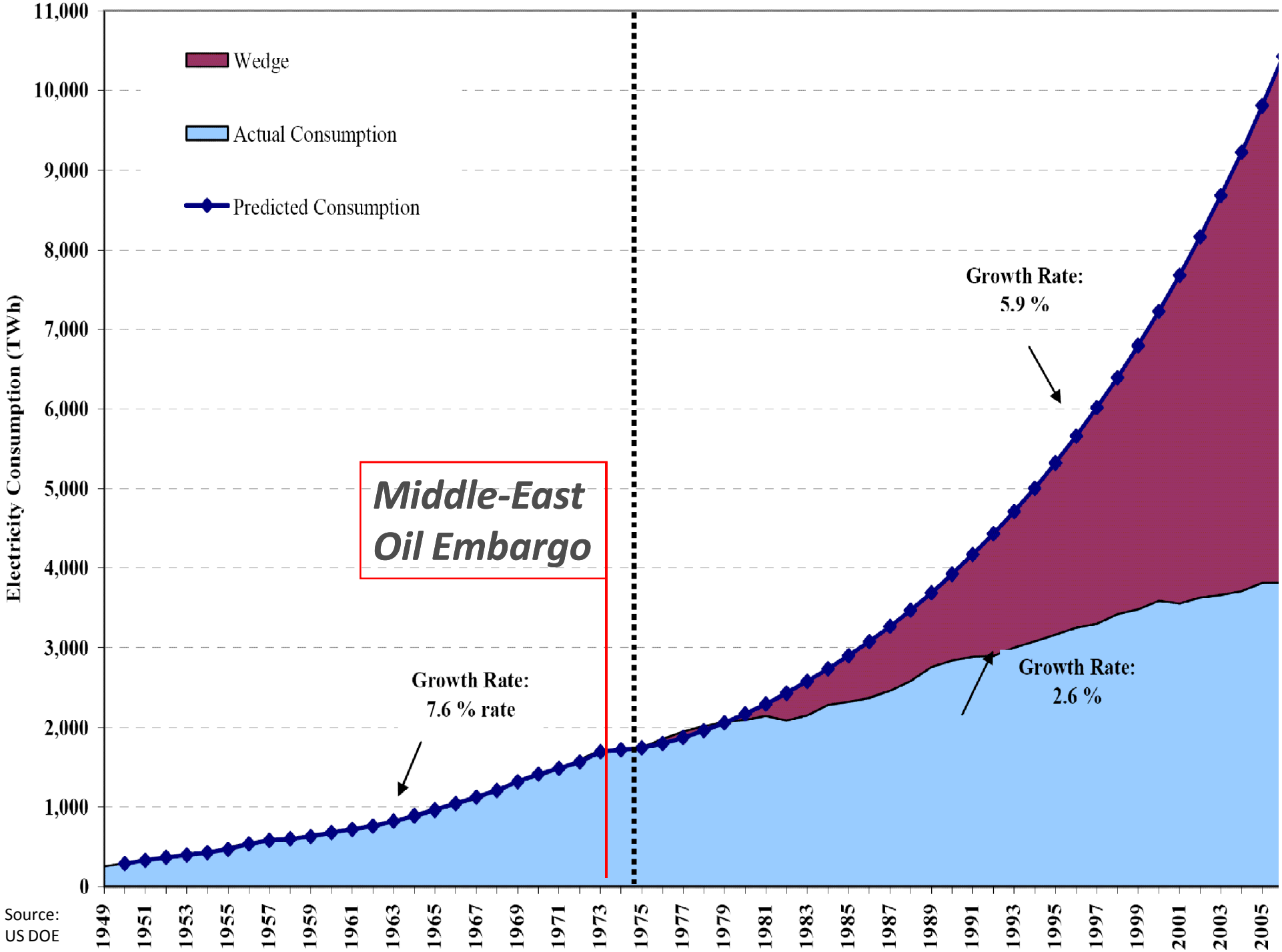


Business Risk in Efficiency: Forecasting Errors

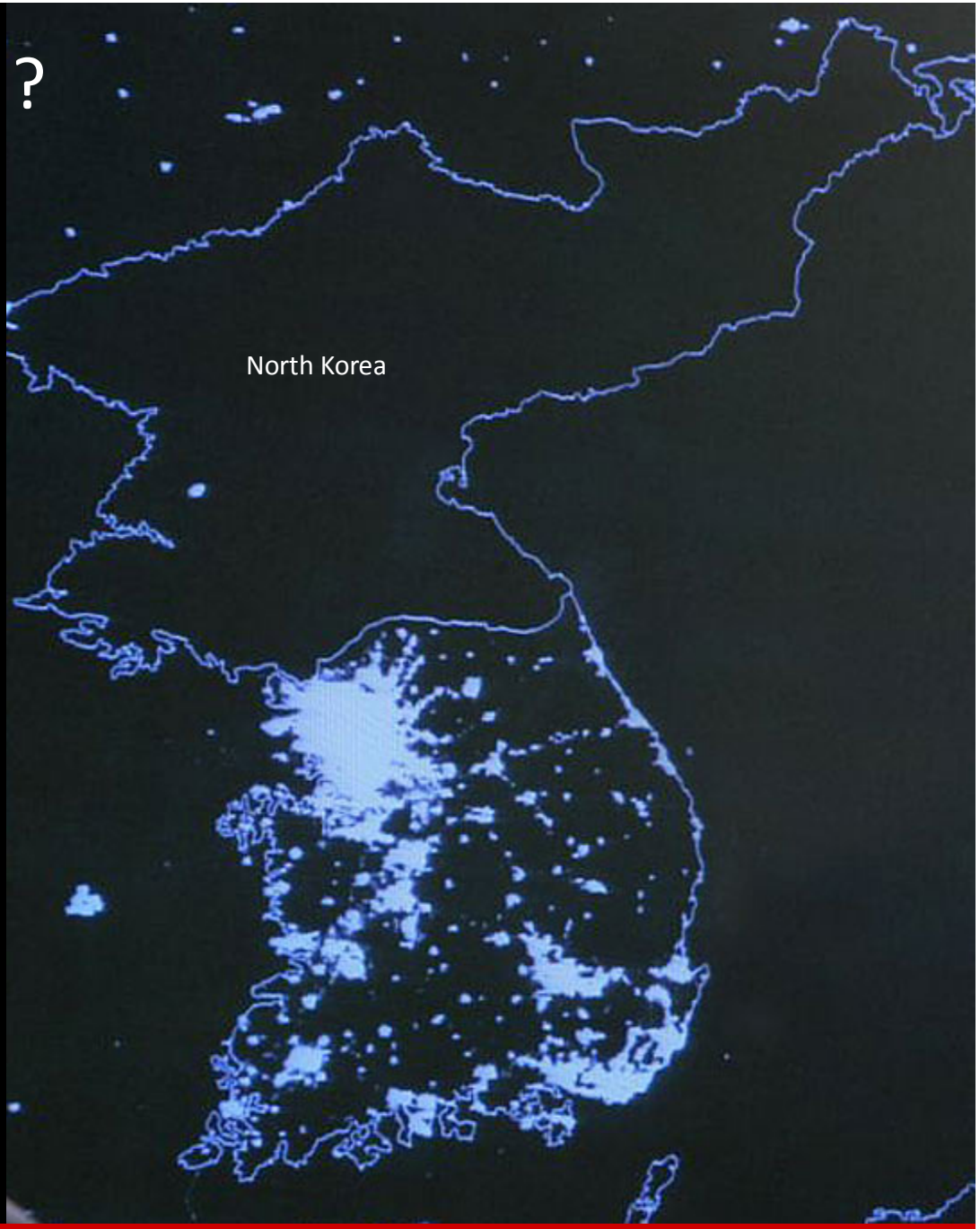

Electricity Price ($/kWh)
12
10
8
6
4
2
0
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Middle-East
Oil Embargo
Actual Price (0.2% growth rate over 1975-2006)
Projected Price (-2.1% growth rate over 1949-1974)
Source:
US DOE



Source:
US DOE


Wedge
Actual Consumption
Predicted Consumption
Electricity Consumption (TWh)
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Middle-East Oil Embargo
Growth Rate: 7.6 % rate
Growth Rate: 5.9 %
Growth Rate: 2.6 %
Source: US DOE

Energy Efficiency ?



Source: US DOE

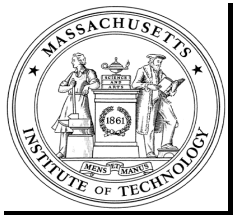
CIA Fact Book

Top 10 Oil Importers

Rank	Countries	Amount
#1	**United States**:	10,400,000 barrels per day
#2	**Japan**:	5,300,000 barrels per day
#3	**Germany**:	2,600,000 barrels per day
#4	**France**:	1,850,000 barrels per day
#5	**Italy**:	1,690,000 barrels per day
#6	**China**:	1,600,000 barrels per day
#7	**Spain**:	1,500,000 barrels per day
#8	**India**:	1,200,000 barrels per day
#9	**Turkey**:	584,326 barrels per day
#10	**Thailand**:	539,973 barrels per day

Unsustainable trajectory for developing nations: eg Thailand
Total energy imports 11% of GDP 2006 (9.9% GDP in 2005)

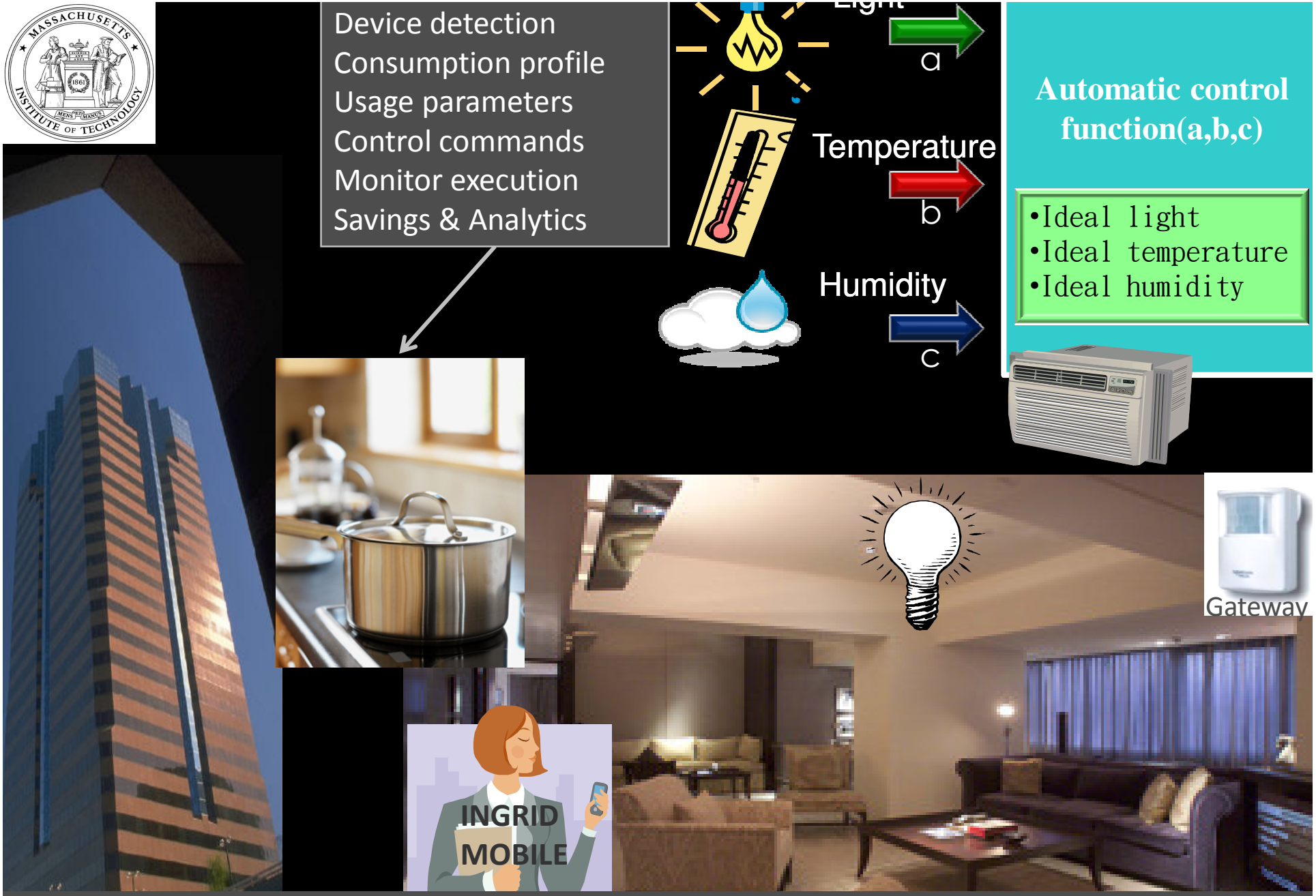
Channel NewsAsia 19 July 2007

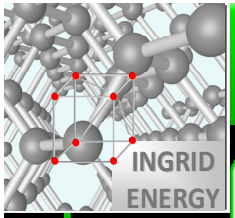


Enabling Tools and Technology

Energy Efficiency:

