The Intersection of Smart Grid and Buildings

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Cities with 10 Million People

By 2020, more than 30 mega cities* in the now less-developed world. By 2050, nearly 60 such cities.

Note: * Mega city 10 million population or greater

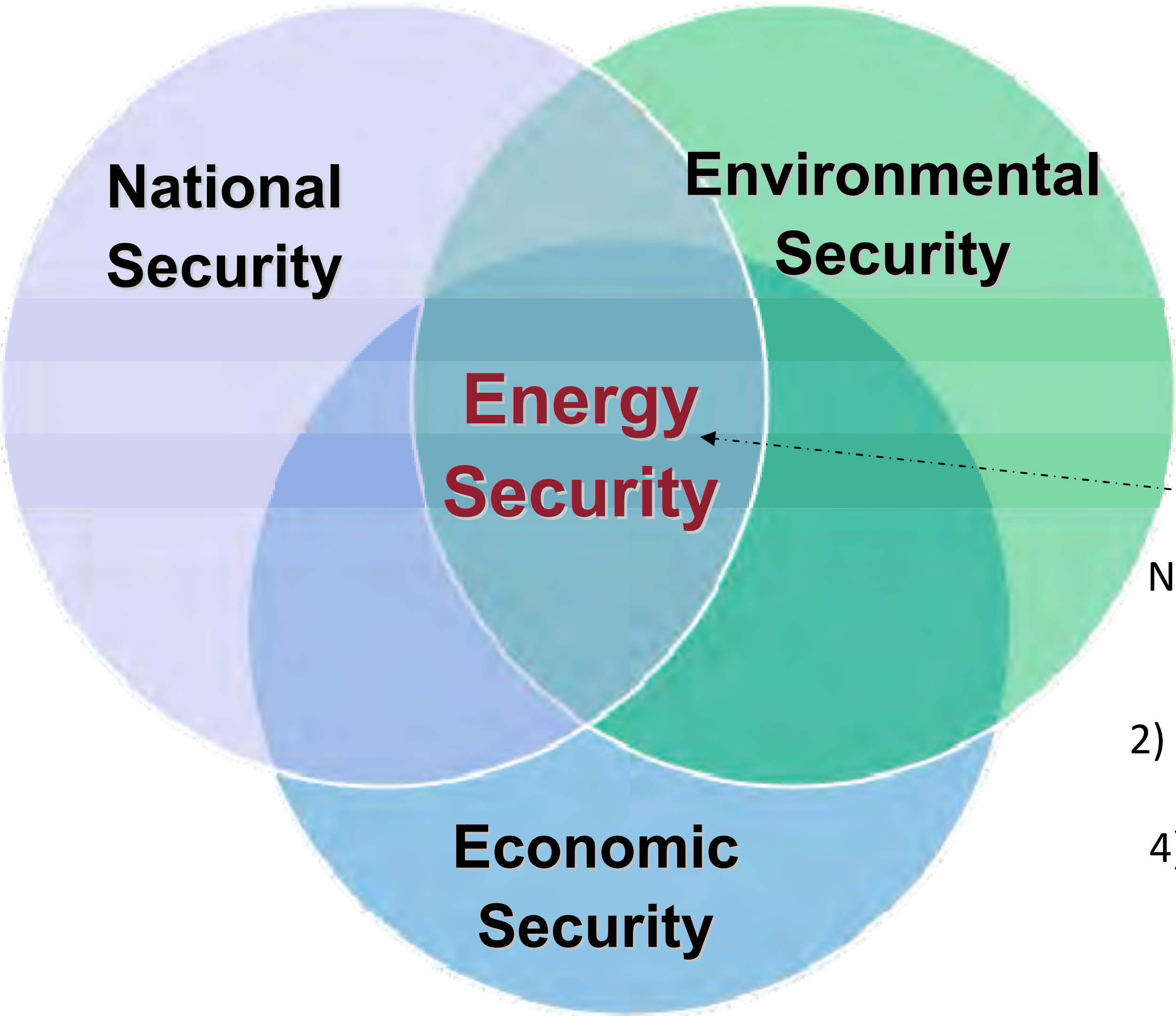
- **World's electricity supply will need to triple by 2050 to keep up with demand, necessitating nearly 10,000 GW of new generating capacity.**

The Energy Gap

- Half the world's population subsists on agrarian or lower levels of energy access, and
- Their population density generally exceeds the carrying capacity of their environment

Energy Security: System of Systems

The Energy Crises Taught Us Interdependency



System of Systems:

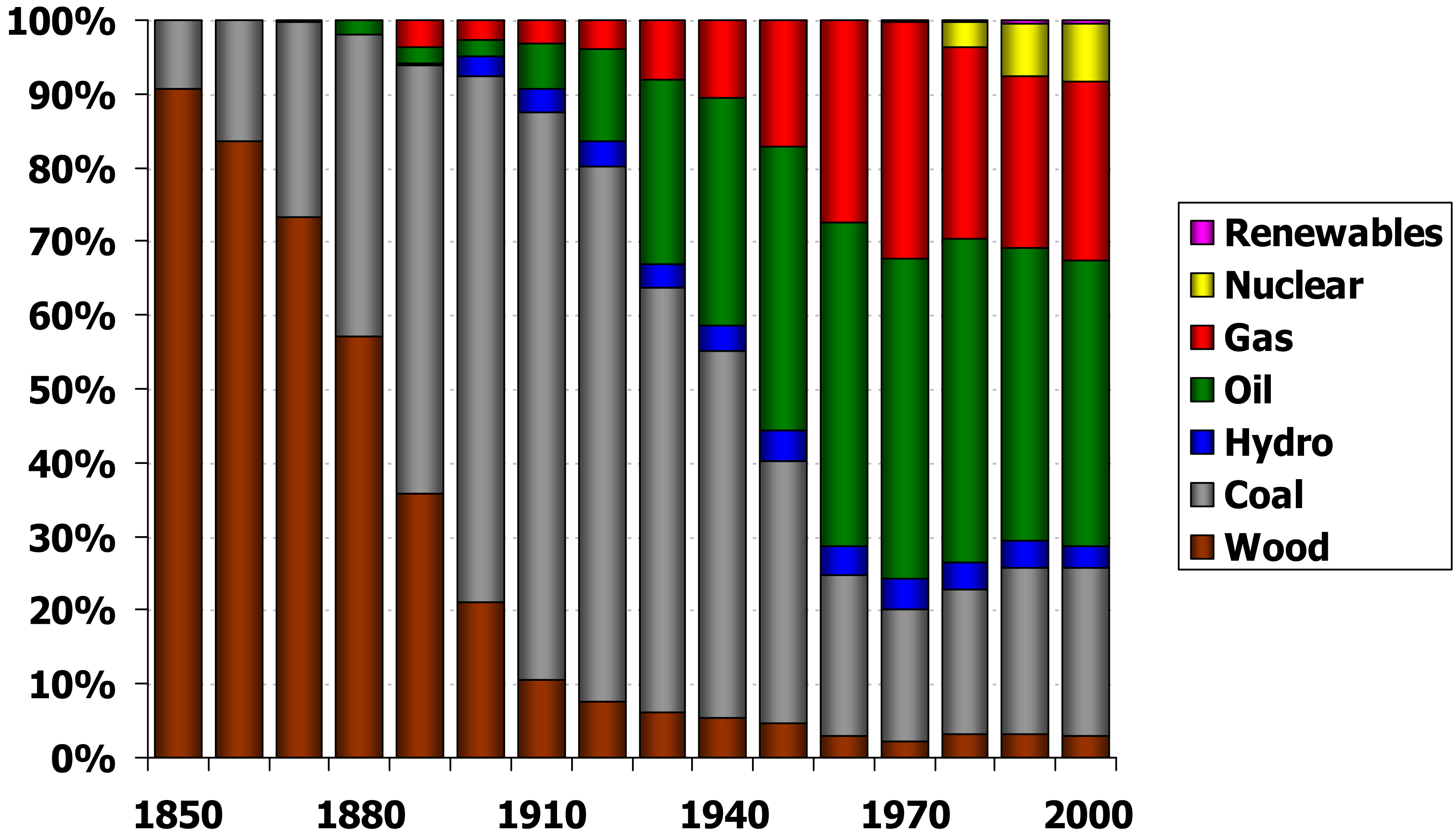
No "magic bullets" but there are many innovative bullets, including:

1) Green the power supply,
2) Energy systems & end-use efficiency,
3) Electrify transportation,
4) Build a stronger & smarter grid with massive storage integrating greener electrical energy.

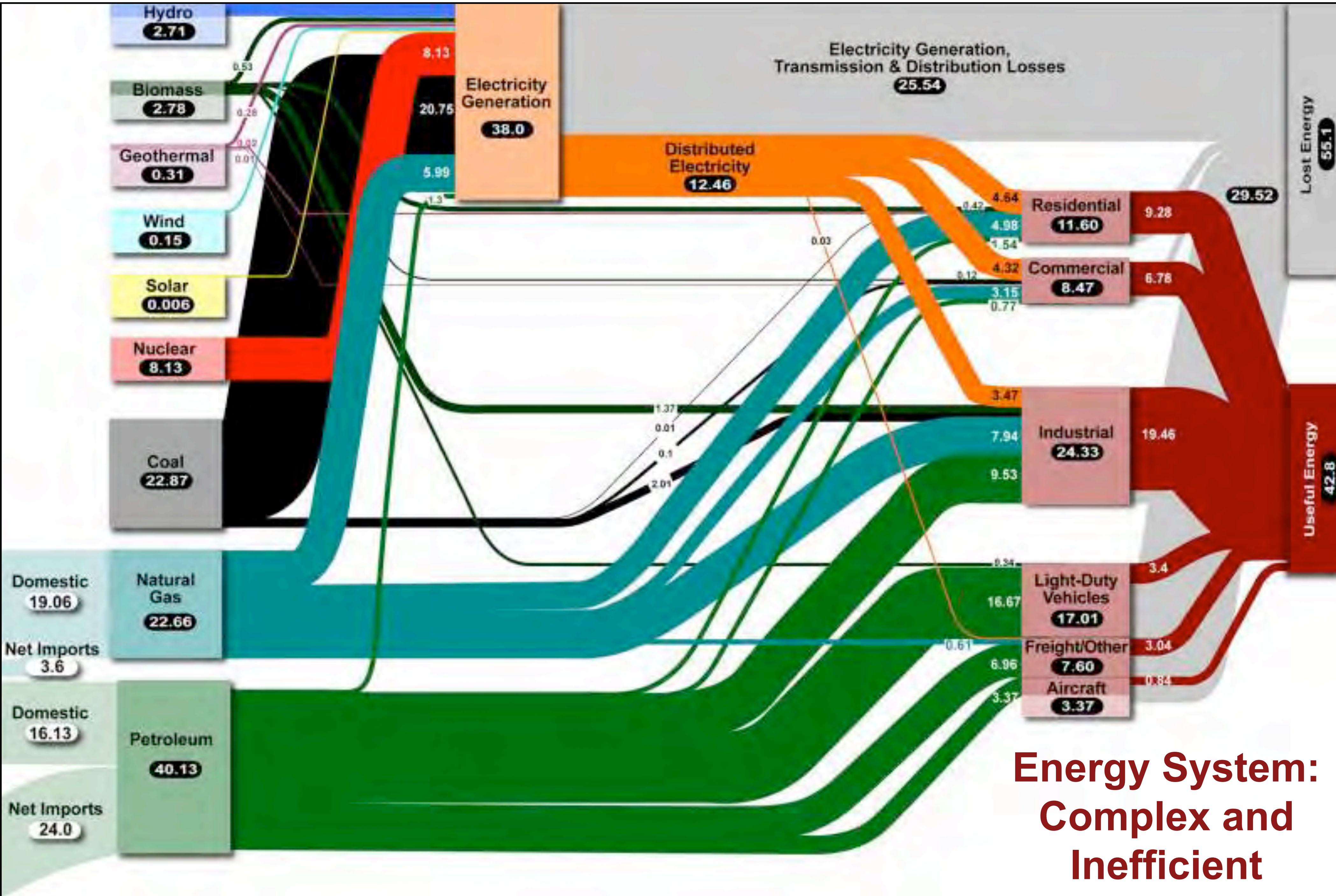
Source: Massoud Amin's Congressional briefing s on March 26 and Oct. 15, 2009

Focus: Energy Demand Growth and Fuel Substitution

U.S. Energy Supply Since 1850



Author: Koonin Source: EIA



Energy System: Complex and Inefficient

Energy map adapted from the U.S. DOE and LBNL

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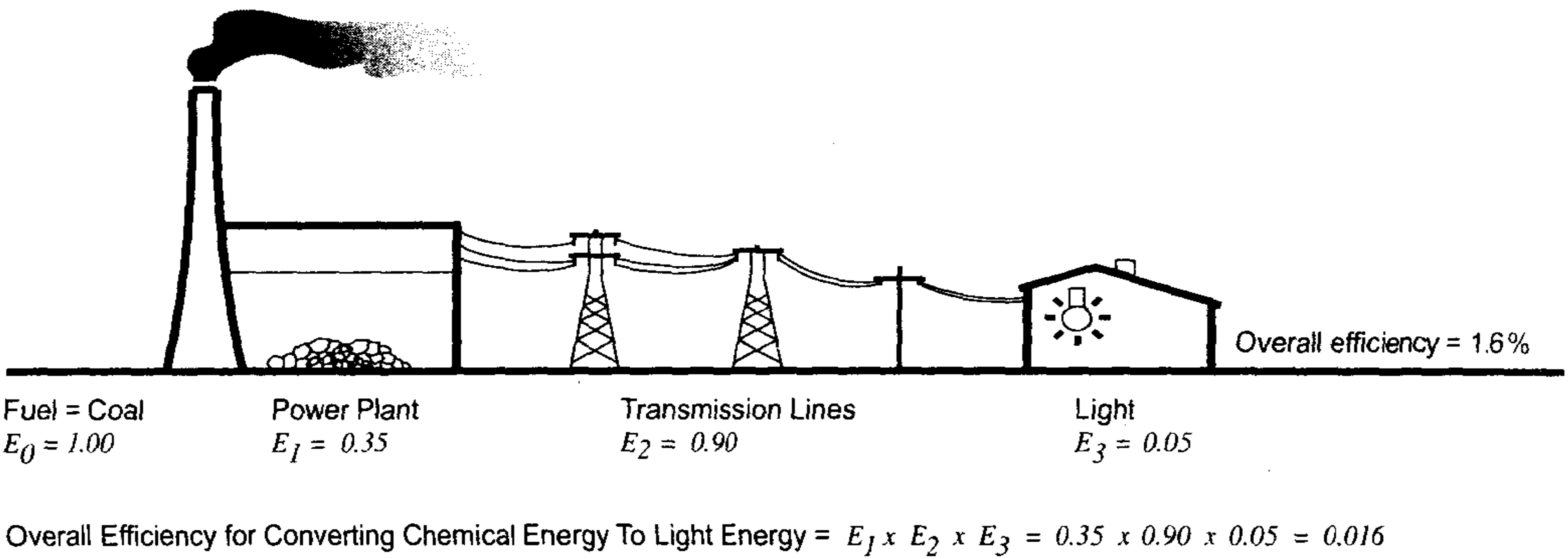
End-to-end Electric Power System

End-to-End Energy Inefficiency

Losses as high as 98.4%

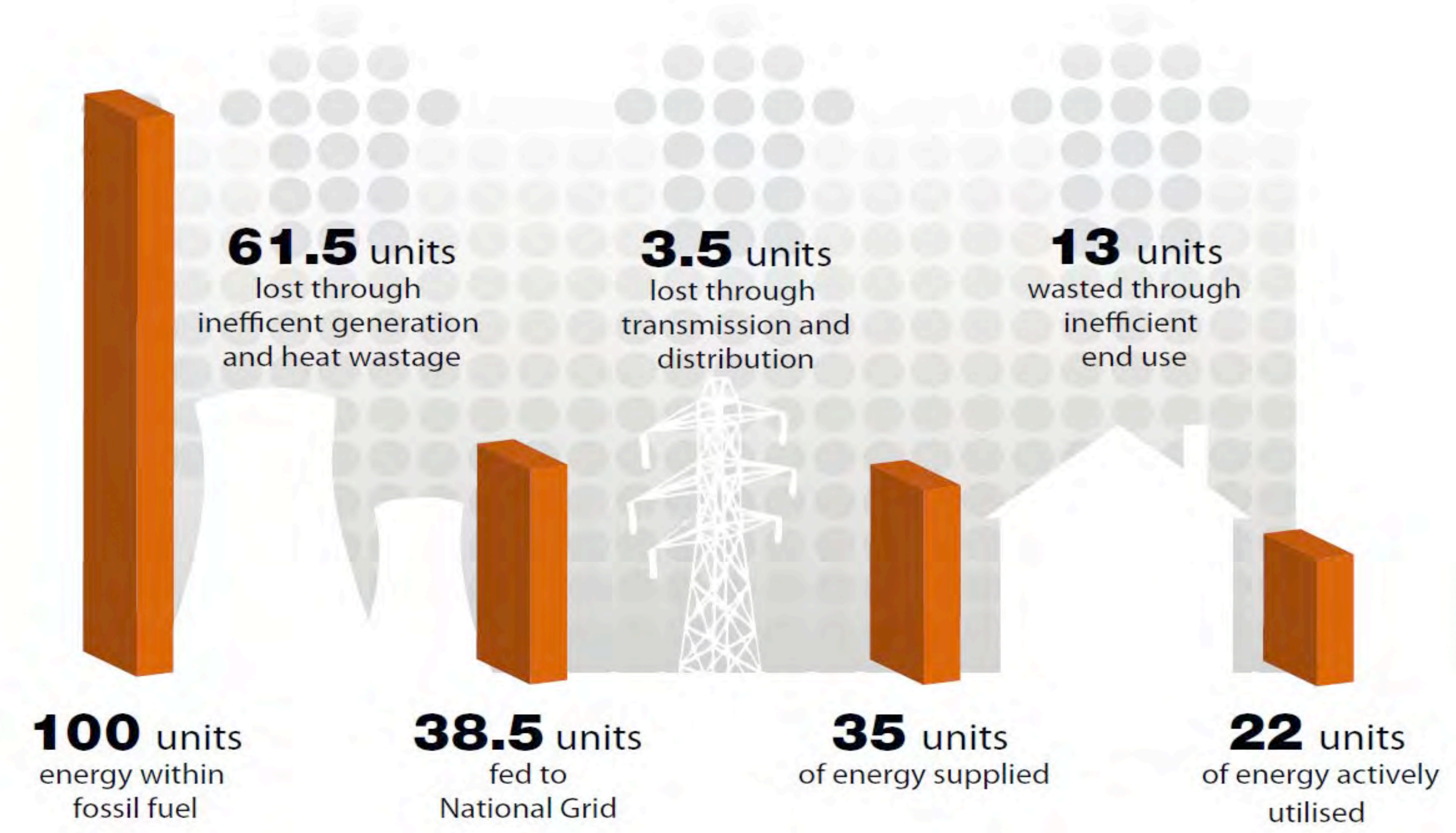


Opportunities to improve the situation:

- Use more efficient power plants, energy storage, modern transmission systems
- Use co-generation plants where useful (electricity and heat or desalination)
- Upgrade efficiency of use (change to many times more efficient LED or fluorescent lamps)

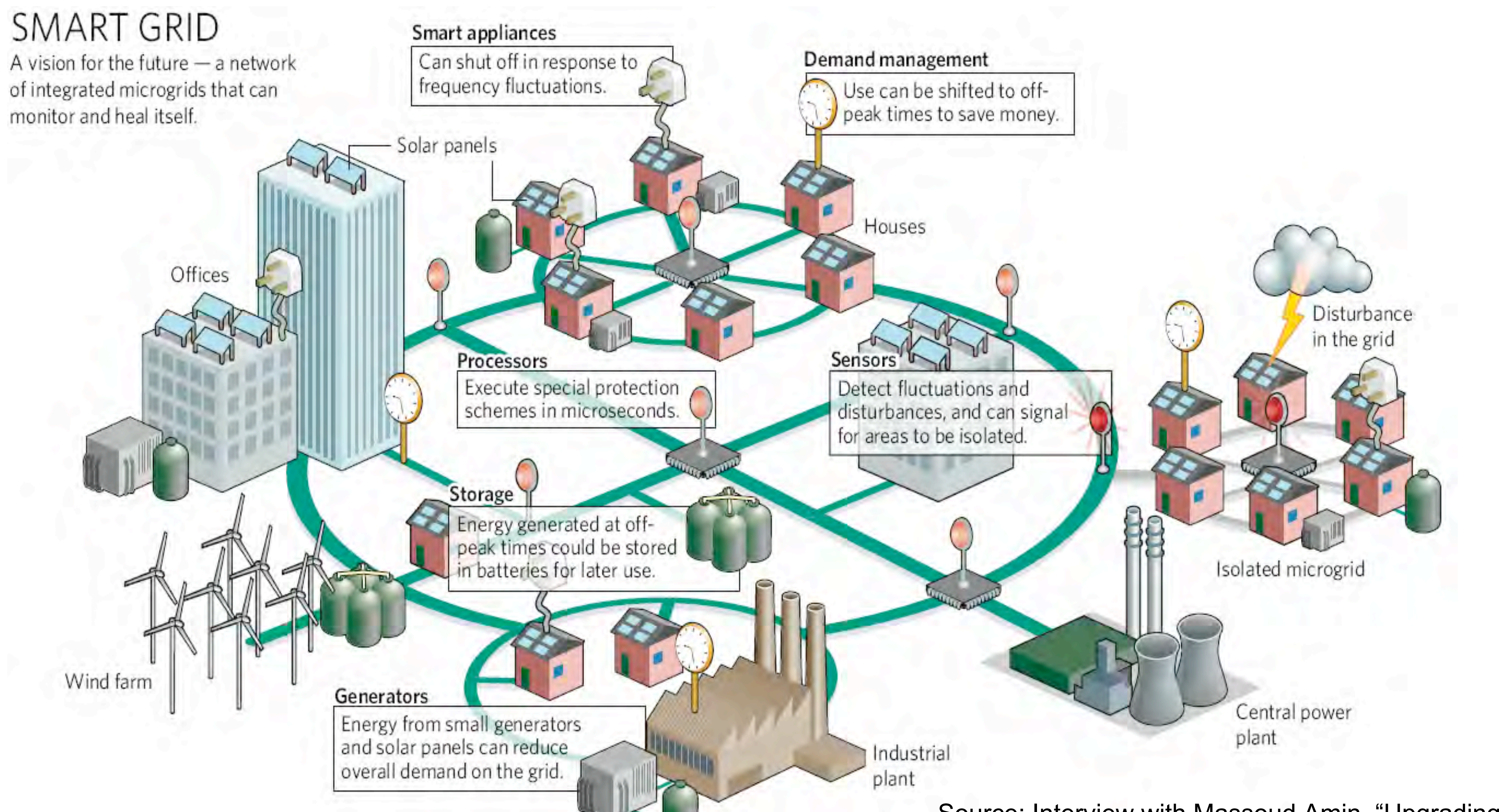
Source: NRC, 2009

End-to-End Energy Inefficiency



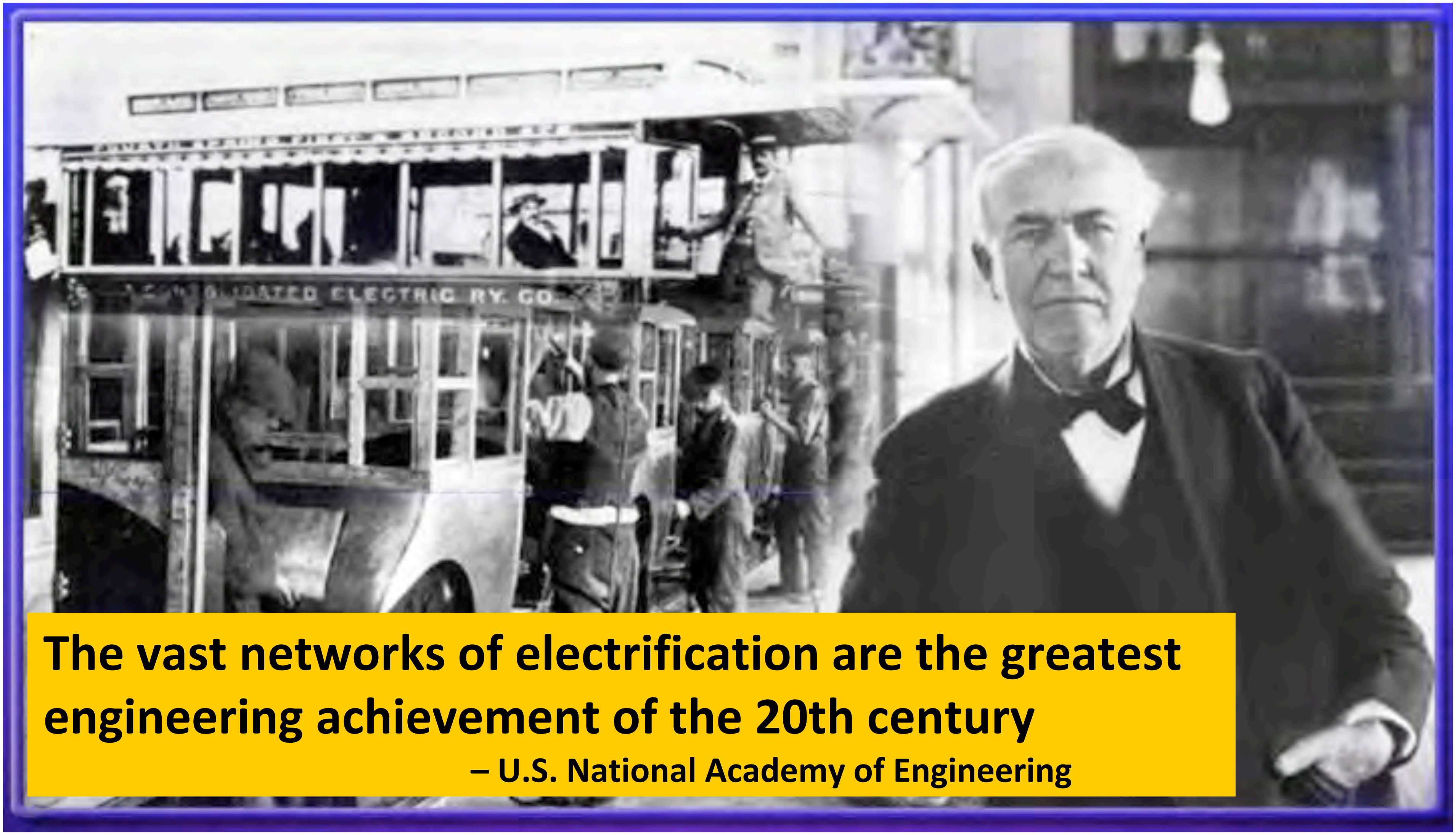
Smart Grids

Integrate microgrids, diverse generation and storage resources into a smart self-healing grid system



