Smart Grid: Toward stronger, smarter, and more secure energy infrastructure

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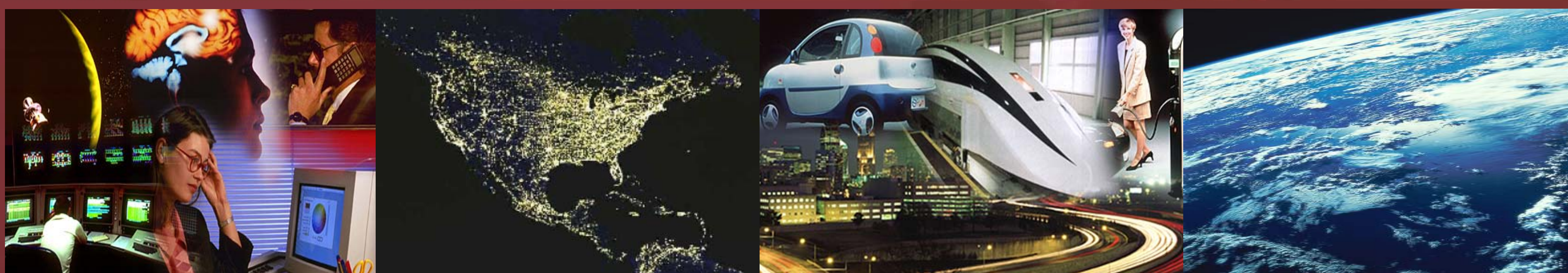

MN Senate Energy, Utilities, Technology & Communications Committee

February 16, 2010, 3:00-5:30 p.m.

Material from the Electric Power Research Institute (EPRI), and support from EPRI, NSF, and ORNL for my graduate students' doctoral research is gratefully acknowledged.

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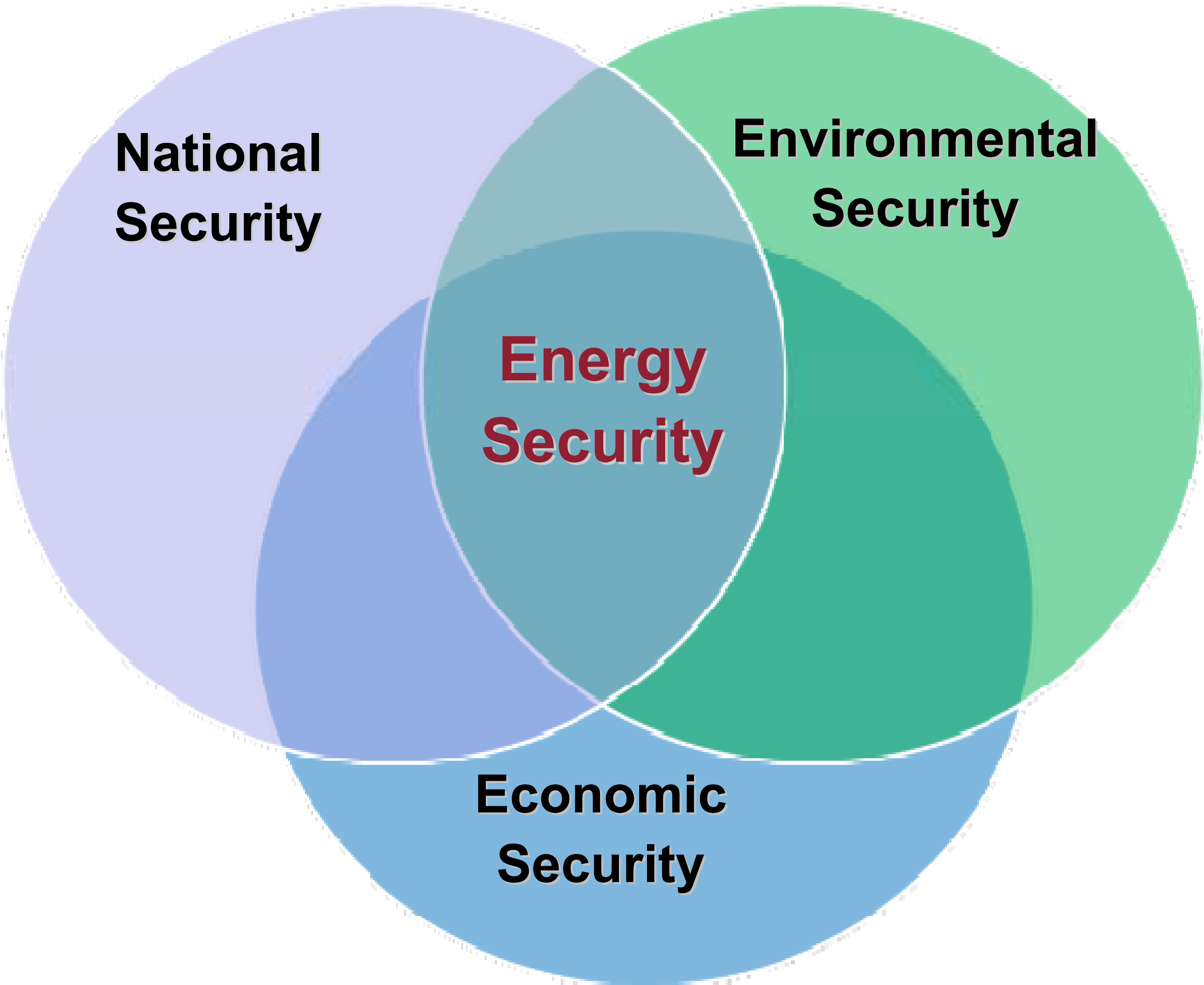
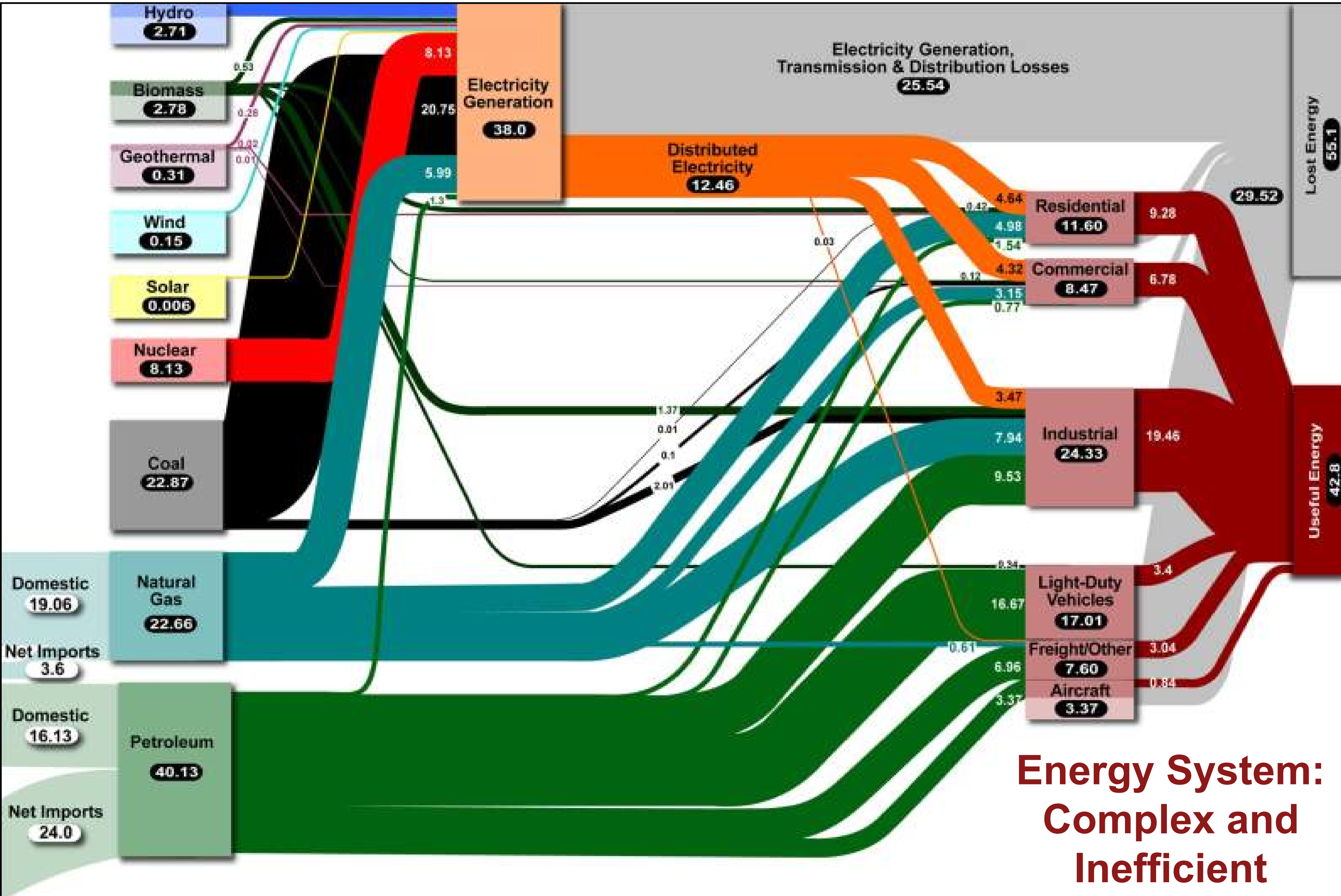
The Energy Crises Taught Us Interdependency