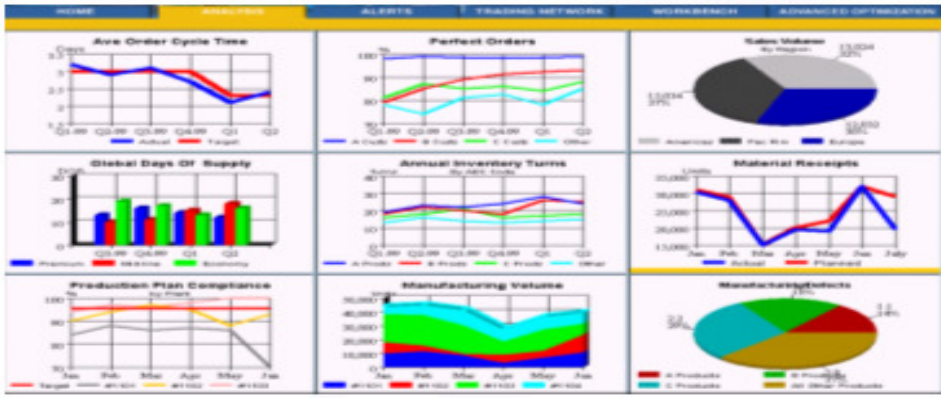
- **US WSN** Ubiquitous Secure Wireless Sensor Networks
- **ROI** Return on Investment
  - **Savings**
  - **Carbon Credits**
- **Methodology & Certification**

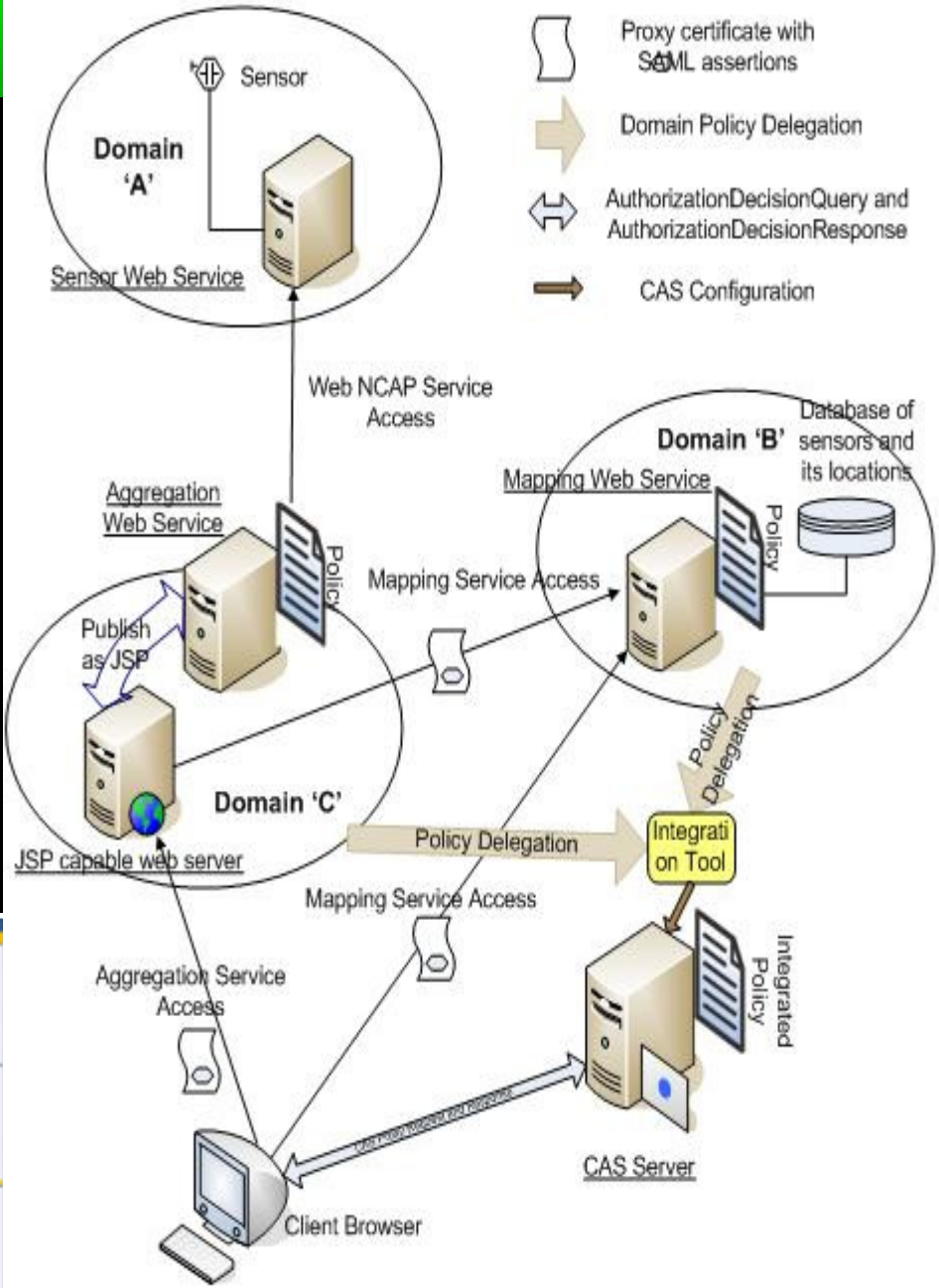

Device detection
Consumption profile
Usage parameters
Control commands
Monitor execution
Savings & Analytics
Light
a
Temperature
b
Humidity
c
Automatic control function(a,b,c)
•Ideal light
•Ideal temperature
•Ideal humidity
Gateway
INGRID
MOBILE
Did I turn off the kitchen stove in my flat?



intelligent reports using data

- Analysis and announce of system efficiency monitor
- Early warning of system exception
- Analysis for power consumption
- Parameter Analysis of environmental sensor
- Customization reports for warning and monitor data



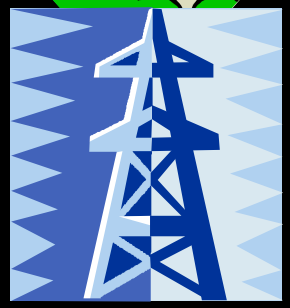


Energy Conservation: Utility Landscape

Spot Markets (Procurement) | Cost / KWH | Energy Operations | Weather Forecast | Building Cooperative

INTERNET

Generation



Transmission

Contract / Bill Procurement Audit

Energy Management Systems

Building Management System

HVAC Light Sprinkler
LIFTS Fire Security

Distributed Generation

Business Services

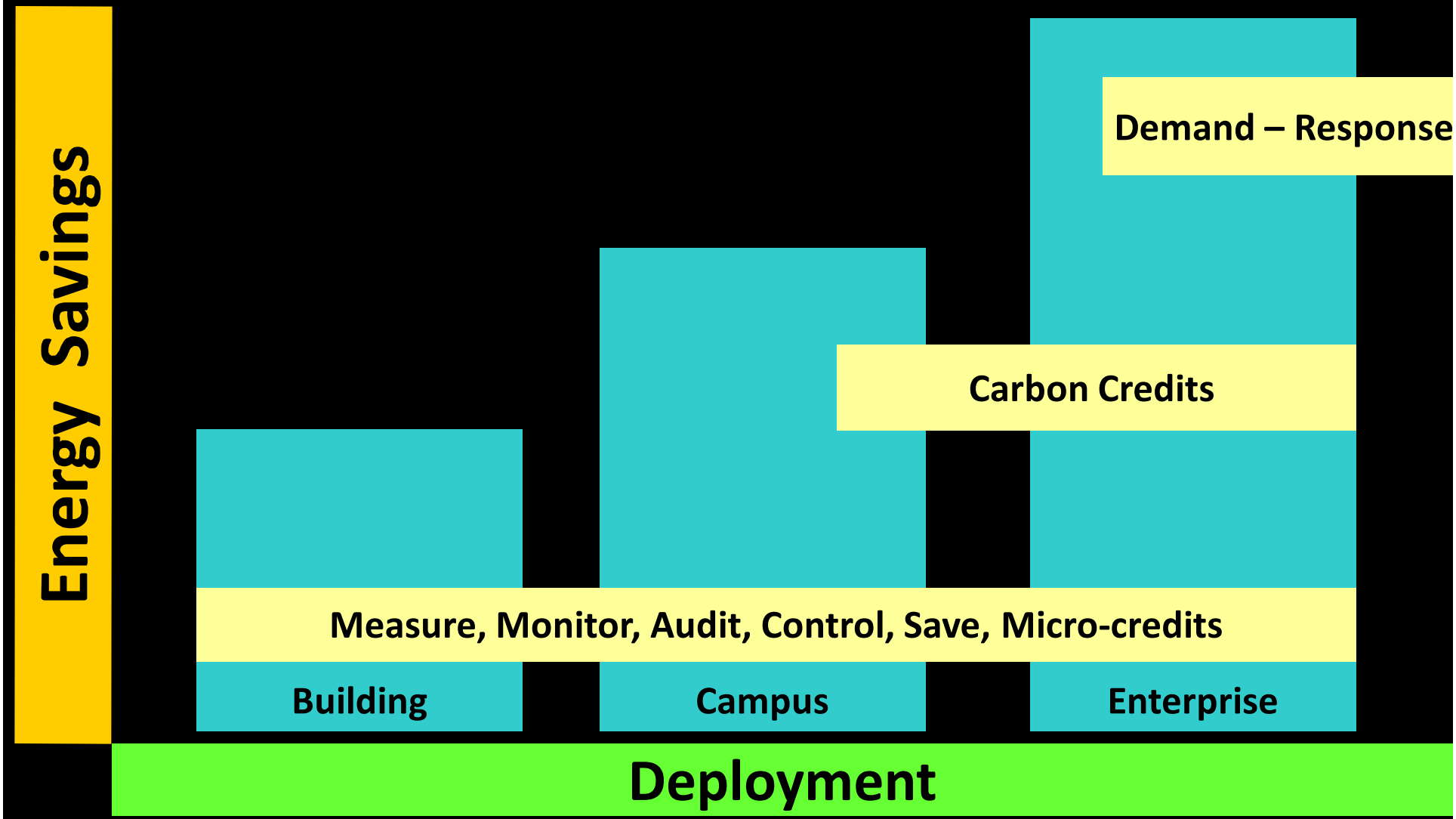
Bills – Audit Energy Analytics

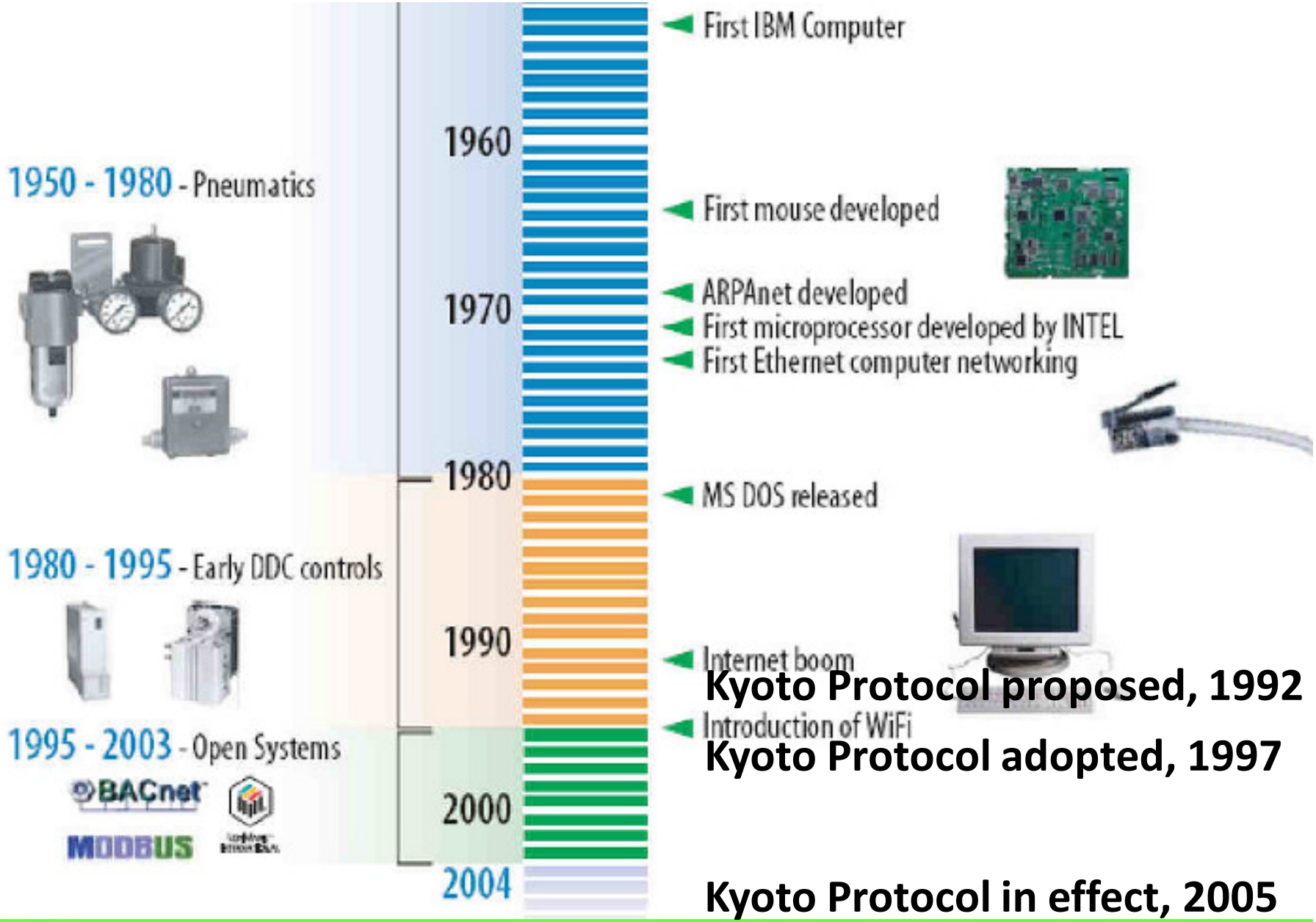
MEMS Installers

Analysts - Lawyers

Factory / Building / Facility / Apartment / Shopping Mall / Hotel

Energy Efficiency : Optimization -Aggregation





Beyond 2005 → Intelligent Energy Transparency [iET]