Source: Interview with Massoud Amin, "Upgrading the grid," *Nature,* vol. 454, 570–573, 30 July 2008

Transforming Society

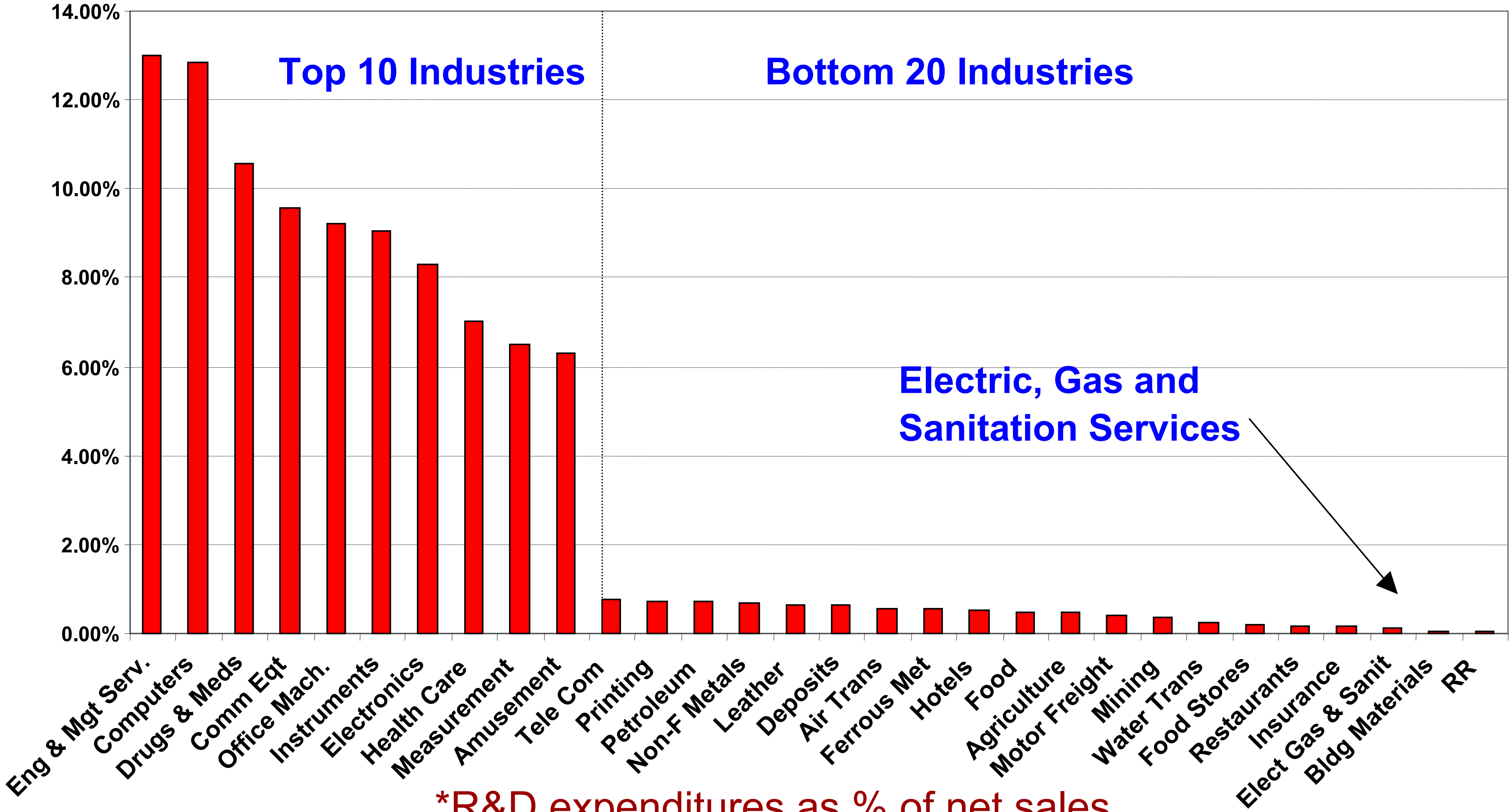


The vast networks of electrification are the greatest engineering achievement of the 20th century

– U.S. National Academy of Engineering

R&D Expenditures… The Real World

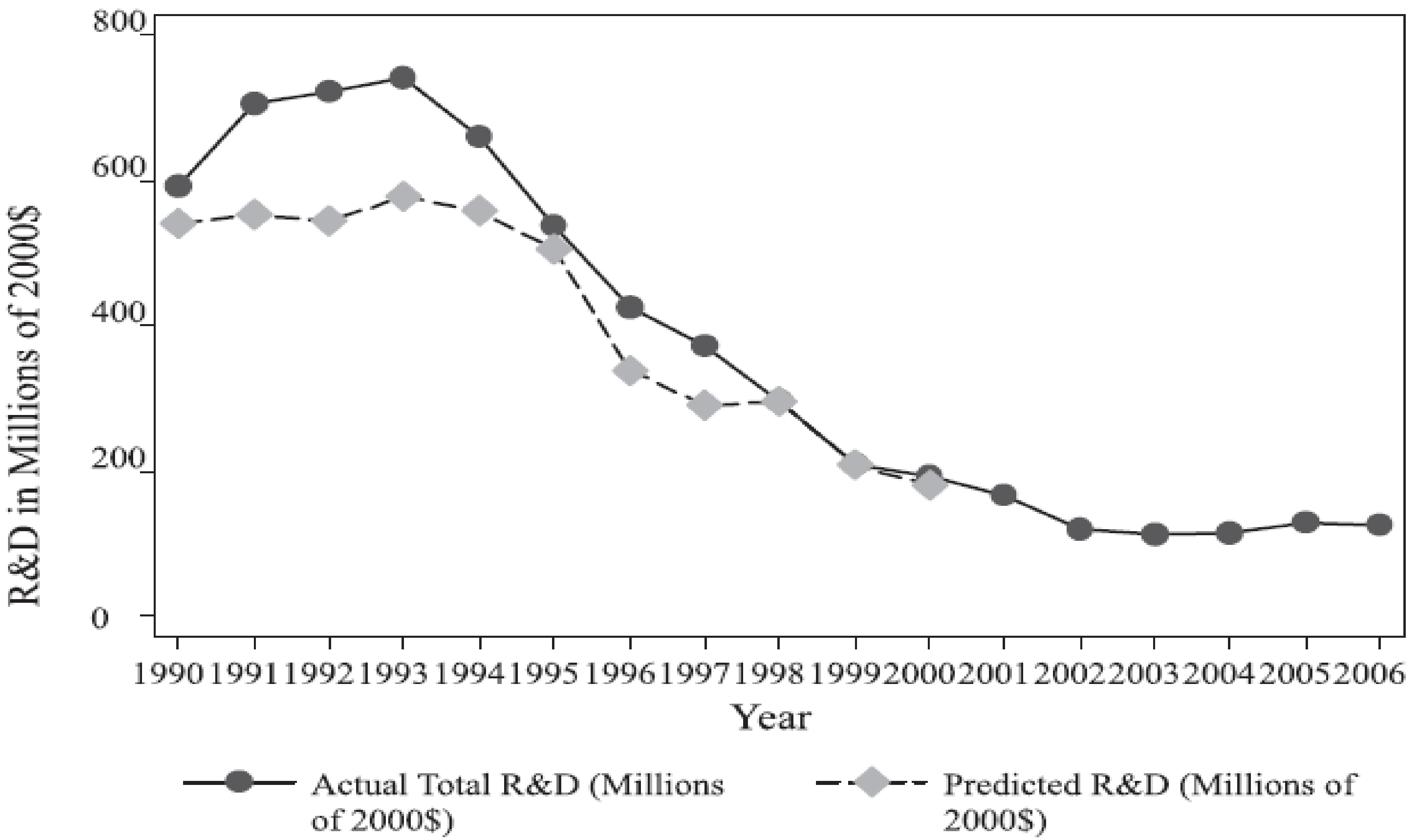
Pet food industry spends more in R&D than the electric power industry



*R&D expenditures as % of net sales

U.S. Electric Utilities R&D: 1990-2006

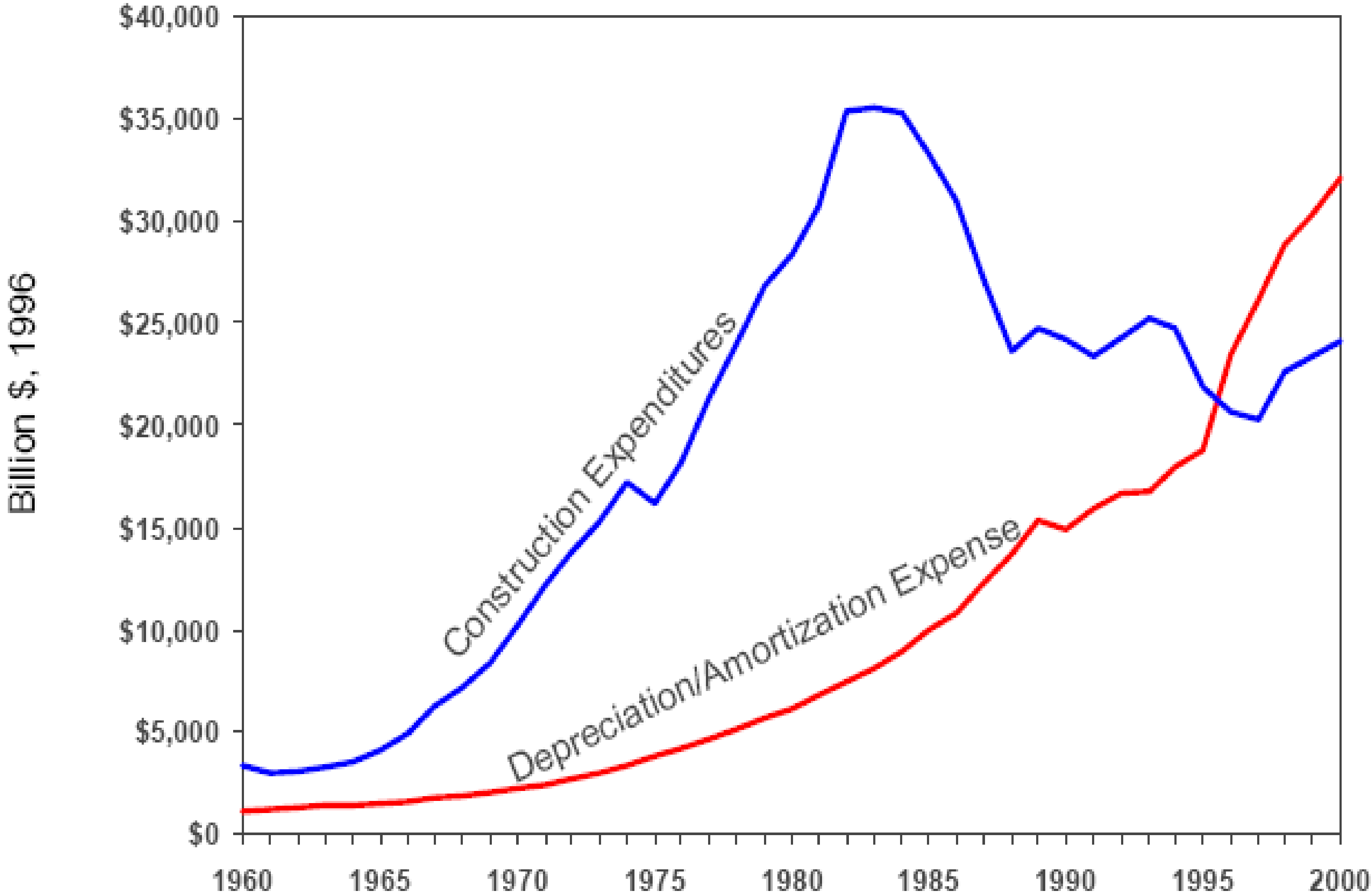
Annual R&D in the lowest rates of any major industrial sector with the exception of the pulp and paper



Source: "Powering Progress: Restructuring, Competition, and R&D in the U.S. Electric Utility Industry," by *Paroma Sanyal and Linda Cohen, The Energy Journal*, Vol. 30, No. 2, 2009

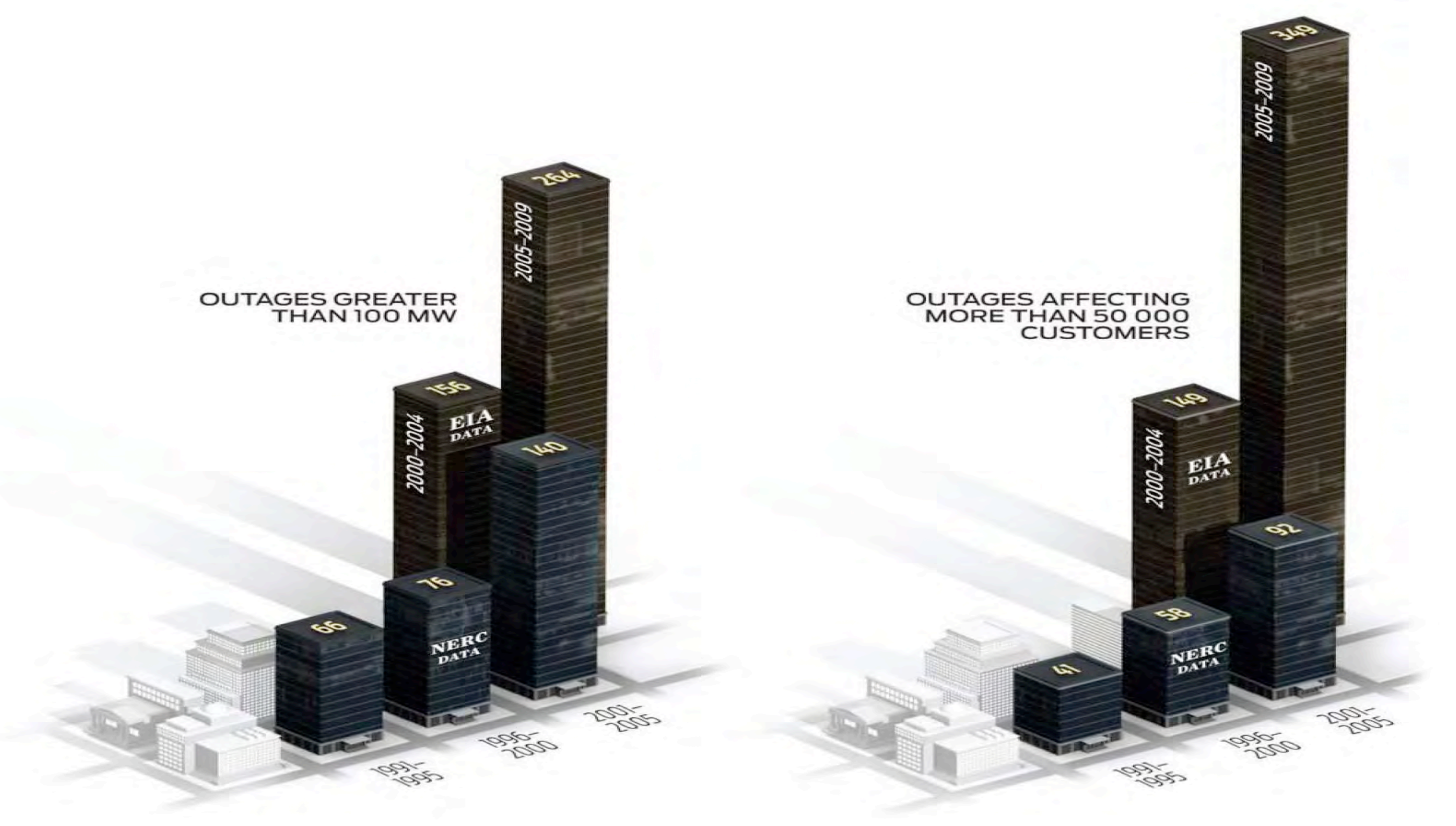
Utility construction

Overharvesting



Source: "Historical Statistics of the Electric Utility Industry" and "EEI Statistical Yearbook" - EEI

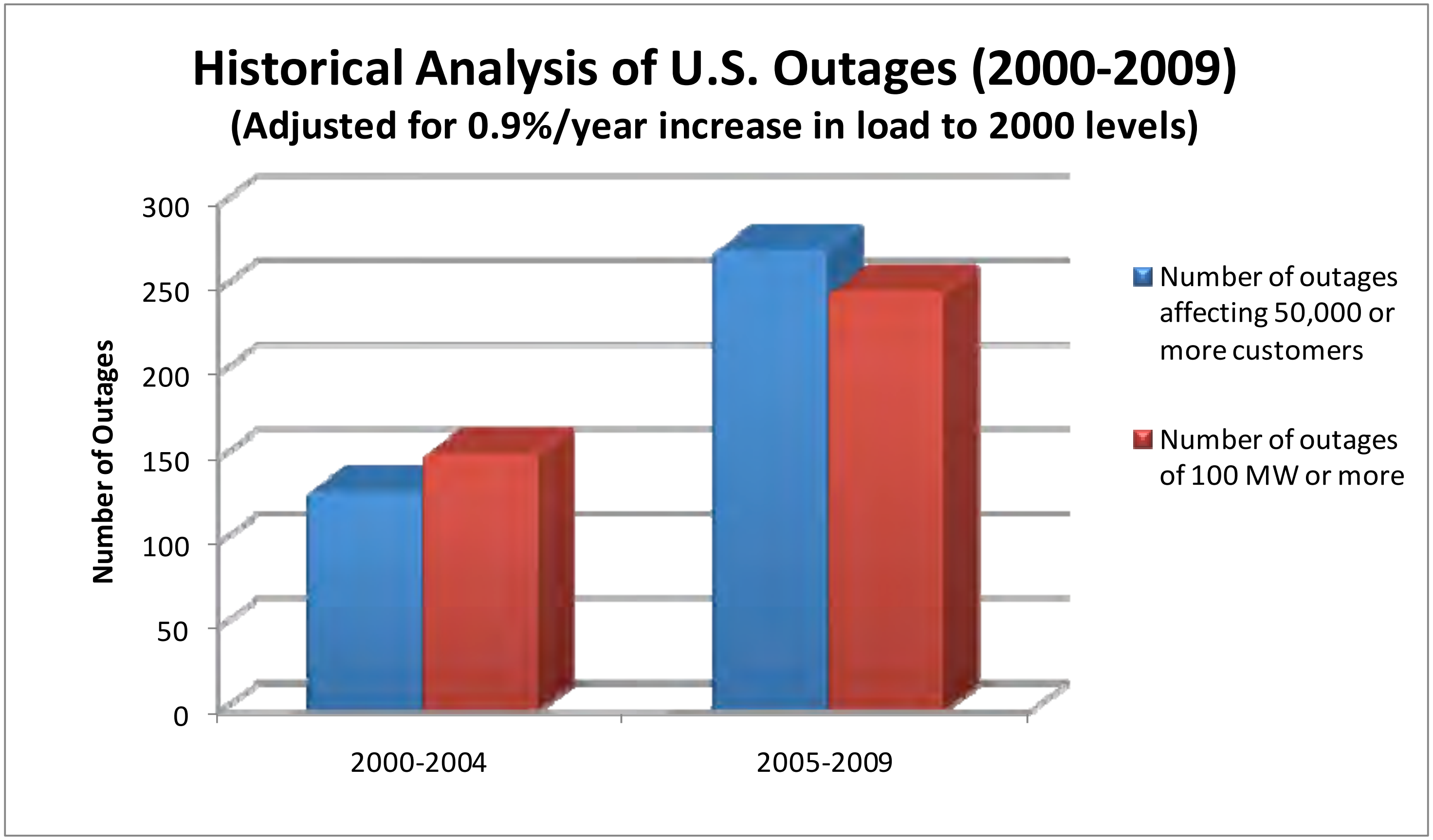
Less Reliable Grid: Power Outages have steadily increased



Source: Massoud Amin, “U.S. Electrical Grid Gets Less Reliable”
IEEE Spectrum, January 2011

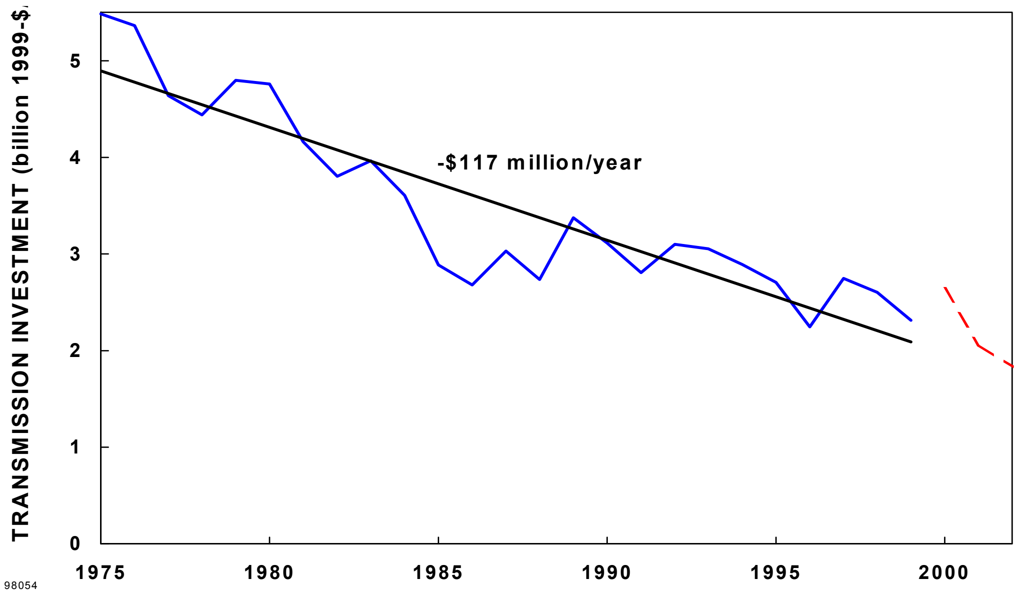
Less Reliable Grid

U.S. Electric Power Outages over 100MW and affecting over 50,000 Consumers (2000-2009), adjusted 0.9% annual load increase

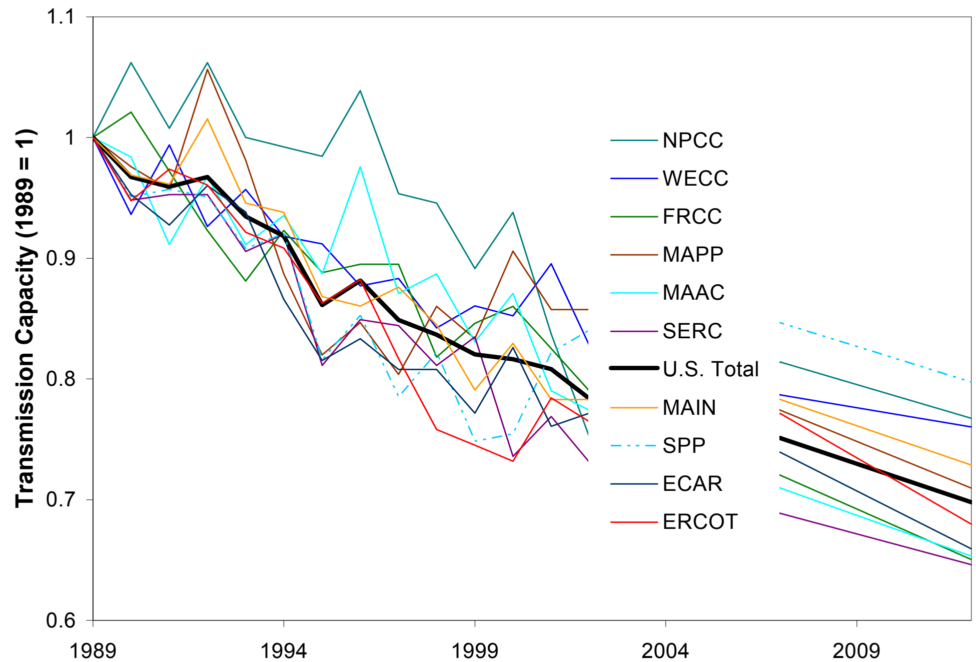


	Occurrences of 100MW or more	> 50,000 consumers
2000-2004	152	130
2005-2009	248	272

Increasing Outage Events: Transmission Investment



Transmission *investment* ($) since 1975



Transmission *capacity margin* in every NERC region since 1982

Transmission investment lags load growth and will remain very difficult in the future due to environmental, political, and cost issues.