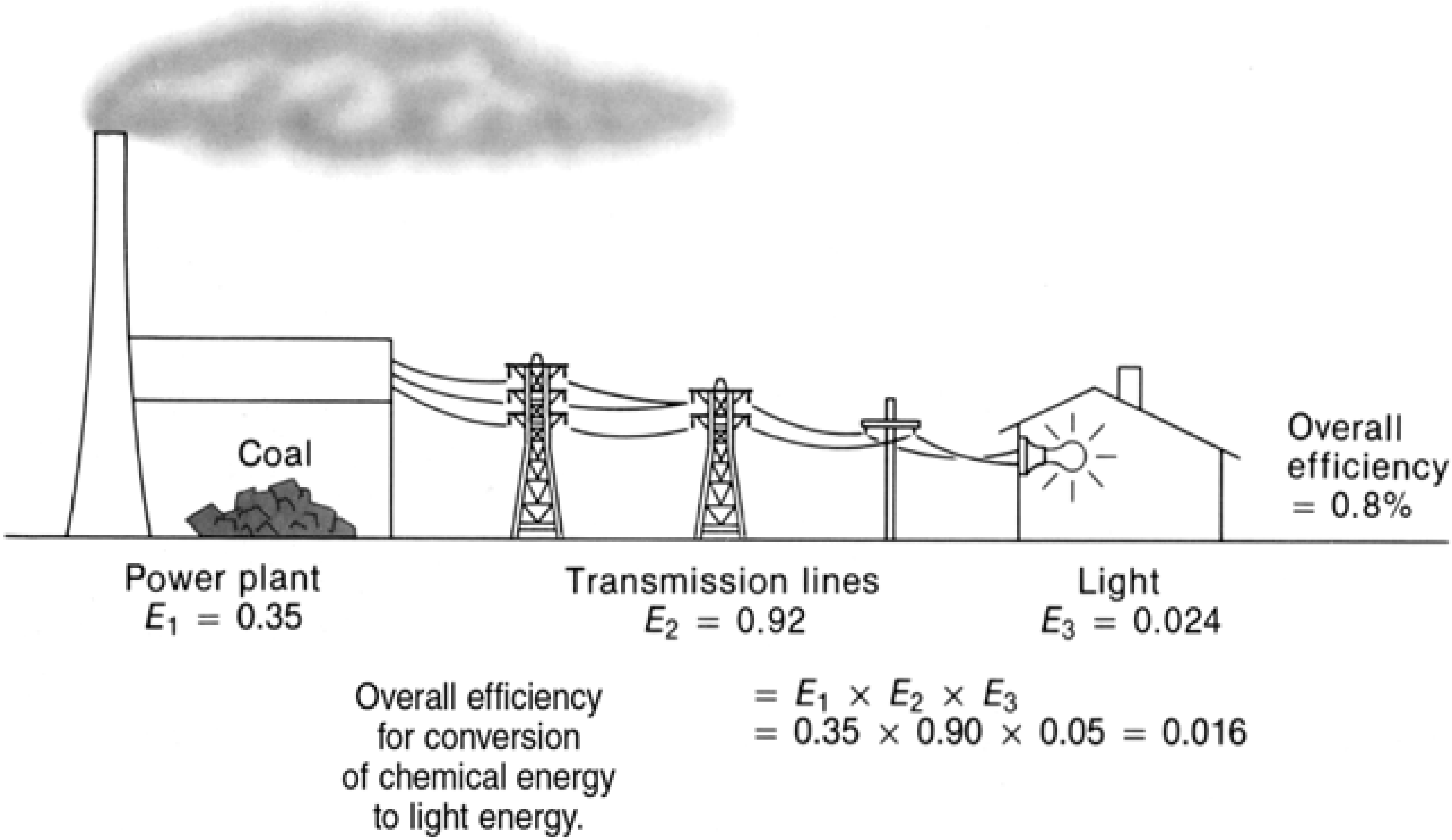
Source: RAND



Energy System: Complex and Inefficient

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

End-to-End Energy Inefficiency
Losses as high as 98.4%



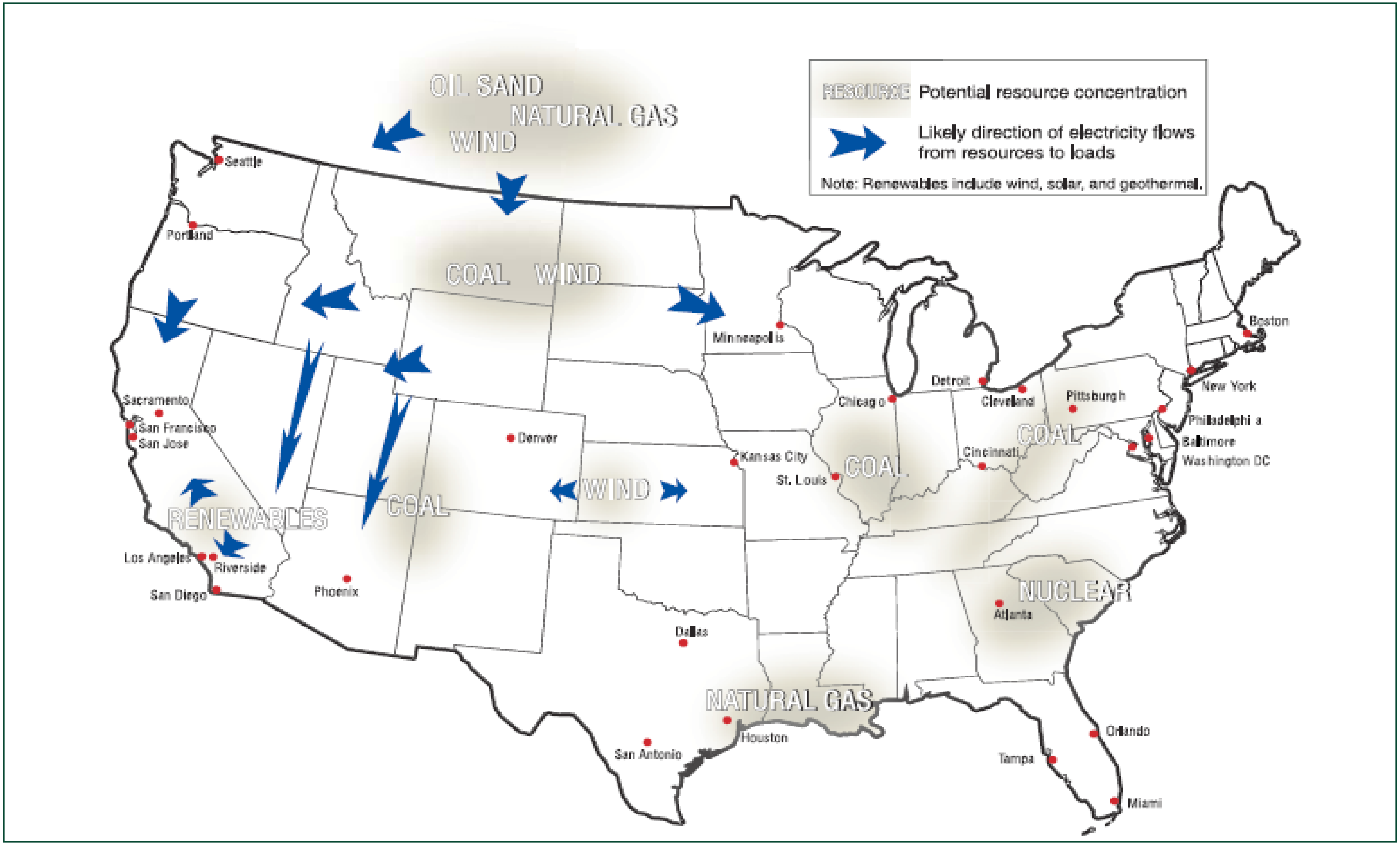
Source: NRC, 2009

Goals and Recommendations

- **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**

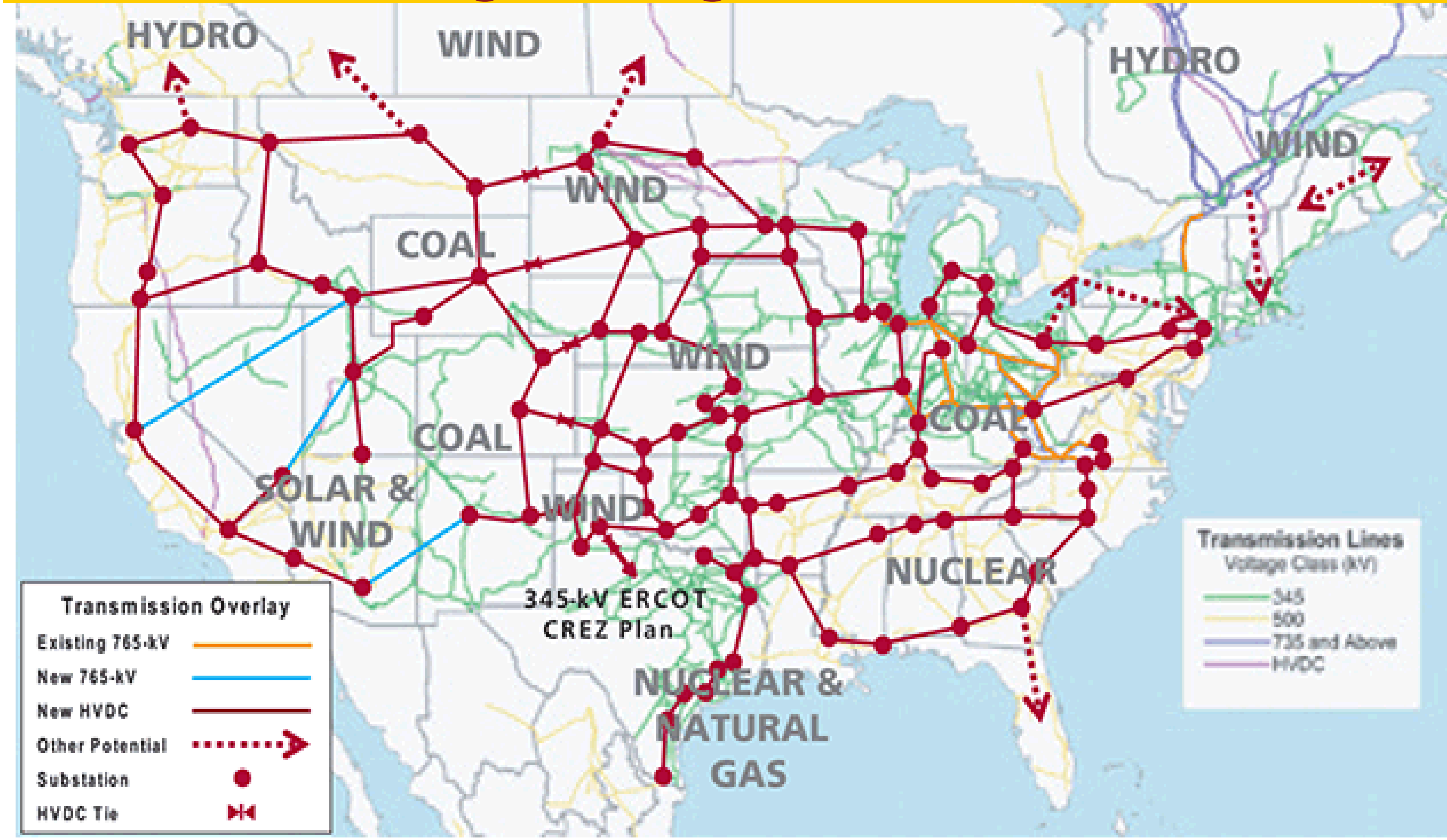
Source: IEEE Energy Policy Committee, 2009, and M. Amin's briefing s at the Congressional R&D Caucus (March 26, 2009), and on Oct. 15, 2009

Emerging Supply and Demand Patterns



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

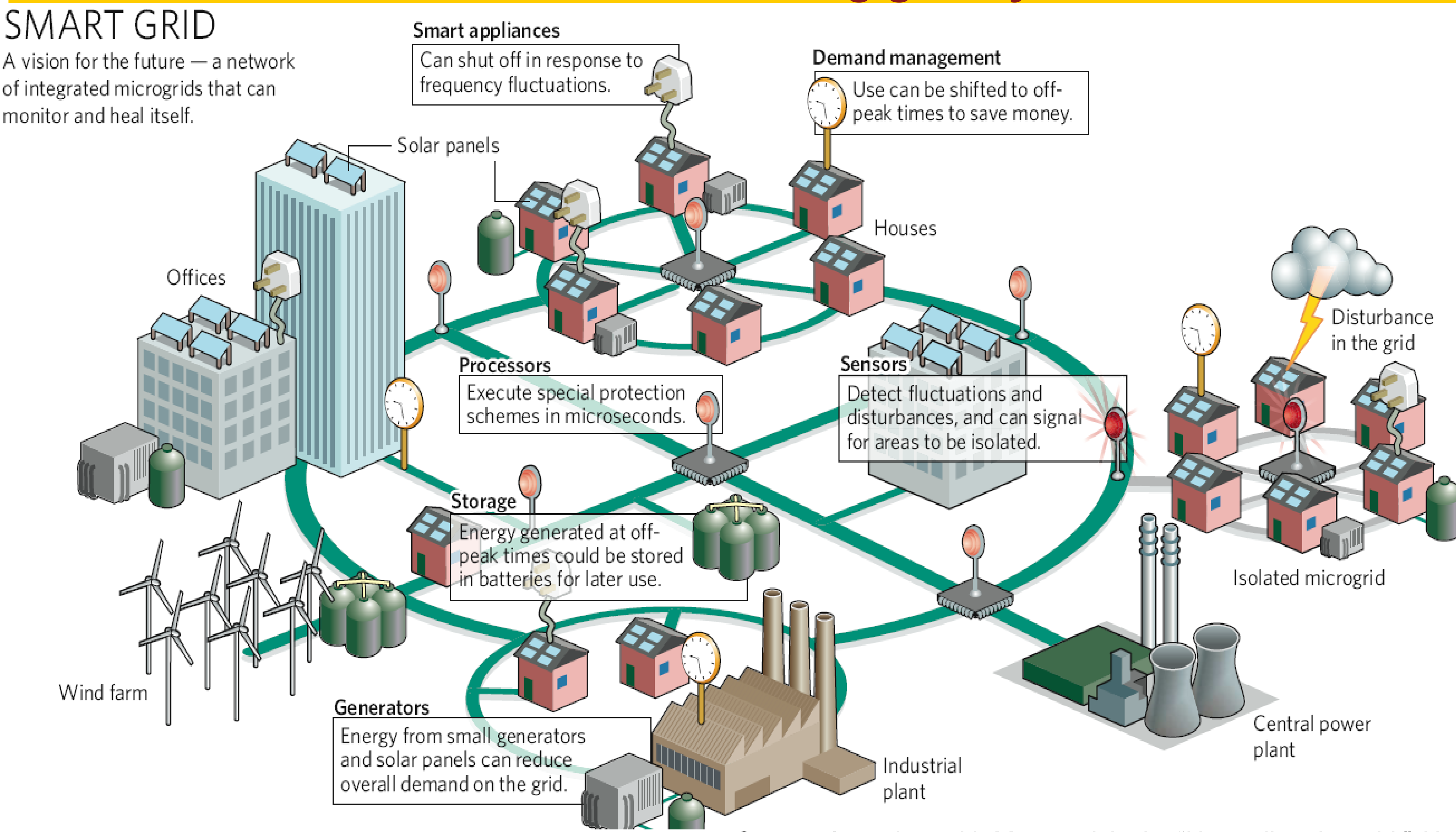
A Multi-layer Grid System in need of Strengthening and Protection



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

Enable the Future

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, pp. 570–573, 30 July 2008

The Smart Grid: Integrating dispersed renewables into a modernized transmission system to provide energy to centers of demand

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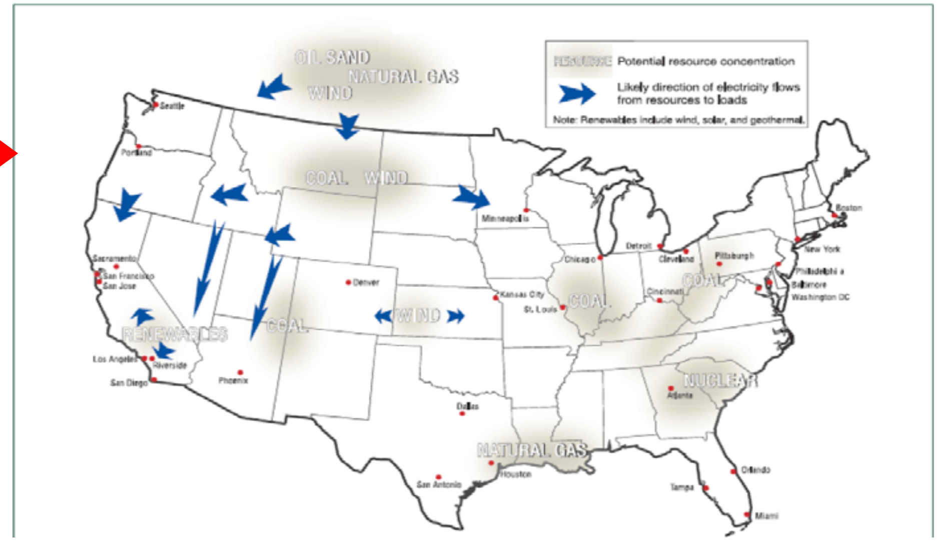
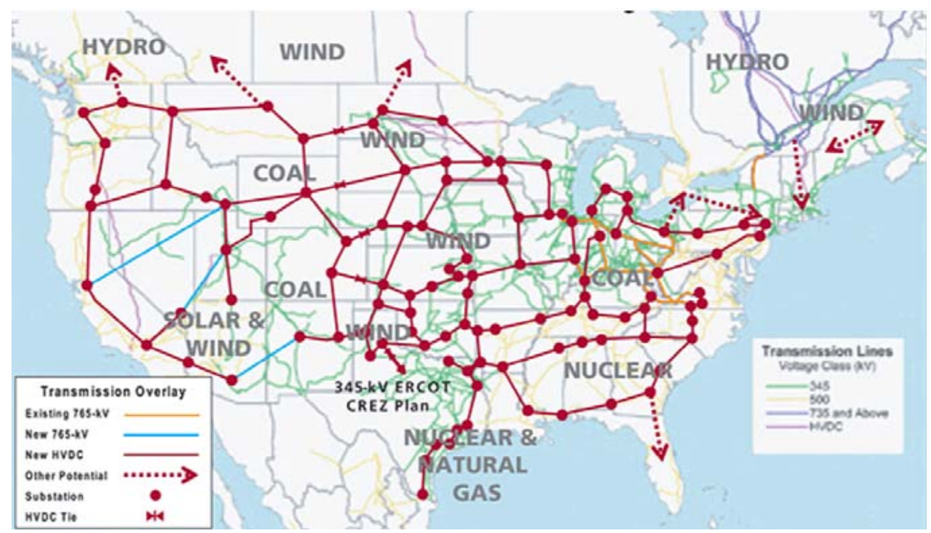




Source: Massoud Amin, Congressional briefings, March 26 and October 15, 2009

Overview of focused research areas (1998-2003):

Programs Initiated and developed at EPRI

1999-2001

EPRI/DoD Complex Interactive Networks (CIN/SI)

Underpinnings of Interdependent Critical National Infrastructures

Tools that enable secure, robust & reliable operation of interdependent infrastructures with distributed intelligence & self-healing

Y2K2000-present

Enterprise Information Security (EIS)

1. Information Sharing
2. Intrusion/Tamper Detection
3. Comm. Protocol Security
4. Risk Mgmt. Enhancement
5. High Speed Encryption

2002-present

Infrastructure Security Initiative (ISI)

Response to 9/11 Tragedies

1. Strategic Spare Parts Inventory
2. Vulnerability Assessments
3. Red Teaming
4. Secure Communications

2001-present

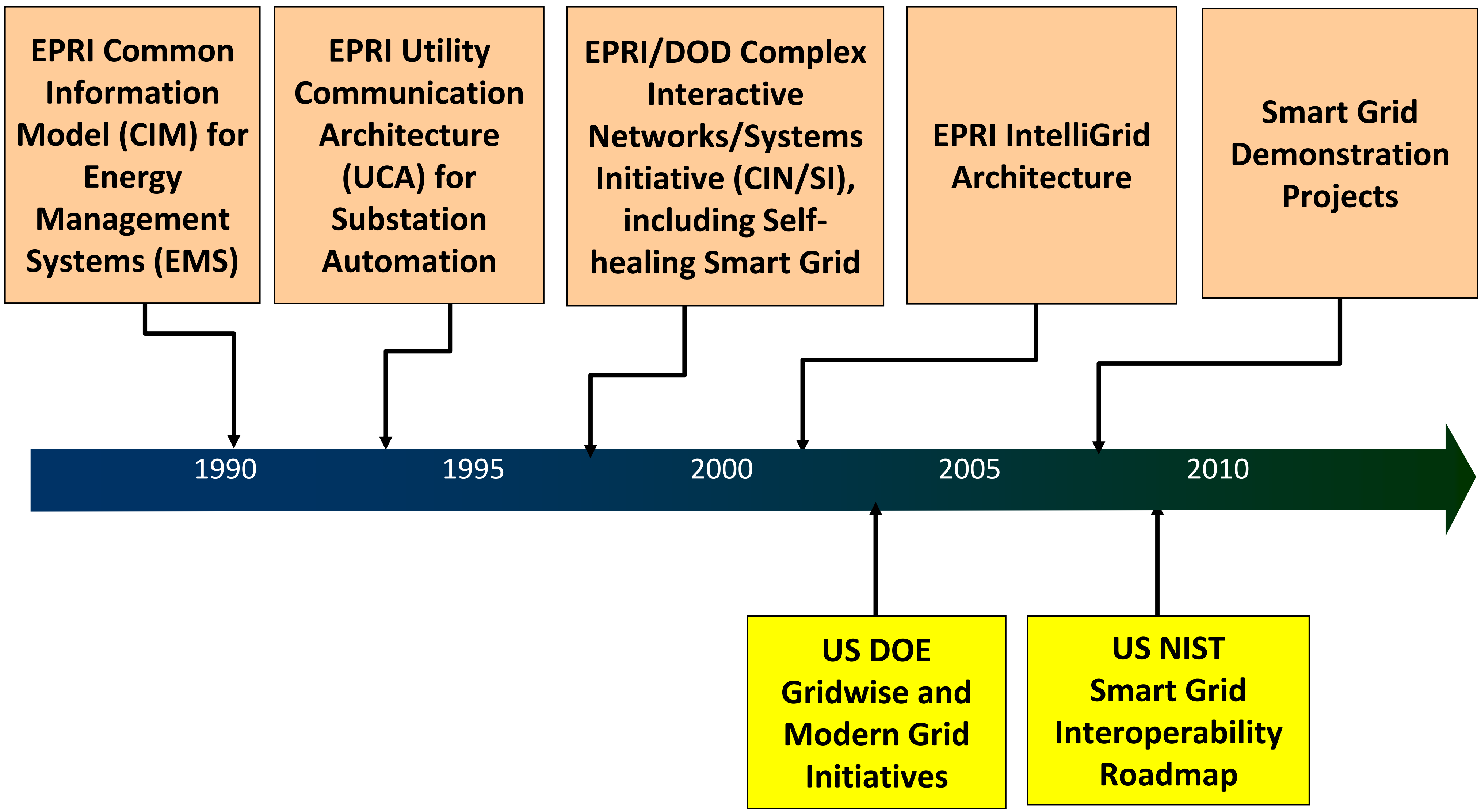
Consortium for Electric Infrastructure to Support a Digital Society (CEIDS)

1. Self Healing Grid
2. IntelliGrid™
3. Integrated Electric Communications System Architecture
4. Fast Simulation and Modeling

The Smart Grid: 12 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

Evolution of Smart Grid Programs at DOE and EPRI



Definition: "Self-Healing" Smart Grid (1998-present, M. Amin)

- **What is a smart grid?**

  The term "smart grid" refers to the use of computer, communication, sensing and control technology which operates in parallel with an electric power grid for the purpose of enhancing the reliability of electric power delivery, minimizing the cost of electric energy to consumers, improving security, quality, resilience, robustness, and facilitating the interconnection of new generating sources to the grid.