Level 3 - Enterprise

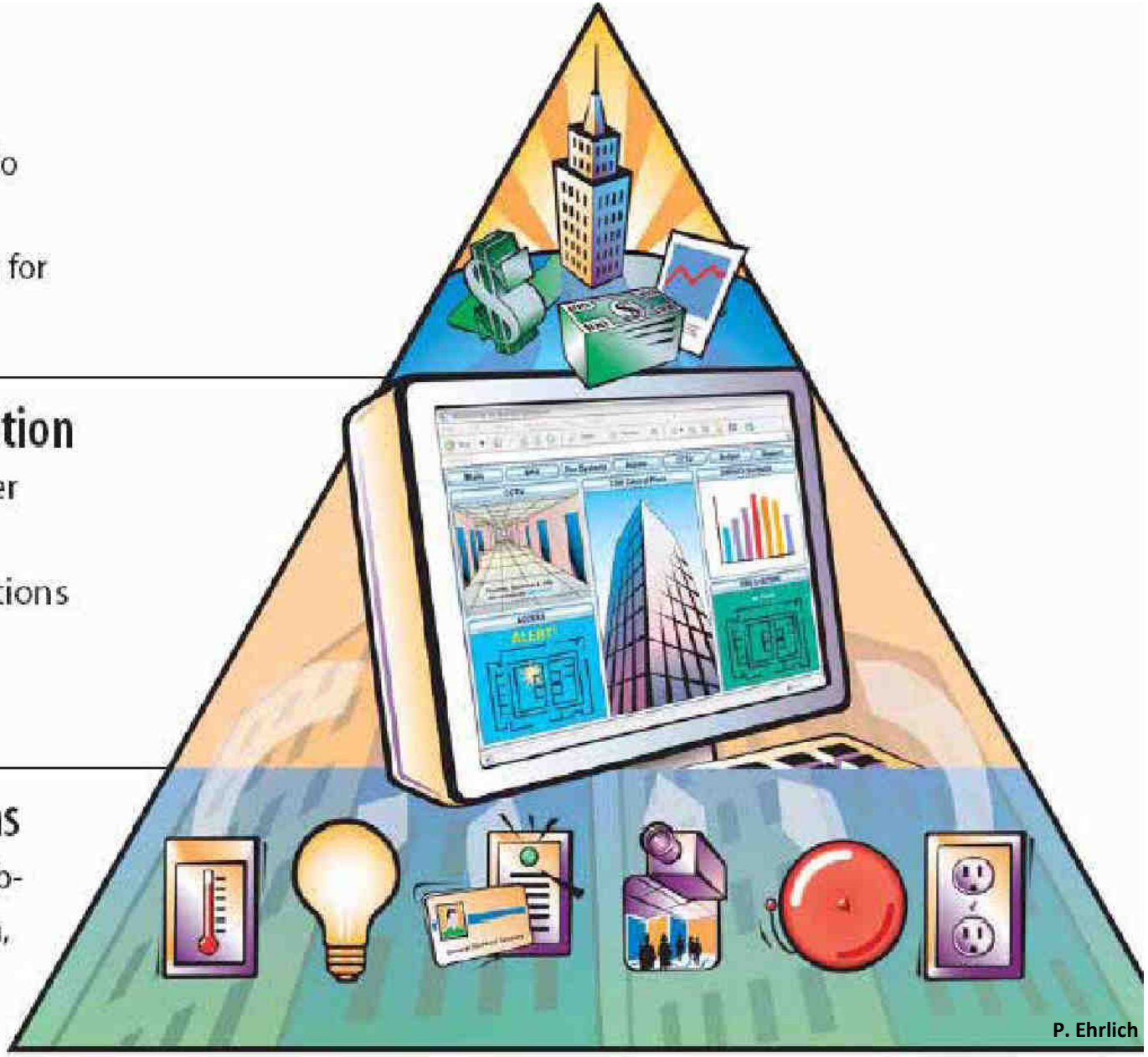
- Connects building systems to business systems
- Connects multiple buildings for remote operations

Level 2 - Systems Integration

- Connects systems together within a building
- On site and remote operations

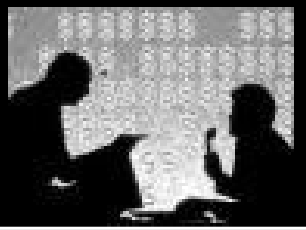
Level 1 - Building Systems

- Major building system or sub-system (i.e. HVAC, Fire Alarm, CCTV, Security, Lighting, etc.)
- Devices within a system (i.e. controllers, smoke detectors, etc.)



P. Ehrlich

HIERARCHY
GRANULARITY

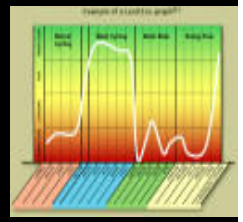


Intelligent Agents

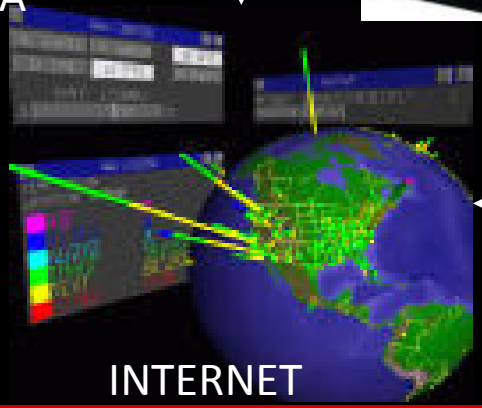
Financial Analytics

Real-time Monitoring

Building Automation System



SCADA



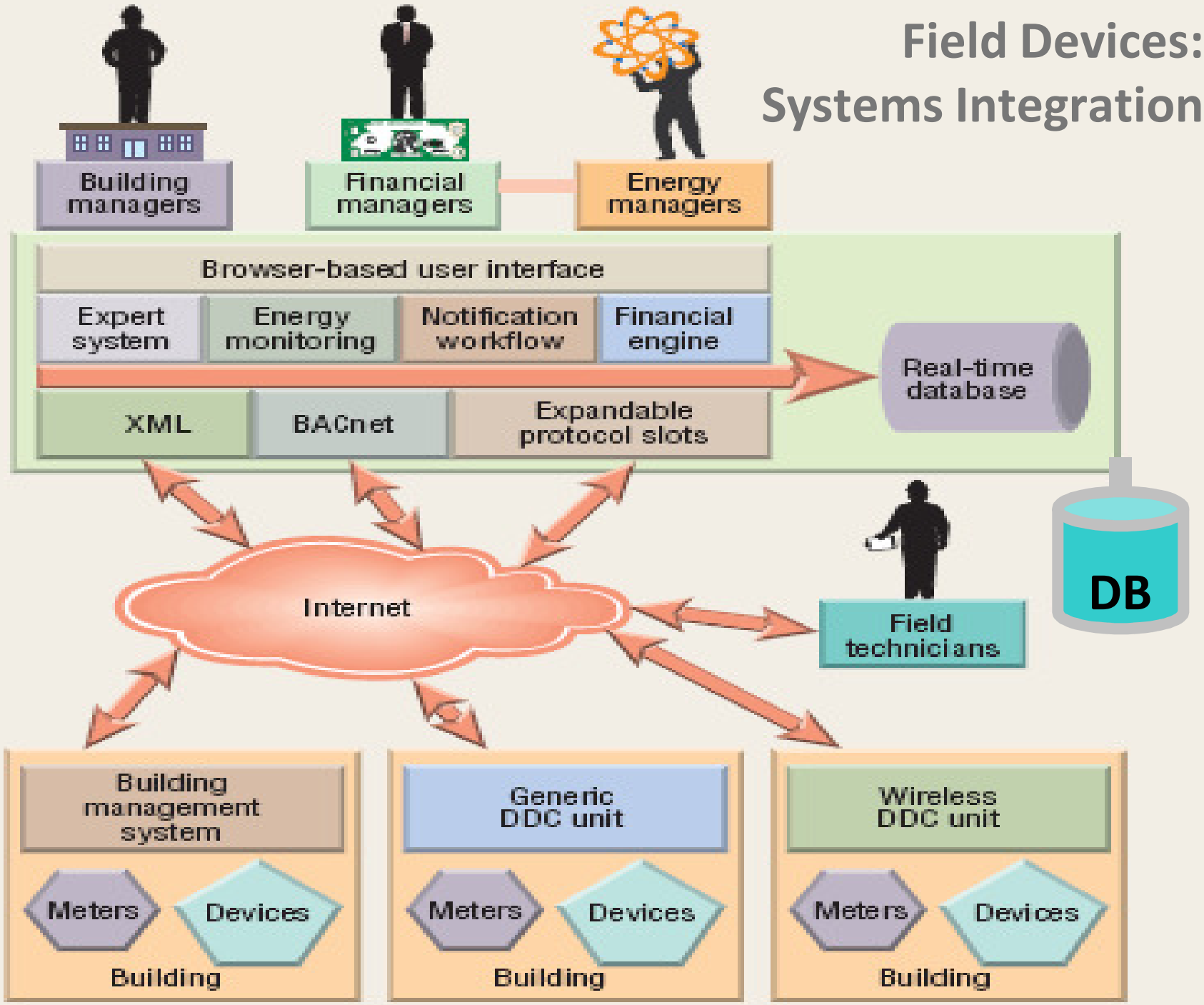
Energy Consuming Devices

Meters

INTERNET

Real-time DB

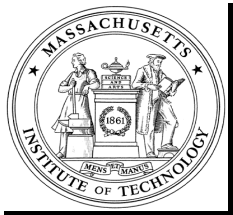
Field Devices: Systems Integration



Knowledge Management

- Knowledge from energy managers
- Strategies relating to Occupancy, Water Pressure, Light, Duct Pressure, Precooling, Thermal Strategies, etc.
- Acquisition tools

- Representing acquired strategies in AI systems (rule based and goal based) as heuristics



iET 101

- Schedule: start chiller at 0430 am at 55F
- Simple light sensor: sun comes up, switch off parking lot lights
- Feedback: keep zone 1 temperature between 68F to 72F
- Algorithms: compounds of the above
- But allow
- Neural Network Learning - Predictions
- Heuristics [re-arranging living room with spouse] aren't algorithms.