North American Grid: Underinvested and a Complex Ownership

Country	Investment in High Voltage Transmission (>230 kV) Normalized by Load for 2004–2008 (in US$M/GW/year)	Number of Transmission-Owning Entities
New Zealand	22.0	1
England & Wales (NGT)	16.5	1
Denmark	12.5	2
Spain	12.3	1
The Netherlands	12.0	1
Norway	9.2	1
Poland	8.6	1
Finland	7.2	1
United States	4.6 (based on representative data from EEI)	450 (69 in EEI)

Source: IEEE PES

U.S. energy use per dollar of GDP, 1850–2006

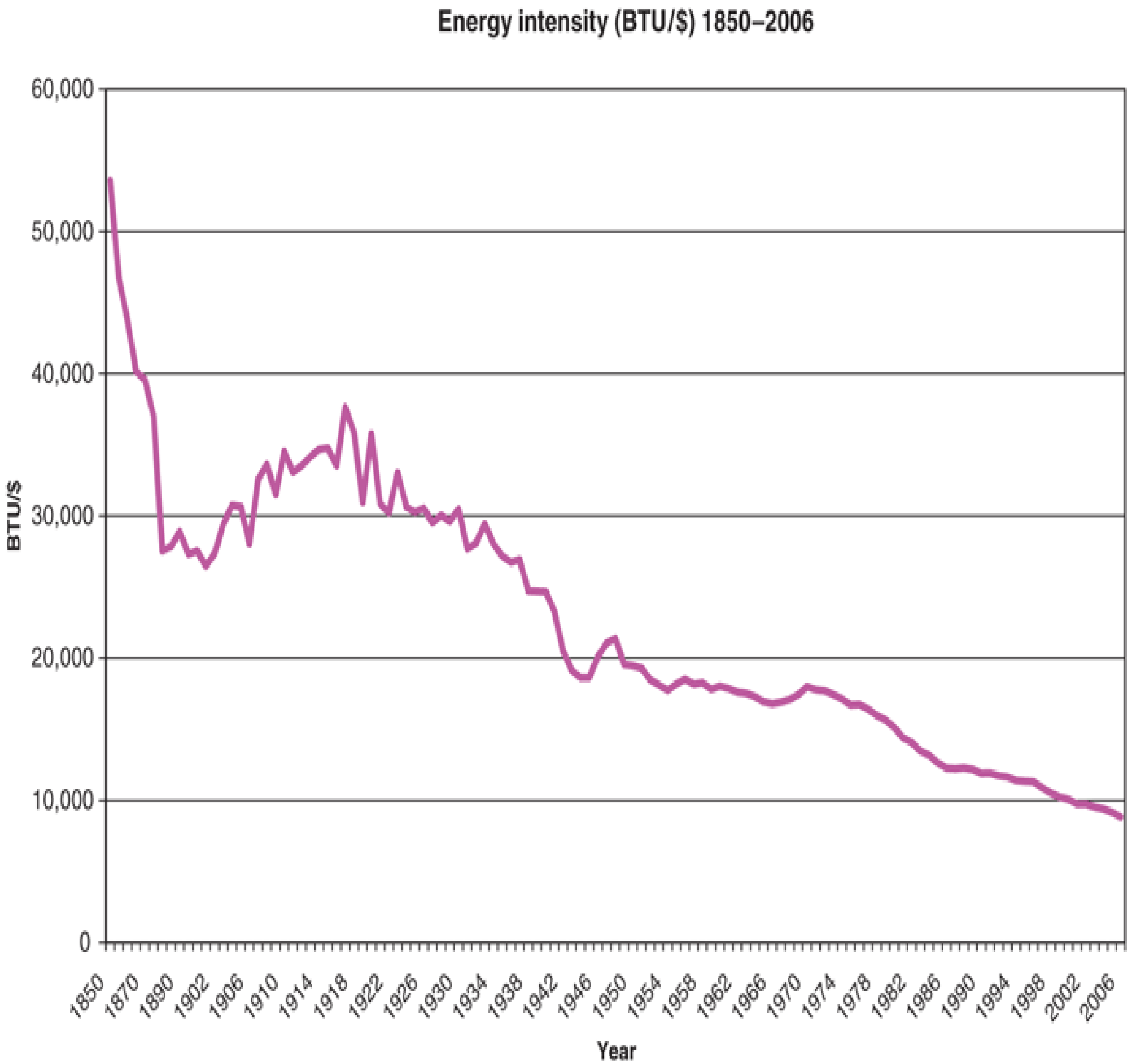
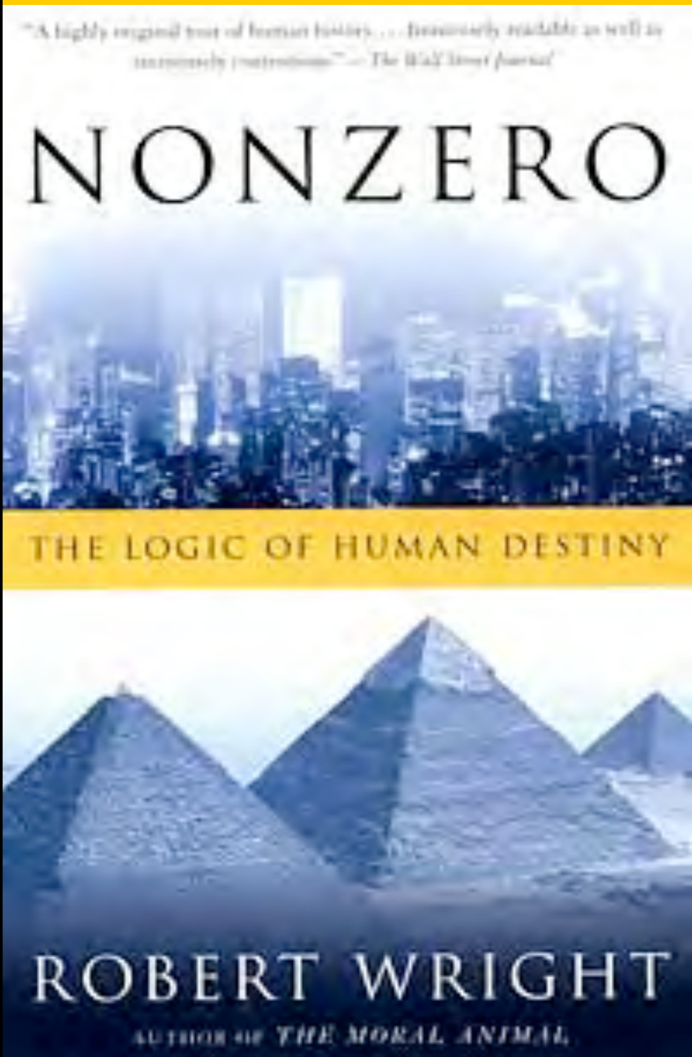


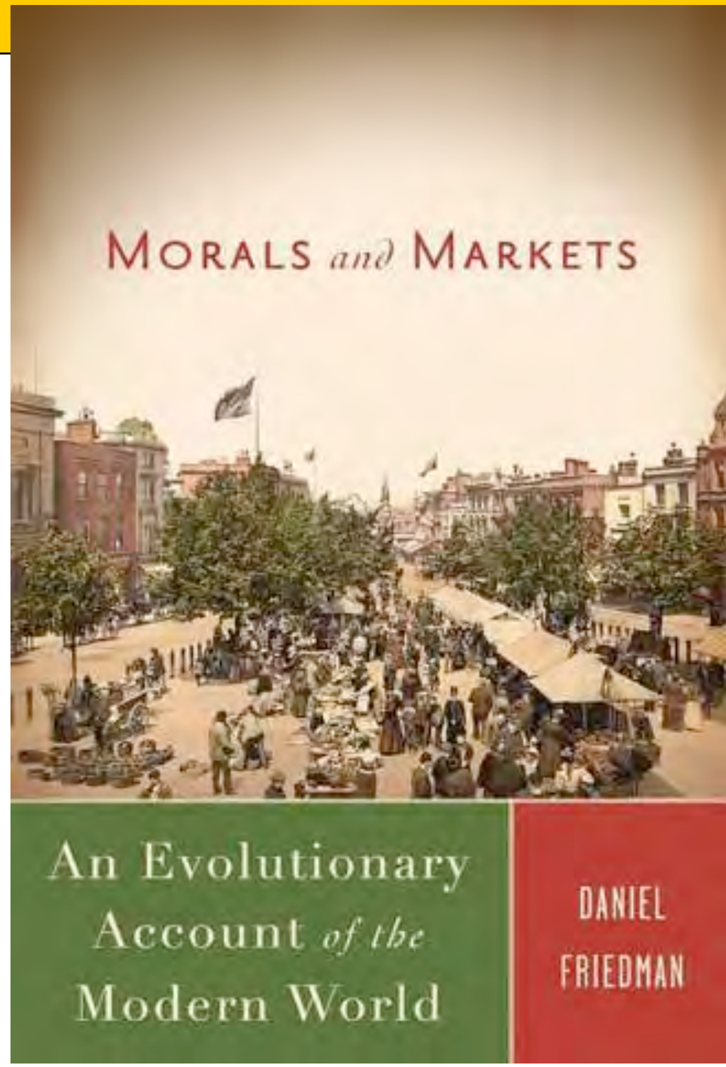
TABLE 1 Energy Use in 2005—Per Capita and Per Dollar of GDP

	BTU per person (million BTUs)	BTU per dollar of GDP
United States	340	9,113
Japan	177	4,519
Denmark	153	4,845
France	182	7,994
Germany	176	7,396

Source: EIA, 2009b,c.

Technologies are diverse value creation mechanisms

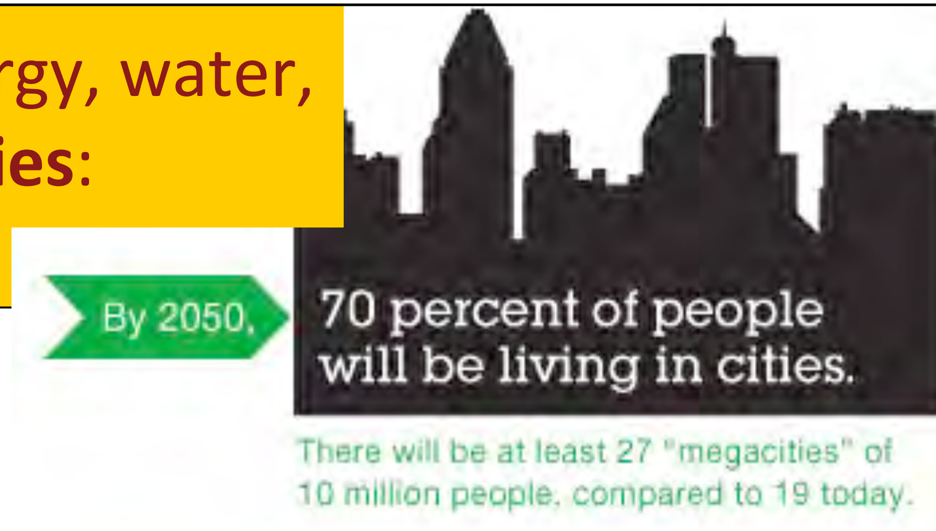




Source: IBM, please also see Paul Romer's Charter Cities Video: http://www.ted.com/talks/paul_romer.html

Smarter about education, safety, energy, water, food, transp., e-gov, … **Innovative Cities**:

- **Smarter transportation**
  Stockholm, Dublin, Singapore and Brisbane are working with IBM to develop smart systems ranging from predictive tools to smart cards to congestion charging in order to reduce traffic and pollution.
- **Smarter policing and emergency response**
  New York, Syracuse, Santa Barbara and St. Louis are using data analytics, wireless and video surveillance capabilities to strengthen crime fighting and the coordination of emergency response units.
- **Smarter power and water management**
  Local government agencies, farmers and ranchers in the Paraguay-Paraná River basin to understand the factors that can help to safeguard the quality and availability of the water system. Malta is building **a smart grid** that links the power and water systems, and will detect leakages, allow for variable pricing and provide more control to consumers. Ultimately, it will enable this island country to replace fossil fuels with sustainable energy sources.
- **Smarter governance**
  Albuquerque is using a business intelligence solution to automate data sharing among its 7,000 employees in more than 20 departments, so every employee gets a single version of the truth. It has realized cost savings of almost 2,000%.



'Cities are perfect for promoting change and renewable energies. Cities can serve as innovation platforms, creating clusters of business around green energy."

Claude Turmes
Member of the European Parlament,
Reuters, February 10, 2009

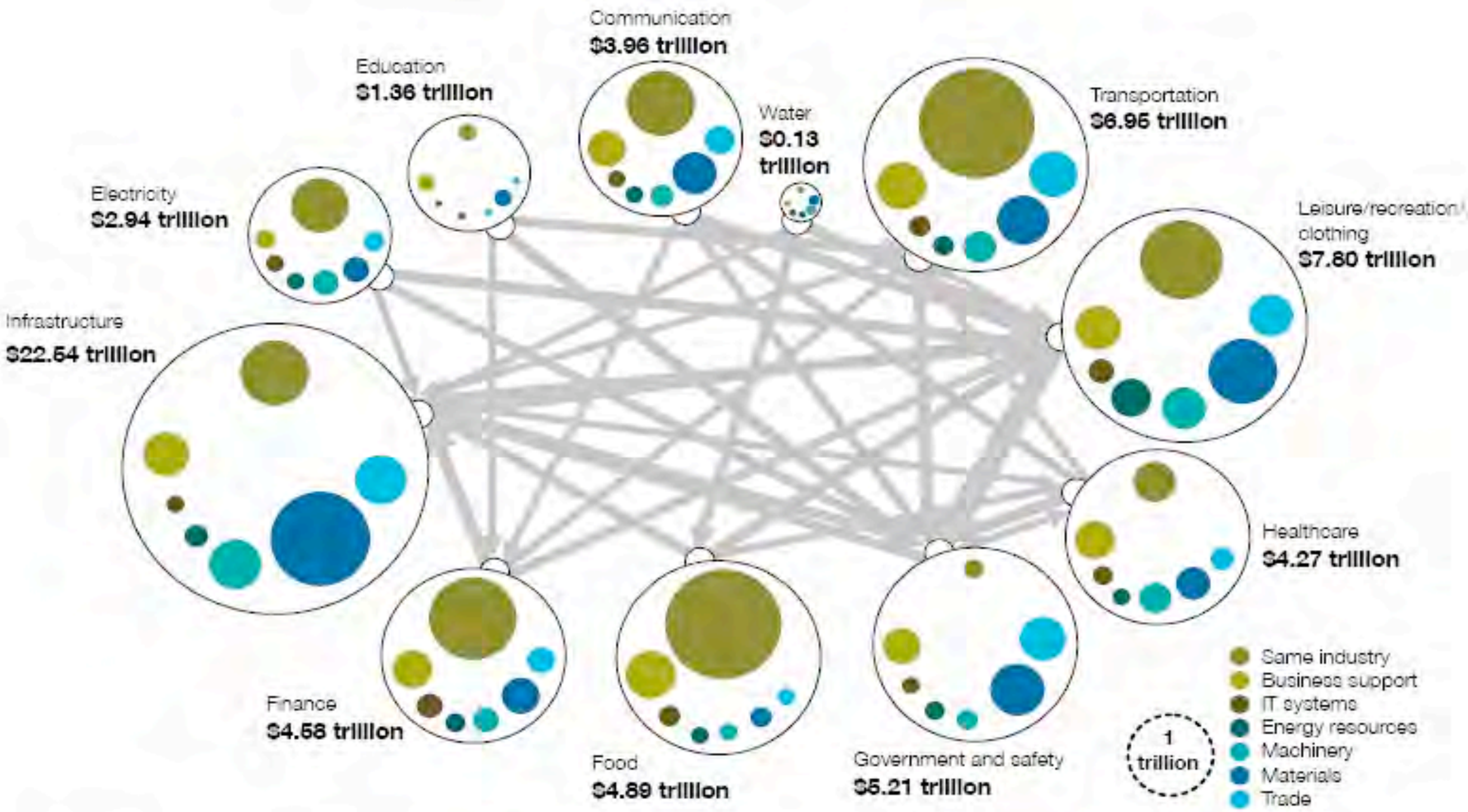
Top 10 cities

Rank	Country	City	Rating
1	Canada	**Vancouver**	98.0
2	Austria	**Vienna**	97.9
3	Australia	**Melbourne**	97.5
4	Canada	**Toronto**	97.2
5	Canada	**Calgary**	96.6
6	Finland	**Helsinki**	96.2
7	Australia	**Sydney**	96.1
8=	Australia	**Perth**	95.9
8=	Australia	**Adelaide**	95.9
10	New Zealand	**Auckland**	95.7

Source: IBM and Economist

Holistic Modeling:

The world as a $54 trillion system of systems (Korsten & Seider 2010)

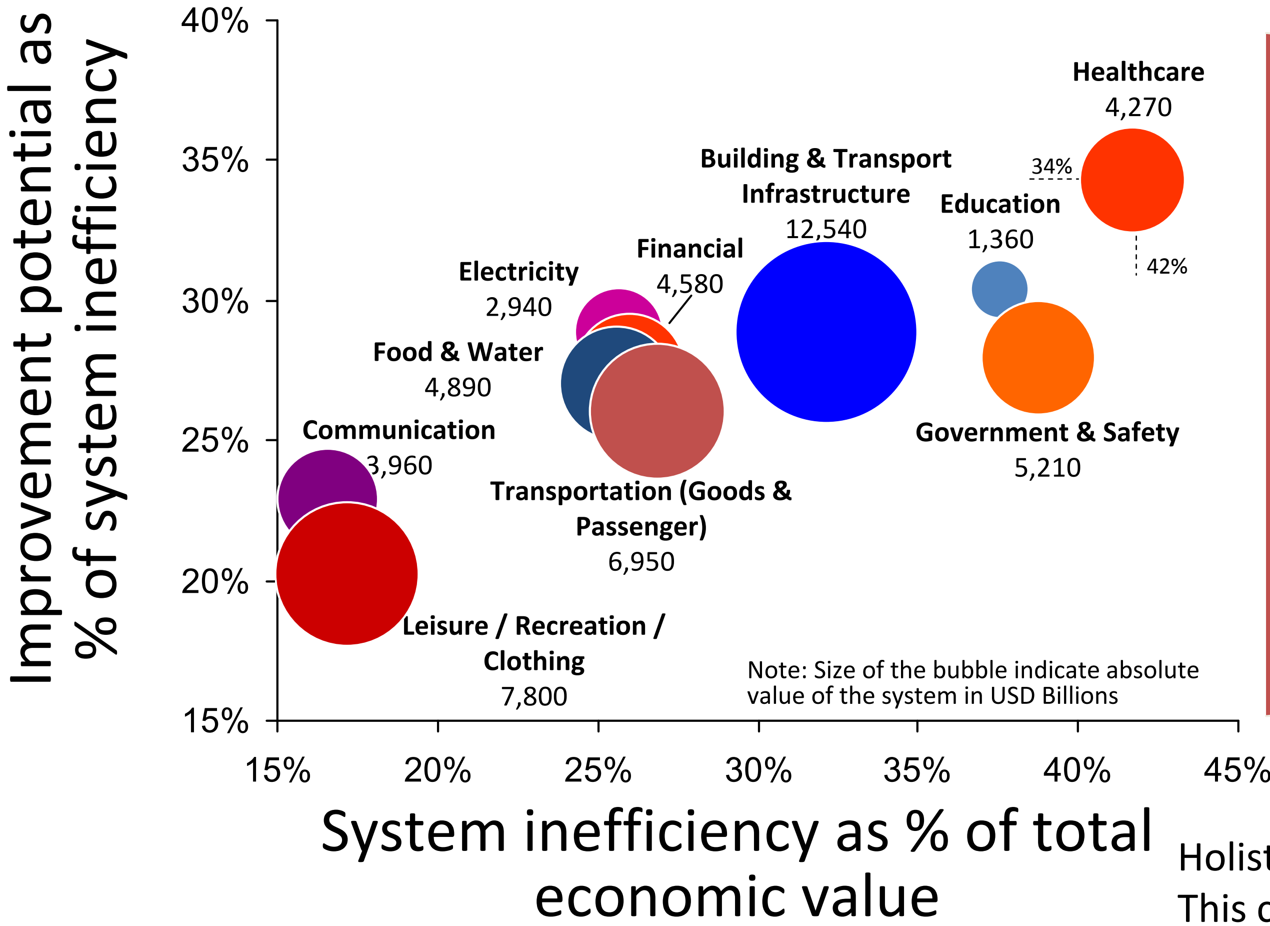


Note: Size of bubbles represents systems' economic values. Arrows represent the strength of systems' interaction.
Source: IBM Institute for Business Value analysis of Organisation for Economic Co-operation and Development (OECD) data.

Figure 1: We live and work within a complex, dynamic and interconnected US$54 trillion system of systems.

Economists estimate, that all systems carry inefficiencies of up to $15 Tn, of which $4 Tn could be eliminated

Analysis of inefficiencies in the planet's system-of-systems



Global economic value of

System-of-systems	**$54 Trillion** 100% of WW 2008 GDP
Inefficiencies	**$15 Trillion** 28% of WW 2008 GDP
Improvement potential	**$4 Trillion** 7% of WW 2008 GDP

How to read the chart:

For example, the Healthcare system's value is $4,270B. It carries an estimated inefficiency of 42%. From that level of 42% inefficiency, economists estimate that ~34% can be eliminated (= 34% x 42%).

Holistic Modeling: Korsten & Seider 2010
This chart shows 'systems' (not 'industries')
Source: IBM economists survey 2009; n= 480

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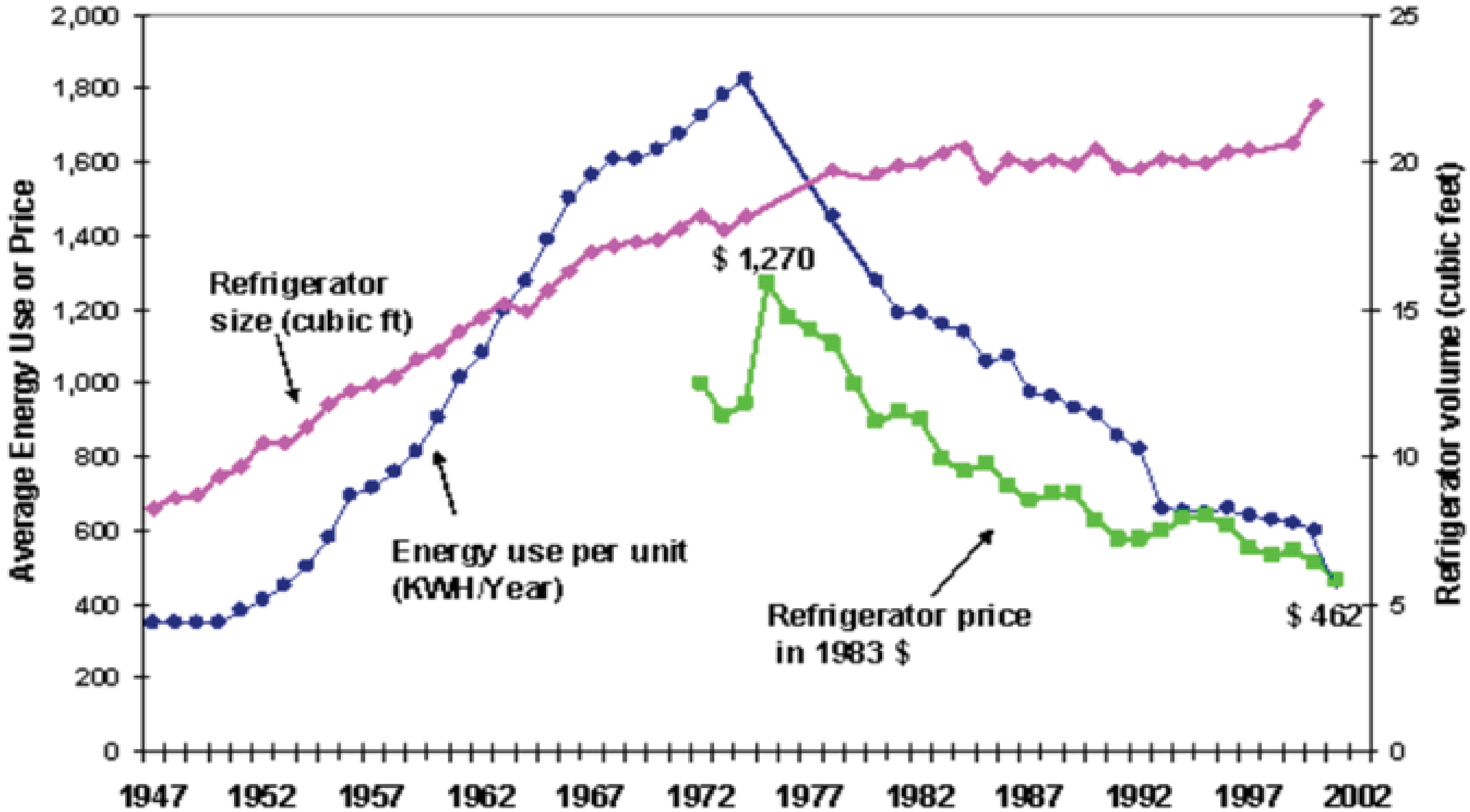
Example: Energy Efficiency of refrigerator



Source: NRC, 2009

Example: Energy Use in Buildings

81 million single-family houses, 25 million multifamily residences, 7 million mobile homes, together with 75 billion sqft of commercial floor space…

… account for 73% of electricity use and 40% of total energy use in the U.S.