- **What are the power grid's emerging issues?** They include

  1) integration and management of DER, renewable resources, and "microgrids";
  2) use and management of the integrated infrastructure with an overlaid sensor network, secure communications and intelligent software agents;
  3) active-control of high-voltage devices;
  4) developing new business strategies for a deregulated energy market; and
  5) ensuring system stability, reliability, robustness, security and efficiency in a competitive marketplace and carbon constrained world.

Smart Grid Definitions

New enabling smart grid technologies are fuelling the modernization and development of a smart distribution grid

- Distribution Grid of the future will:

– **Allow 2-way power and information flows**

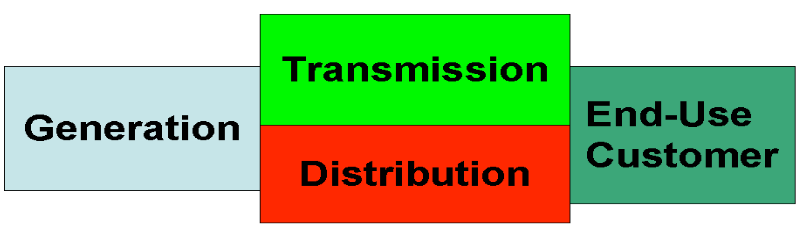
– **Enable clean and renewable energy and help decarbonize power system**

– **Enable effective demand management, customer choice and efficient operation of the grid**

Information systems that facilitate renewable energy, demand response, new technologies and other things to be prescribed later.

Ontario Electricity Act, amended section 2(1) and new subsection (1.3)

Smart Grid Value Chain



An automated, widely distributed energy delivery network, the Smart Grid will be characterized by a two-way flow of electricity and information and will be capable of monitoring everything from power plants to customer preferences to individual appliances. It incorporates into the grid the benefits of distributed computing and communications to deliver real-time information and enable the near-instantaneous balance of supply and demand at the device level."

The Smart Grid: An Introduction – U.S. Department of Energy

Source: various presentations from the Canadian Smart Grid Summit, Oct 2009

Smart Grid Definitions

FERC: *"Grid advancements will apply digital technologies to the grid and enable real-time coordination of information from both generating plants and demand-side resources."*

DOE: *"A smarter grid applies technologies, tools, and techniques available now to bring knowledge to power – knowledge capable of making the grid work far more efficiently…"*

GE: *"The Smart Grid is in essence the marriage of information technology and process-automation technology with our existing electrical networks."*

IEEE: *"The term 'Smart Grid' represents a vision for a digital upgrade of distribution and transmission grids both to optimize current operations and to open up new markets for alternative energy production."*

Wikipedia: *"A Smart Grid delivers electricity from suppliers to consumers using digital technology to save energy, reduce cost, and increase reliability."*

Functionality Common themes:	Technology	Reliability	Efficiency
	Two-way communication	Interconnectivity	Demand response
	Advanced sensors	Renewable integration	Consumer savings
	Distributed computing	Distributed generation	Reduced emissions

Smart Grid Functionalities (DOE 2008)

The functions of a smart grid have been defined as:

- "Self - healing" from power disturbance events
- Enabling active participation by consumers in demand response
- Operating resiliently against physical and cyber attacks
- Providing power quality for 21st century needs
- Accommodating all generation and storage options
- Enabling new products, services, and markets
- Optimizing assets and operating efficiently."

The Smart Grid: An Introduction – U.S. DOE, http://www.oe.energy.gov/smartgrid.htm

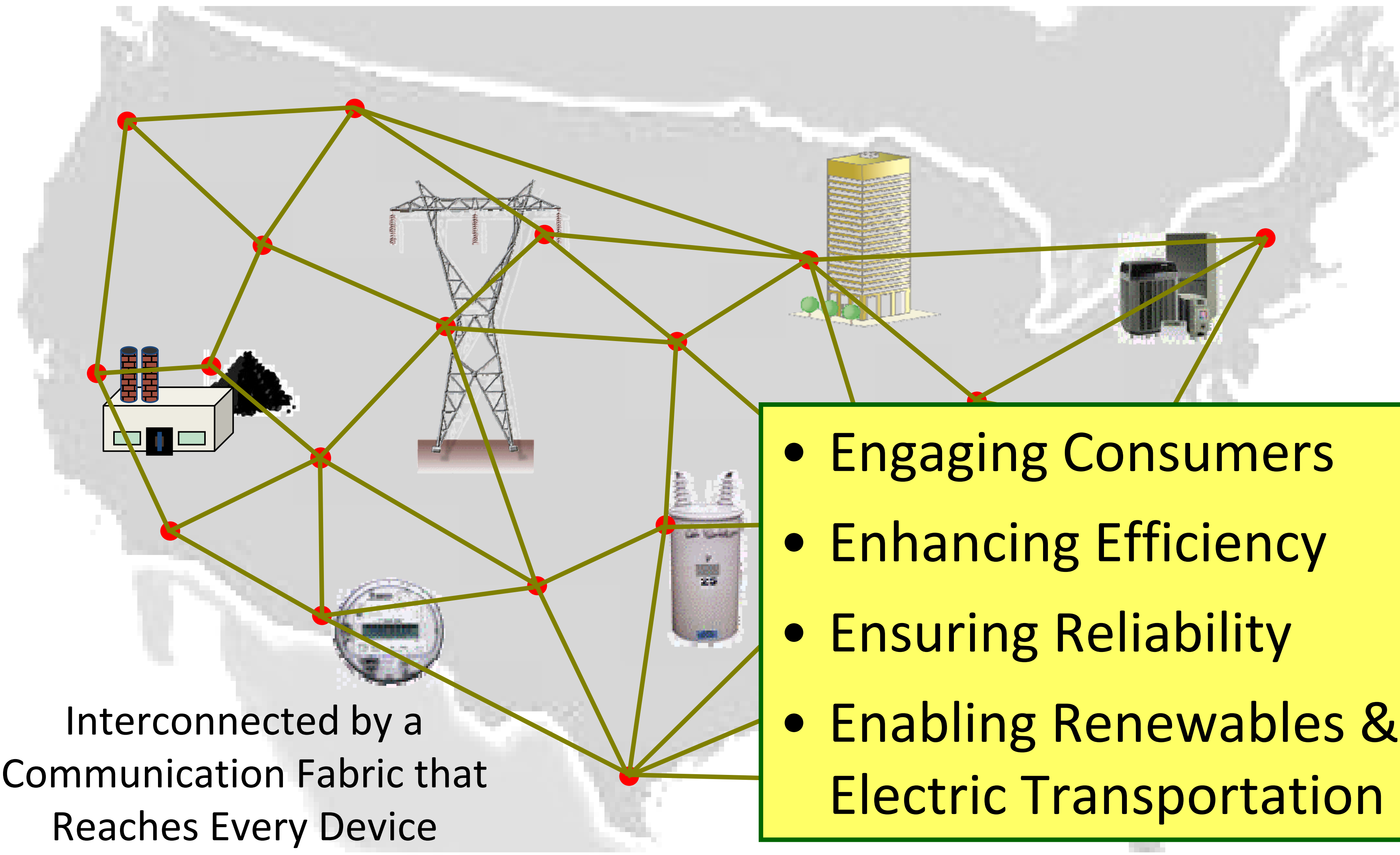
Customers benefit from a smarter transmission system; the use of select Smart Grid technologies provides customers with

- ***Increased reliability***
  - Fewer interruptions to business
  - Improved customer satisfaction
- ***Enhanced event analysis***
  - Quicker response to events
  - Identification of corrective actions

Visualizing the Smart Grid

Many Definitions – But One VISION

Highly Instrumented with Advanced Sensors and Computing



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

Interconnected by a Communication Fabric that Reaches Every Device

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R&D Overview

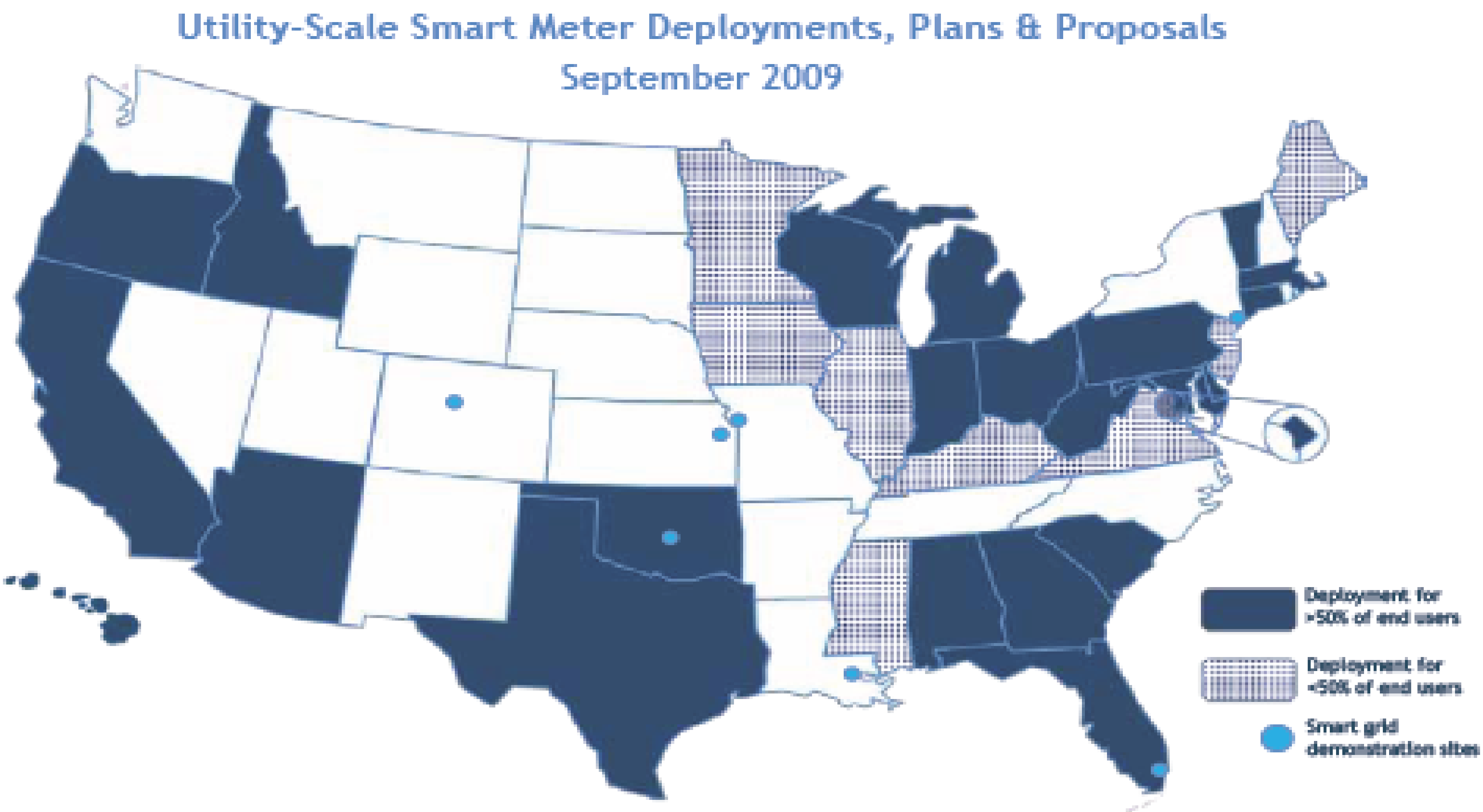
- EPRI: UCA, CIN/SI, Intelligrid, Fast Simulation and Modeling
- Initiatives at several utilities, including Xcel, AEP, Austin Energy, SCE, PG&E, FPL, BG&E, ISOs, and also in companies including GE, Honeywell, IBM, Siemens, etc.
  - Austin Energy journey as an example:
    - Delivering SG1.0 (power plant - transmission, distribution - meter - customer info/bill and back) by August 2009 for 1 million consumers, 43,000 businesses, 440 square miles, 500,000 devices, and 100 terabytes.
    - Planning SG 2.0 (SG 1.0 integration to Smart Appliances, Distributed Generation, Storage, and Plug-in Hybrid EVs - EVs) via the Pecan Street Project - www.pecanstreetproject.org

- Energy Bill passed in December 2007: Title XIII Smart Grid, Sections 1301 -1309
  - Establishes a statement of policy supporting modernization of the grid; authorizes a biennial status report and survey of barriers to modernization