iET: Expert Systems and Neural Networks based on Goals

Weather Forecast, Price of Energy

Goals as Triggers

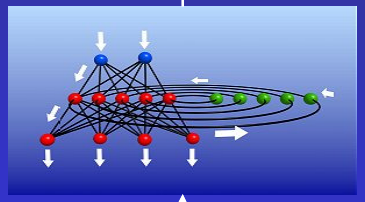
Business As Usual

Emergency Curtailment

Agent Decisions

Strategy Agents: Light, Pre-cool, SAT

Neural Net Forecasts



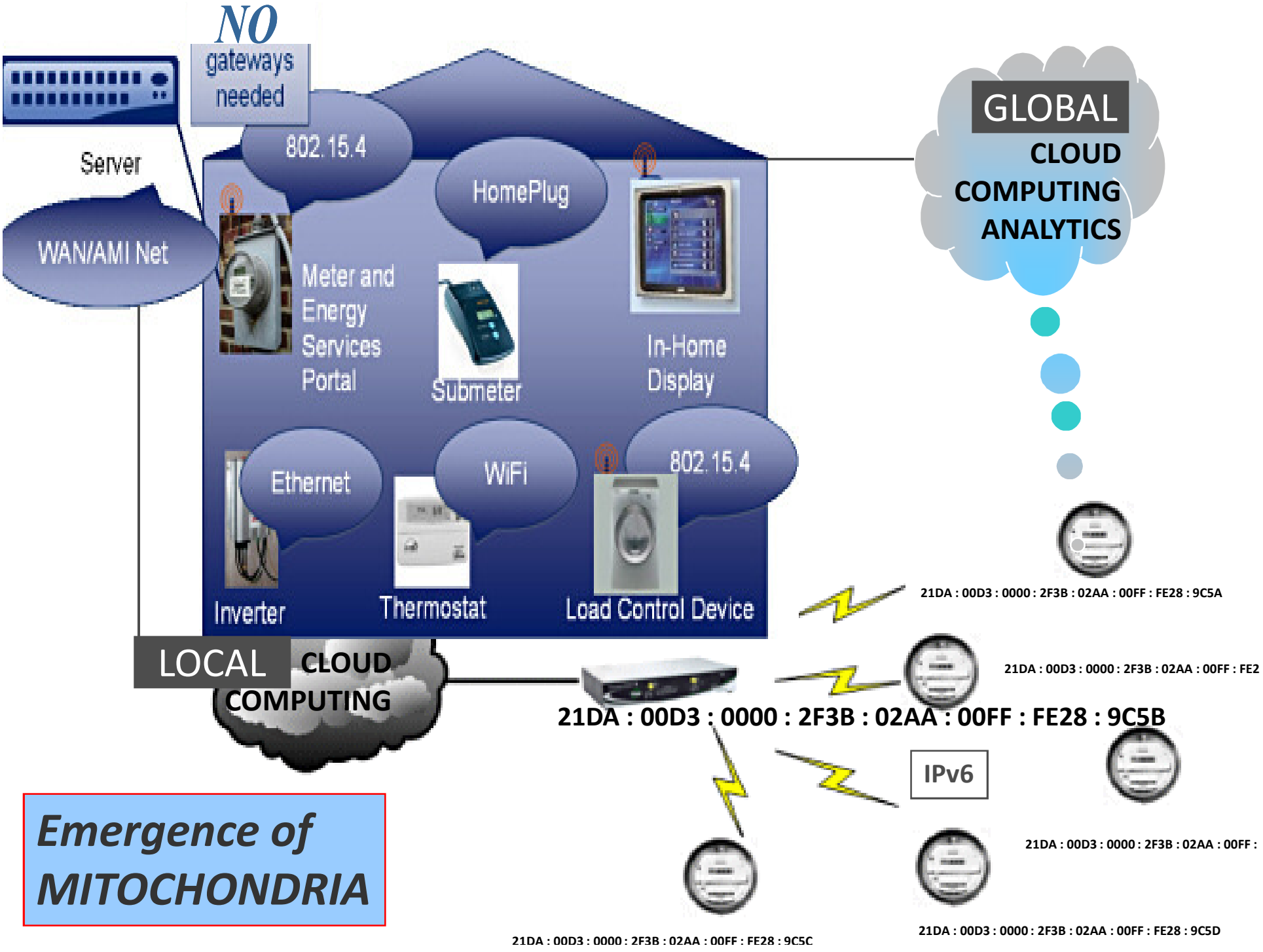
Device Forecaster

Device Proxy

Device Read/Write

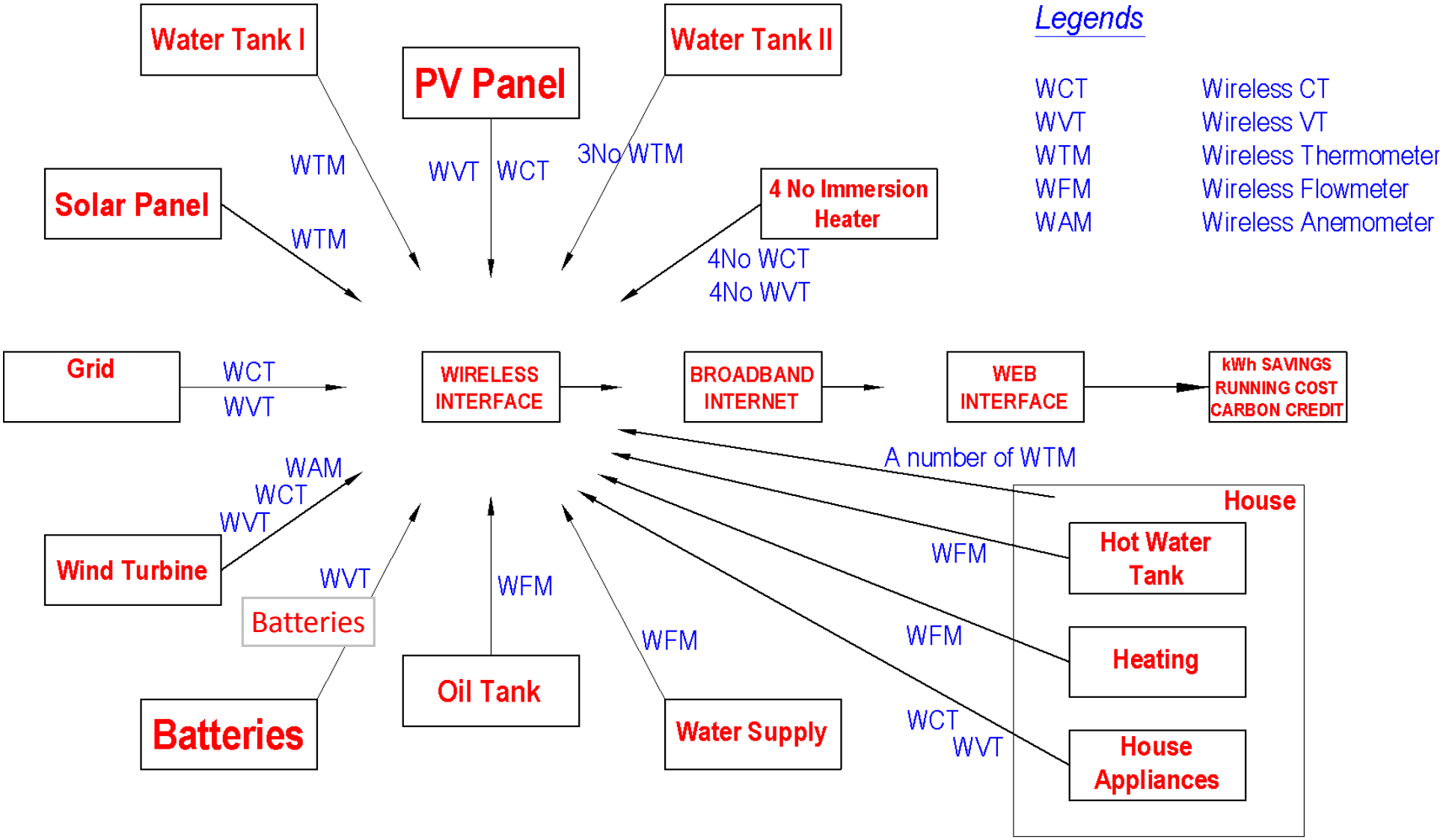
Sensor Data

Control Signal



Emergence of MITOCHONDRIA

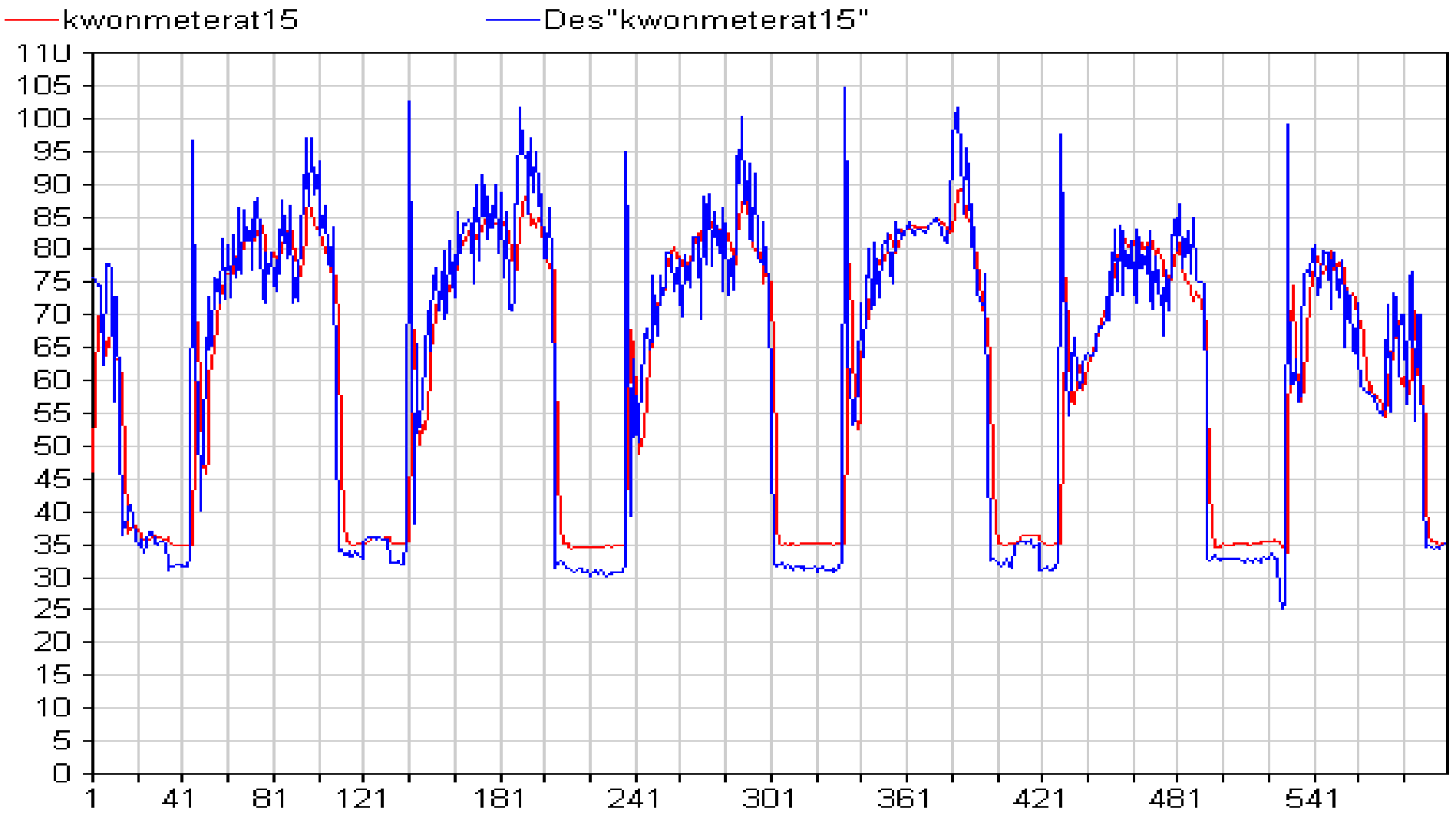
Conceptual Energy Box: Dynamic Optimization Aggregation for Energy Efficiency and Savings



Continuous ANN Training: Predicted vs Observed

Output vs. Desired Plot

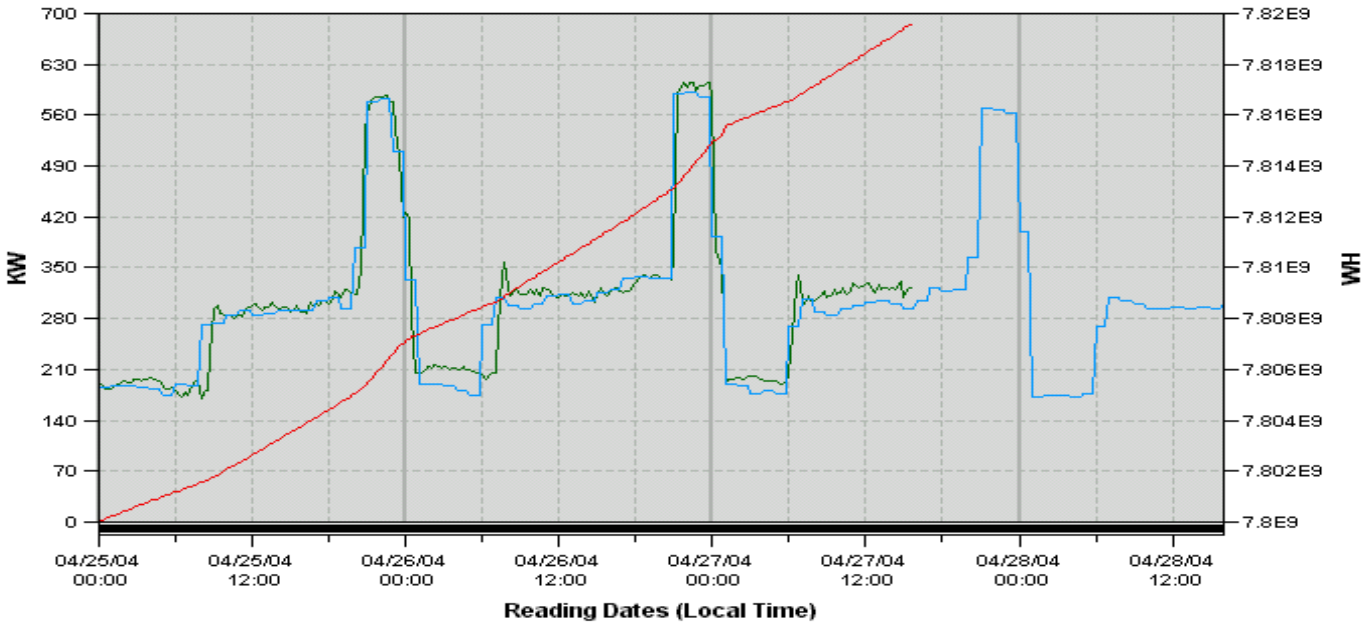
D. Mahling



Demand Forecast

Intelligent Use of Energy

D. Mahling



Graph Legend

Univ. of Miami : Miami : Wellness Center : Wellness Center Electric Meter

- Wellness Center Electric Meter -> Demand 15 Minute (KW)
- Wellness Center Electric Meter -> Forecast (KW)
- Wellness Center Electric Meter -> Meter KWH (WH)