- From 1975 to 2005, despite increased energy efficiencies, an increase in the number of residences and the amount of commercial space led to substantial increases in total energy use—15 percent in residential buildings and 50 percent in commercial buildings

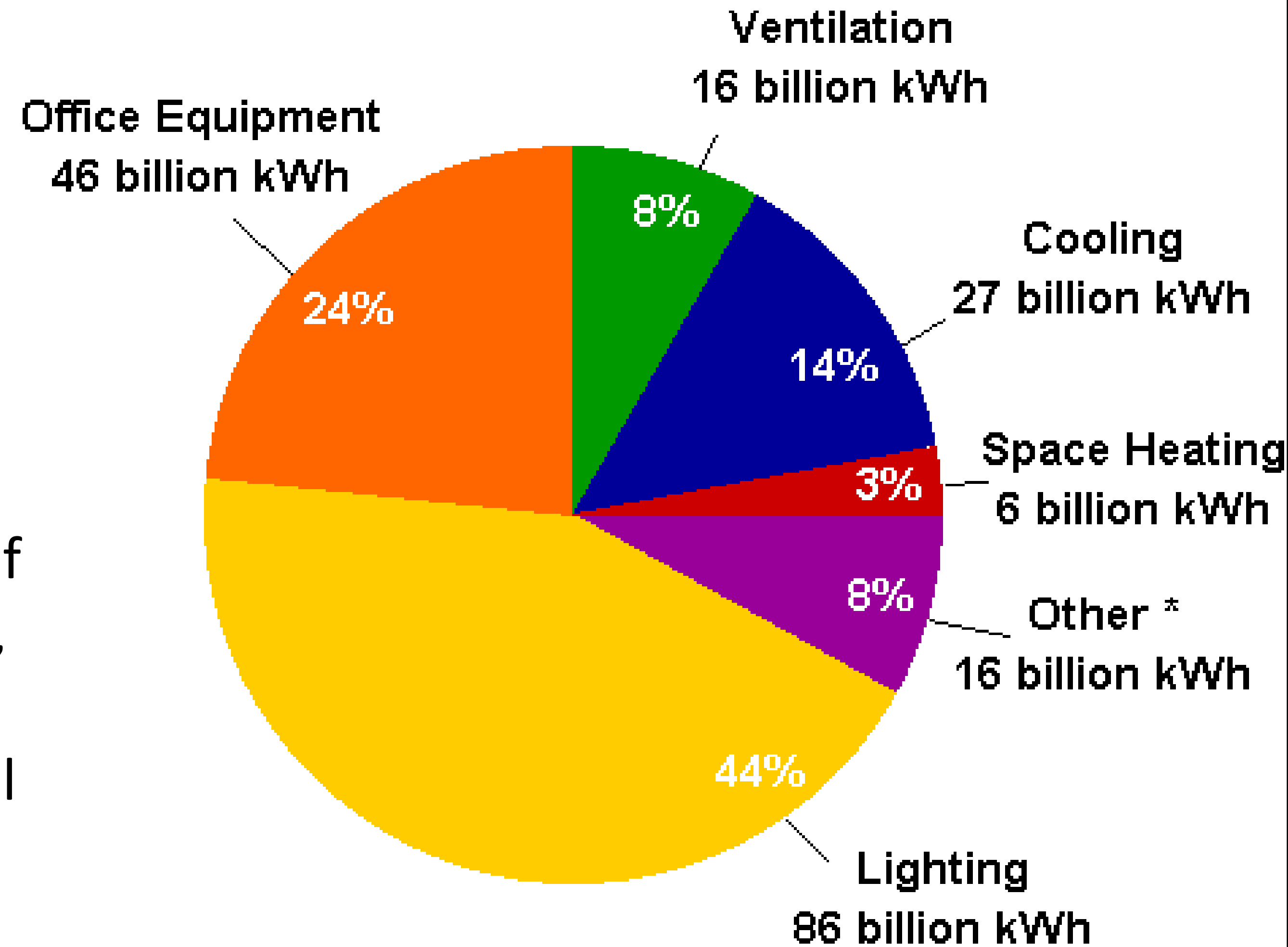
- The efficiency gains, which were made in refrigerators and lighting, as well as in air conditioners, building envelopes, and many appliances, were promoted by Energy Star labeling of appliances and even of buildings

- For example, the number of new residences that attained Energy Star status increased from 57,000 in 2001 to 189,000 in 2006. For buildings, the median cost-effective and achievable potential (taking barriers to implementation into account) are 24 percent for electricity and 9 percent for natural gas (sensitive to price, especially for natural gas)

Electricity use in office buildings

How do they use electricity?

- Office buildings use 198 billion kWh within the building) each year.
- An electricity intensity of 18.9 kWh per square foot, a bit higher than the average for all commercial buildings.



* Other includes miscellaneous uses (13 billion kWh), water heating (2 billion kWh), refrigeration (1 billion kWh), and cooking (<1 billion kWh).

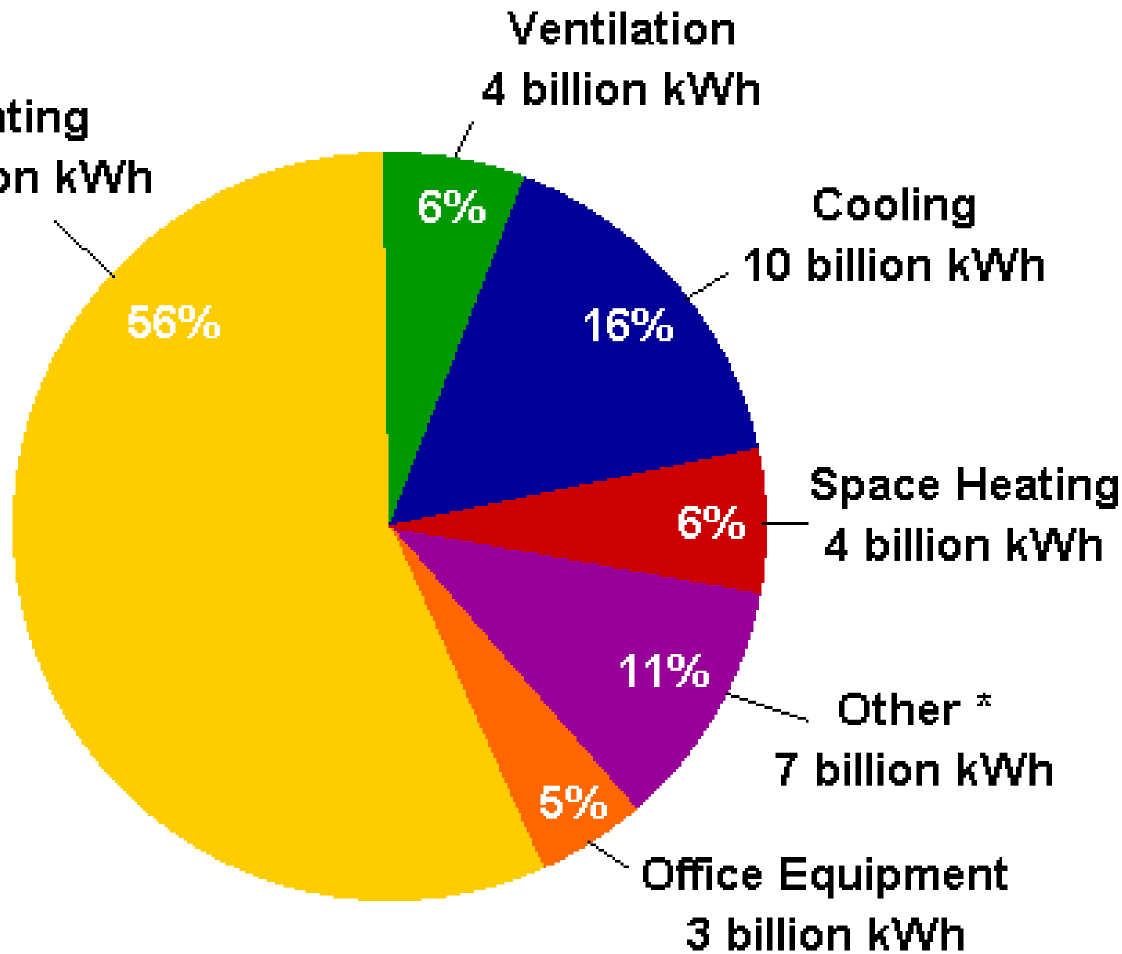
Source: U.S. DOE EIA

Electricity use in education buildings

How do they use electricity?

- 65 billion kWh electricity used within the building each year

- An electricity intensity of 8.4 kWh per square foot, lower than the average for all commercial buildings

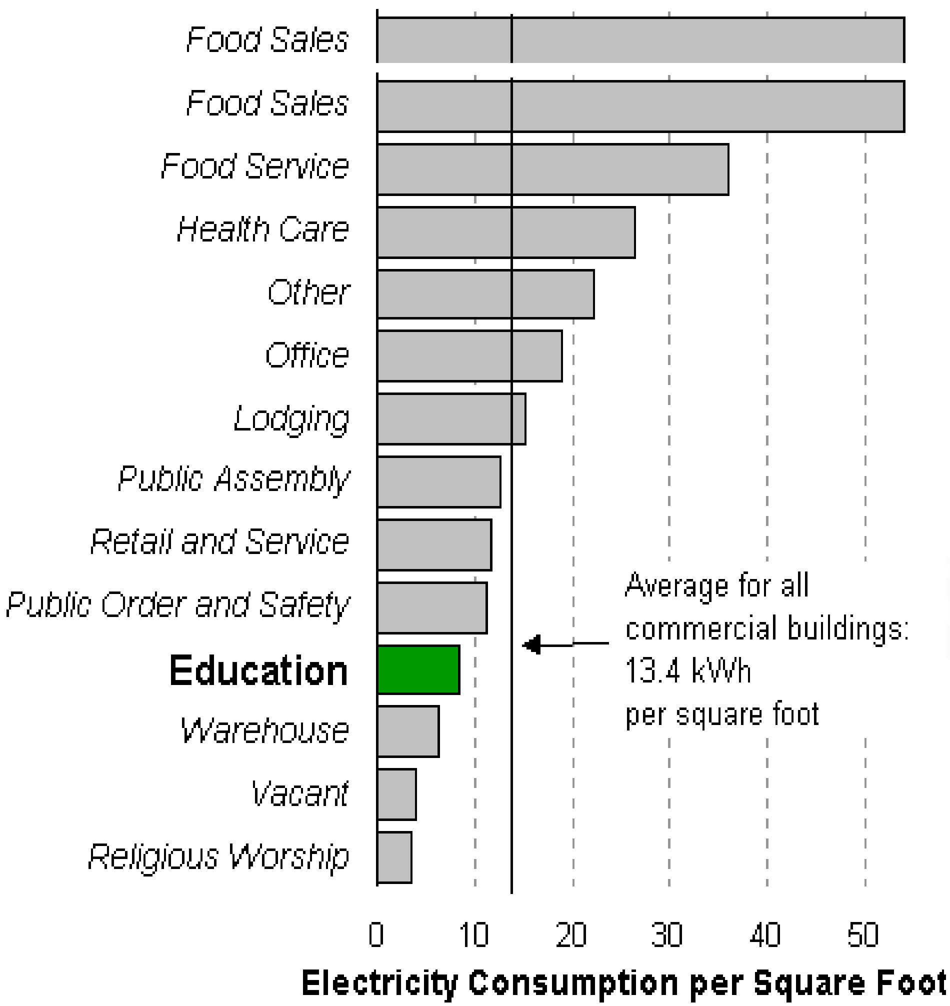


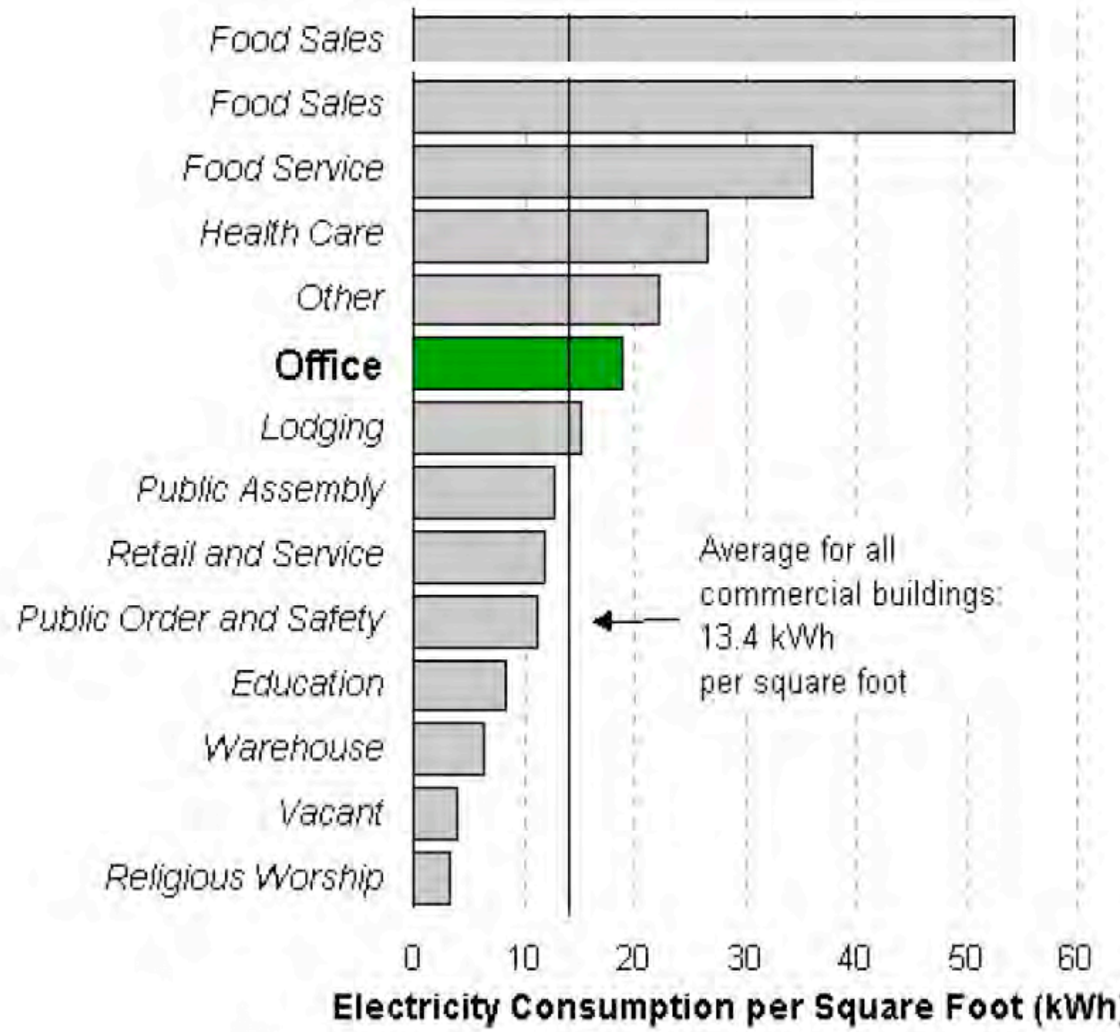
* Other includes miscellaneous uses (2 billion kWh), water heating (2 billion kWh), refrigeration (2 billion kWh), and cooking (1 billion kWh).

Source: U.S. DOE EIA

Electricity use in education and office buildings

How do they use electricity?

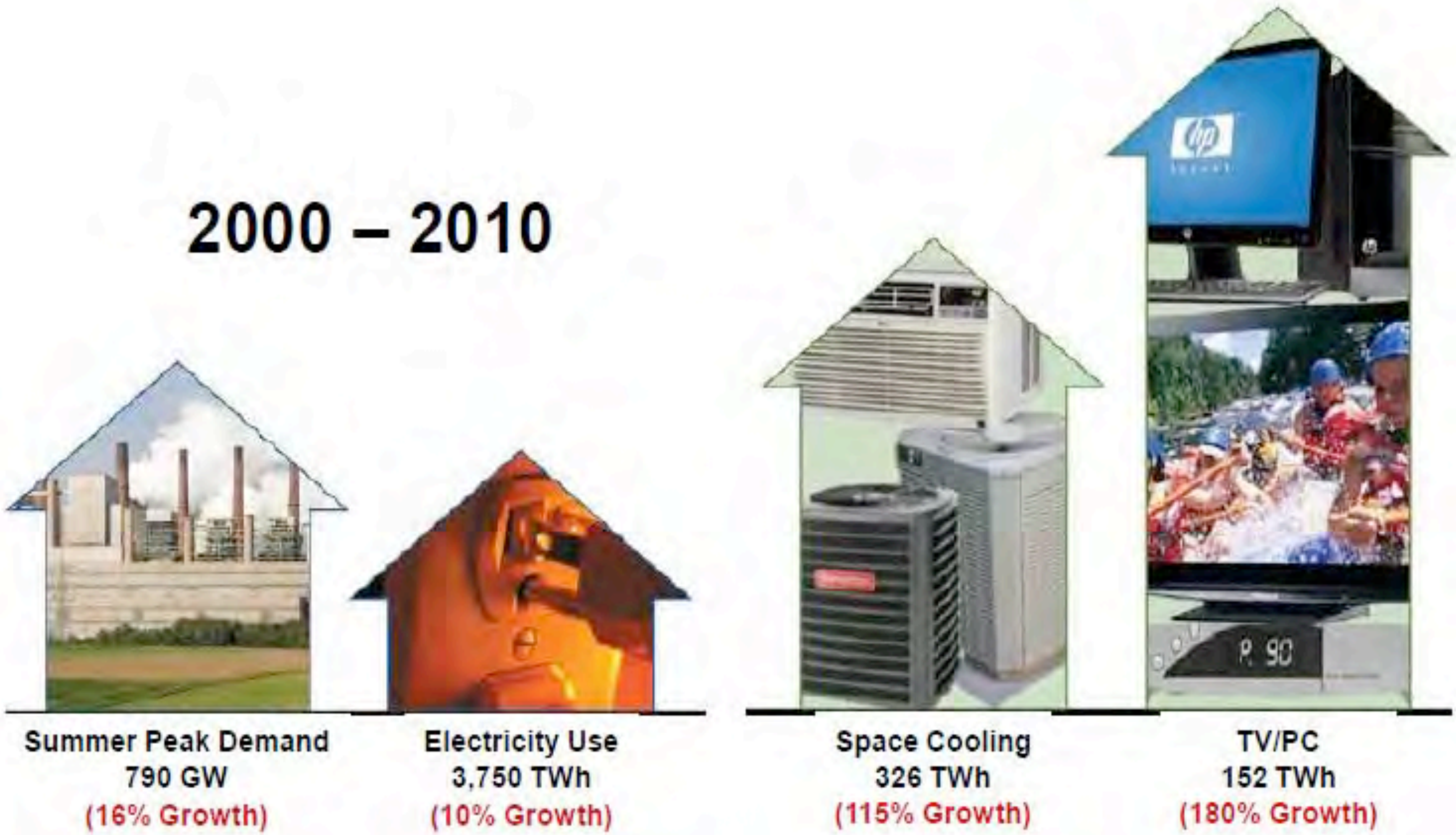




Source: U.S. DOE EIA

Trends in Electricity Use (2000-2010)

Electronics and Continued Electrification Drive the Growth



Source: EPRI

Consumer Technology's Next Trend?

Digitization of Society…in its infancy

2011…one billion tweets sent every week!

At 0.025 watt-hours per tweet >>> 2500MWh

Internet TV

Online Gaming

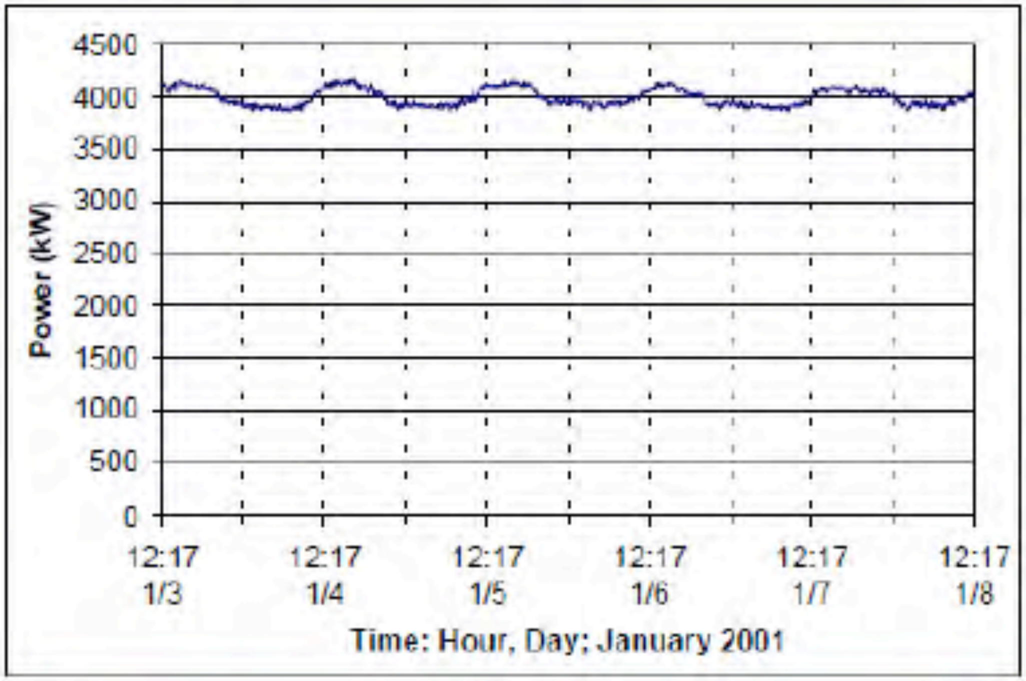
Digitization of Records

Digital Technologies… Store, Route, Stream data and video… like never before!

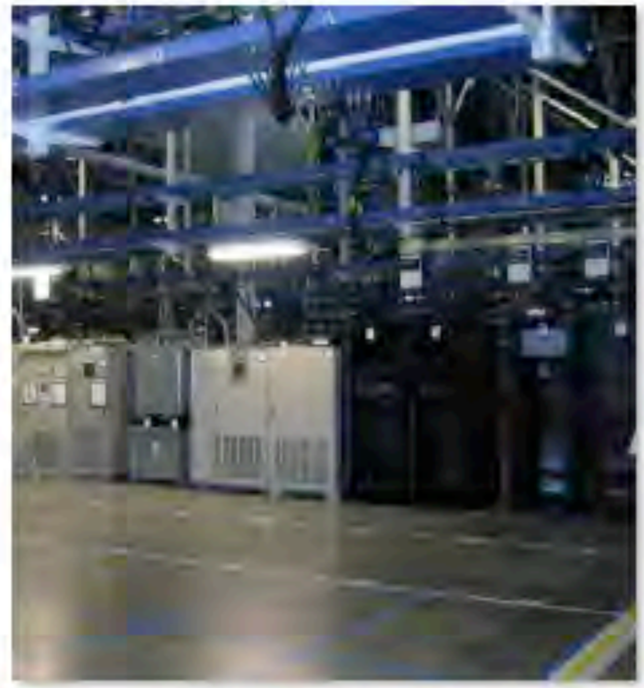
Source: EPRI

The Next "Industrial Revolution"…Data Centers

Expected to Double Every 5 Years…



Flat Load Profile of Data Centers



Data Center Server Room

By 2030 Could Reach 20% of Total U.S. Electricity Use

-- How many watts used per iPhone, Smart Phone and Blackberry device?

-- What infrastructure quality of service and security do we expect?

Source: EPRI

Integrate Dispersed Energy Sources into a Modern Grid to Provide Energy to Centers of Demand

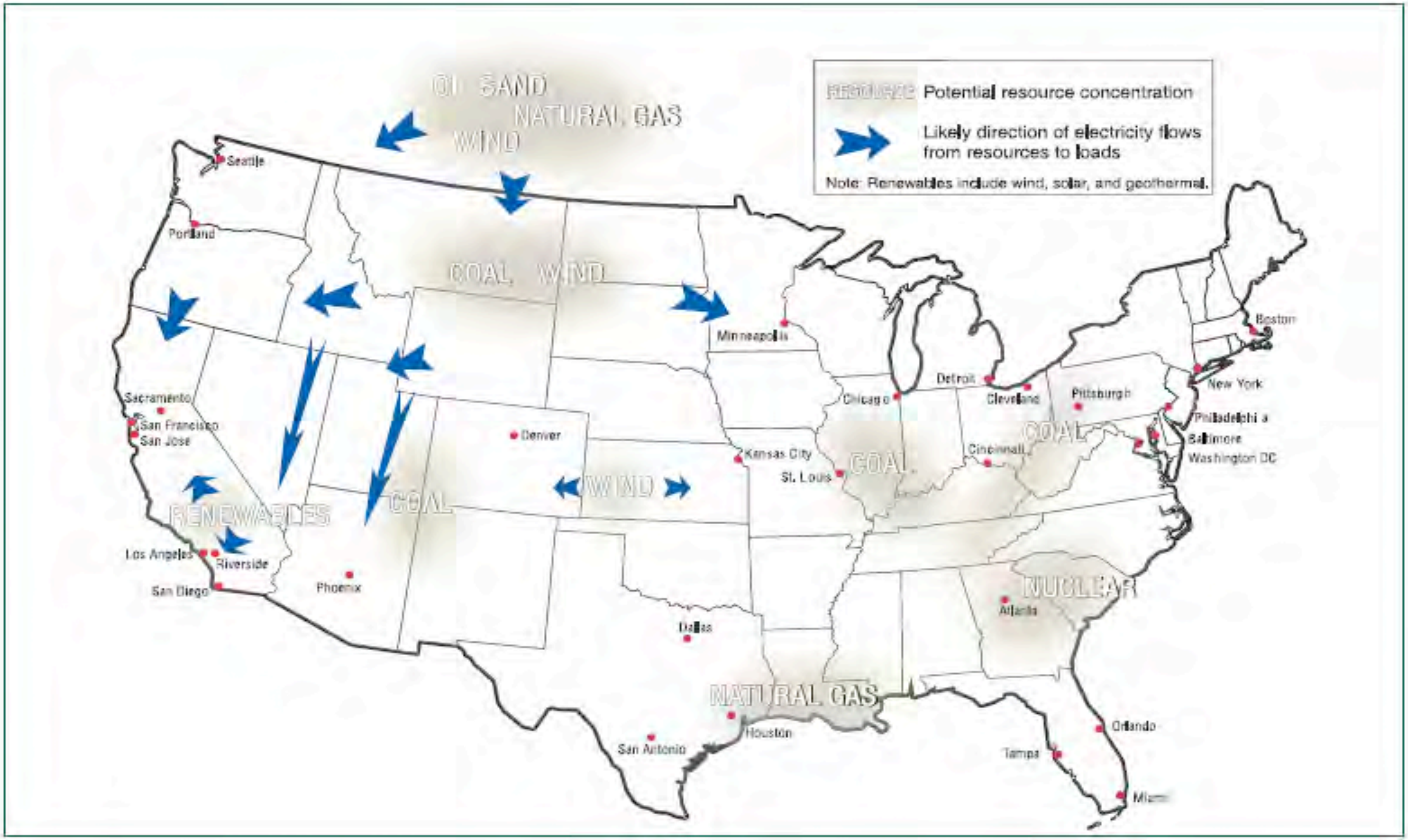
Recommendations for moving to energy systems to meet demand of tomorrow

- **Build a stronger and smarter electrical energy infrastructure**
  - Transform the Network into a Smart Grid
  - Develop an Expanded Transmission System
  - Develop Massive Electricity Storage Systems
- **Break our addiction to oil by transforming transportation**
  - Electrify Transportation: Plug-In Hybrid Electric Vehicles
  - Develop and Use Alternative Transportation Fuels
- **Green the electric power supply**
  - Expand the Use of Renewable Electric Generation
  - Expand Nuclear Power Generation
  - Capture Carbon Emissions from Fossil Power Plants
- **Increase energy efficiency**