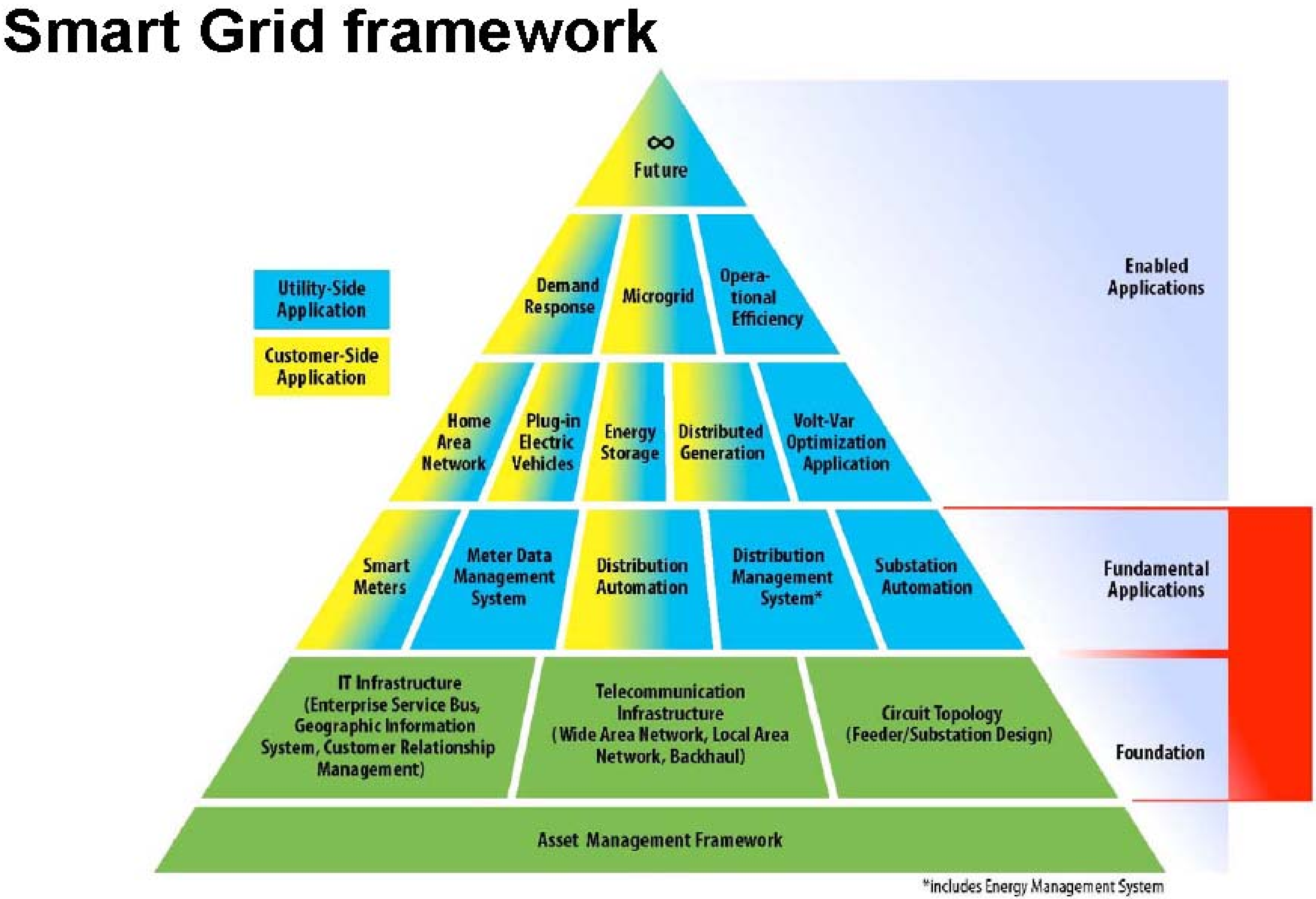
- US Department of Energy: Gridwise and Modern Grid Initiatives

- University of Minnesota Center for Smart Grid Technologies

Leaders & Laggards



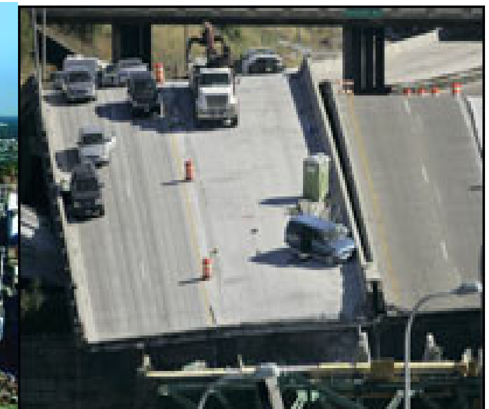
End-to-End Smart Grid Opportunities

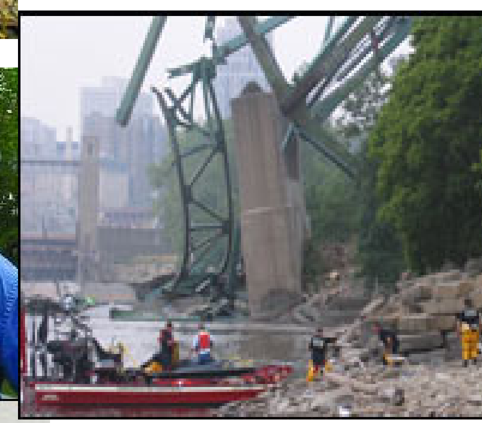


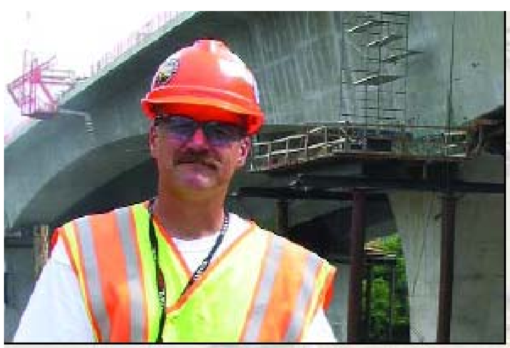
Source: BC Hyrdo, Canadian Smart Grid Summit, Oct. 2009

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







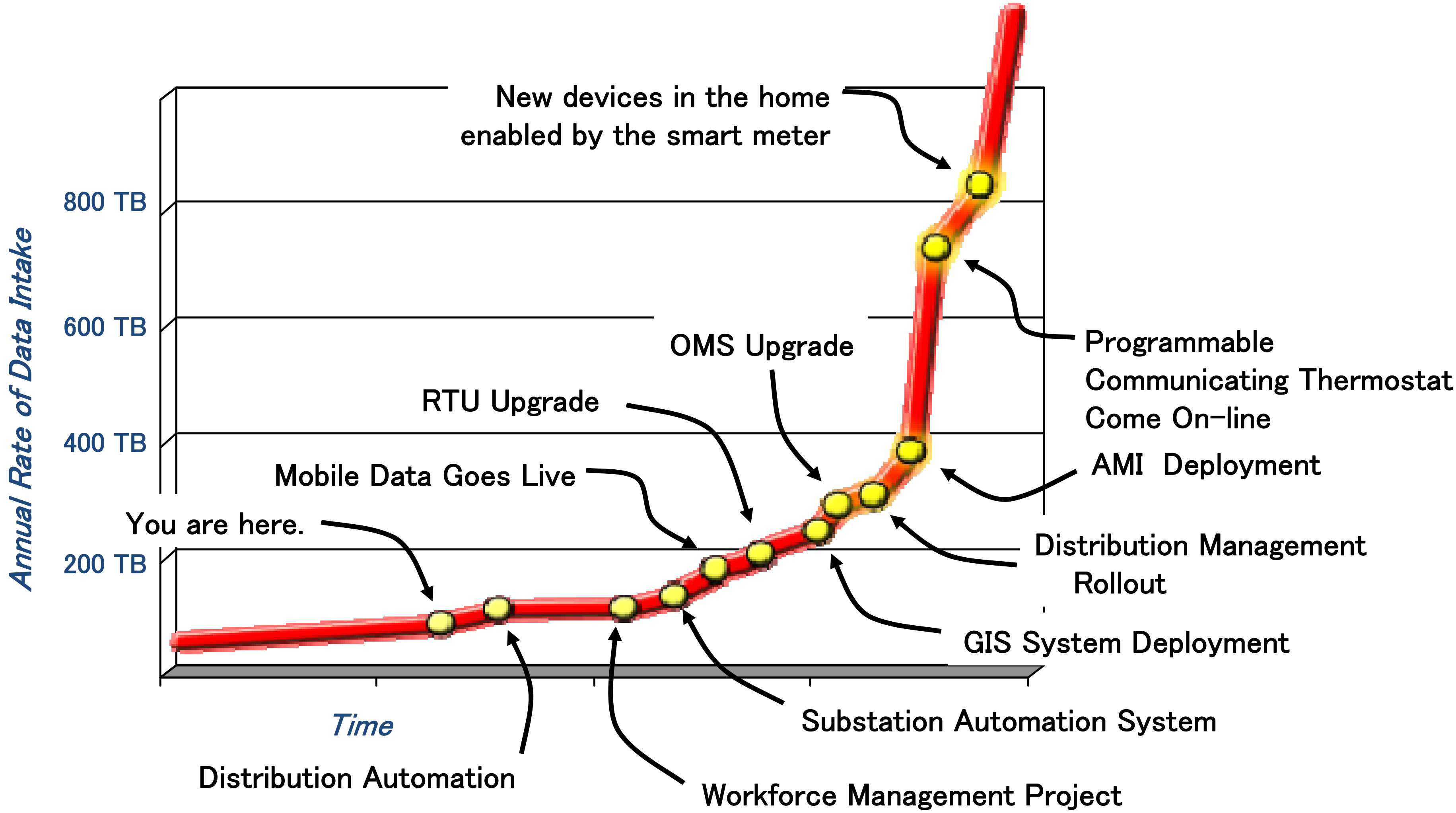
Terry Ward

Heidi Hamilton

Val Svensson

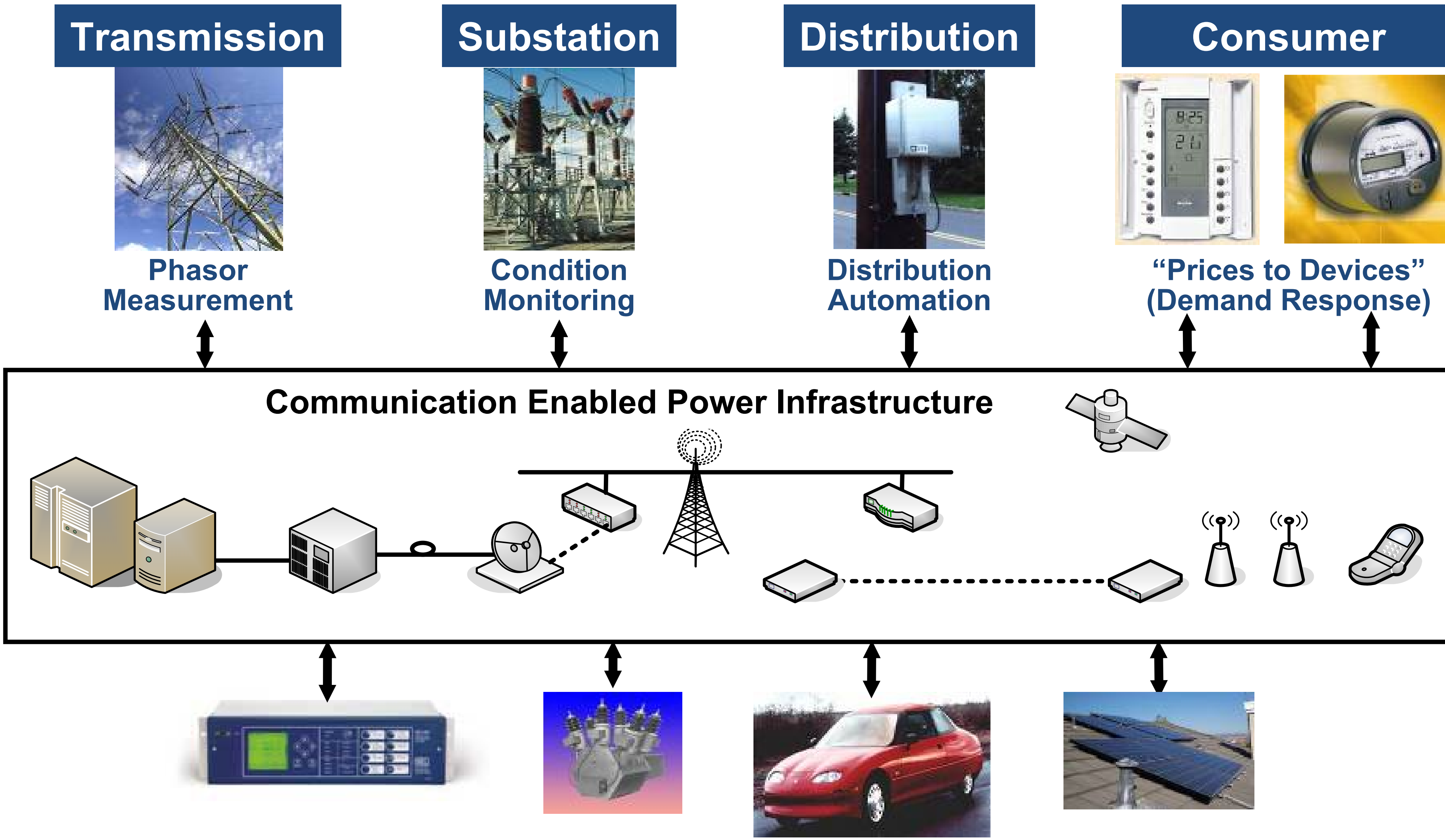
Joe Nietfeld

Smart Grid: 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

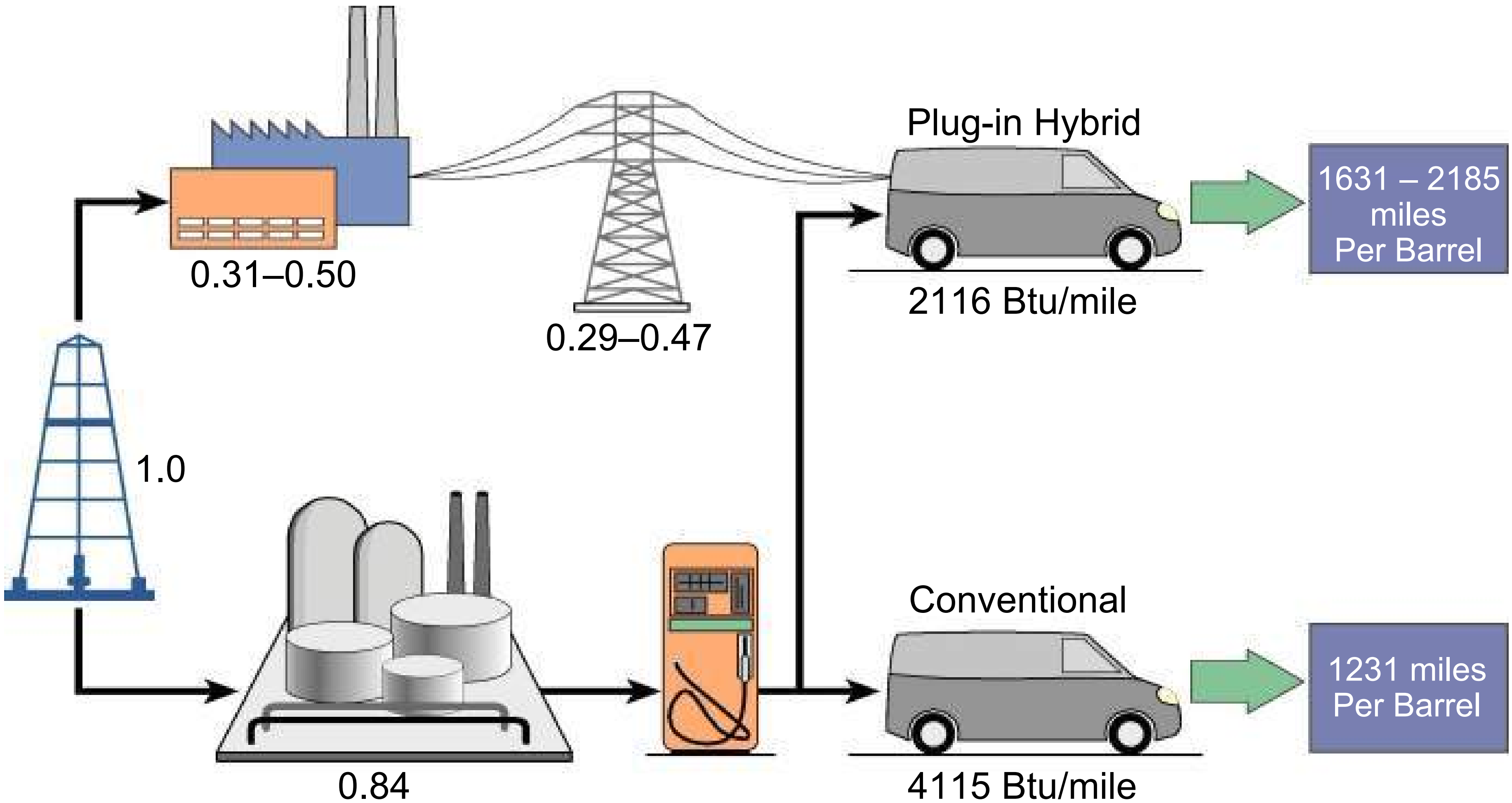
Core of the Smart Grid – The Exchange of Information Seamlessly Across the Enterprise