View Statistics

From Date	04/25/2004	To Date	04/28/2004
Start Time	00:00	End Time	15:54

Line Calendar

SAT *at work*

Agent	Device	Time	Command	Space Temp	kw
	Wellness AHU08	11:10		69	40
SAT	Wellness AHU08	11:12	Presetting SAT Reset to 58	69	40
SAT	Wellness AHU08	11:13	Setting SAT Register to 1	69	40
SAT	Wellness AHU08	11:14	Writing SAT Reset 60	69	37
	Wellness AHU08	11:16		69	37
	Wellness AHU08	11:18		69	37
	Wellness AHU08	11:20		69.5	37
SAT	Wellness AHU08	11:22	Setting SAT Register to 0	69.5	40
	Wellness AHU08	11:24		69.5	40
	Wellness AHU08	11:26		69.5	40
	Wellness AHU08	11:28		69.5	40
	Wellness AHU08	11:30		69	40

D. Mahling

Case Study: AI for Demand Response

- Electronic signal was sent from CA-ISO to building system
  - curtail 2 Megawatts of load for 4 hours across 78 retail sites
- Base load for 78 properties approx 10 Megawatts
- Signal received at 1:45 PM [15 minutes ahead of the start time of 2PM]
- Curtailment commenced at 2PM and completed at 6PM PDST

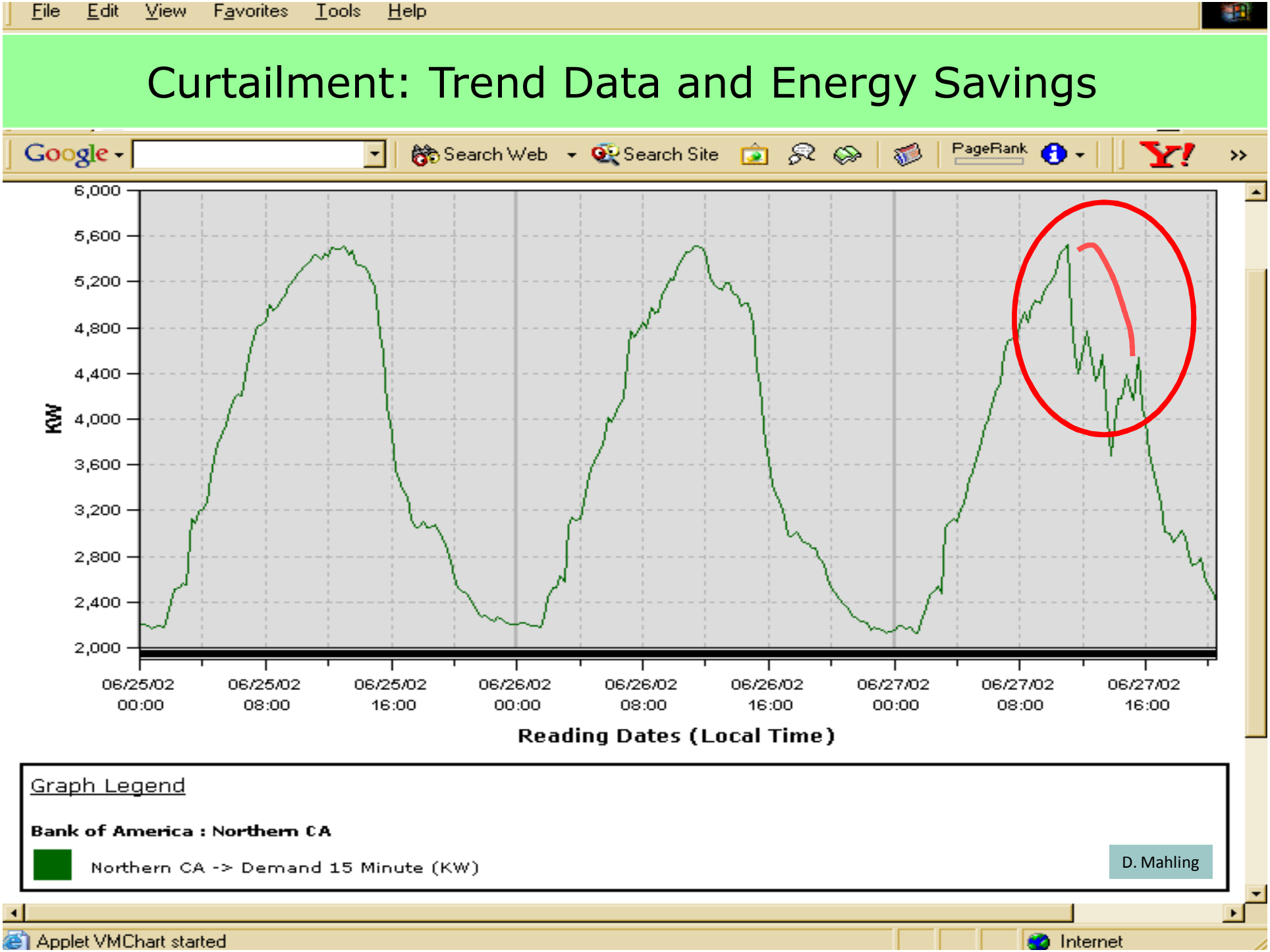
D. Mahling

Sequence of Events

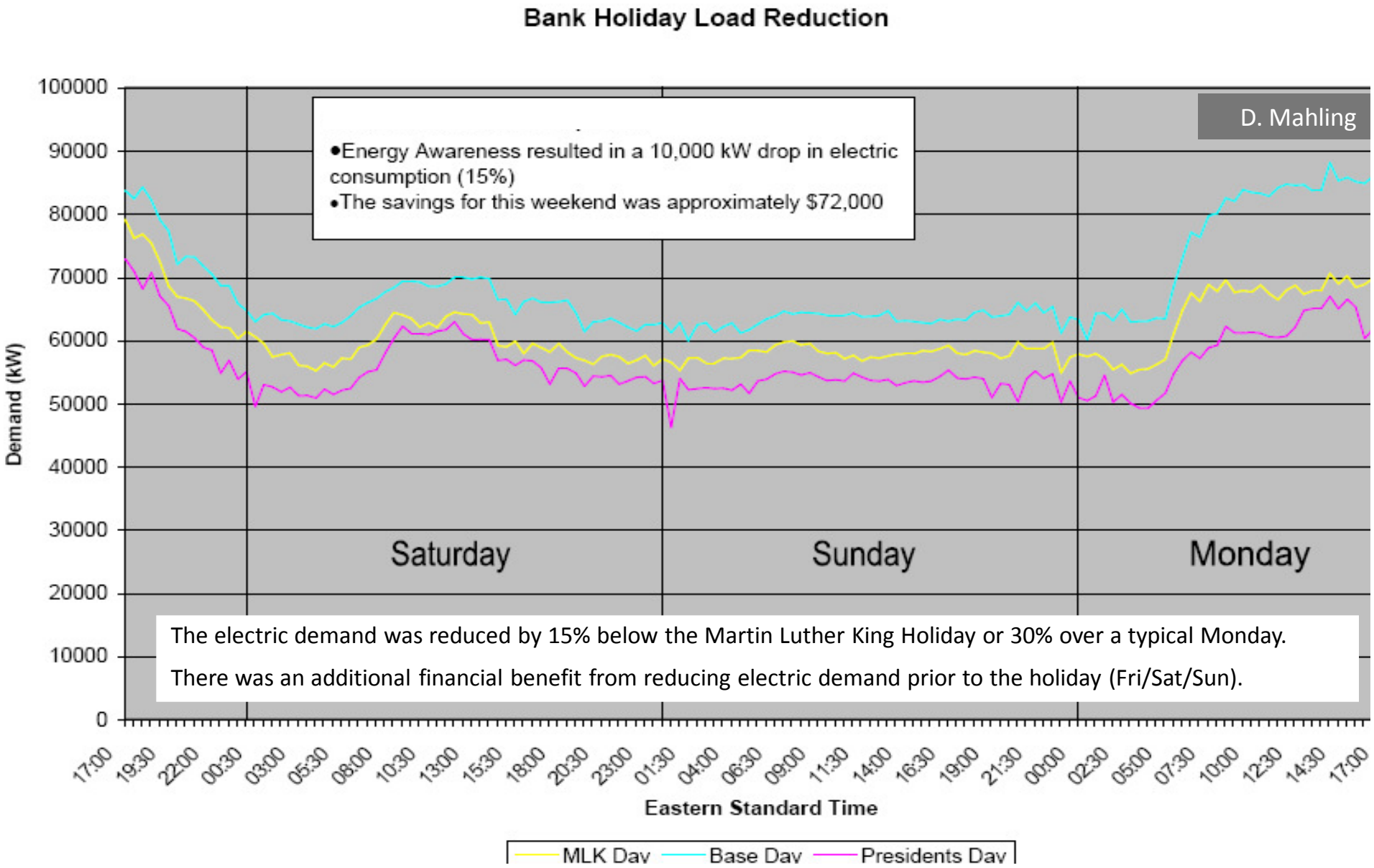
- 1:45 – DR signal received
- 1:46 – Agents shift from BAU mode to curtailment mode
- 1:47 – Energy Operator dials in 2 MW curtailment goal
- 2:00 – L/R agent deploys speed reduction on largest fans in North and South
- 2:10 – 1MW reduction
- 2:15 – Agent releases first L/R; Agent assembles second L/R set; deploys
- 2:20 – 2MW reduction
- Repeats until 3pm
- 3:00 – SAT agent raises SAT at select buildings
- 3:15 – SAT shifts buildings
- 3:05 – 1.2 MW reduction
- 3:20 – L/R rotates groups
- Etc