Source: Massoud Amin's Congressional briefings on March 26 and Oct. 15, 2009

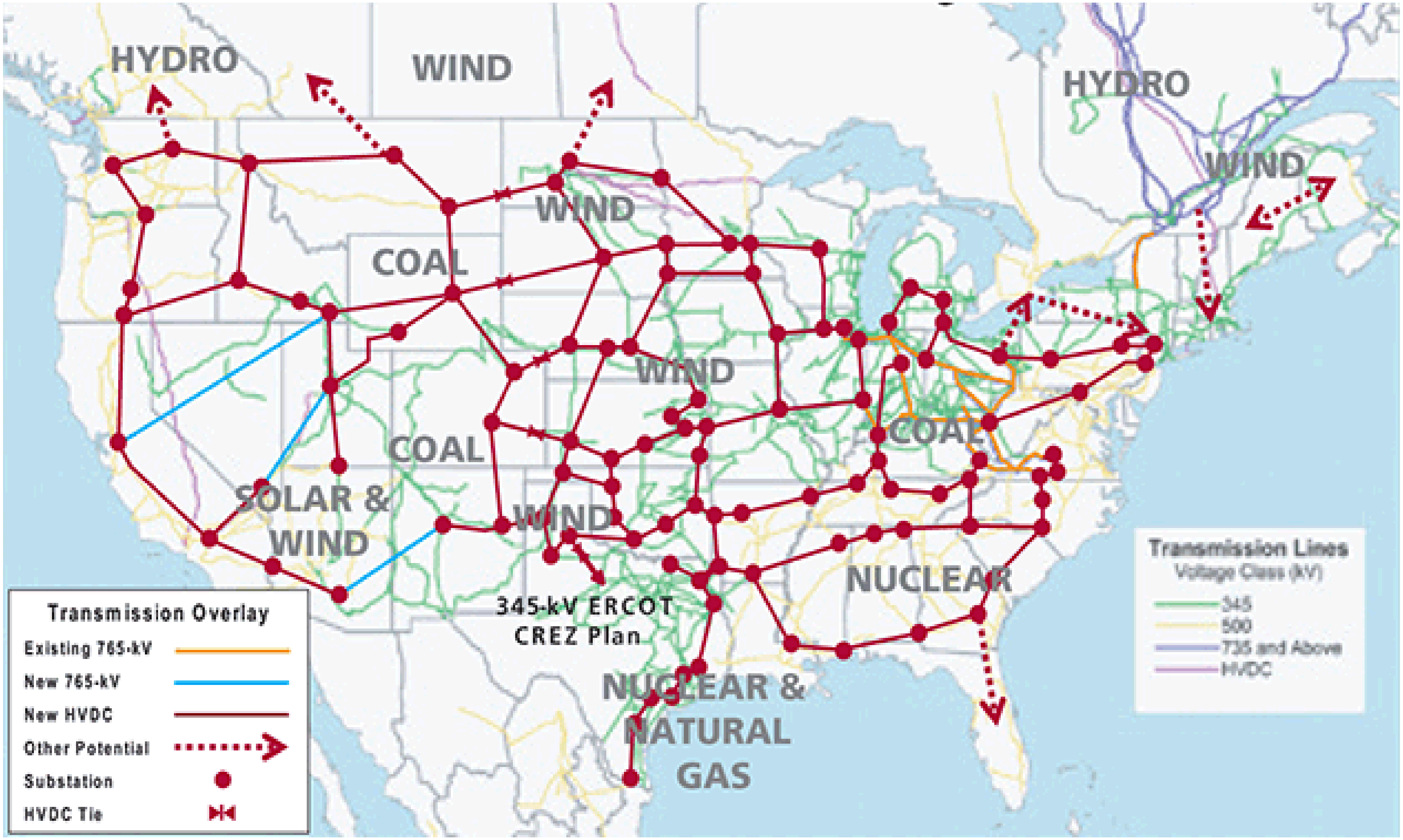
Stronger Grid

Emerging Supply and Demand Patterns



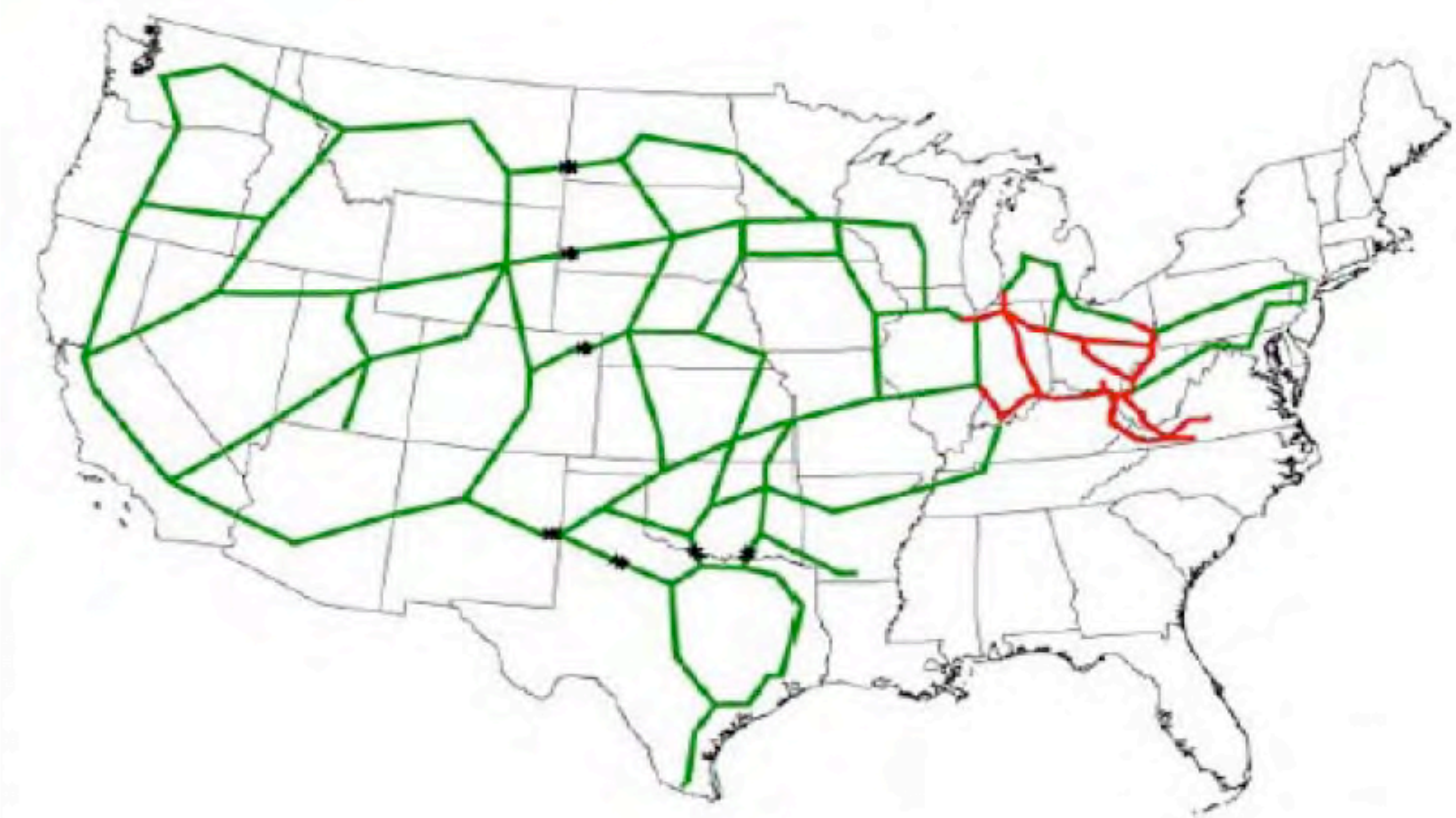
Map adapted from the U.S. DOE National Electric Transmission Congestion Study

A Multi-layer Grid System in need of Strengthening and Protection



Map adapted from the U.S. DOE National Electric Transmission Congestion Study

Transmission System Upgrade Assessments



New 765-kV lines are shown in green and new interties in black, complementing the existing 765-kV system shown in red, to facilitate deployment of up to 400 GW of additional wind capacity.

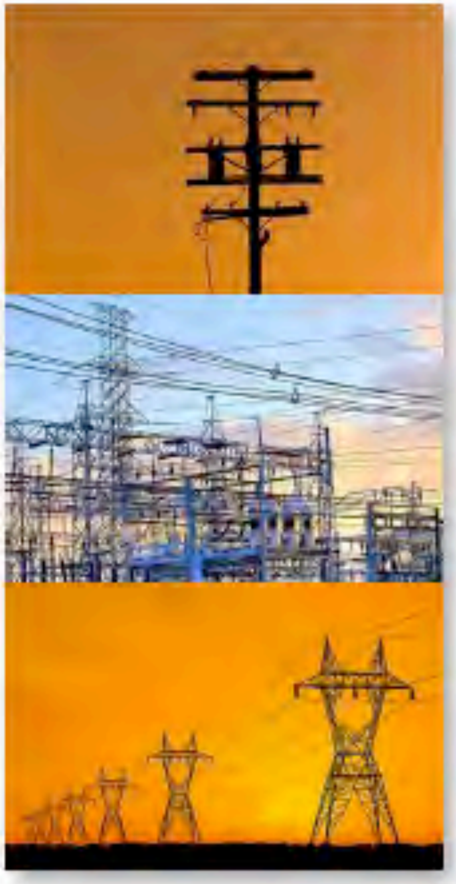
Sources: AEP 2007; DOE 2008

Smart Grid: Technological Innovations

Customer

- Smart Appliances
- Electric Vehicles
- Energy Efficiency
- Demand Response
- Distributed Energy Resources

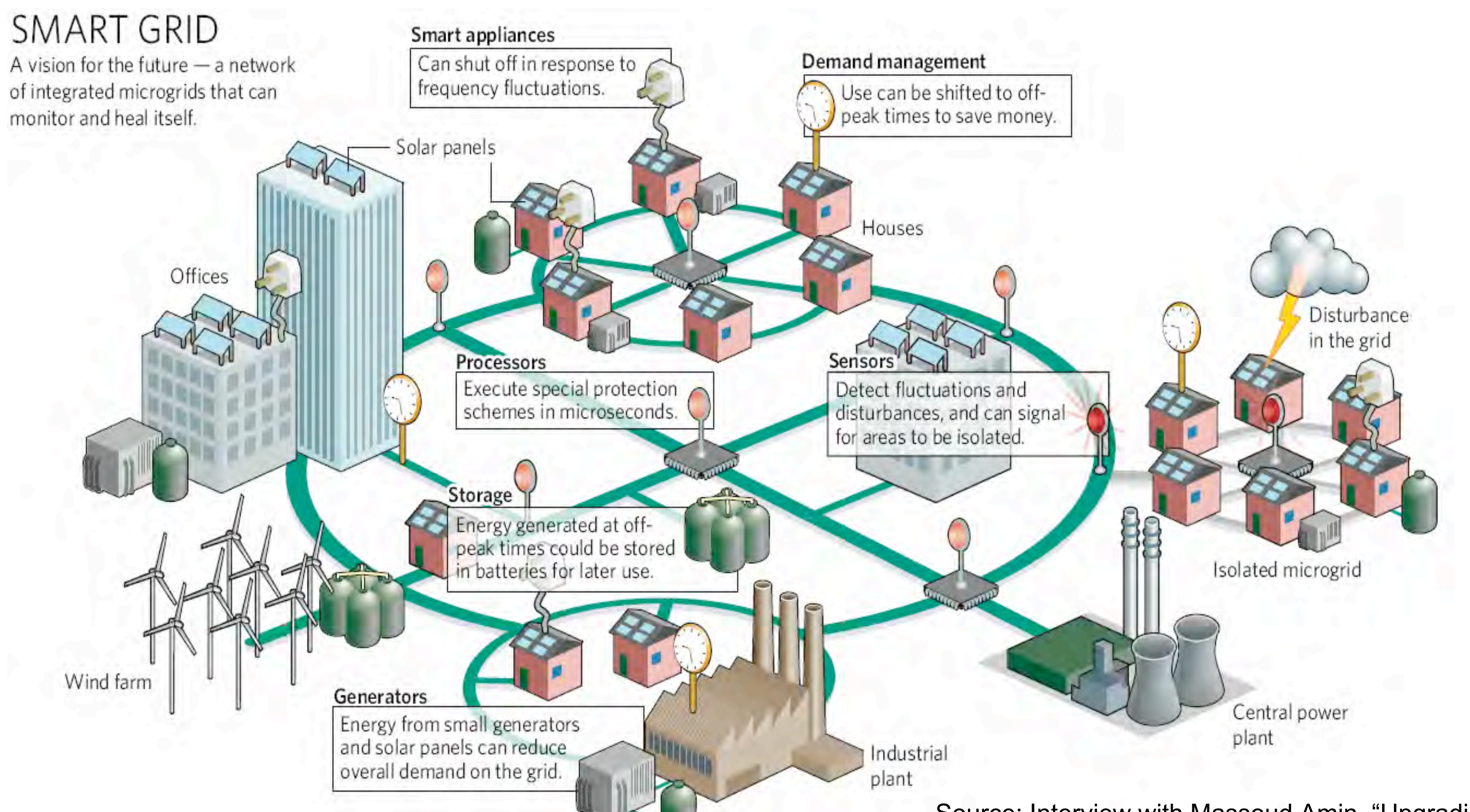
Smart Grid and Power Delivery



- Intelligent Sensors, Communication and Analysis
- Increase and Flexible Power Flow
- Secure From Cyber and Physical Attack

Smart Grids

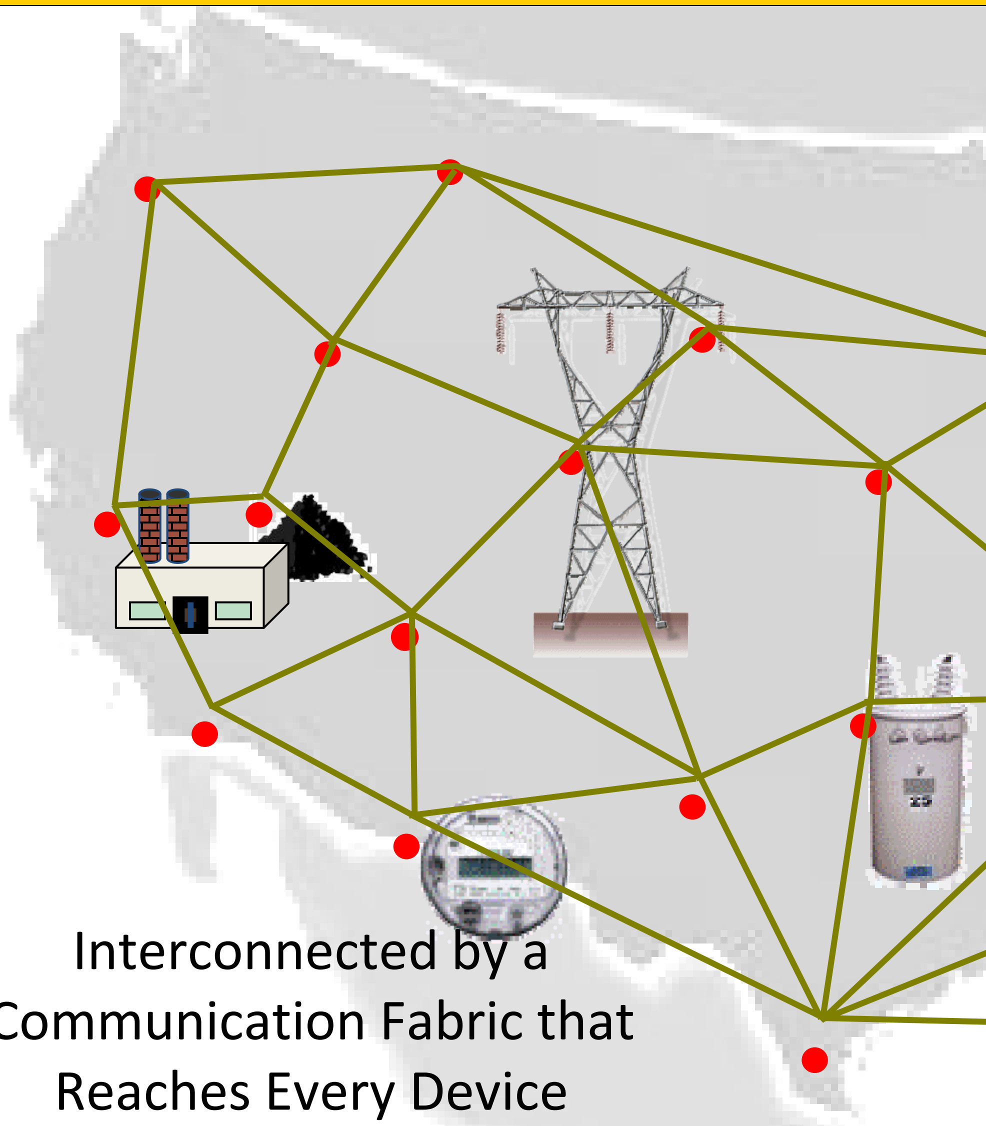
Integrate microgrids, diverse generation and storage resources into a smart self-healing grid system



Source: Interview with Massoud Amin, "Upgrading the grid," *Nature*, vol. 454, 570–573, 30 July 2008

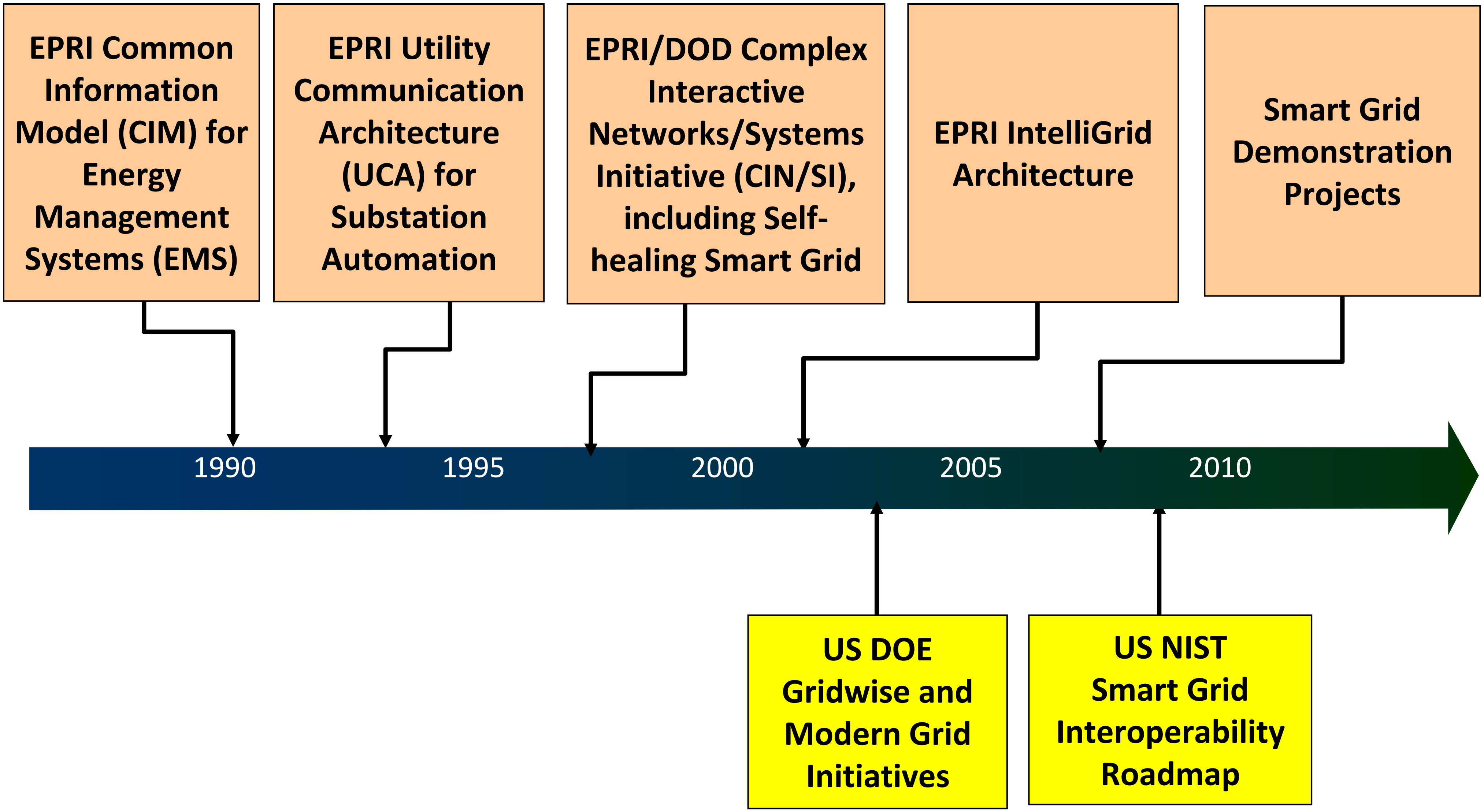
Many Definitions – But One VISION

Visualizing the Smart Grid



- Engaging Consumers
- Enhancing Efficiency
- Ensuring Reliability
- Enabling Renewables & Electric Transportation

Evolution of Smart Grid Programs at DOE and EPRI

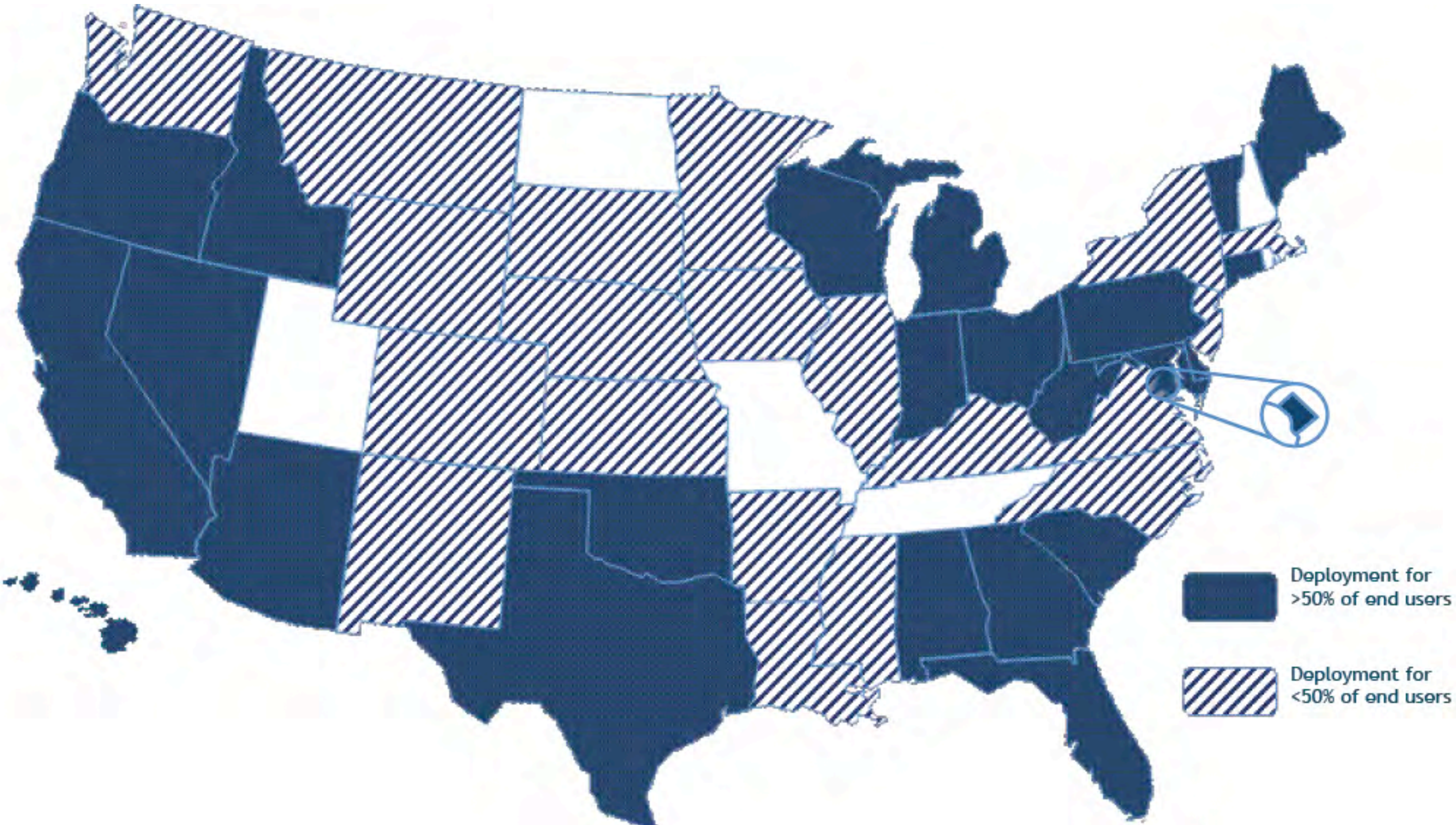


14 Years in the Making

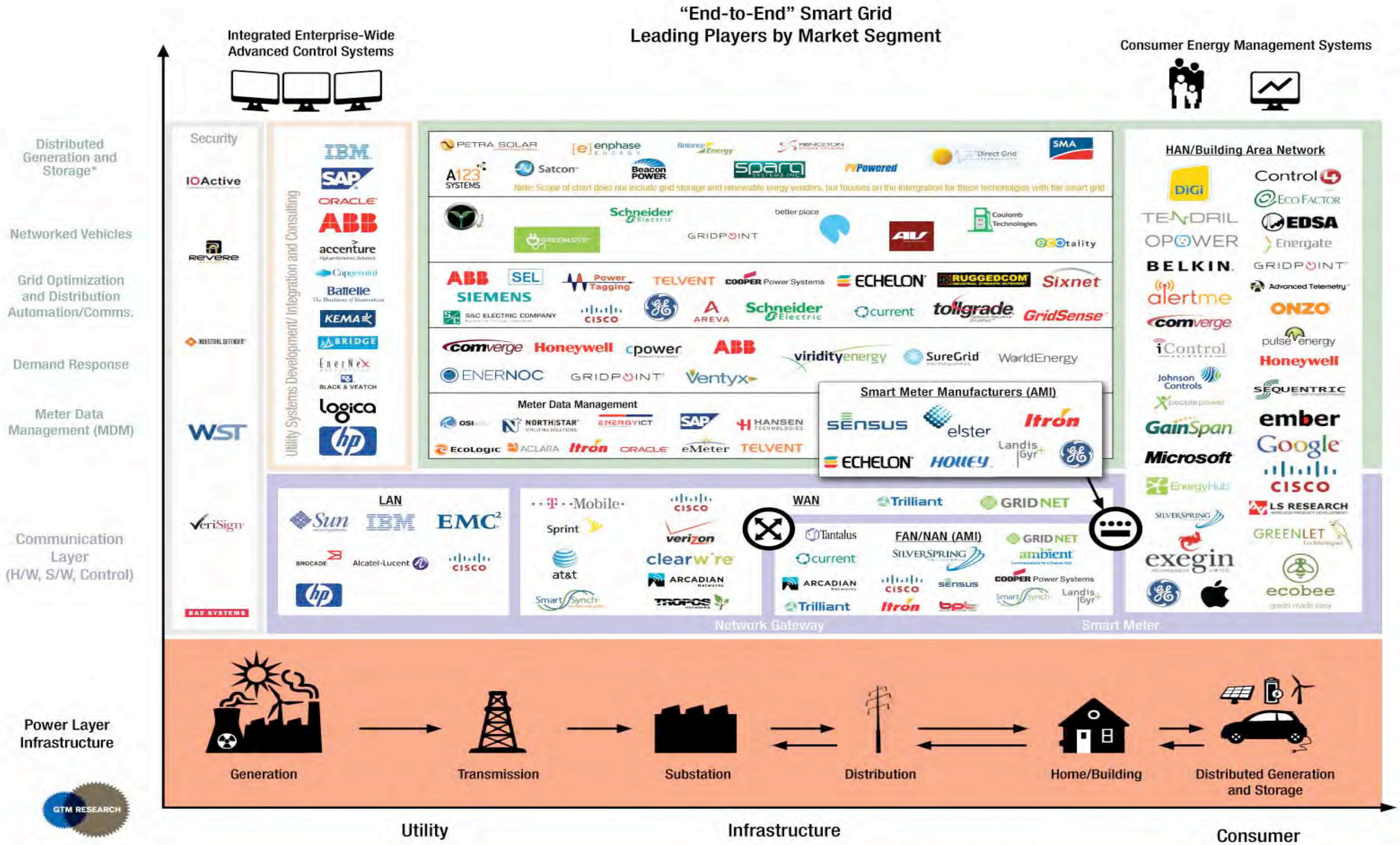
- Self-Healing Grid (May 1998- Dec. 2002)
  - 1998-2002: EPRI/DOD Complex Interactive Networks/Systems Initiative (CIN/SI):
  - 108 professors and over 240 graduate students in 28 U.S. universities funded, including Carnegie Mellon, Minnesota, Illinois, Arizona St., Iowa St., Purdue, Harvard, MIT, Cornell, UC-Berkeley, Wisconsin, RPI, UTAM, Cal Tech, UCLA, and Stanford.
  - 52 utilities and ISO (including TVA, ComEd/Exelon, CA-ISO, ISO-NE, etc.) provided feedback; 24 resultant technologies extracted.
- Intelligrid (2001-present): EPRI trademarked
- Smart Grid: Final name adopted at EPRI and DOE