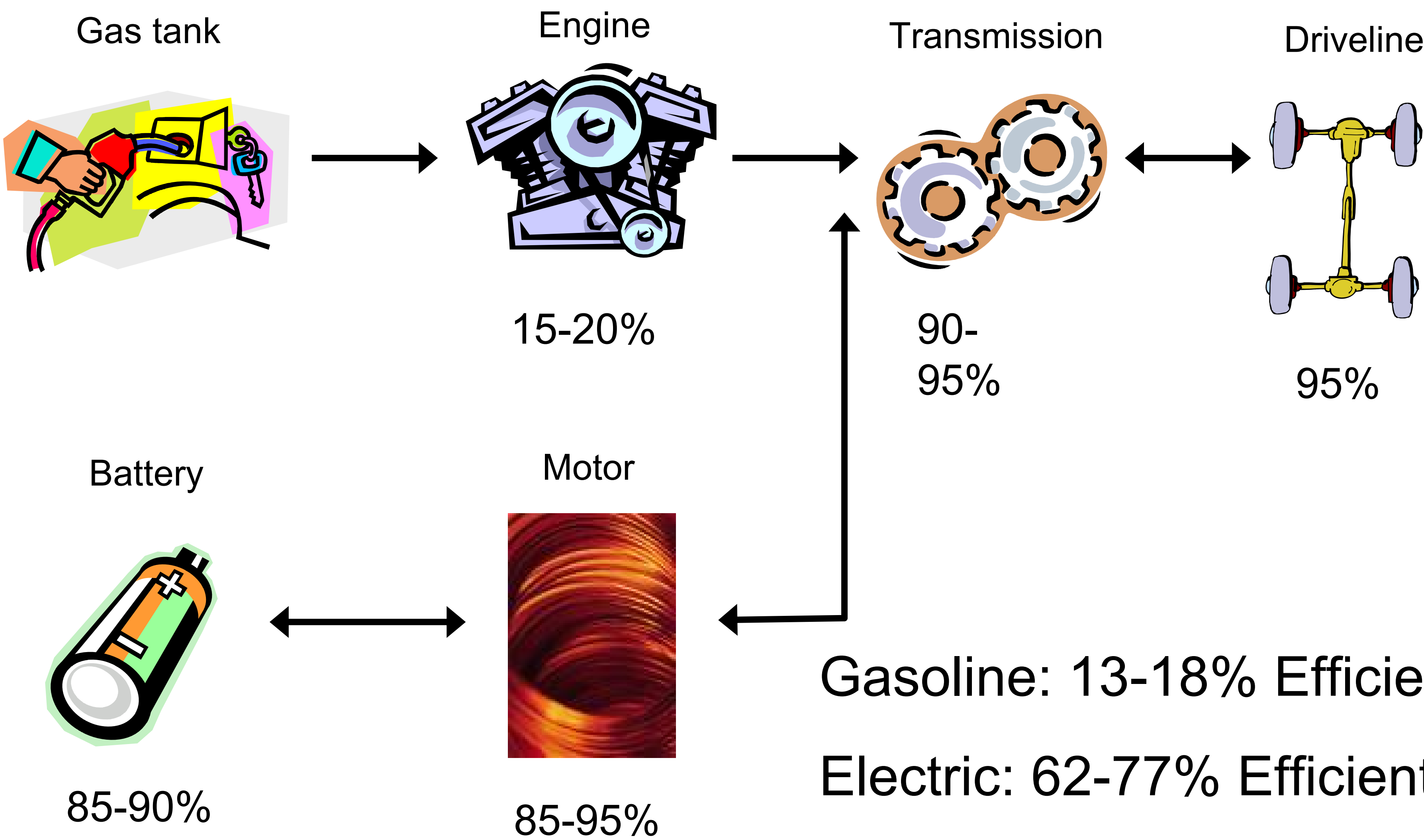
Foresight

Integration of Renewables, Infrastructure, and the Electrification of transportation

Full Fuel Cycle Efficiency Comparison



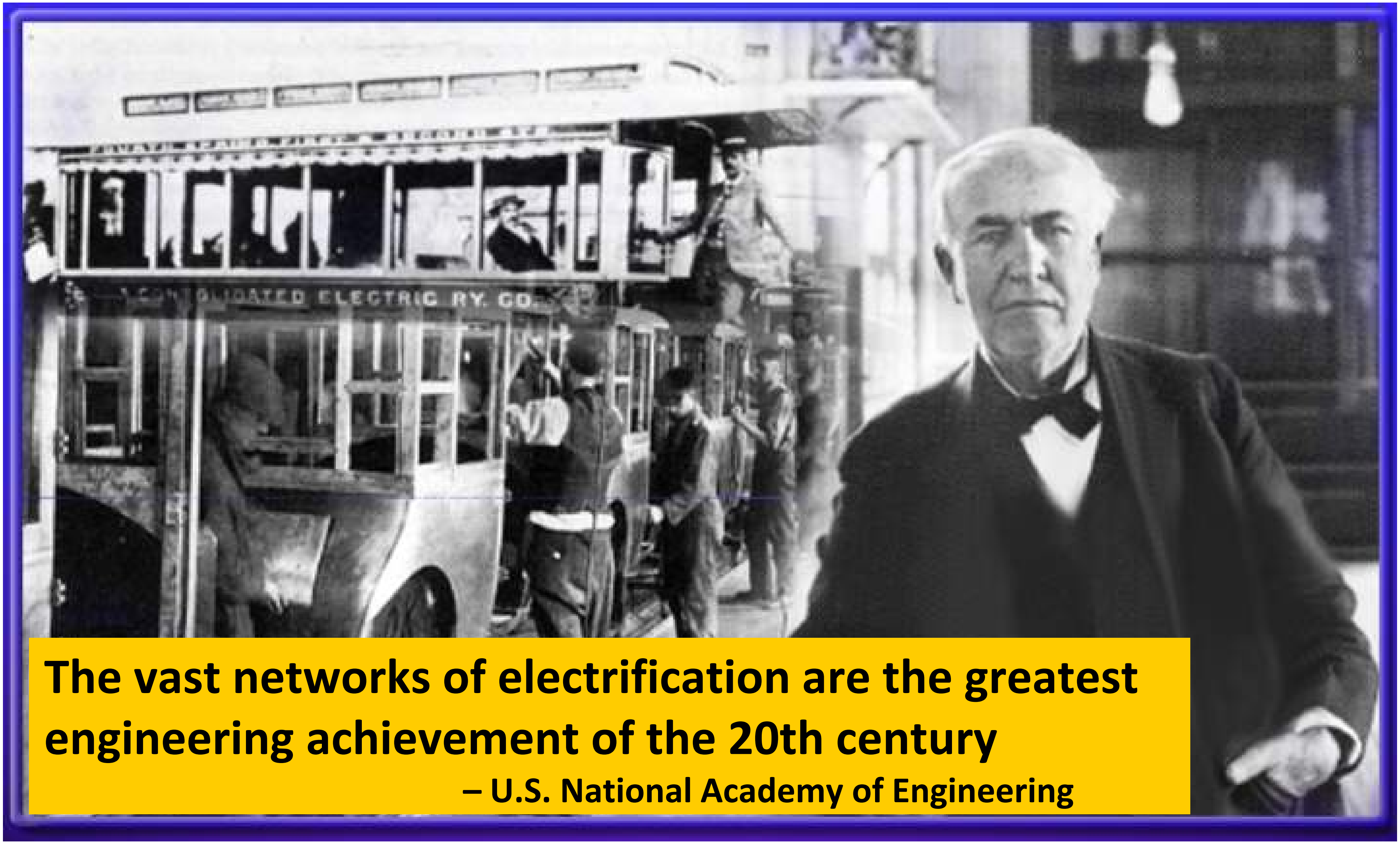
Why the Interest in Hybrids: Vehicle Efficiency



Gasoline: 13-18% Efficient

Electric: 62-77% Efficient

Transforming Society

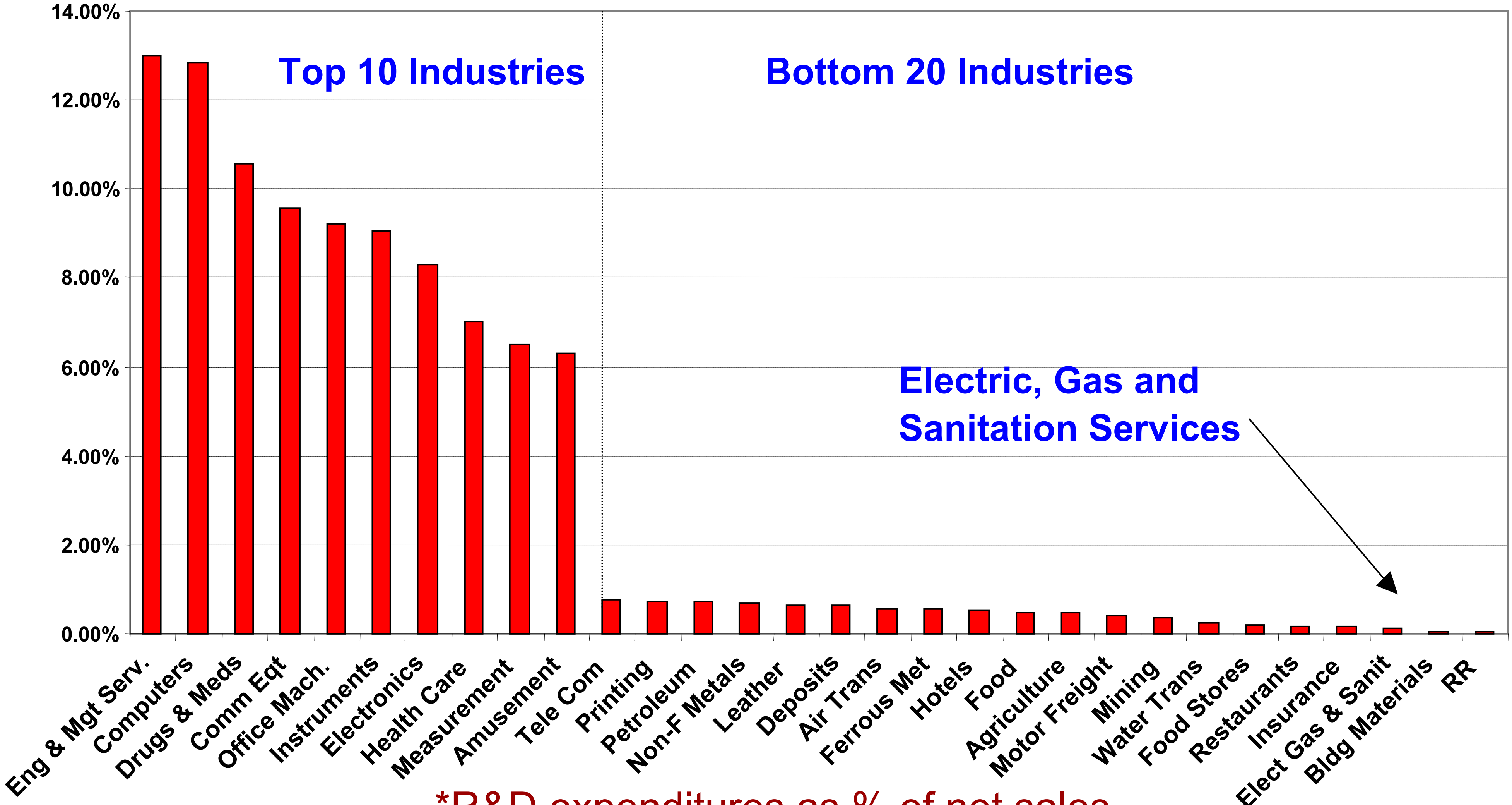


The vast networks of electrification are the greatest engineering achievement of the 20th century

– U.S. National Academy of Engineering

R&D Expenditures… The Real World

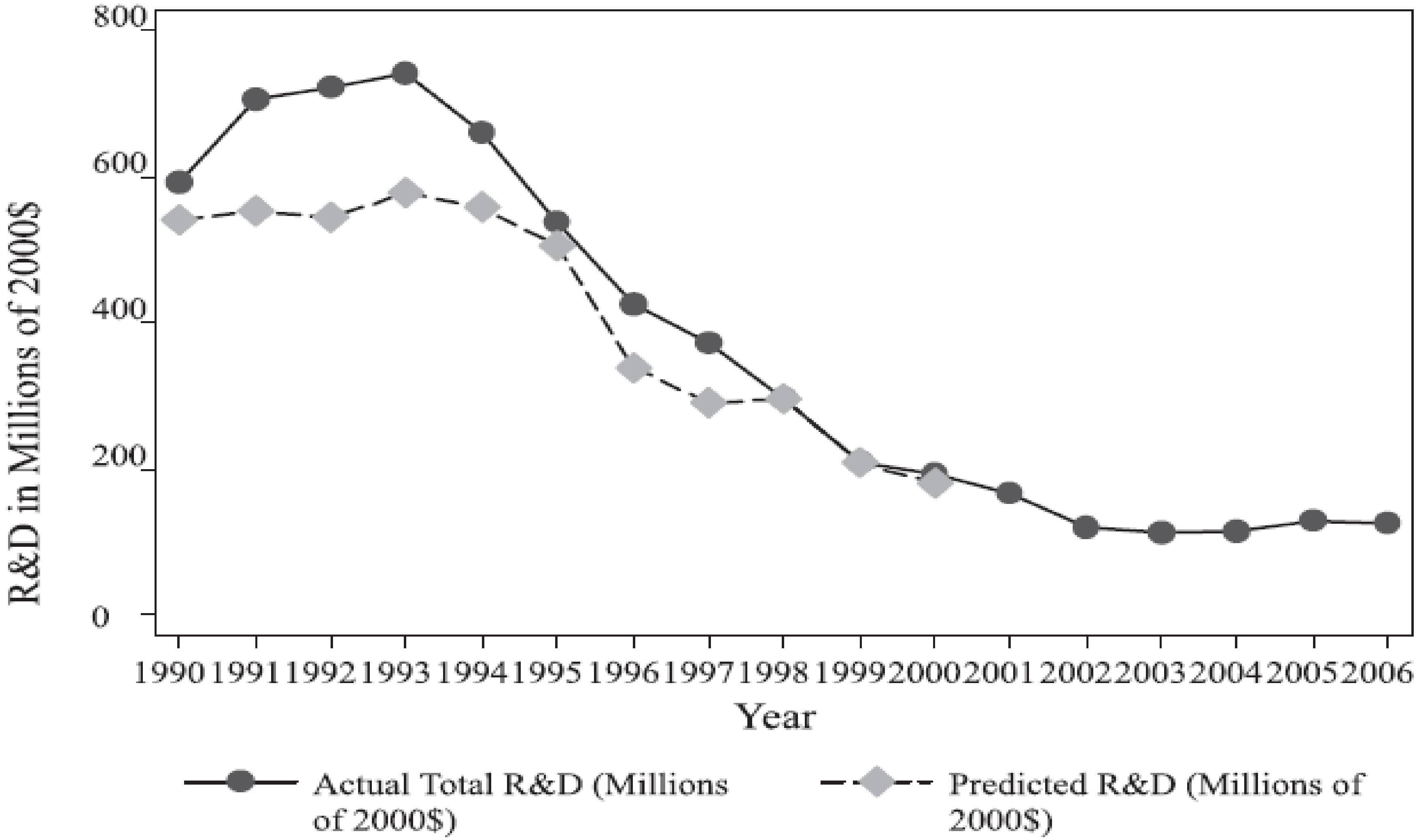
Pet food industry spends more in R&D that the electric power industry