D. Mahling

Curtailment: Trend Data and Energy Savings



AI based systems learn to further reduce energy use

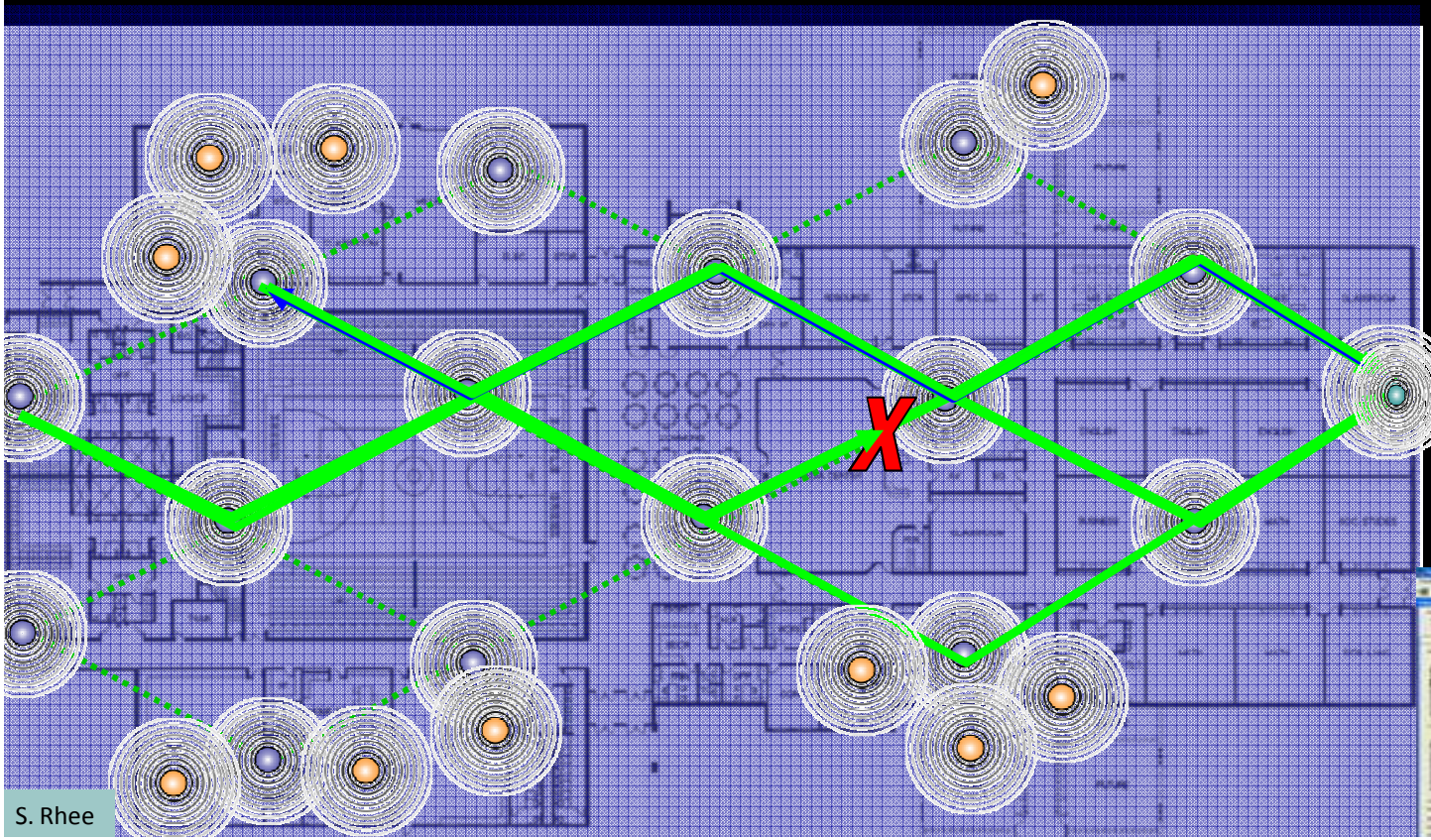


The electric demand was reduced by 15% below the Martin Luther King Holiday or 30% over a typical Monday.

There was an additional financial benefit from reducing electric demand prior to the holiday (Fri/Sat/Sun).

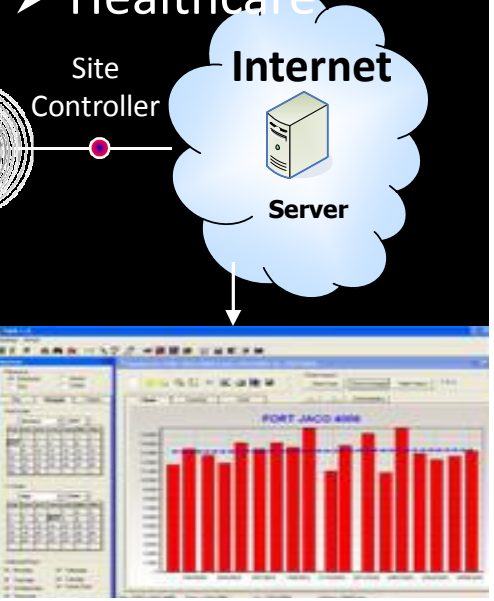
Ubiquitous Secure Wireless Sensor Network

- Sensors distributed over a wide range
- Multiple dynamics and penetration of barriers
- No single point of failure
- Grid power not necessary
- Bi-directional data monitoring, reset, reconfiguration, control



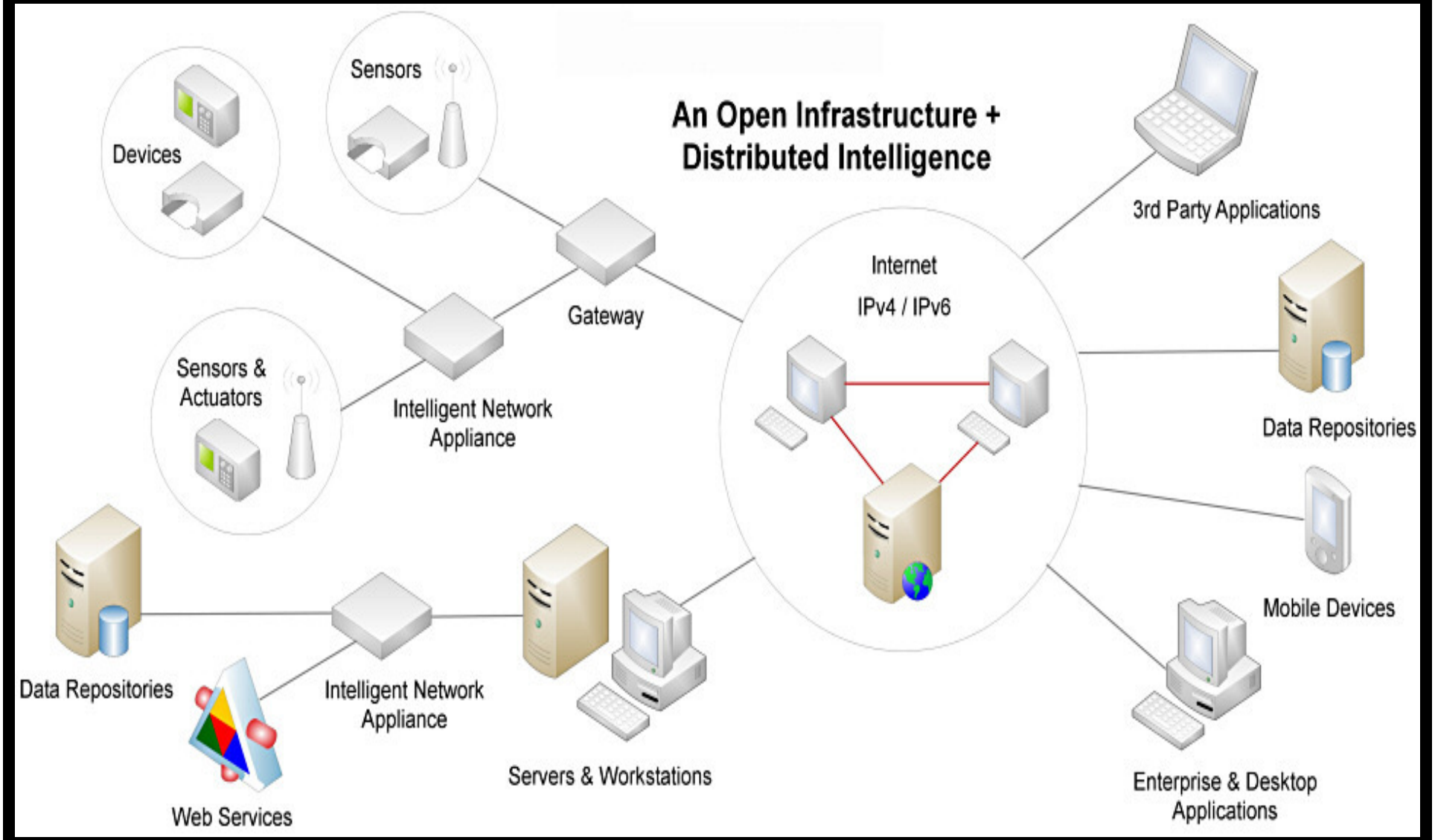
Useful to manage:

- Energy Efficiency
- Security & Safety
- Healthcare

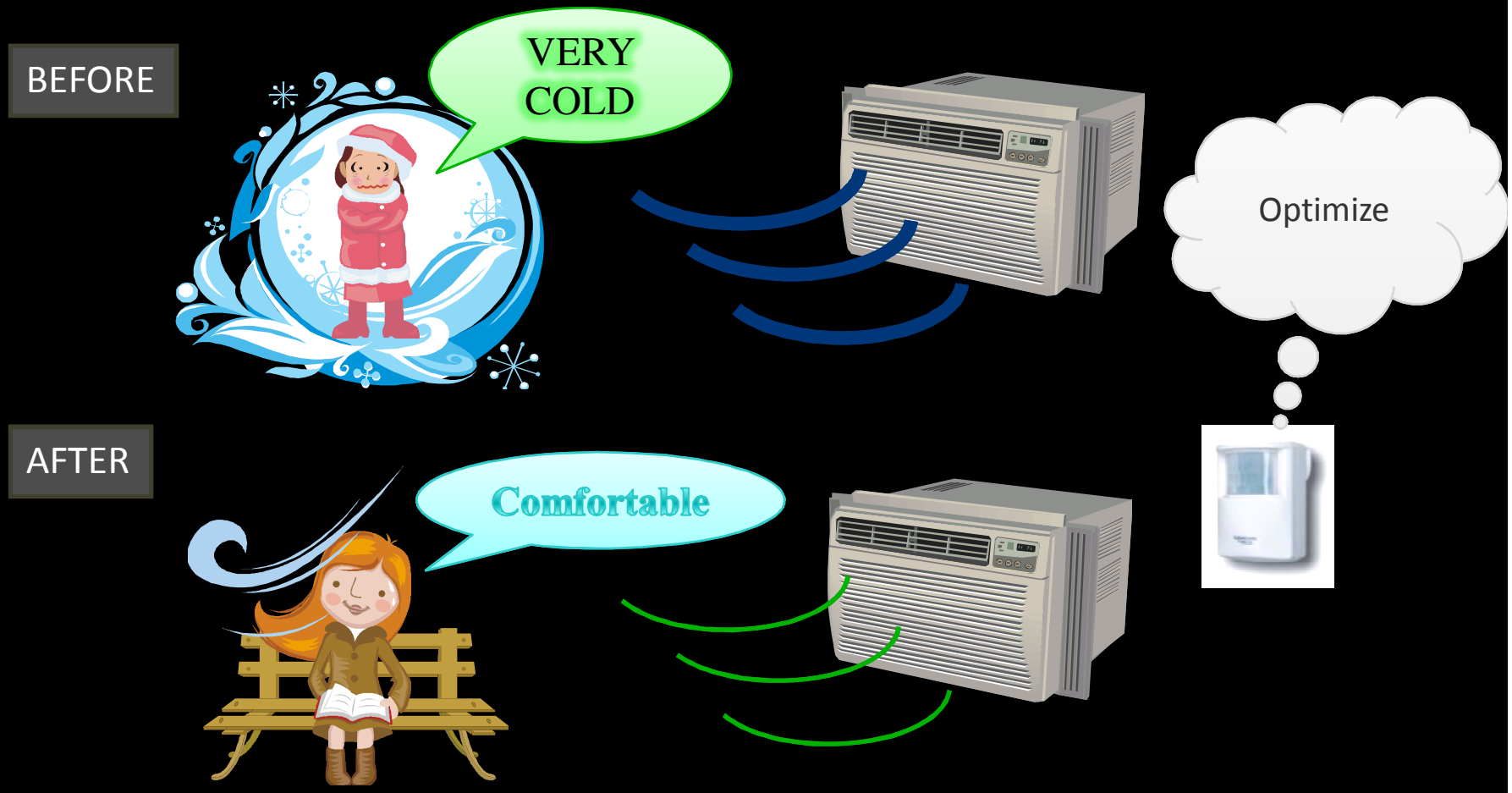


S. Rhee

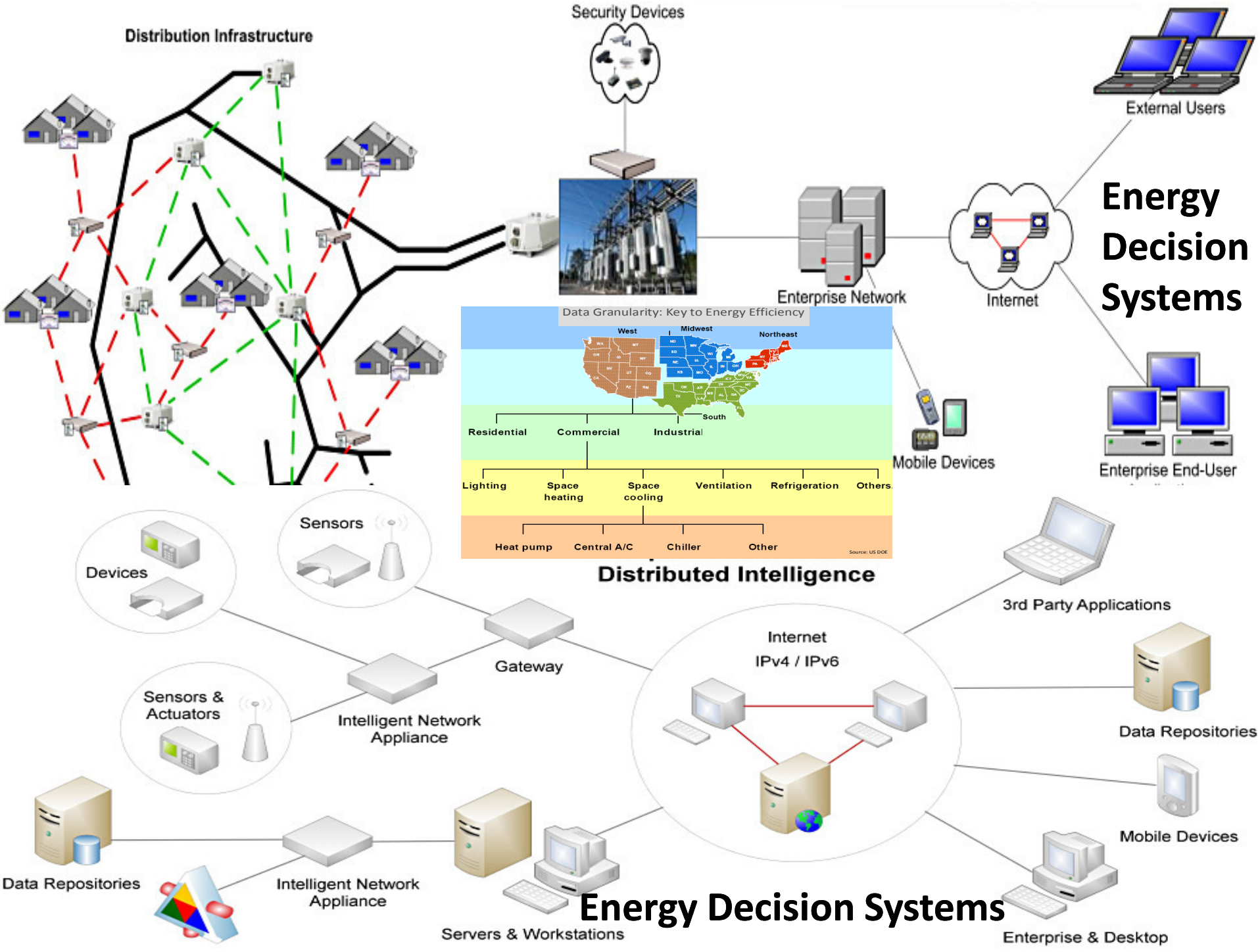
ENERGY EFFICIENCY: Preliminary Solutions Approach



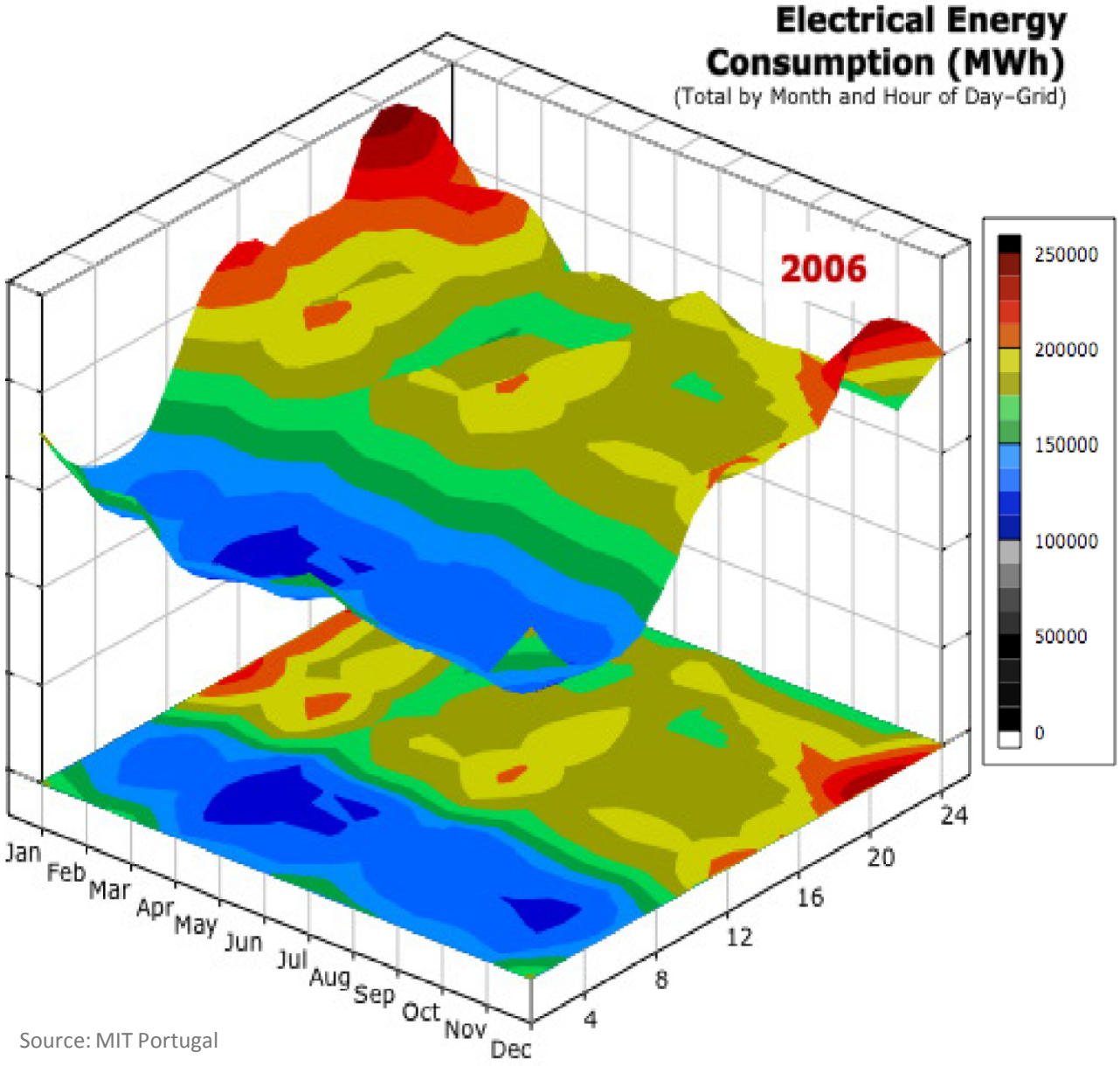
Answers, not numbers: Immediate Customer Satisfaction



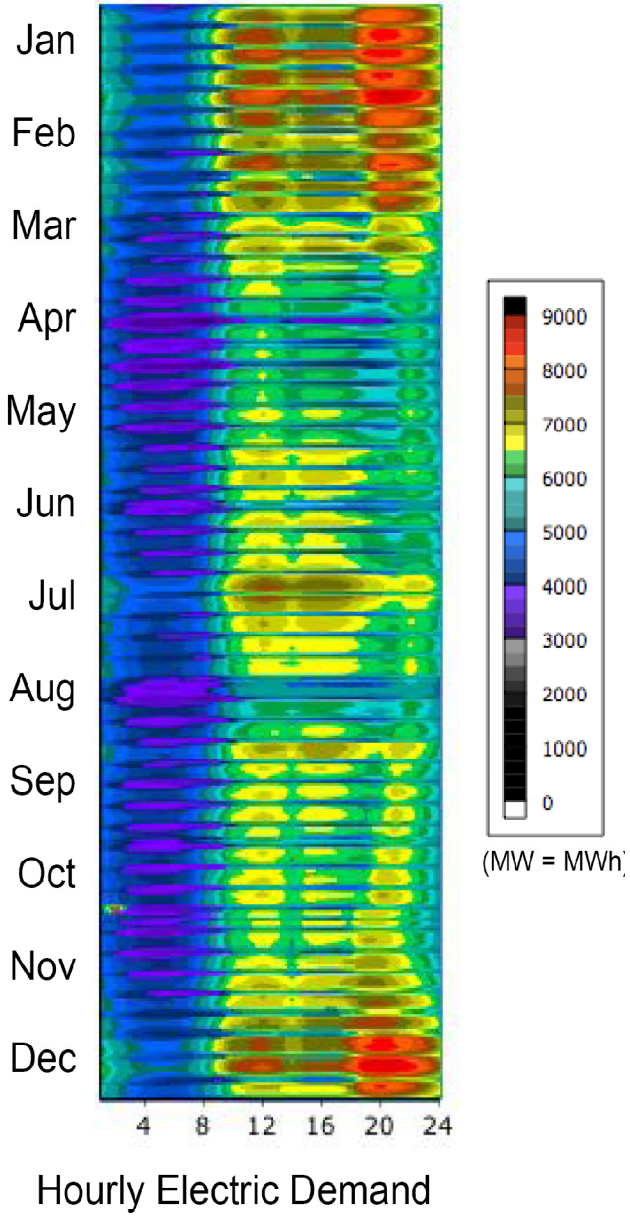
FUTURE OF ENERGY EFFICIENCY:
A Global Network Systems Solutions Approach


Distribution Infrastructure
Security Devices
External Users
Energy Decision Systems
Enterprise Network
Internet
Mobile Devices
Enterprise End-User
Data Granularity: Key to Energy Efficiency
West
Midwest
Northeast
South
Residential
Commercial
Industrial
Lighting
Space heating
Space cooling
Ventilation
Refrigeration
Others
Heat pump
Central A/C
Chiller
Other
Source: US DOE
Distributed Intelligence
Devices
Sensors
Gateway
3rd Party Applications
Internet
IPv4 / IPv6
Sensors & Actuators
Intelligent Network Appliance
Data Repositories
Mobile Devices
Data Repositories
Intelligent Network Appliance
Servers & Workstations
Enterprise & Desktop
Energy Decision Systems