Smart Meters: Utility-Scale Smart Meter Deployments, Plans & Proposals (Sept. 2010)

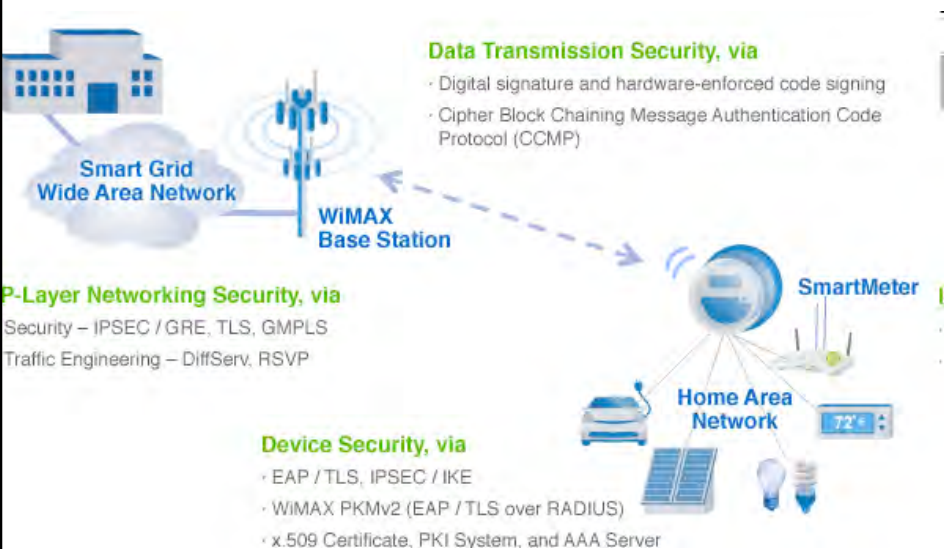
Leaders & Laggards



End-to-End Smart Grid Players/Opportunities



Sample "Smart Grid" Components & Devices



Secure Smart Grids are architected with standards (source: Gridnet)

Smart Meters

Source: IBM Smart Grid

Control4's EMS-100

Google Power Meter

Foresight: Integration Technologies

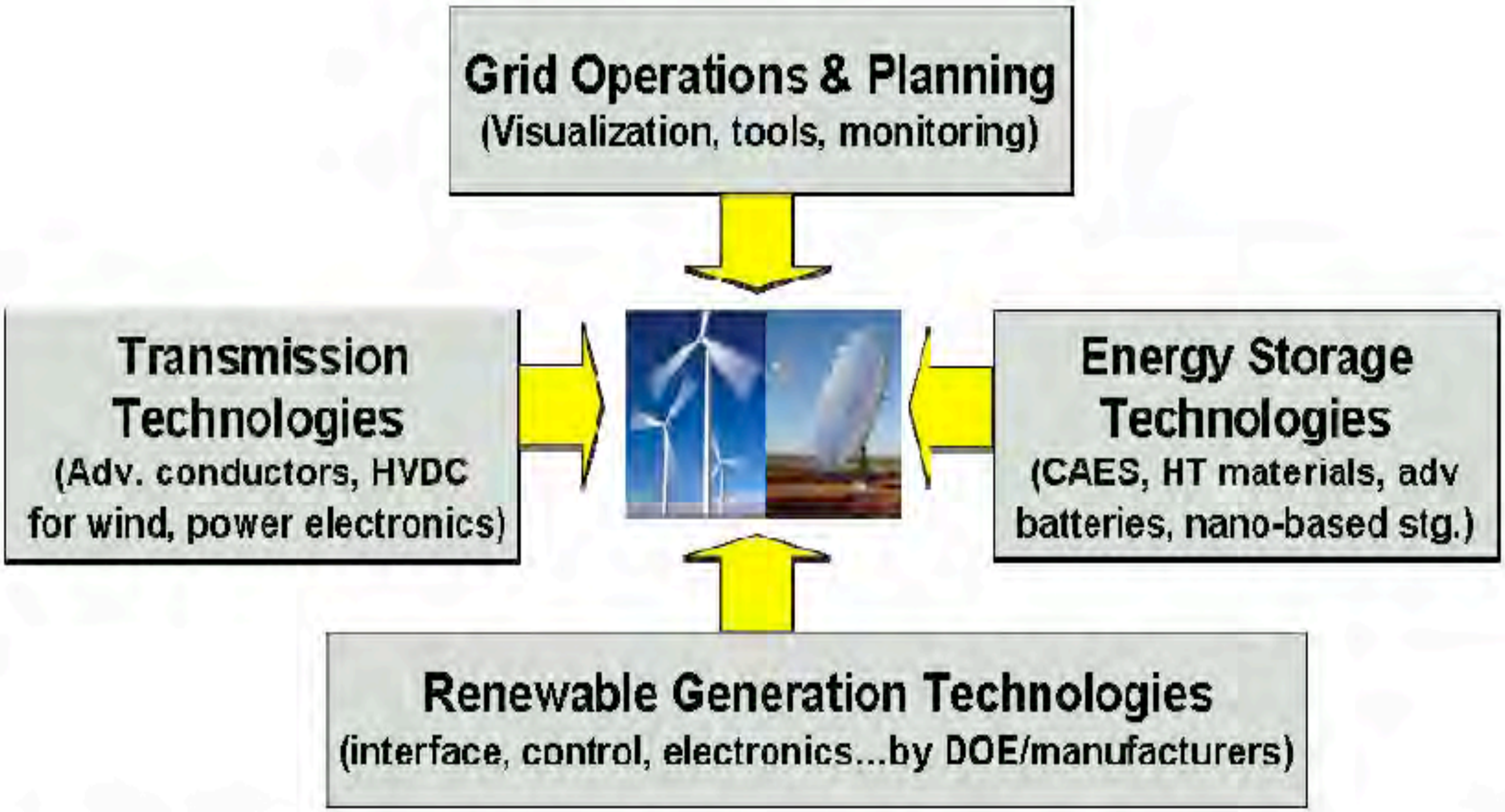
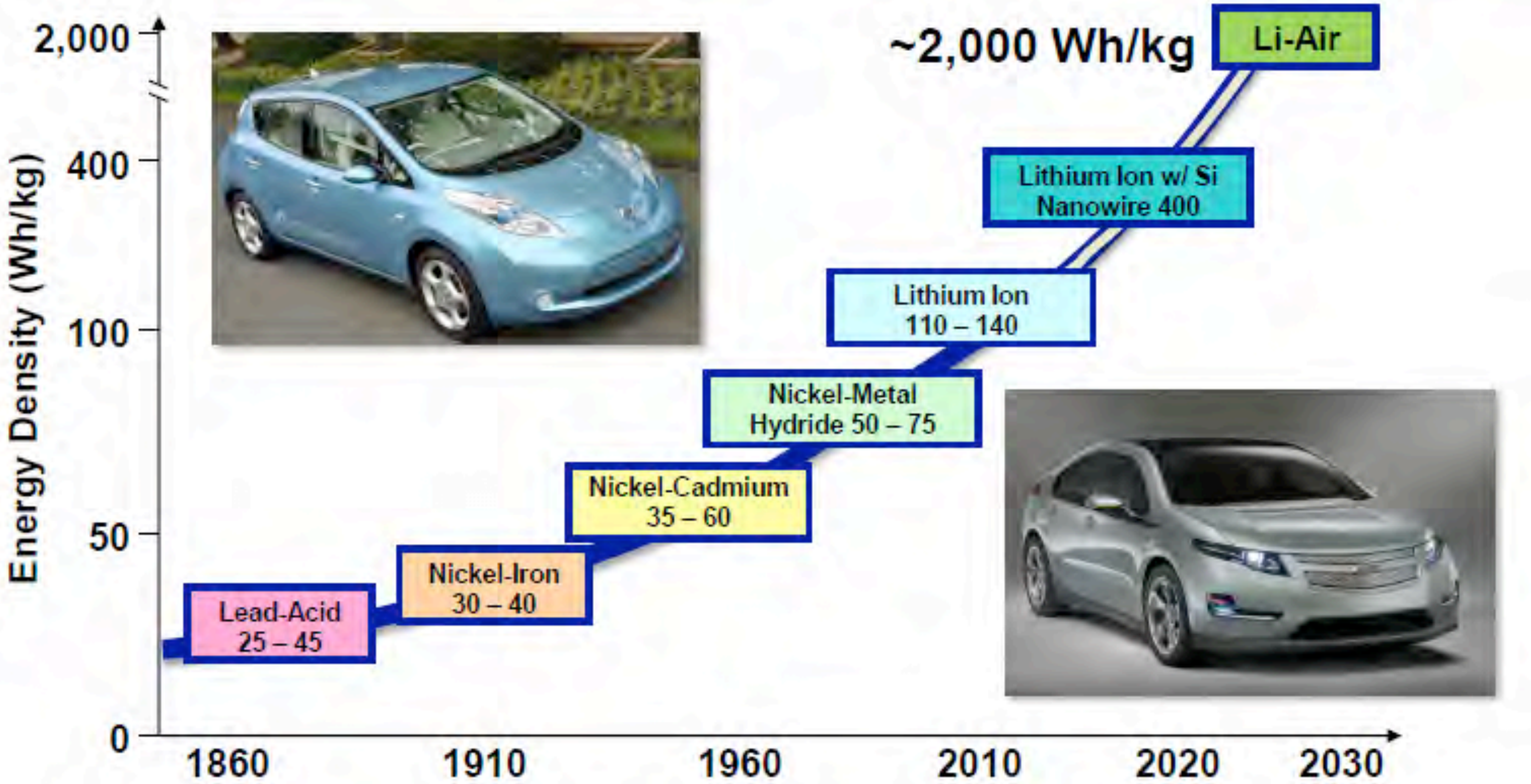


Figure 4-10
Several Different Integration Technologies Will Combine to Ease Integration of Renewable Energy Resources

Renewable Energy Technical Assessment: EdF Annual Update 2008: Solar Photovoltaics, Solar Thermal, and Grid Integration Technologies and Greenhouse Gas Emissions Control. EPRI, Palo Alto, CA: 2009. 1018492.

Smart Grid: Technological Innovations

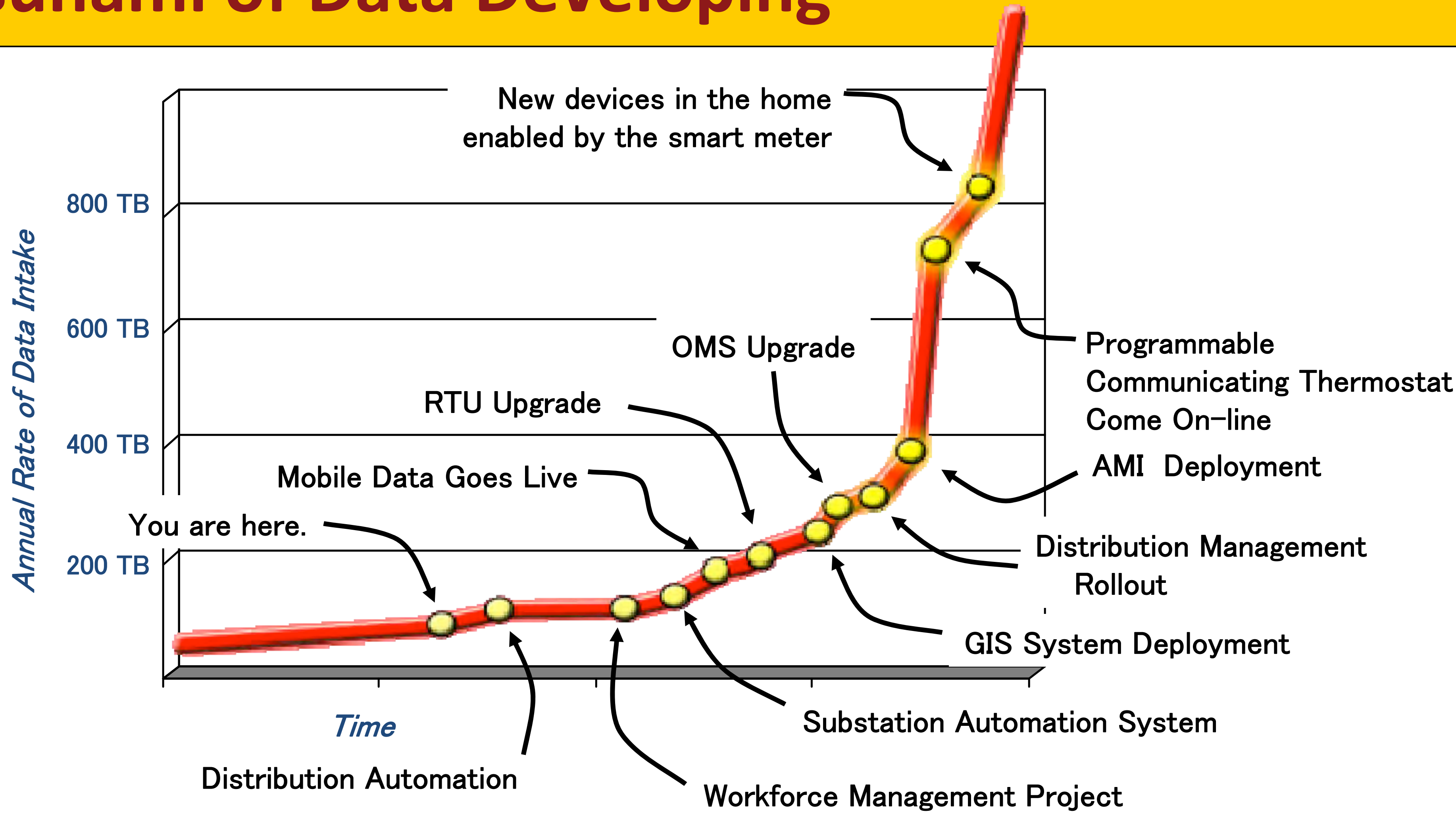
Energy Storage



Sources: EPRI

Smart Grid: Applications and Data

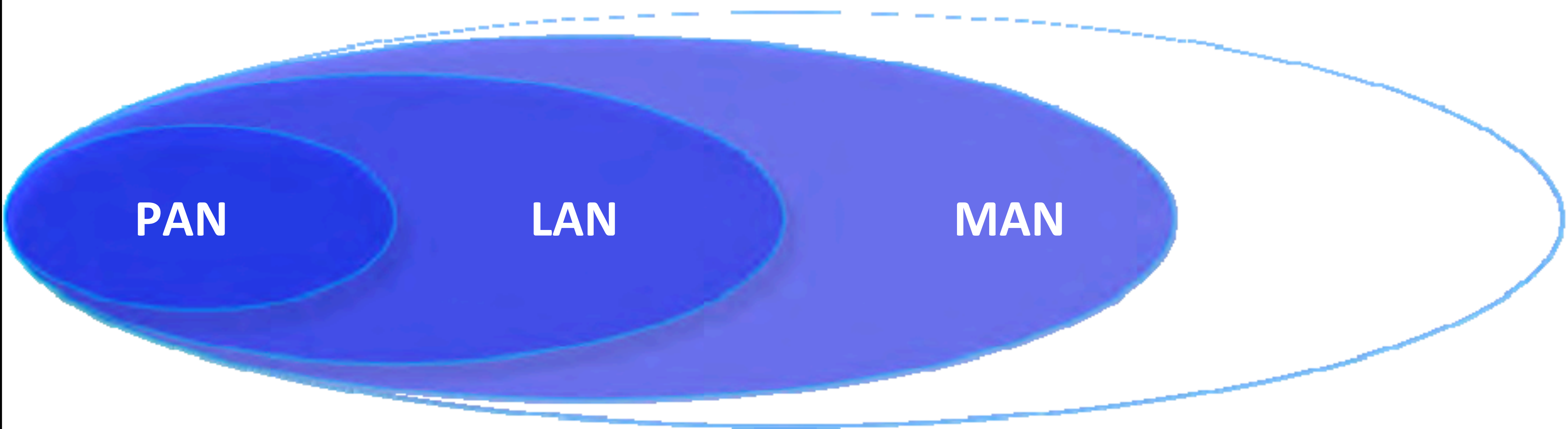
Tsunami of Data Developing



Tremendous amount of data coming from the field in the near future
- paradigm shift for how utilities operate and maintain the grid

Interface of Smart Grid and Buildings

Personal Space | On-Campus / Public | City, Community | Cellular/ PCS /Satellites



Bluetooth, Zigbee
(Feet to 10's of feet)

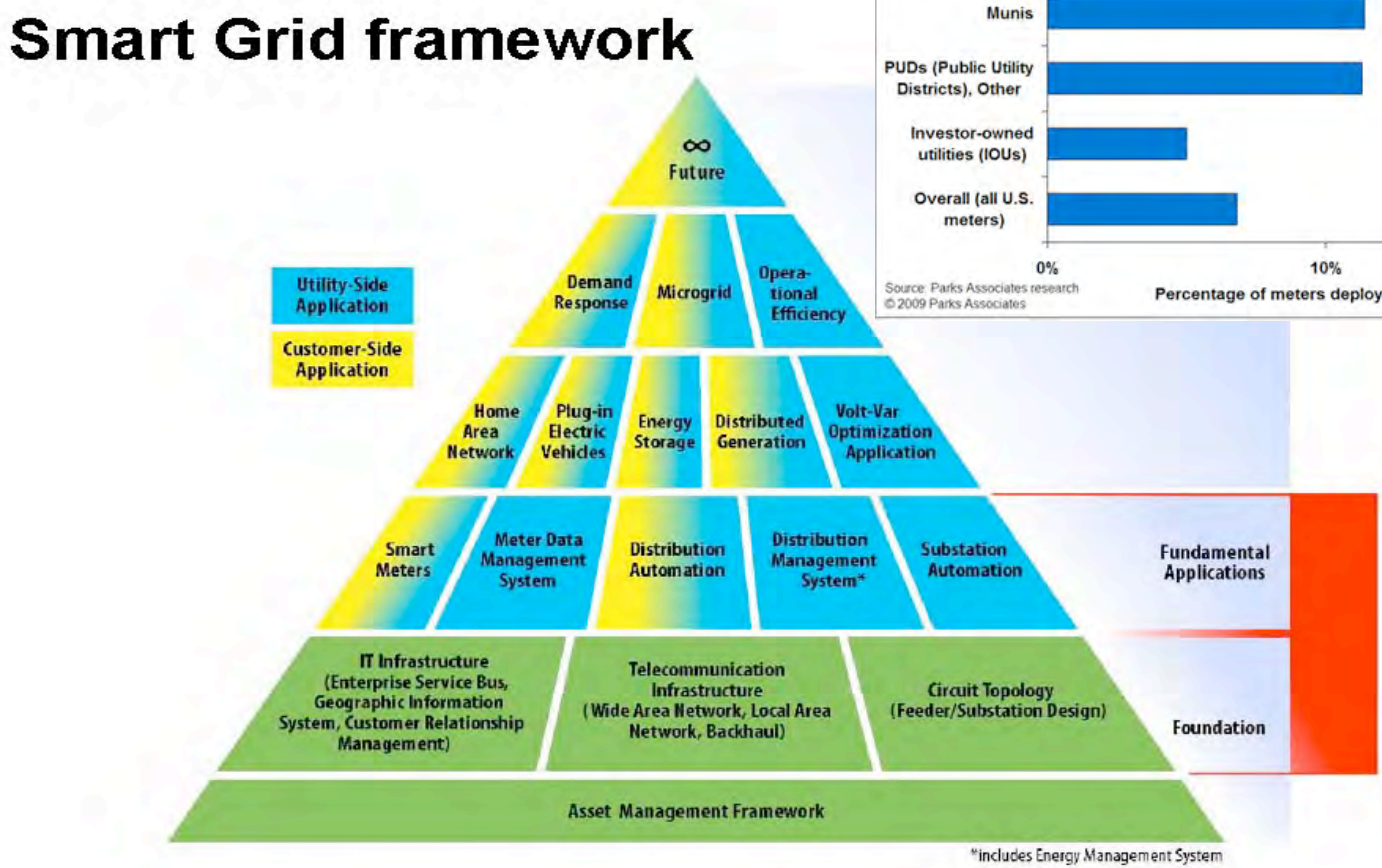
WLAN 802.11X
(10's, 100's of feet)

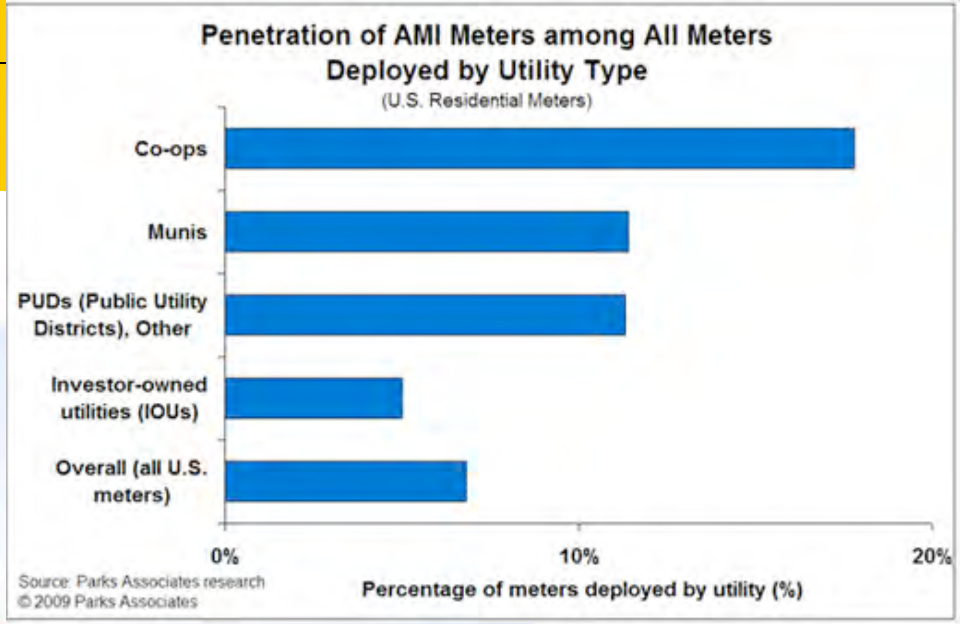
WMAN 802.16, 802.20,
Ad-hoc, Beam Forming

Cellular/Satellite

Source: IBM

End-to-End Smart Grid Opportunities





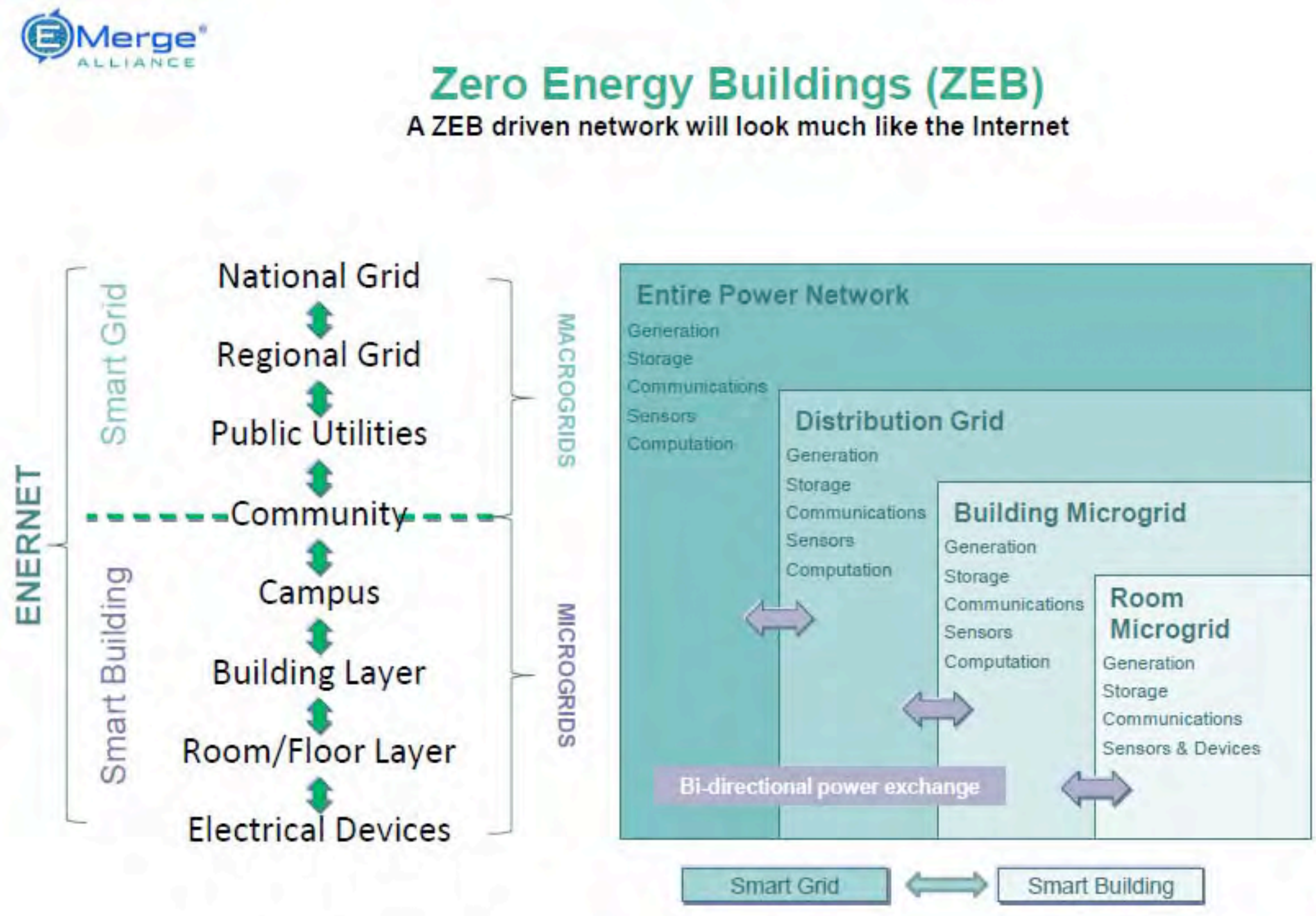
Source: BC Hyrdo

What is Smart Grid and why consider it?