*R&D expenditures as % of net sales

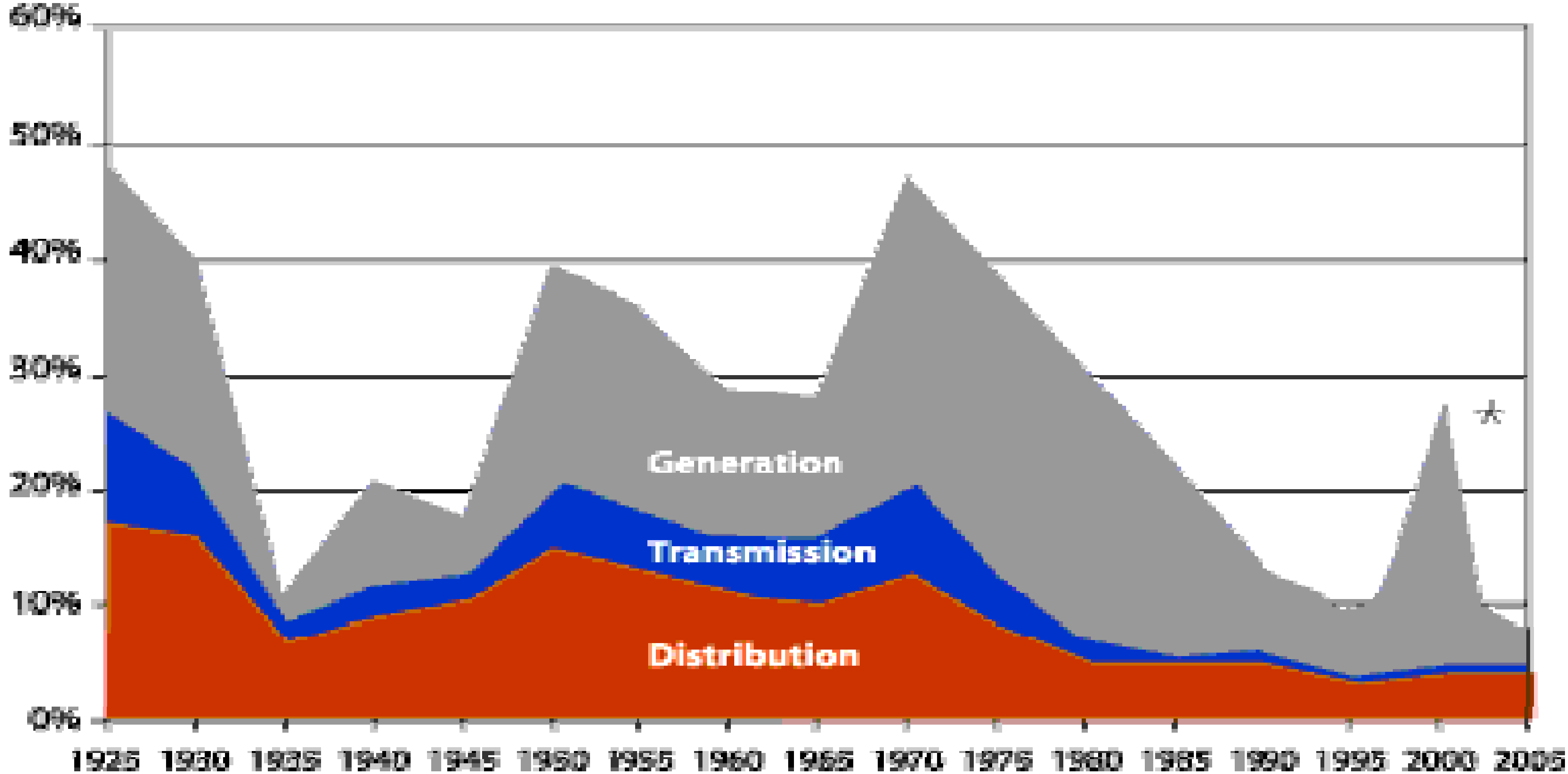
U.S. Electric Utilities R&D: 1990-2006

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

Capital Invested as % of electricity revenue



Sources: Electric Utility Industry Statistics, and 2001 Financial Review, Edison Electric Institute

Capital invested as % of electricity revenues

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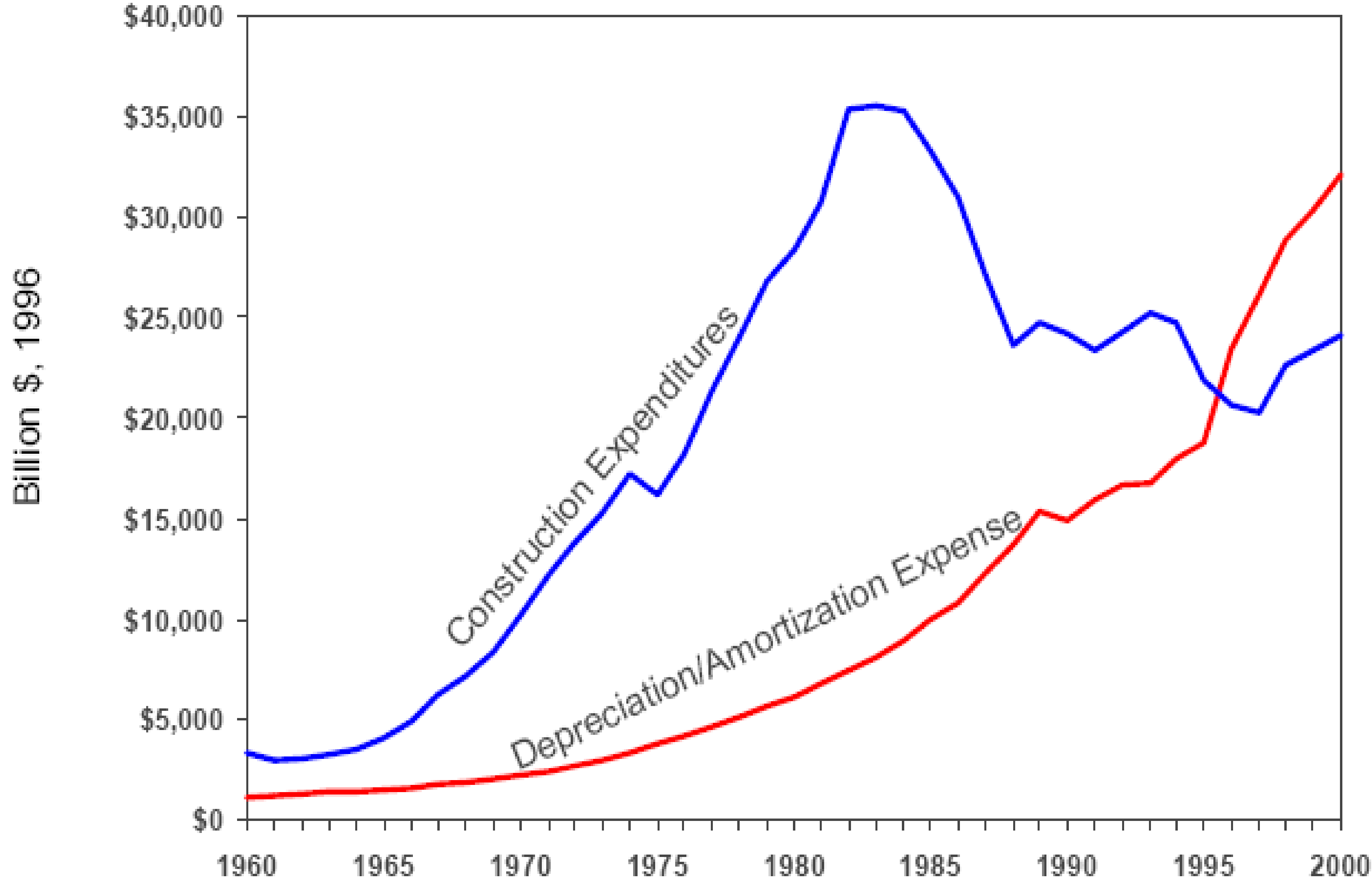
Utility construction: Overharvesting



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

Historical Analysis of U.S. outages (1991-2005)

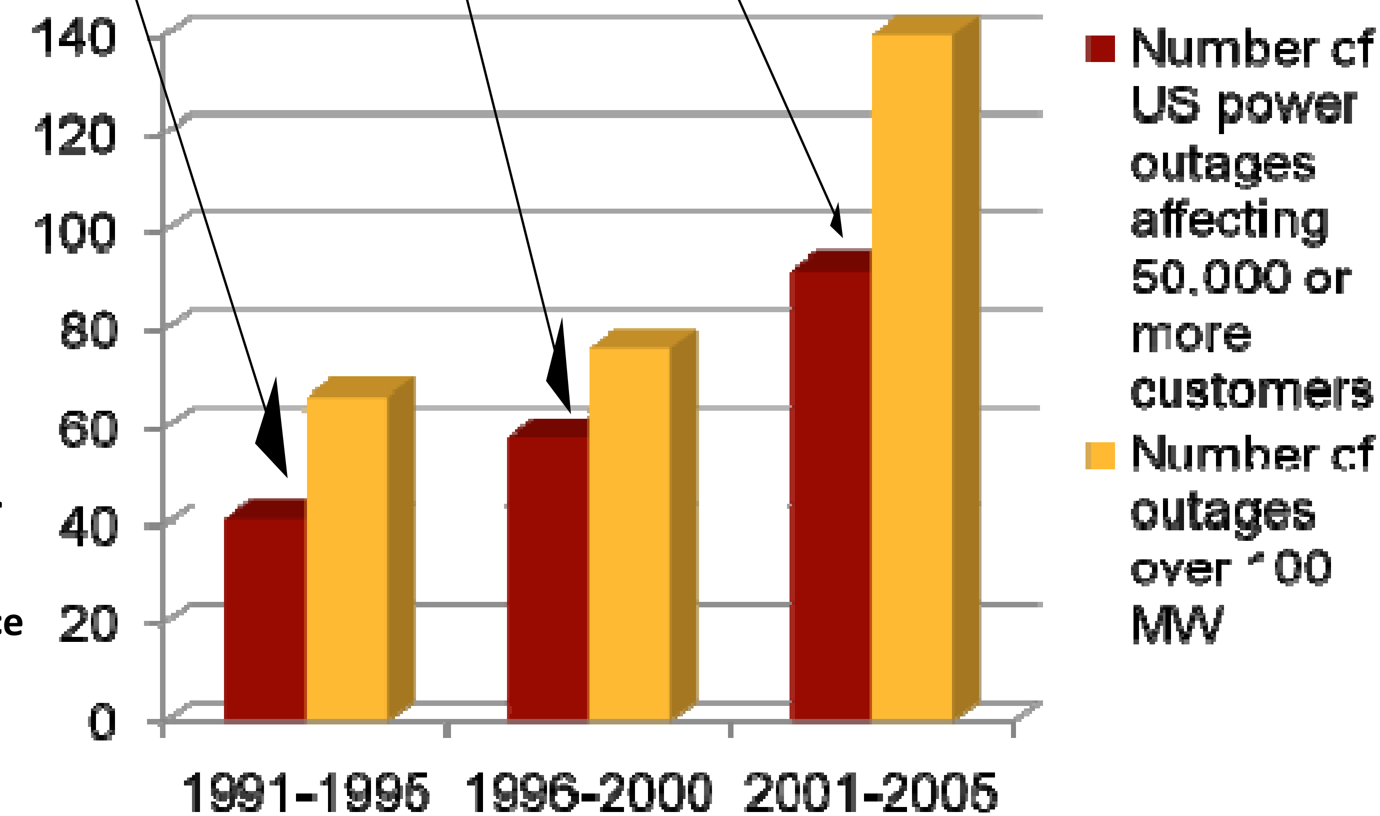
66 Occurrences over 100 MW
41 Occurrences over 50,000* Consumers

76 Occurrences over 100 MW
58 Occurrences over 50,000* Consumers

140 Occurrences over 100 MW
92 Occurrences over 50,000* Consumers

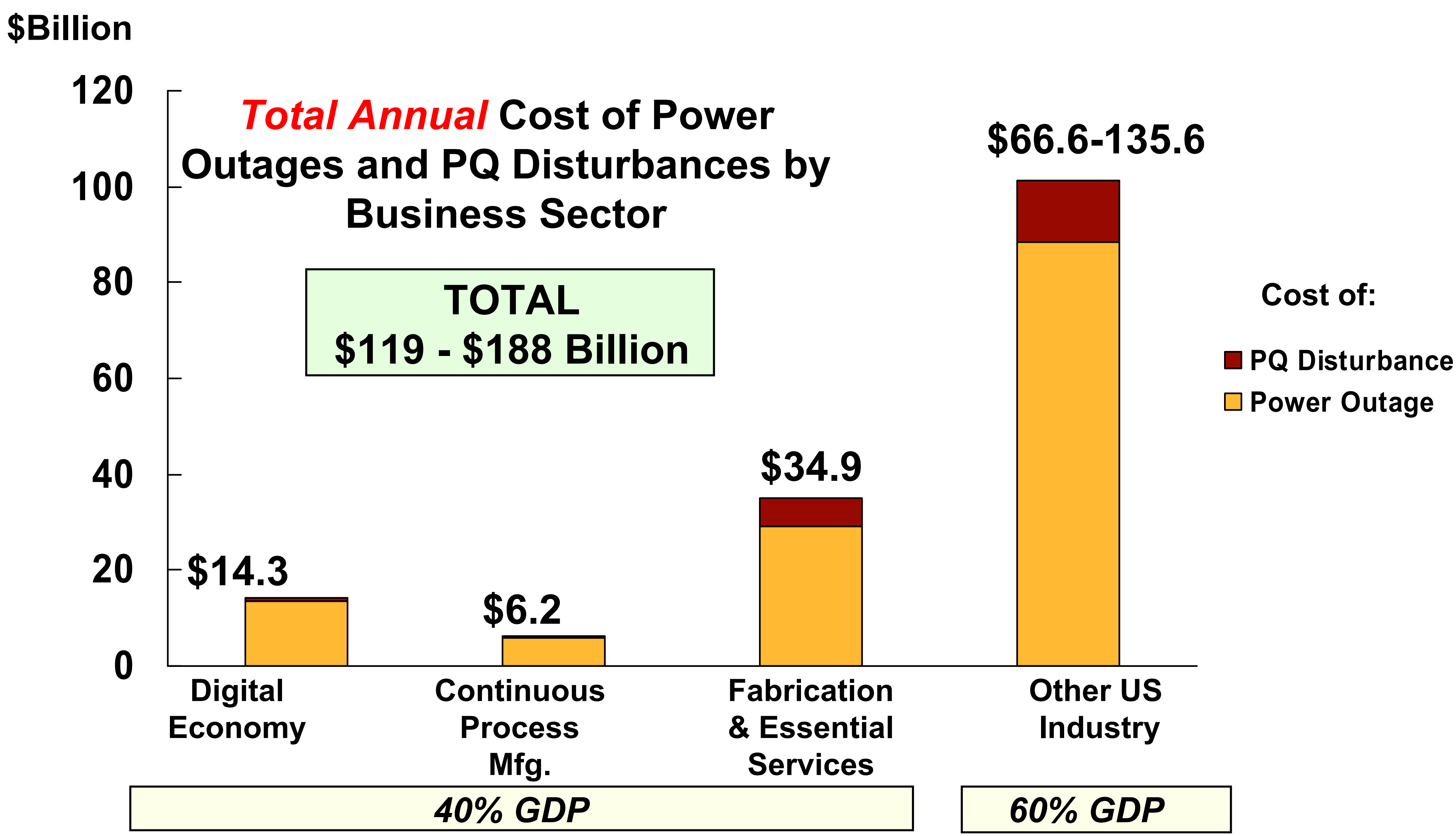
Result: Large blackouts are growing in number and severity.

***Analyzing 2006 outages:**
24 Occurrences over 100 MW
34 Occurrences over 50,000* or more Consumers
Data courtesy of NERC's Disturbance Analysis Working Group database



*Note: Annual increase in load (about 2%/year) and corresponding increase in consumers should be taken into account.