Volatility of Supply-Demand: Insufficient Data Granularity

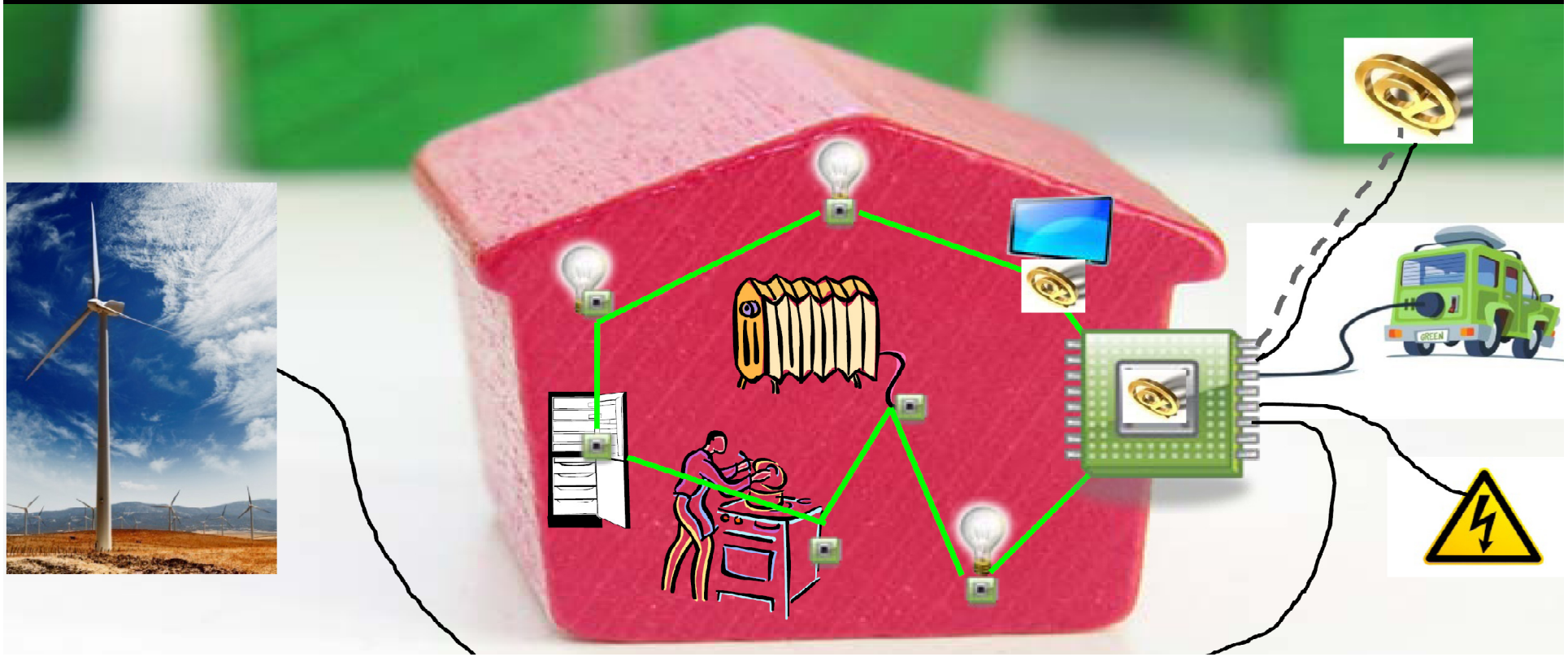


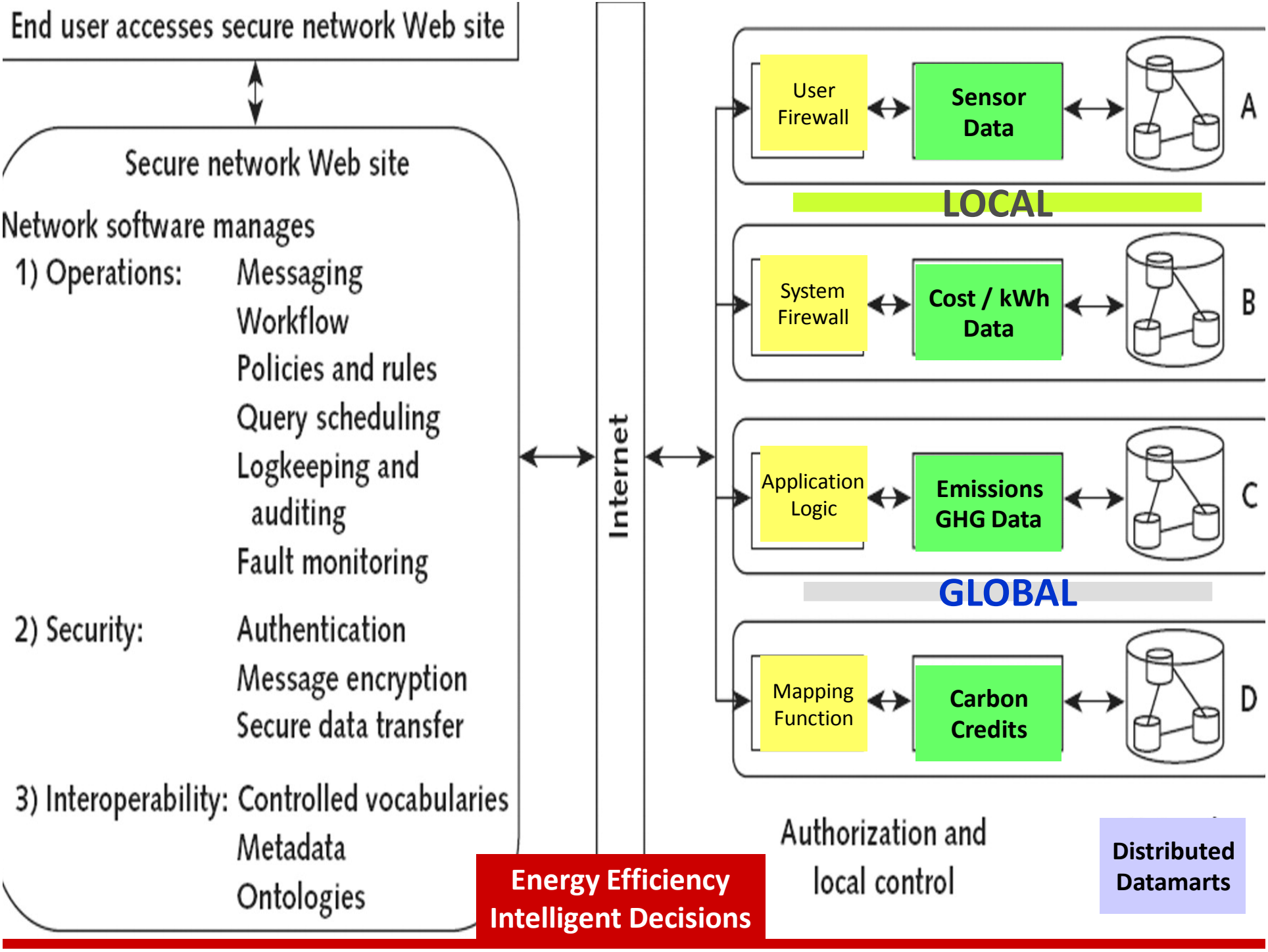
Source: MIT Portugal

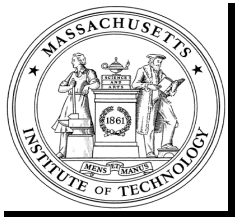


Hourly Electric Demand

Wireless Sensor Networks in Energy Efficiency: Data Granularity

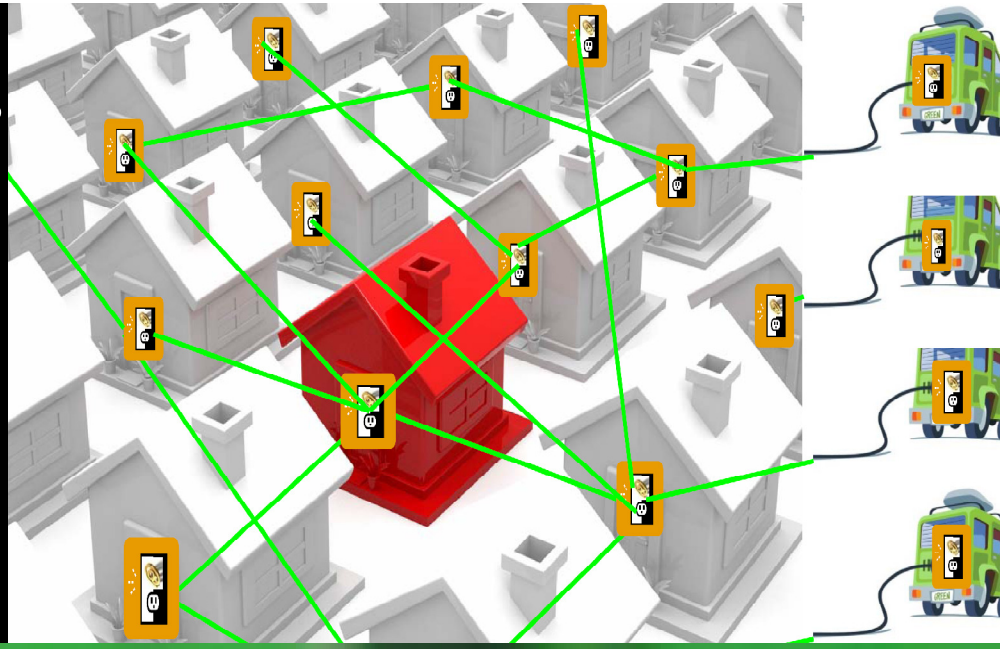


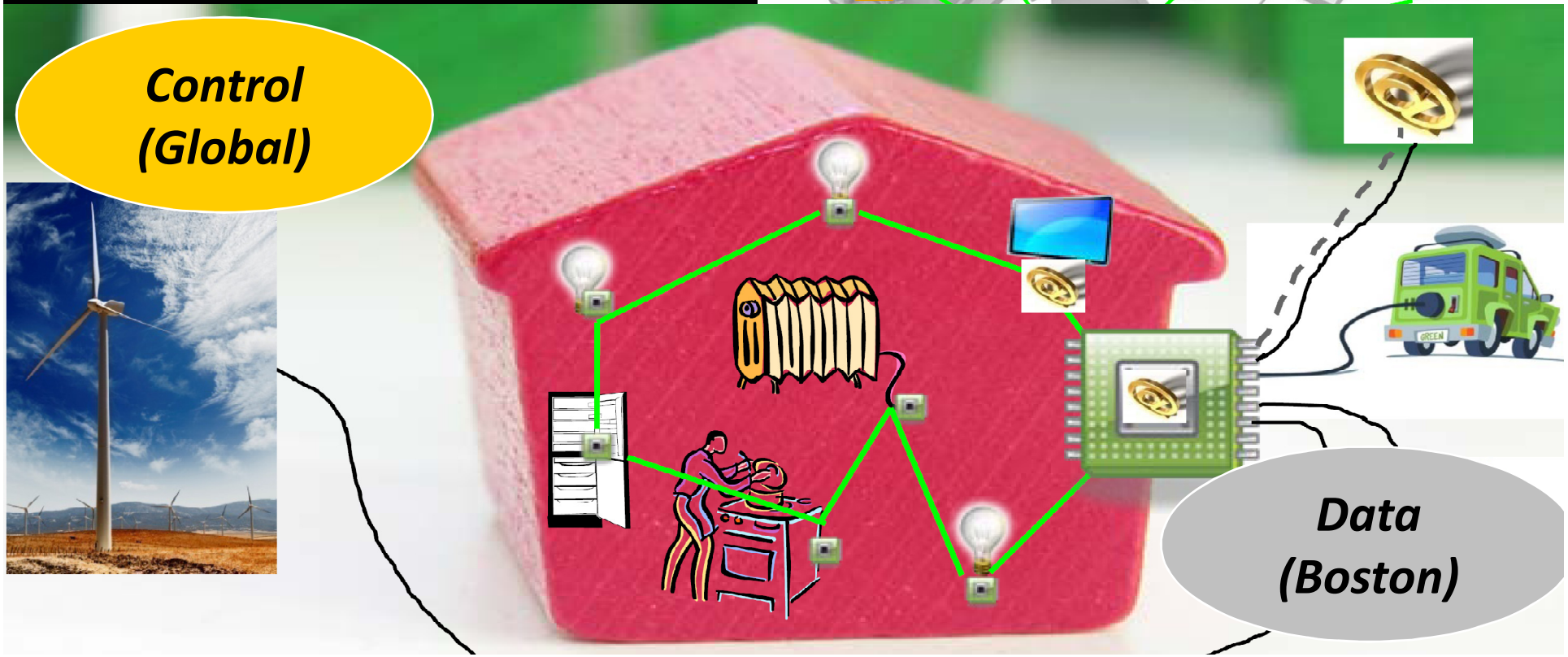

End user accesses secure network Web site
Secure network Web site
Network software manages
1) Operations:
Messaging
Workflow
Policies and rules
Query scheduling
Logkeeping and auditing
Fault monitoring
2) Security:
Authentication
Message encryption
Secure data transfer
3) Interoperability:
Controlled vocabularies
Metadata
Ontologies
Internet
User Firewall
Sensor Data
A
LOCAL
System Firewall
Cost / kWh Data
B
Application Logic
Emissions GHG Data
C
GLOBAL
Mapping Function
Carbon Credits
D
Authorization and local control
Distributed Datamarts
Energy Efficiency Intelligent Decisions



Network Software Systems

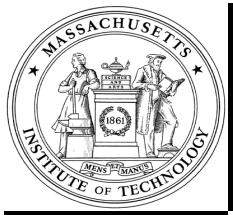
Energy Efficiency: Intelligent Decisions





SUMMARY: Temporary Advantages

- Implement WSN to monitor and record carbon emissions for carbon footprint audit
- Profit from control to improve savings and incentives due to energy efficiency or conservation measures
- Install carbon reduction management tool (iET) to balance carbon liabilities in commercial/industrial risk management
- Innovate on carbon trading options through cooperatives of carbon micro-credits
- Optimize ROI through energy savings, carbon credits and alternative energy portfolio (user and supplier)
- Interface with grid to curtail volatility and dynamic pricing



Submission of article for consideration of UNFCCC – UN Climate Summit 2009
QUEST FOR INTELLIGENT MITOCHONDRIA
http://dspace.mit.edu/handle/1721.1/45552

UNFCCC Programs

4.	Improvements to emissions trading and the project-based mechanisms (AWG-KP) Views on possible improvements to emissions trading and the project-based mechanisms (See FCCC/KP/AWG/2009/L.2, paragraph 2)	24 April
5.	Coverage of greenhouse gases, sectors and source categories, common metrics, possible approaches for targeting sectoral emissions and other issues (AWG-KP) Views on the coverage of greenhouse gases, sectors and source categories, common metrics, possible approaches for targeting sectoral emissions and other issues considered under agenda item 5 (h) (See FCCC/KP/AWG/2009/L.7/Rev.1, paragraph 4)	24 April
6.	Definitions, modalities, rules and guidelines for the treatment of land use, land-use change and forestry (LULUCF) in the second commitment period (AWG-KP) Views and proposals for further elaboration of the options, elements and issues contained in the annex "Options and proposals on how to address definitions, modalities, rules and guidelines for the treatment of land use, land-use change and forestry" (See FCCC/KP/AWG/2009/L.3, paragraph 3)	24 April
7.	Consideration of information on potential environmental, economic and social consequences, including spillover effects, of tools, policies, measures and methodologies available to Annex I Parties (AWG-KP) Further views on the issues contained in Annex "Text for further consideration by the Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol at its eighth session" (See FCCC/KP/AWG/2009/L.4, paragraph 4)	4 May

Acknowledgements

- MIT Building Technology Program
  Dr D. Mahling and Mr S. Samohous
- MIT Field Intelligence Laboratory
  Professor Sanjay Sarma
- MIT Energy Initiative
- MIT Forum for Supply Chain Innovation
- Bureau of Energy Efficiency, Government of India
  Dr Ajay Mathur
- UN Climate Congress, University of Copenhagen
  Professor Katherine Richardson
- EMC2 Laboratory, Oak Ridge National Laboratory, US DOE