- A collection of technologies that monitor and manage energy consumption
  - Support alternate sources of energy
  - Improve monitoring of systems
  - Provide better supply and demand data
  - Provide greater resiliency
  - Improve electrical security and reliability
  - Become a launch pad for innovation and jobs
- A critical component for building environmentally, socially, and economically sustainable communities, such as the one envisioned for UMore Park

Smart Grid empowers consumers to take control of their energy use.

Interface of Smart Grid and Buildings



Source: EMerge Alliance

Interface of Smart Grid and Buildings

Source: EMerge Alliance

Interface of Smart Grid and Buildings

Optimize and balance

Energy Supply = Energy Demand

- **Microgrids**
- **Local Energy Networks**
- **Energy Efficiency**
  - **AC source to AC loads**
  - **DC source to DC loads**
  - **Intelligent switching in between**
  - **Eliminate conversions**
  - **Use energy how and where it is generated**

Source: IEEE

Interface of Smart Grid and Buildings

- Fossil Fuel
- Long Distance Central Station
- An Aging Infrastructure
- Out of Capacity

- Renewable Power
- On-site
- Zero Energy Building
- Smart Grid

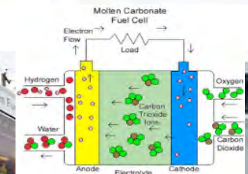












Building's CO2 emission

Reality

New York City:
400' S.F of office space[6]
50 lbs CO_2 / year/S.F.
Total: 10 million tons CO_2 / year

Today

30 ton CO_2 / year

Long time ago

How it started?
1 Kg of wood
=1.8 kg of CO_2

When life was simple

0.1-1 ton CO_2 / year

Interface of Smart Grid and Buildings

Social Cost of CO_2, 2010 – 2050 (in 2007 dollars)

Current Market Value

Discount Rate Year	5% Avg	3% Avg	2.5% Avg	3% 95th
2010	[illegible]	[illegible]	35.1	64.9
2015	5[illegible]	23.8	38.4	72.8
2020	6[illegible]	26.3	41.7	80.7
2025	8.[illegible]	29.6	45.9	90.4
2030	9.[illegible]	32.8	50.0	100.0
2035	11.[illegible]	36.0	54.2	109.7
2040	12.[illegible]	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	[illegible]	[illegible]	136.2

Innovation

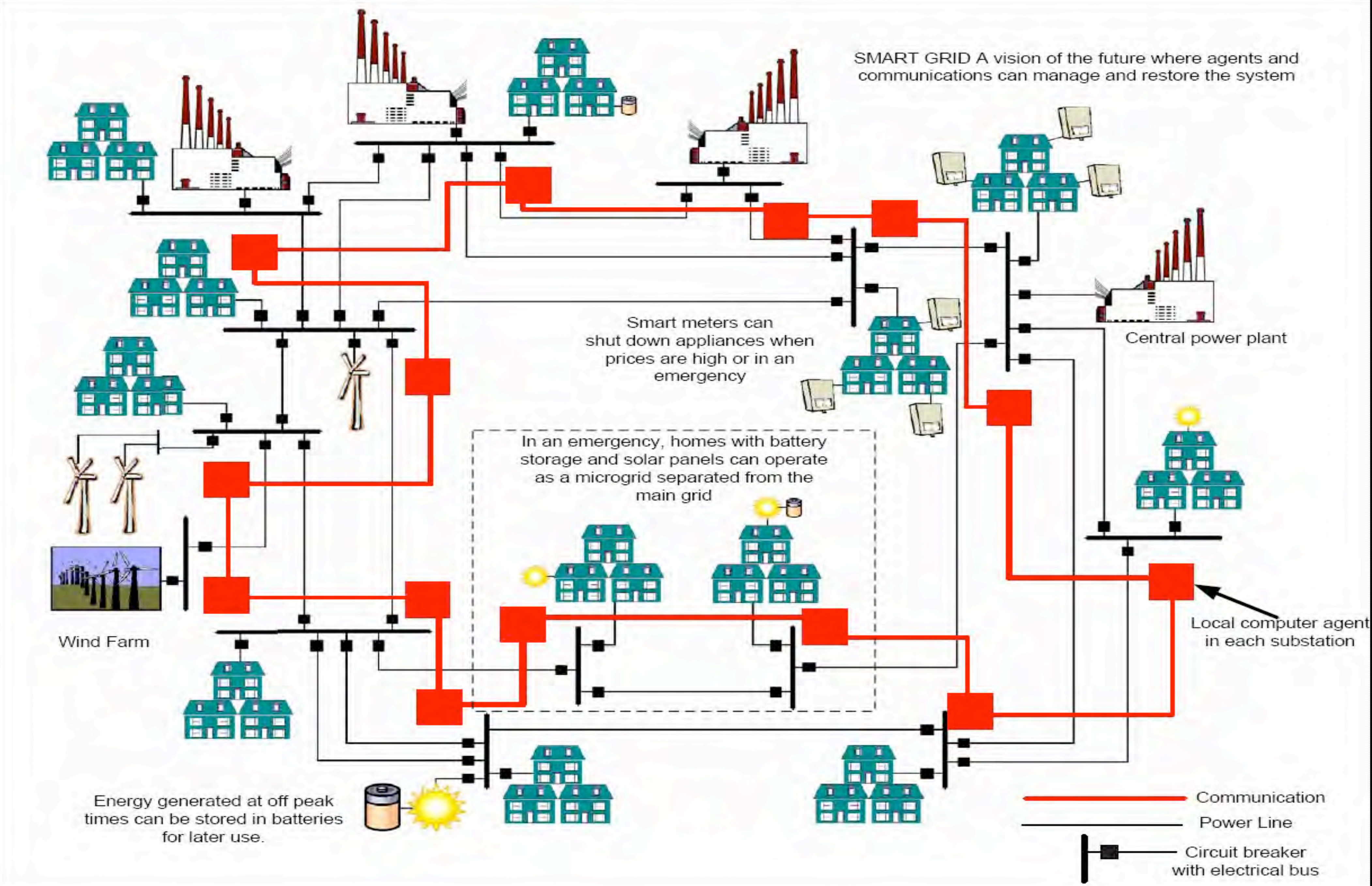
Future Market Value

Source: EPA

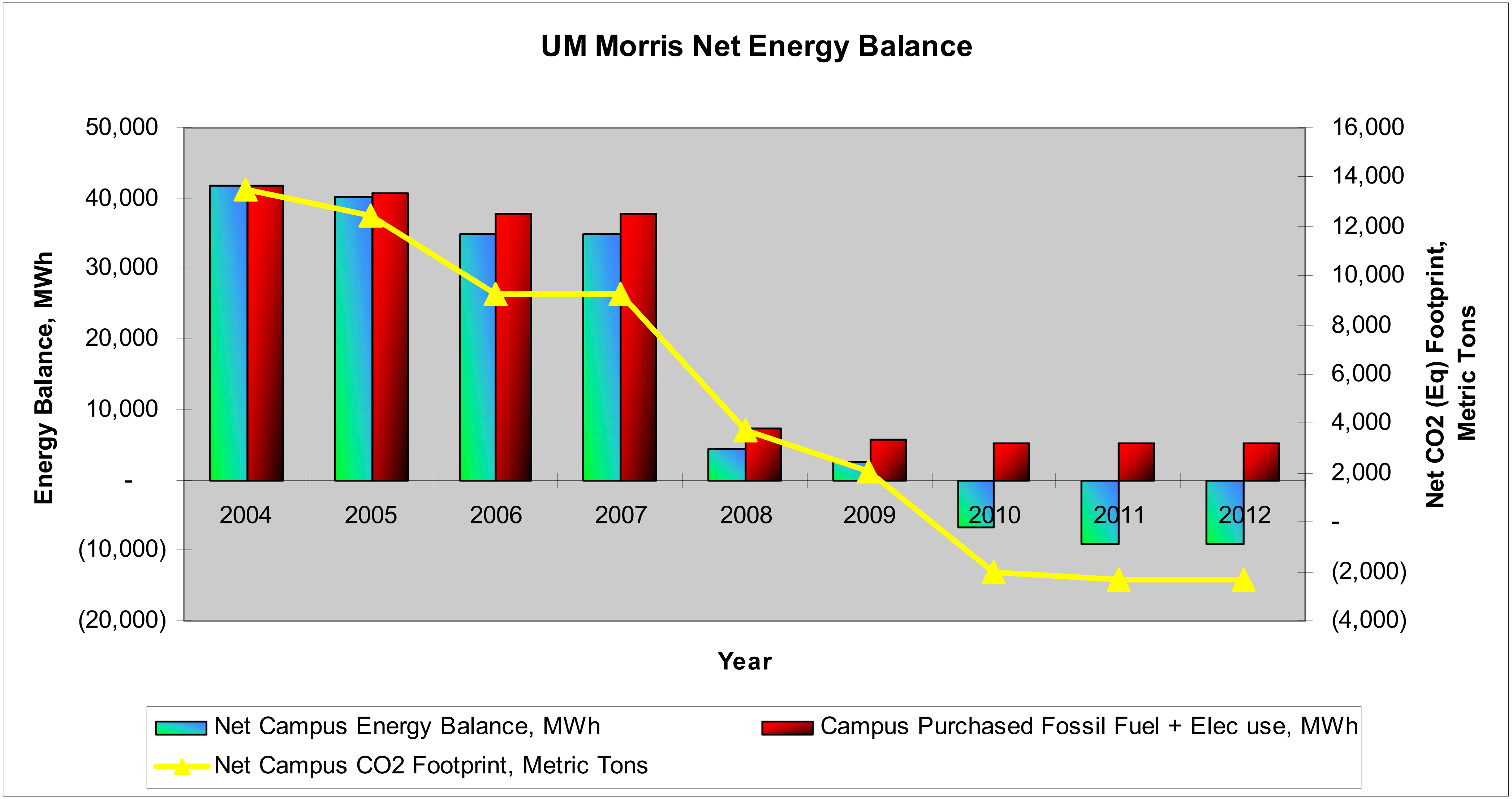
Key Technology Areas

Technology Area	Description
Integrated Communications	High-speed, fully integrated, two-way communication technologies will make the modern grid a dynamic, interactive "mega-infrastructure" for real-time information and power exchange. Open architecture will create a plug-and-play environment that securely networks grid components to talk, listen and interact.
Sensing and Measurement	These technologies will enhance power system measurements and enable the transformation of data into information. They evaluate the health of equipment and the integrity of the grid and support advanced protective relaying; they eliminate meter estimations and prevent energy theft. They enable consumer choice and demand response, and help relieve congestion.
Advanced Control Methods	New methods will be applied to monitor essential components, enabling rapid diagnosis and timely, appropriate response to any event. They will also support market pricing and enhance asset management and efficient operations.
Improved Interfaces and Decision Support	In many situations, the time available for operators to make decisions has shortened to seconds. Thus, the modern grid will require wide, seamless, real-time use of applications and tools that enable grid operators and managers to make decisions quickly. Decision support with improved interfaces will amplify human decision making at all levels of the grid.

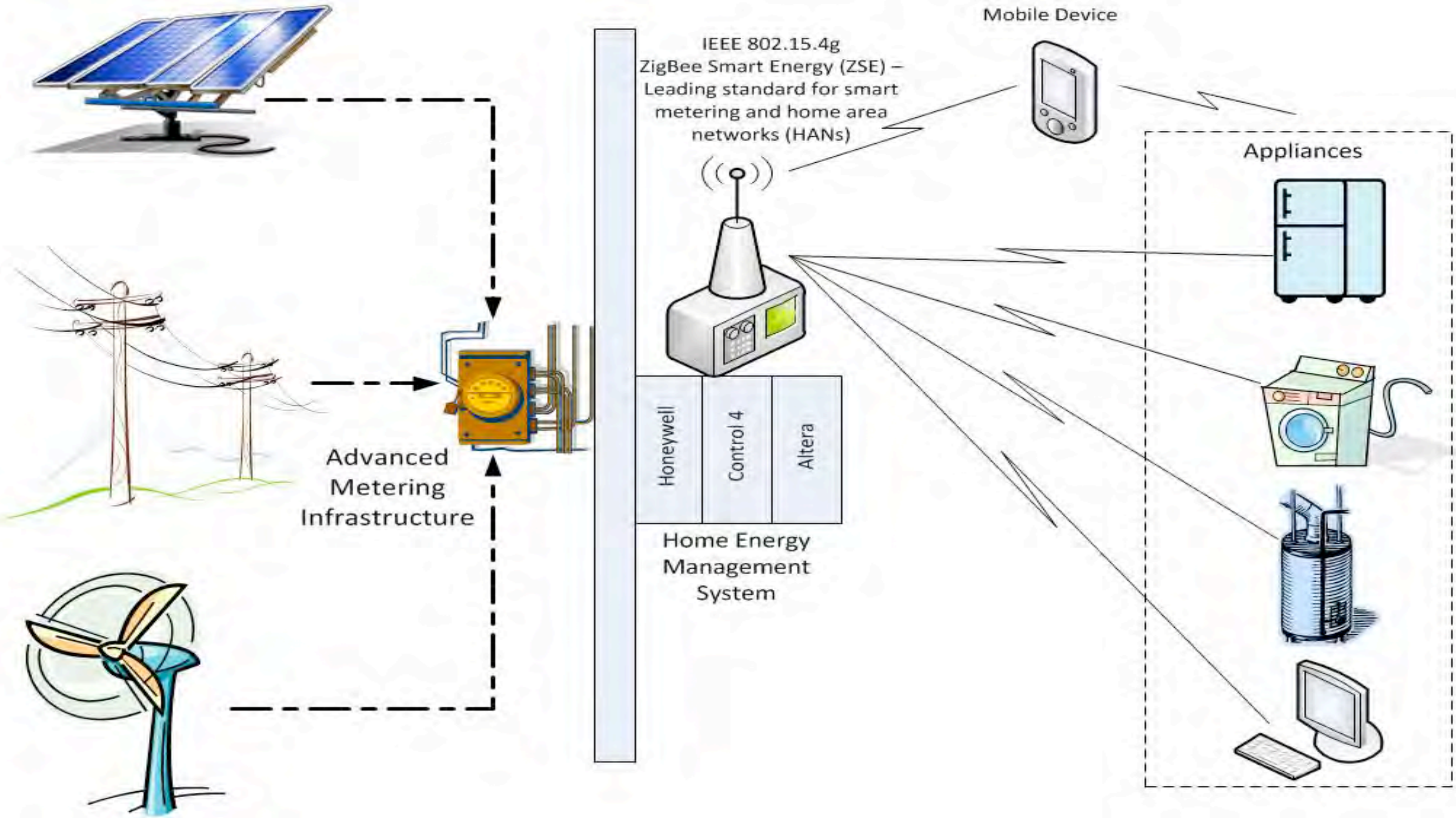
Our team's Smart Grid Research



Going Carbon Negative…

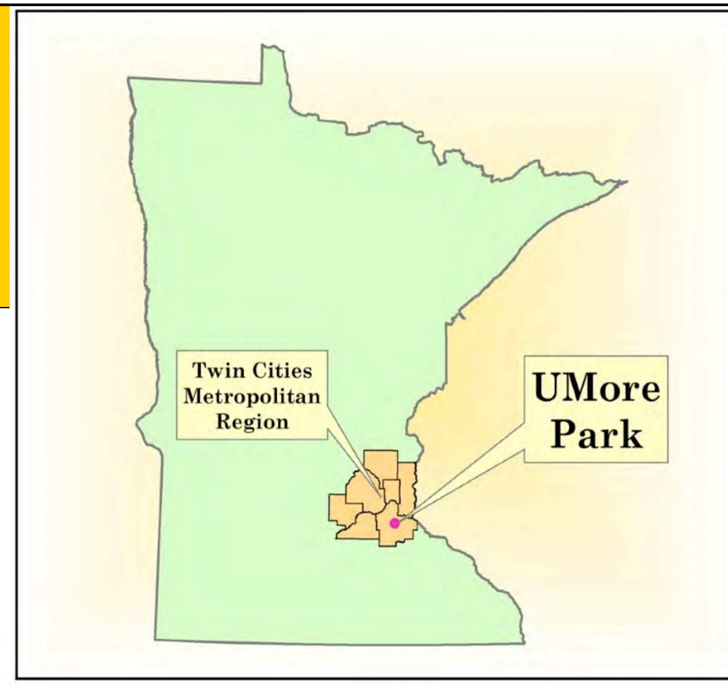


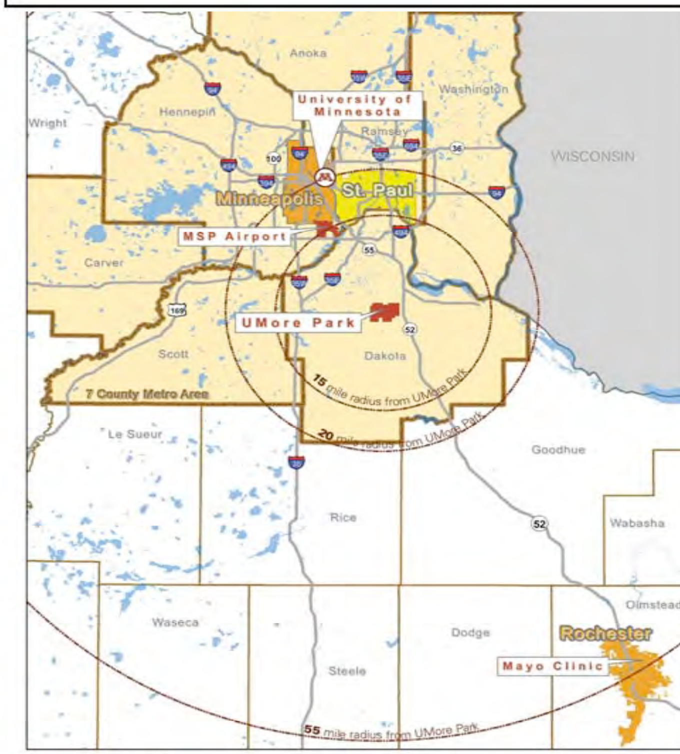
Local System Communication Overlay



Smart Grid assessment for UMore Park

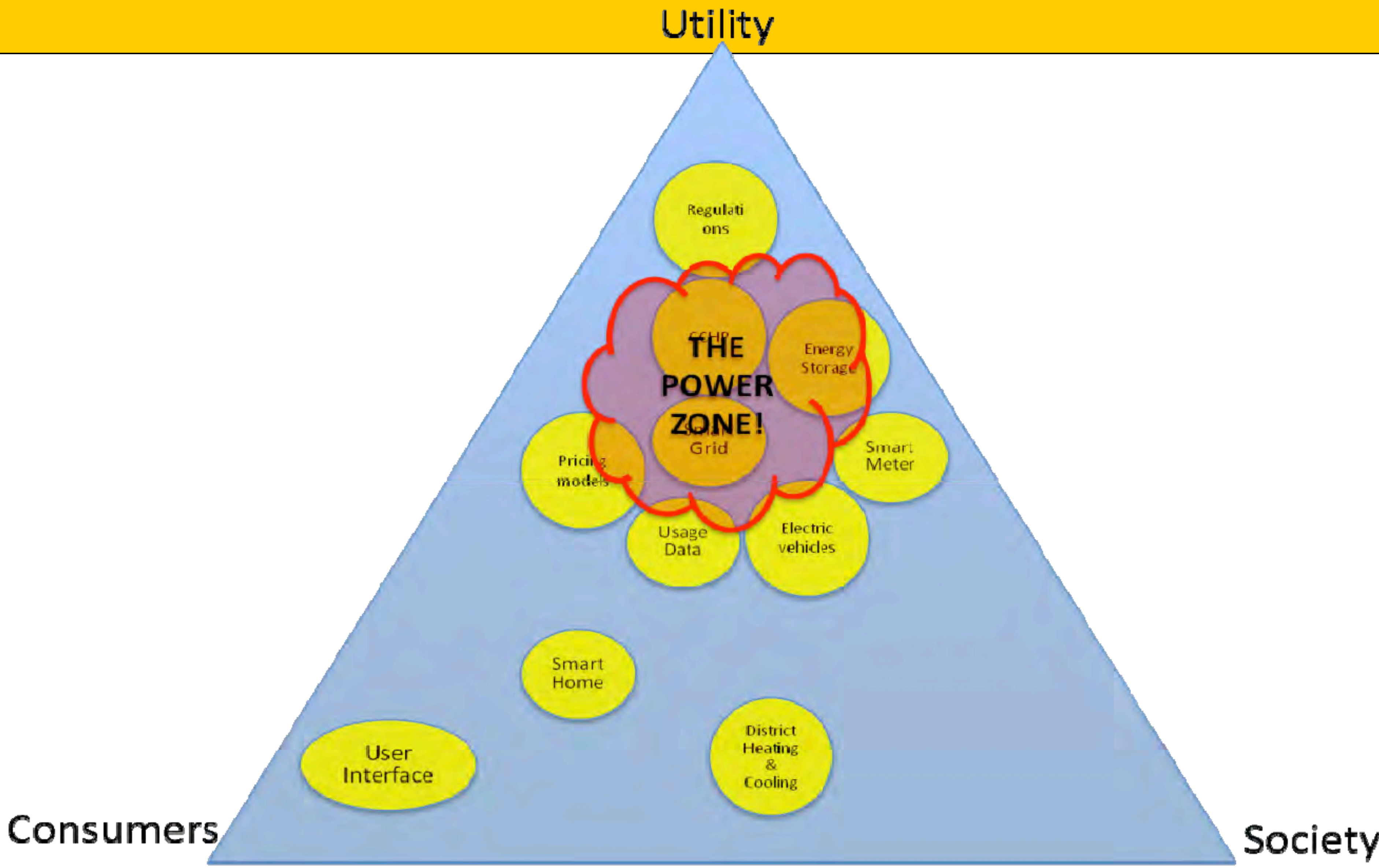
- Can the application of smart grid technologies, and more broadly, smart systems provide a method for managing the energy needs of the community?