Outages Cost the U.S. Economy Over $100B Per Year



Source: Primen Study: The Cost of Power Disturbances to Industrial & Digital Economy Companies

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Grid Ownership & Investment in the United States and in International Competitive Markets

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)

North American Grid: underinvested and a complex ownership

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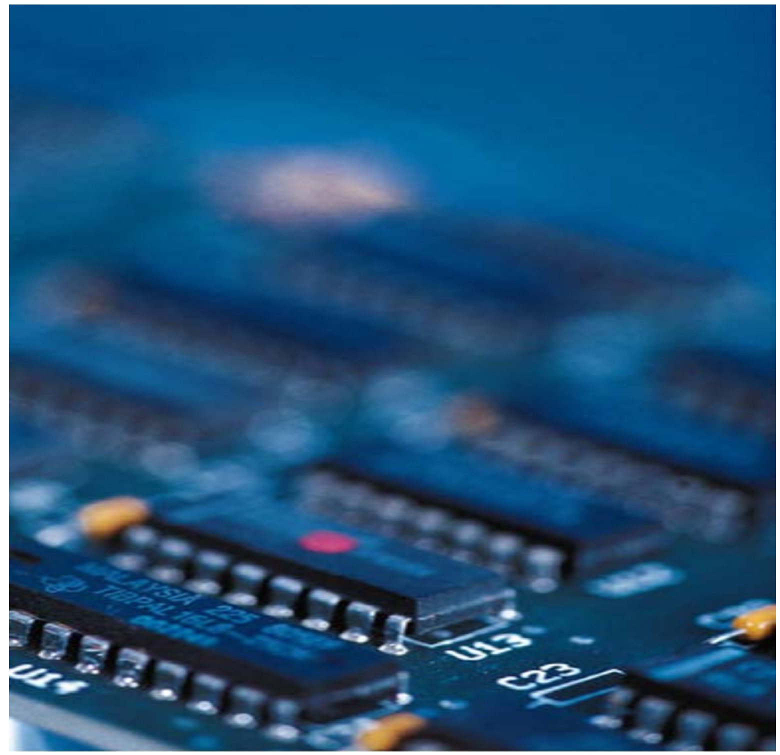
Source: IEEE PES, 2006

Security

Unconventional Threats to Security

Connectivity



Complexity

The Threat Situation

Continuing serious cyber attacks on information systems, large and small; targeting key federal, state, local, and private sector operations and assets…

- Attacks are organized, disciplined, aggressive, and well resourced; many are extremely sophisticated.
- Adversaries are nation states, terrorist groups, criminals, hackers, and individuals or groups with intentions of compromising federal information systems.
- Effective deployment of malicious software causing significant exfiltration of sensitive information (including intellectual property) and potential for disruption of critical information systems/services.

-- Dr. Ron Ross
NIST, *Computer Security Division*
Information Technology Laboratory

"As you well know, the next world war could happen in the cyber space and that would be a catastrophe."

- ITU secretary-general, Hamdoun Toure, Oct. 7, 2009.

"We're the most vulnerable nation on the Earth because we're the most dependent."

- John "Mike" McConnell, former director of national intelligence, CIO Magazine, Sept. 23, 2009

"I think we're really at a crisis point where we have no confidence in the security of our information."

- Amit Yoran, former director of the US-CERT, DHS,
former CEO In-Q-Tel and CEO Net Witness,
CIO Magazine Sept. 23, 2009

What is at Risk?

- Federal information systems supporting agencies within the federal government; state and local information systems.
- Private sector information systems supporting U.S. industry and businesses (intellectual capital).
- Information systems supporting critical infrastructures within the United States (public and private sector) including:
  - **Energy (electrical, nuclear, gas and oil, dams)**
  - **Transportation (air, road, rail, port, waterways)**
  - **Public Health Systems / Emergency Services**
  - **Information and Telecommunications**
  - **Defense Industry**
  - **Banking and Finance**
  - **Postal and Shipping**
  - **Agriculture / Food / Water / Chemical**

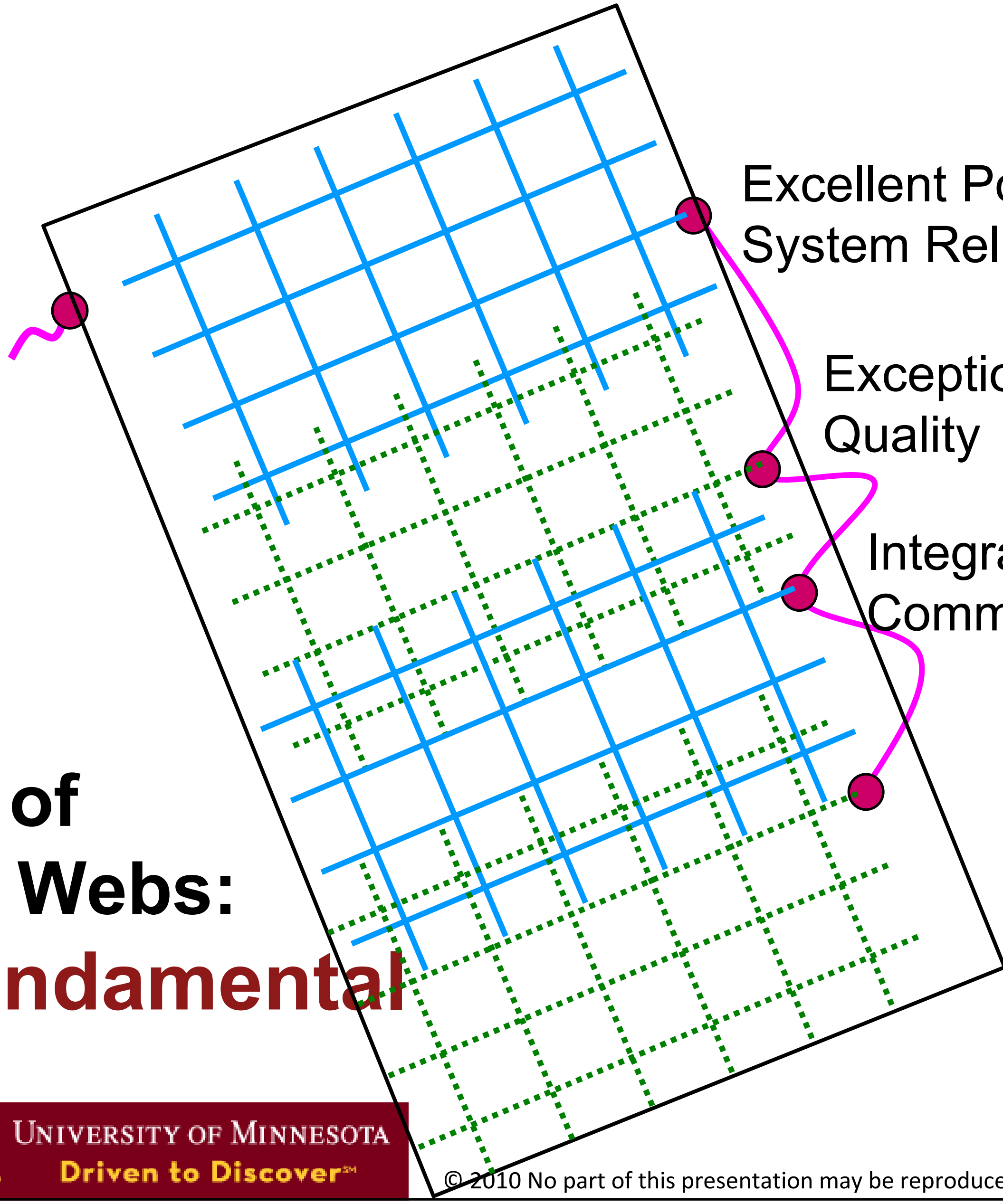
The North American Economy is Dependent on Electronic Communications

- **North America uses:**
  - **42% of world's computing power**
  - **60% of world's Internet assets**
  - **90% of large & 75% of small companies have Local Area Networks**

- **Number* of documented computer attacks increasing--from about 2,100 in 1997, 3,700 (1998), 9,800 (1999), 21,750 (2000), to 52,600 in 2001**
  - **Costs* of Worldwide economic impact (in billions of dollars):**
    - 1999: Explorer ($1B), Melissa ($1.1B)
    - 2000: Love Bug ($8.8B)
    - 2001: Nimda ($0.6B), SirCam ($1.2B), Code Red($2.6B)

*sources: Computer Emergency Response Team, Computer Economics, and USA Today

The Smart Infrastructure for a Digital Society

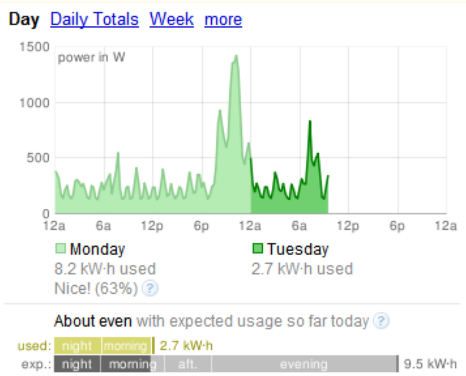


A Complex Set of Interconnected Webs:

Security is Fundamental

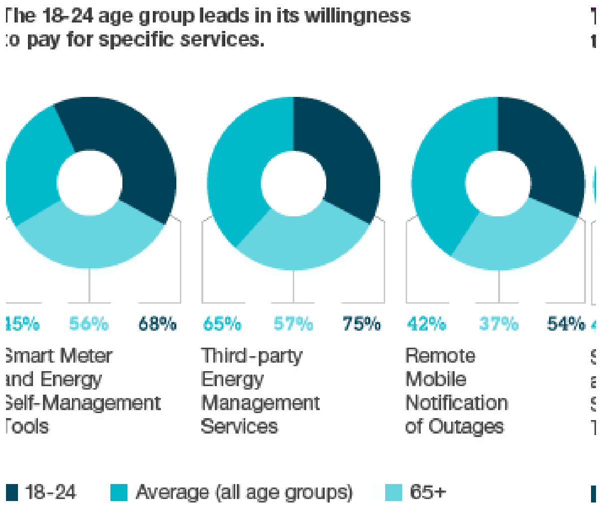
“Smart Grid” Components & Devices

Smart power strip (bridge) by Hyuk Jae Chang



Google Power Meter

Smart Meters

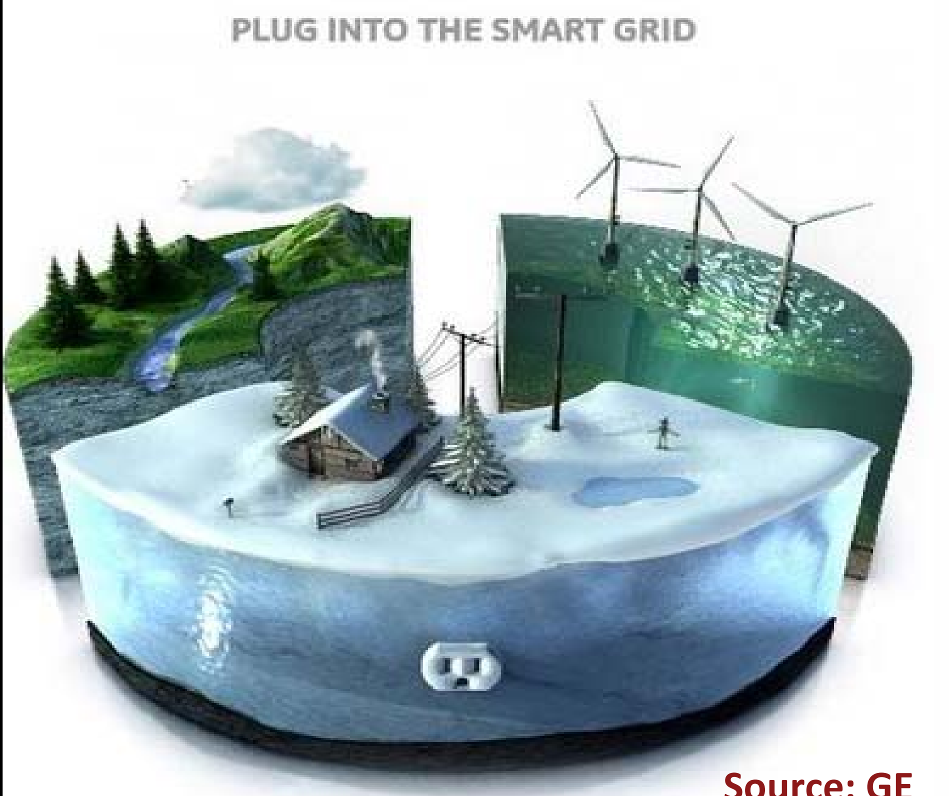


Source: IBM Smart Grid

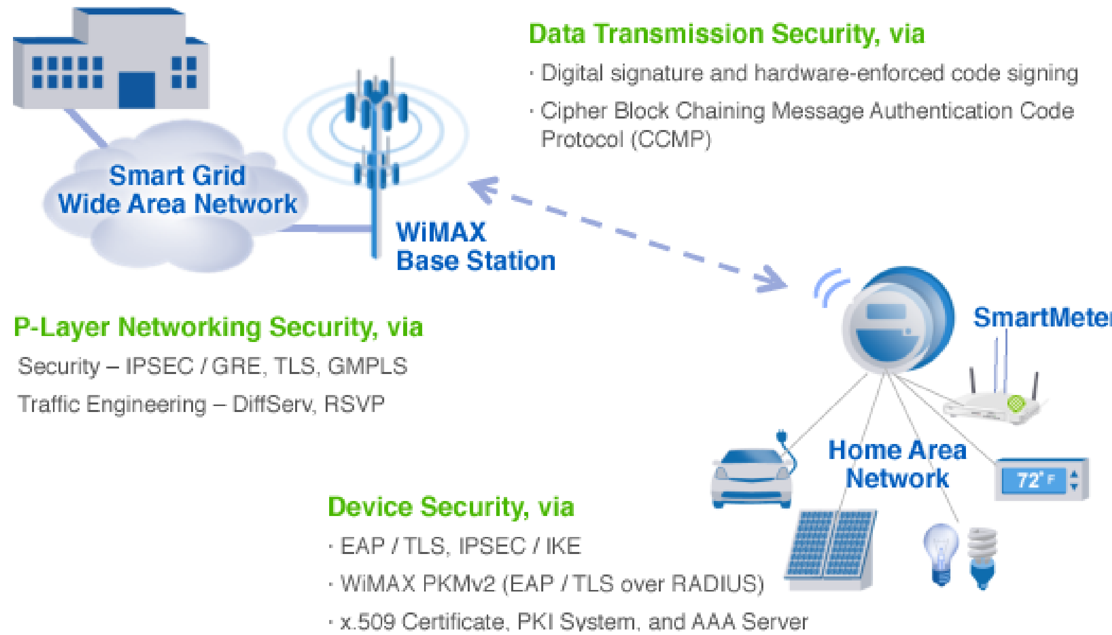
Fast Company

"Smart Grid" Components & Devices

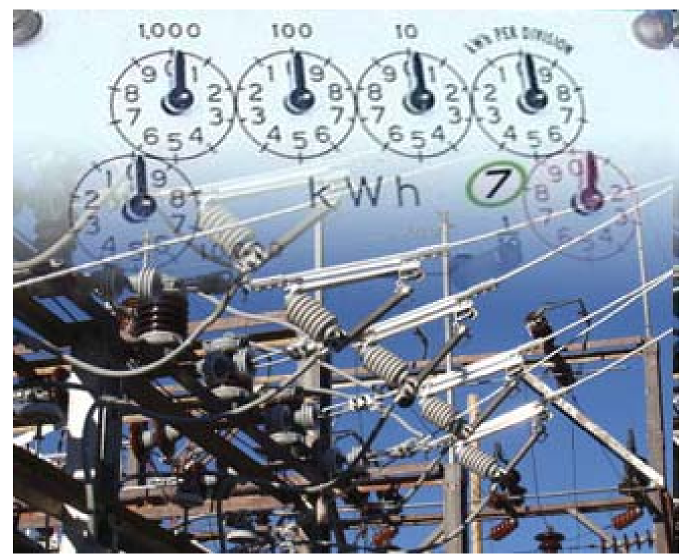
Control4's EMS-100



Source: GE



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



At the University what are we working on?