UMore park UMore Regional Connections
The University of Minnesota

Analysis - Technology Space Map



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Recommendations & Conclusions

Making Moves

Business Strategy

- Differentiation is KEY!
- Co-branding with UMN
- Cost basis for land is low
- Experts for design

Corporate Strategy

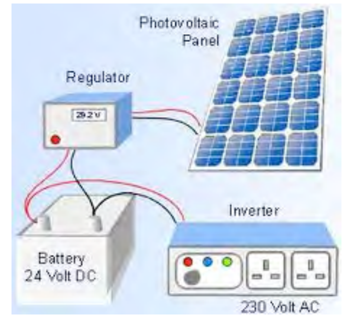
- Partnerships to share risk
- Partnerships/JV
- Xcel
- CenterPoint Energy
- OEMs

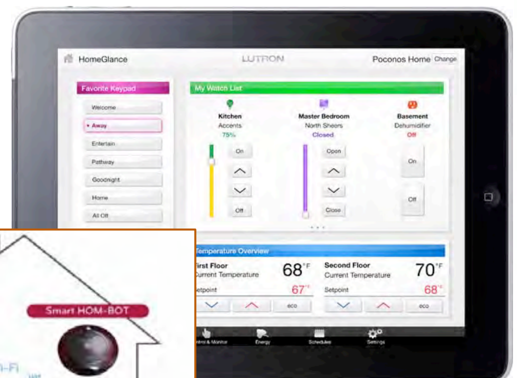
Innovatio n Strategy

- Incorporating new technologies
- Scanning renewable technology

Smart Grid Technologies for Homes at UMore Park

- Photovoltaic inverters
- Smart meters, in-home displays
- Grid-ready appliances
- Electric vehicle power charging station
- Battery storage backup
- Estimated costs: $10,670 to $27,190 per home





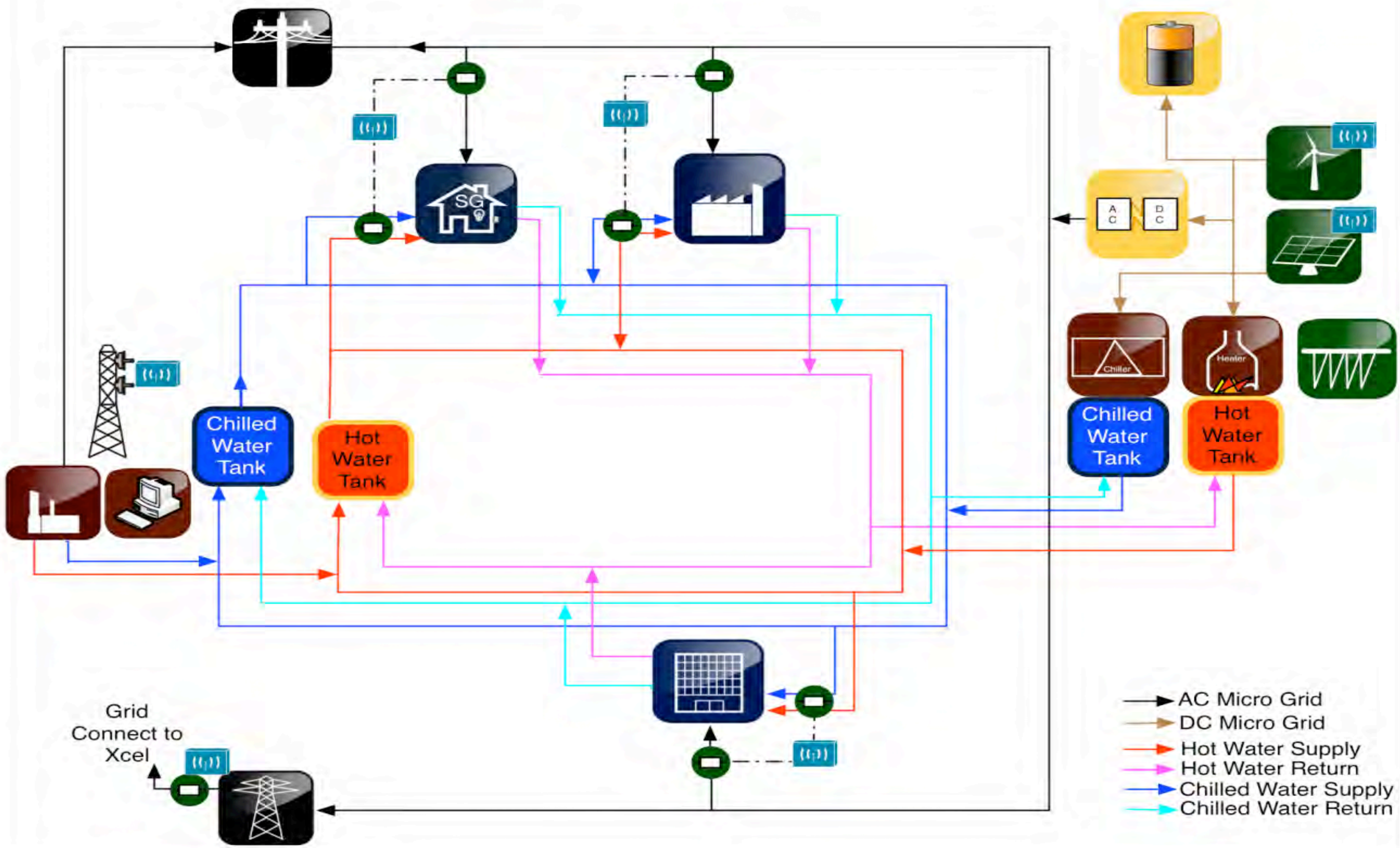
Estimated Prices for Energy-Efficient, Smart Grid Ready Homes in UMore Park

Estimates for Lot Sizes and Home Prices in UMore Park (Maxfield Research, Inc., 2010)						
	Square Foot Range			Estimated Home Pricing		
	Low	High	Average	Low	High	Average
Small Lot	1,600	2,500	2,050	$225,000	$350,000	$287,500
Traditional	1,800	2,800	2,300	$225,000	$410,000	$317,500
Large Lot	2,800	4,500	3,650	$450,000	$725,000	$587,500

Estimates for Energy-Efficient, Smart Grid Ready Homes in UMore Park						
	Price Ranges			Cost Over Traditional Home		
	Low	High	Average	Low	High	Average
Small Lot	$244,920	$379,920	$312,420	$19,920	$29,920	$24,920
Traditional	$244,920	$444,720	$344,820	$19,920	$34,720	$27,320
Large Lot	$487,920	$784,920	$636,420	$37,920	$59,920	$48,920

Average prices are within range of the low-high estimated home prices for UMore Park

A District Energy Model



Interface of Smart Grid and Buildings

Energy Savings
Opportunities for Building Owners

Building Applications *(in priority timing of EMerge Alliance)*	Ave % of Building Energy Used	Potential Energy Savings by Going DC	Keys to Maximizing Efficiency in Going DC
Interiors (Lighting)*	28%*	Up to 15%	LED, Renewables
Data/Telecom	17%	Up to 30%	Higher voltage conversions, Renewables
Service/Utility (HVAC)	36%	Up to 10%	Renewables
Outdoor	6%	Up to 10%	LED, Renewables
Other (misc equip loads)	13%	Up to 5%	Different voltage conversions

*Higher energy use in office buildings, up to 40%

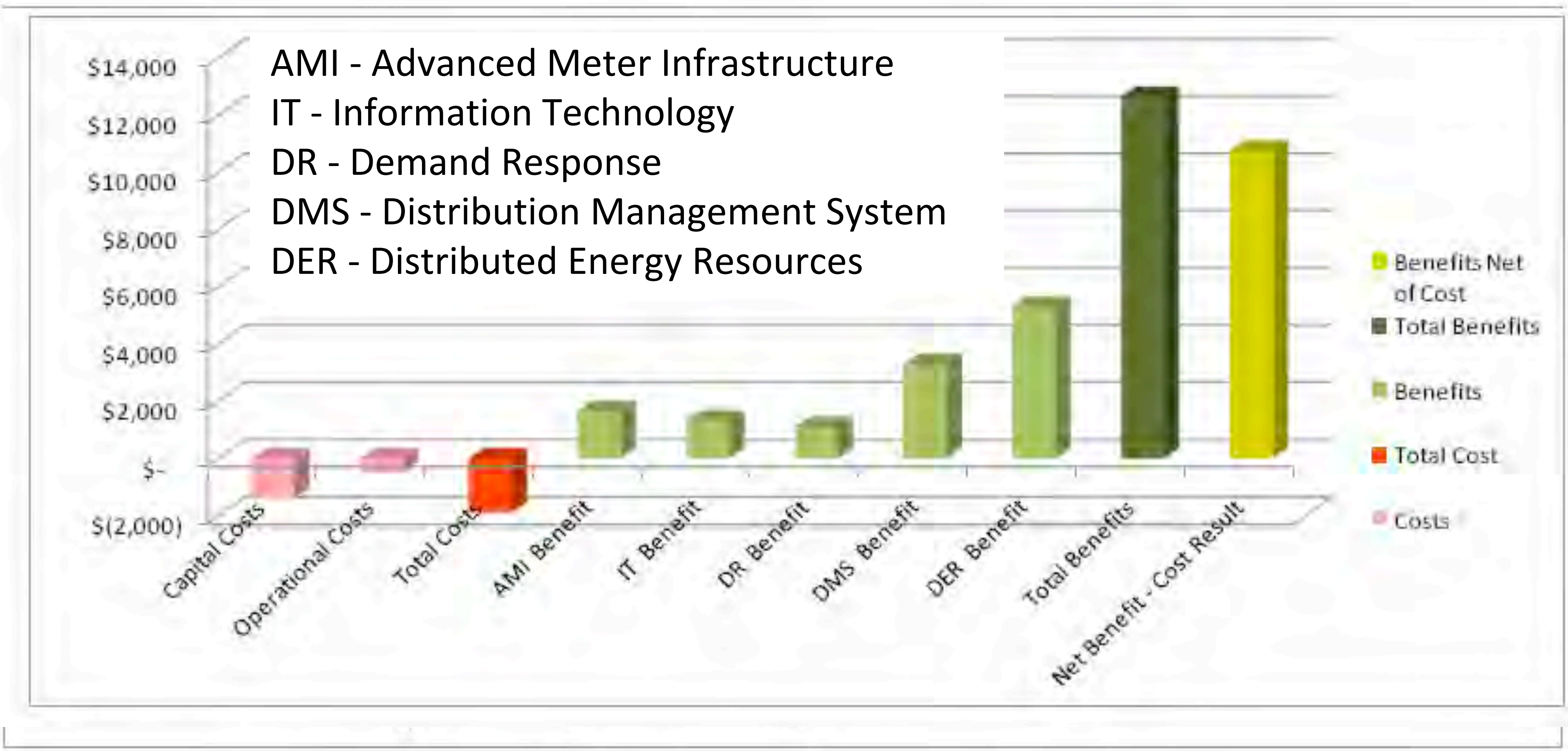
Smart Grid U™

Lessons learned and key messages

- Consider all parts together (Holistic Systems approach)
- Focus on Benefits to Cost Payback
- Remove deficiencies in foundations
- The University as a Living laboratory
- Education and Research → Implement new solutions

- **Consumer engagement critical to successful policy implementation to enable** end-to-end system modernization
- If the transformation to smart grid is to produce real strategic value for our nation and all its citizens, our goals must include:
  - Enable **every building and every node to become an efficient and smart energy node.**
  - **What are the range of new services enabled by smart grids?**
  - **"Smart Grid as a Means to an End—Not an End Unto Itself"**

West Virginia Business Case



Source: National Energy Technology Laboratory

Awareness, Costs and Benefits

Awareness:

- ~68% of consumers in the U.S. don't know what "Smart Grid" is...
  - what is the "Smart Grid"?
  - what are the range of new consumer-centered services enabled by smart grids?
  - what are the smart grid's potential to drive economic growth?

Costs/Benefits:

- EPRI report, "Estimating the Costs and Benefits of the Smart Grid: A Preliminary Estimate of the Investment Requirements and the Resultant Benefits of a Fully Functioning Smart Grid":
  - The new report finds that the estimated net investment needed to realize the envisioned power delivery system of the future is between $338 and $476 billion.
  - Previous EPRI assessments (2004) had put the estimated costs at about $165 billion over 20 years ($8 to $10 billion per year).
- Energy consulting firm Brattle Group: $1.5 trillion spread over 20 years (~$75 billion per year) for an overhaul of the entire electricity infrastructure.
- My work, 1998-present: $160 to $170 billion ($10 to $17 billion per year for 10-20 years).

… Awareness, Costs and Benefits

Smart grid benefits:

- Increases efficiency by 5% ($20.4 billion in savings annually)
- Reduces costs of outages by about $49 billion per year
- Reduces emissions by 12-18%
- Increases overall energy security, and can spur economic growth.
  - Benefits which could be as high as $2.3 trillion for the U.S. —and if the definition were even wider, the long-term benefits would be even greater.

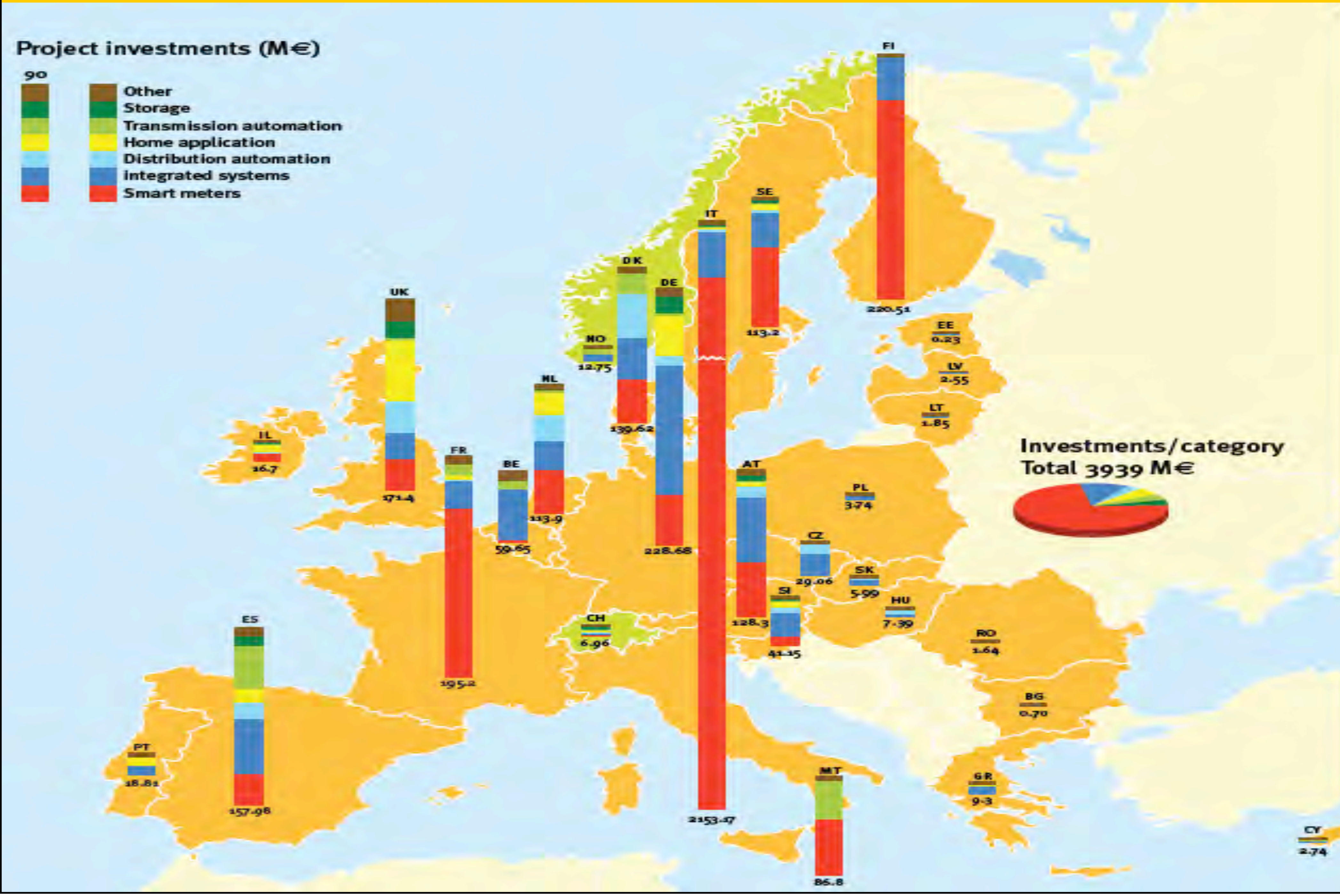
- Our $14 trillion economy depends on reliable, disturbance-free access to electricity.

Investments in Smart Grid Technologies

- Factors that boost smart grid investment and technology in the short term:
  - Analytics: Mining data to increase understanding
  - Standards consolidation
  - Increasing penetration of solar and electric vehicles: Demand shifts, integrate new tools and technologies.

- Nations/regions/cities that best implement new strategies and infrastructure may reshuffle the world pecking order. Emerging markets could leapfrog other nations:
  - **U.S.** investment is at about $7 billion in smart grid technologies
  - **China** invested $7.3 billion; will spend $96 billion in smart grid technology by 2020
    - China's energy needs to double by 2020
    - Many changes will happen in the homes themselves:
    - China will account for 18.2% of global smart grid appliance spending by 2015.
  - **South Korea** at nearly $1 billion:
    - A $65 million pilot program on Jeju Island is implementing a fully integrated grid for 6,000 homes, a series of wind farms and four distribution lines. Its leaders plan to implement smart grids nationwide by 2030.
  - **Brazil**: 60% growth in electricity consumption between 2007 and 2017 with 16-34% increase in renewables from hydro, biomass and wind. But they have an aging grid that is currently a one-way power flow that needs to move in two directions.

Example: Smart Grid projects in Europe



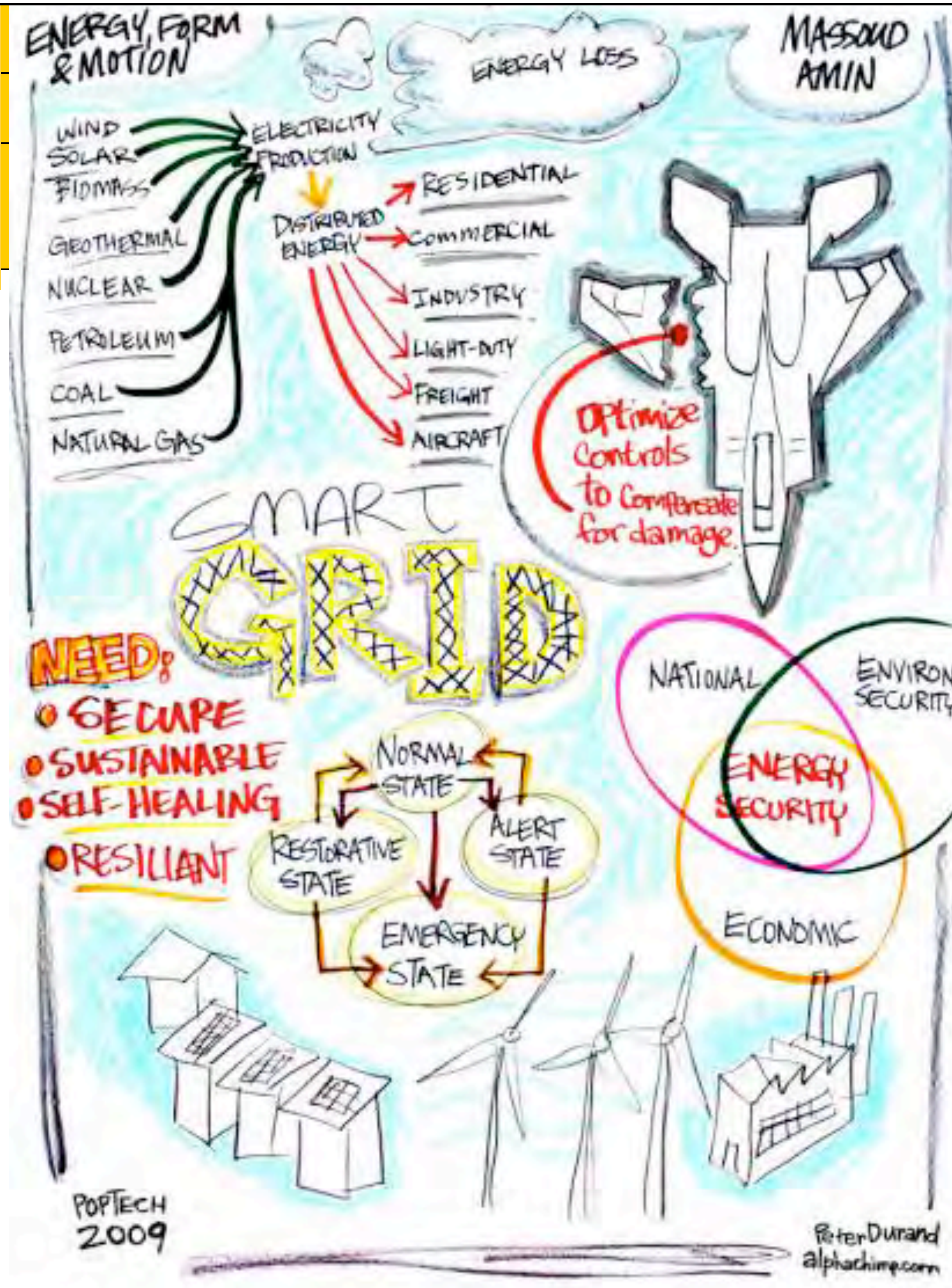
The Emerging Smart Grid or Energy Web:
A Complex Adaptive Infrastructure System

"… not to sell light bulbs, but to create a network of technologies and services that provide illumination…"

"The best minds in electricity R&D have a plan: Every node in the power network of the future will be awake, responsive, adaptive, price-smart, eco-sensitive, real-time, flexible, humming and interconnected with everything else."

-- Wired Magazine, July 2001

http://www.wired.com/wired/archive/9.07/juice.html



Options, Costs and Benefits

"Computers are incredibly fast, accurate, and stupid; humans are incredibly slow, inaccurate and brilliant; together they are powerful beyond imagination."

Albert Einstein

I-35W bridge: Stronger and Smarter

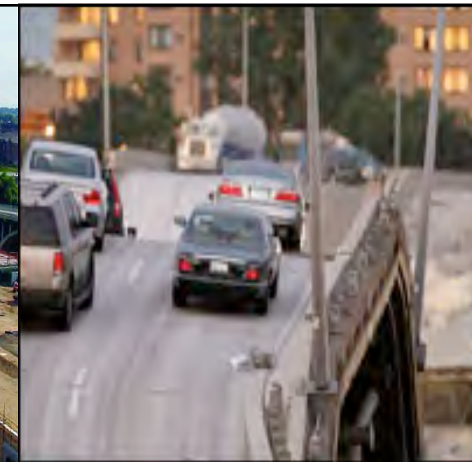
Just after 6:00 p.m. on Aug. 1, Prof. Massoud Amin was at work in his office on the University of Minnesota's West Bank, where he heard and watched the unthinkable happen—the collapse of the I-35W bridge about 100 yards away.

"As an individual, it was shocking and very painful to witness it from our offices here in Minneapolis," says Amin, director of the Center for the Development of Technological Leadership (CDTL) and the H.W. Sweatt Chair in Technological Leadership. Amin also viewed the tragedy from a broader perspective as a result of his ongoing work to advance the security and health of the nation's infrastructure.

In the days and weeks that followed, he responded to media inquiries from the BBC, Reuthers, and the CBC, keeping his comments focused on the critical nature of the infrastructure. He referred reporters with questions about bridge design, conditions, and inspections to several professional colleagues, including Professors Roberto Ballarini, Ted Galambos, Vaughan Voller, and John Gulliver in the Department of Civil Engineering and the National Academy of Engineering Board on Infrastructure and Constructed Environment.

For Amin, Voller, and many others, the bridge collapse puts into focus the importance of two key issues—the tremendous value of infrastructure and infrastructure systems that help make possible indispensable activities such as transportation, waste disposal, water, telecommunications, and electricity and power, among many others, and the search for positive and innovative ways to strengthen the infrastructure.

To improve the future and avoid a repetition of the past:



Sensors built in to the I-35W bridge at less than 0.5% total cost by TLI alumni

Terry Ward

Heidi Hamilton

Val Svensson

Joe Nietfeld

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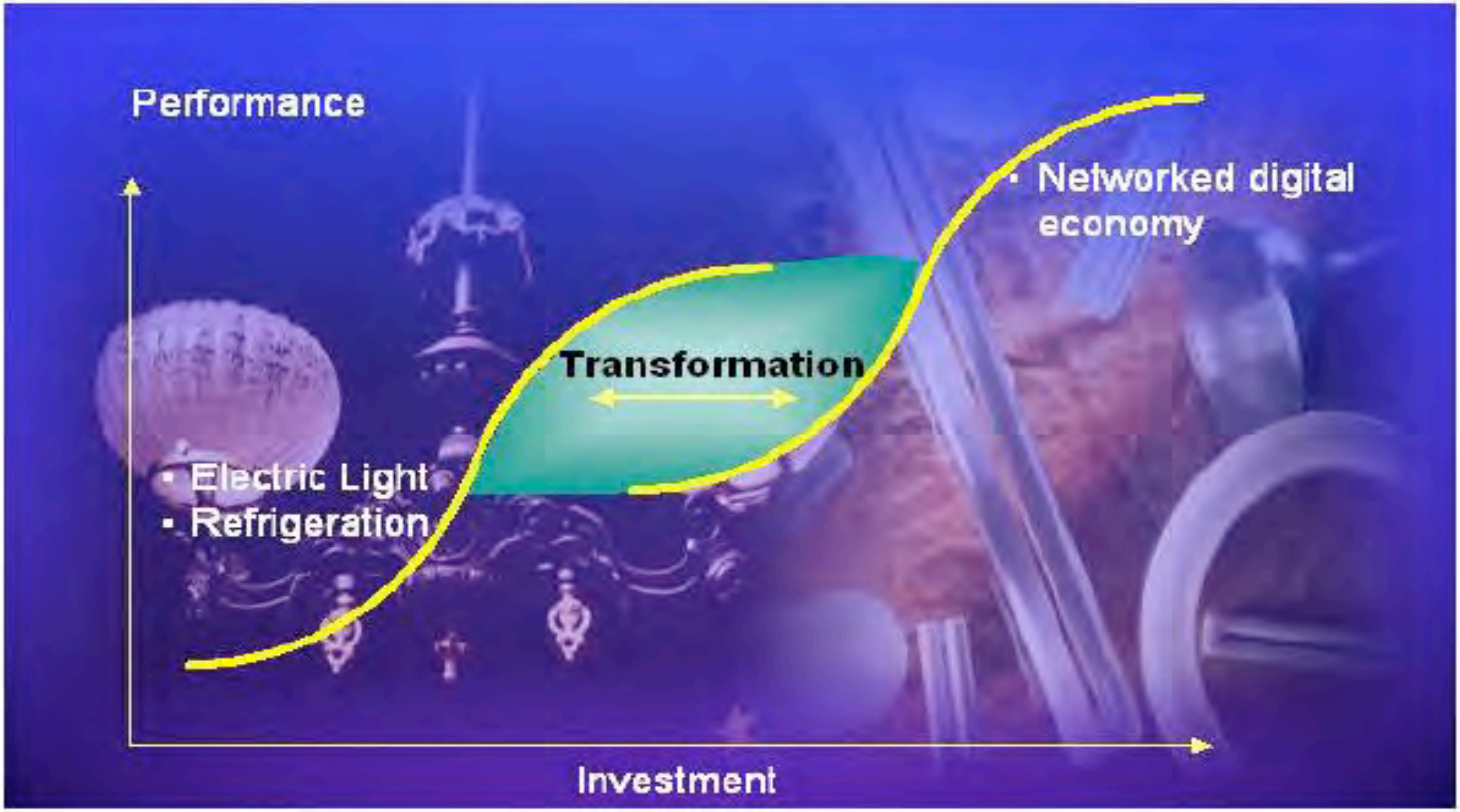
Smart Grid Goals

Source: M. Amin, Chairman, IEEE Smart Grid Newsletter http://smartgrid.ieee.org/publications/smart-grid-newsletter

Breaking the Limits on Electricity Value



Selected References

Downloadable at: http://umn.edu/~amin

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