- Integrating PHEVs into the grid
- Grid agents as distributed computer
- Fast power grid simulation
- Secure Smart Meter Control
- Security of cyber-physical infrastructure

University of Minnesota Center for Smart Grid Technologies
Dept. of Electrical & Computer Engineering
Faculty: Professors Massoud Amin and Bruce Wollenberg
PhD Candidates/Research Assistants: Anthony Giacomoni, Laurie Miller, and Sara Mullen
PI: M. Amin (support from EPRI, NSF, ORNL, and University of Minnesota start-up research funding)

Vision for the Smart Grid U™

- Goal: transform the University of Minnesota's Twin Cities' campus into a *SmartGridU.*
  - Develop system models, algorithms and tools for successfully integrating the components (generation, storage and loads) within a microgrid on the University of Minnesota campus.
  - Conduct "wind-tunnel" data-driven simulation testing of smart grid designs, alternative architectures, and technology assessments, utilizing the University as a living laboratory.
  - Roadmap to achieve a "net zero smart grid" at the large-scale community level – i.e., a self contained, intelligent electricity infrastructure able to match renewable energy supply to the electricity demand.

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

Building a MN Smart Grid Coalition

- July 8, 2009: **"Building a Smart Grid Coalition in Minnesota"** forum hosted by the University of Minnesota–Institute of Technology, in collaboration with the Midwest Energy Technology Alliance (META) which attracted over 100 participants.

- November 18, 2008 **Smart Grid Workshop** offered in conjunction with the Initiative for Renewable Energy and the Environment's E3 Summit in November. **Focused on challenges and opportunities in Energy and Cyber Security, Energy Efficiency, and Integration of Renewables** (with over 160 participants representing a broad spectrum of industry, academia, and government).

- February 11, 2010: The **Smart Grid Roundtable** -- A select group of 30 participants chosen for their interest and expertise in the development of smart grid technologies. Support and hosting from IREE, IoE, MN Office Energy Security, and TLI).

Objective

- **Position Minnesota as a leader in the development and deployment of smart grid technologies, products and services**

- Action plan is to
  - further explore the smart grid opportunities,
  - discover Minnesota's competitive advantage in this market,
  - position Minnesota to take the lead both regionally and nationally,
  - develop a value proposition which will more effectively convey the economic benefits of smart grid technologies to key stakeholders.

Action Plan: Building a MN Smart Grid Coalition

- SEIZING THE OPPORTUNITY – next steps in building a Smart Grid Coalition in Minnesota
  - Who? What? When? Where? How?
  - Laid the foundation for an initiative which will have a significant impact on the economic landscape in Minnesota and the region in the coming years. Workgroups' objectives are:
    - Develop a portfolio for Minnesota Smart Grid capabilities (Lead – Bill Bushnell, with Rod Larkins, Steve Riedel)
    - Articulate the story for stakeholders (Lead – Brian Isle, with Bob Long, Denise Cote, Bruce Sayler)
    - Flesh out the transmission/utility/customer model (Lead – Tariq Samad, with Randy Huston, Dan Gunderson, Richard Kalisch, John Frederick)
    - Develop state regulatory model to support this market (Lead – Bill Glahn, with Georgie Hilker, and Mike Kaluzniak)
    - Determine the kinds of smart grid pilot projects/demonstrations that will be necessary (Lead – Mike Bull, with Gary Smaby, John Setala, Pete Treacy, Jeff Haase)

Policy

Discussion Areas: Building a MN Smart Grid Coalition

- THE SMART GRID OPPORTUNITY – opportunities that exist in the development and deployment of Smart Grid technologies
  - What national economic, environmental, and security problems does the Smart Grid address?
  - What customer problems might the Smart Grid solve?
  - What Smart Grid initiatives are underway in the U.S.?
  - What Smart Grid funding opportunities are available through federal agencies?
  - What does this opportunity represent for Minnesota companies?

- DISCOVERING MINNESOTA'S COMPETITIVE ADVANTAGE - identifying technical and R&D strengths, resources and expertise
  - What industry strengths/resources/expertise is available in the state?
  - What academic strengths/resources/expertise is available in the state?
  - How does Minnesota's energy policy framework support development and deployment of Smart Grid technologies?

Discussion Areas: Building a MN Smart Grid Coalition

- **POSITIONING MINNESOTA TO TAKE THE LEAD – developing a Smart Grid Game Plan**
  - What is Minnesota's strategic advantage and where can we provide leadership to the region and nation?
  - Who are the key players and how do we build a Smart Grid infrastructure in Minnesota?
  - Where is the first, most visible opportunity and how do we begin?
- **DEVELOPING A VALUE PROPOSITION – (e.g. quantifying the benefit for energy efficiency, energy security, and integration of renewables)**
  - What is the business model?
  - What is the economic benefit of the Smart Grid?
  - How do we tell the Smart Grid story – to policymakers, regulators, and customers?

Summary of numbers: Direct Spending

Total Direct Spending for Renewable Energy and Energy Efficiency: The bill provides $16.8 billion in direct spending for renewable energy and energy efficiency programs over the next ten years.

Grid Development: The bill provides $4.5 billion to modernize the nation's electricity grid with smart grid technology. The bill increases federal matching grants for the Smart Grid Investment Program from 20% to 50%.

R&D, Demonstration Projects: The bill provides $2.5 billion for renewable energy and energy efficiency R&D, demonstration and deployment activities.

Federal Power Marketing Administrations: The bill provides $6.5 million for capital investments by certain federal power marketing administrations in electric power transmission systems.

Advanced Battery Grants: The bill provides $2 billion for grants for the manufacturing of advanced batteries and components. This includes the manufacturing of advanced lithium ion batteries, hybrid electrical systems, component manufacturers, and soft-ware designers.

Defense Energy and Efficiency Programs: The bill provides $300 million to the DOD for the purpose of research, testing and evaluation of projects to energy generation, transmission and efficiency. The bill provides an additional $100 million for Navy and Marine Corps facilities to fund energy efficiency and alternative energy projects.

Study of Electric Transmission Congestion: The bill requires the Secretary of Energy to include a study of the transmission issues facing renewable energy in the pending study of electric transmission congestion that is due to be issued in August 2009.

Summary of numbers: Tax Incentives

Three-Year Extension of PTC: The bill provides a three-year extension of the Production Tax Credit (PTC) for electricity derived from wind facilities through December 31, 2012, as well as for geothermal, biomass, hydropower, landfill gas, waste-to-energy and marine facilities through December 31 2013.

Investment Tax Credit (ITC) Accessible to All Renewable Energy: The bill provides project developers of wind, geothermal, biomass and other technologies eligible for the PTC, the option of instead utilizing the 30% ITC that previously only applied to solar and other clean technology projects.

Advanced Energy Manufacturing Credits: The bill provides $2 billion worth of energy related manufacturing investment credits at a 30% rate. These credits apply to projects creating or retooling manufacturing facilities to make components used to generate renewable energy, storage systems for use in electric or hybrid-electric cars, power grid components supporting addition of renewable sources, and equipment for carbon capture and storage (CCS).

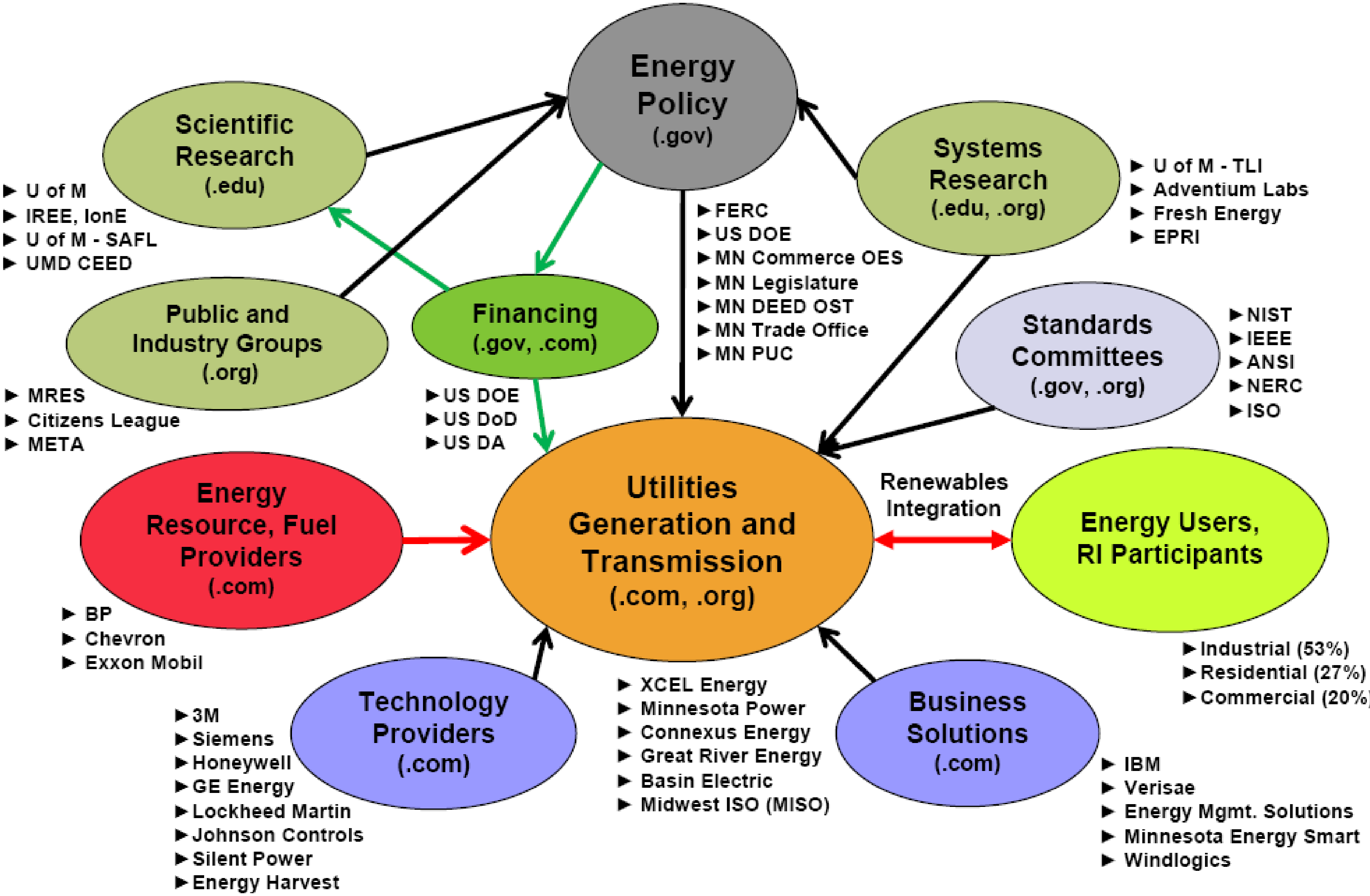
Plug-in Electric Drive Vehicle Credit: The bill increases the tax credit for qualified plug-in electric drive vehicles for the first 200,000 placed in service. The base amount of the credit is $2500. Batteries with at least 5 kilowatt hours of capacity have a credit of $2917. The credit is further increased by $417 for every kilowatt hour in excess of 5 kilowatt hours, but cannot exceed $5000.The credit is allowed to be taken against the alternative minimum tax.

Observations

- **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:
  - To seamlessly integrate and optimize electricity supply and demand, and
  - To 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"

Midwest Regional Ecosystem - Stakeholders
(Objective: Long-Term Sustainability)



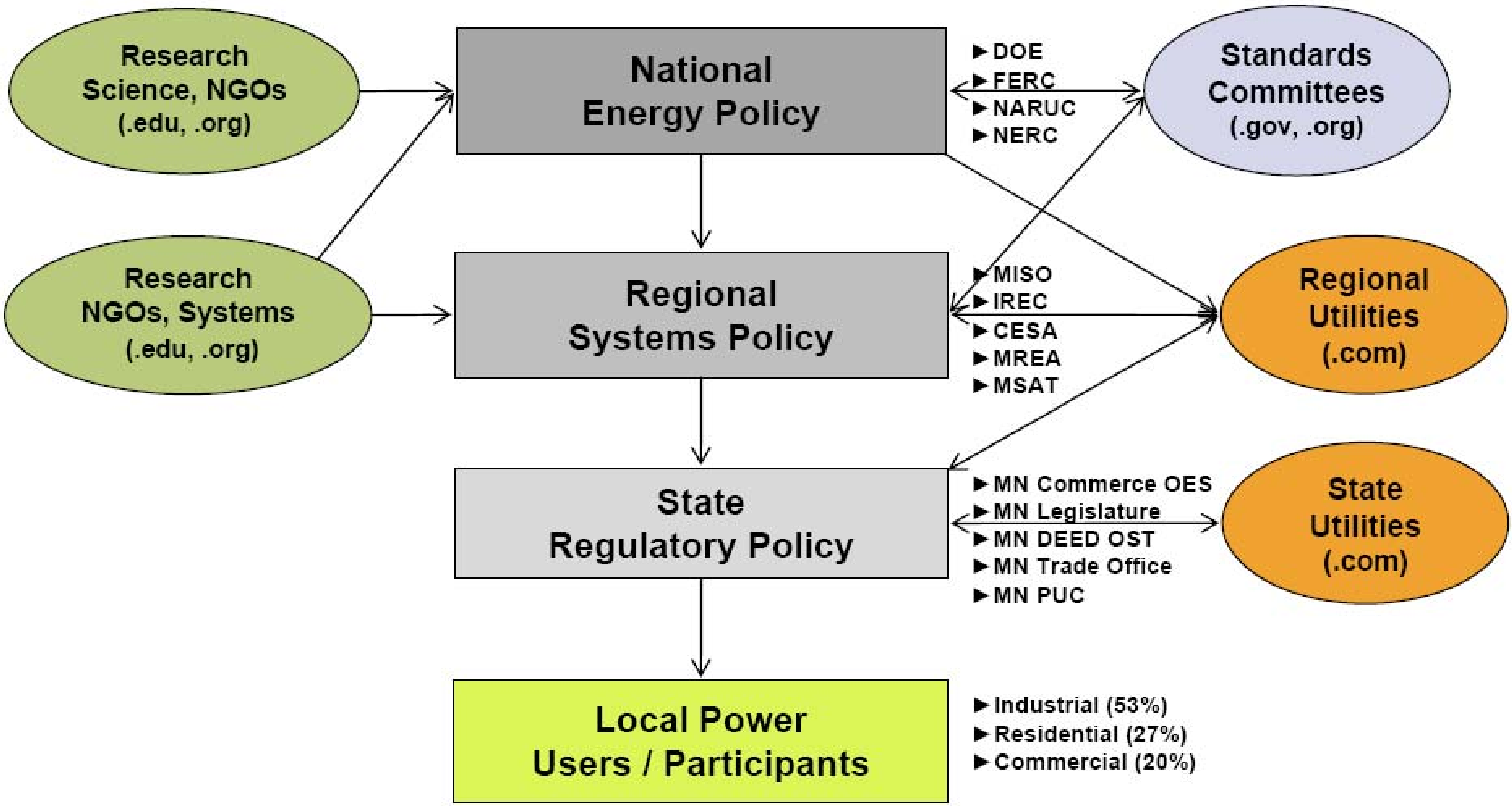
Technological Leadership Institute

University of Minnesota
Driven to Discover℠

Source: Bill Bushnell

Smart Grid Systems View

Policy Perspective - Key Levels



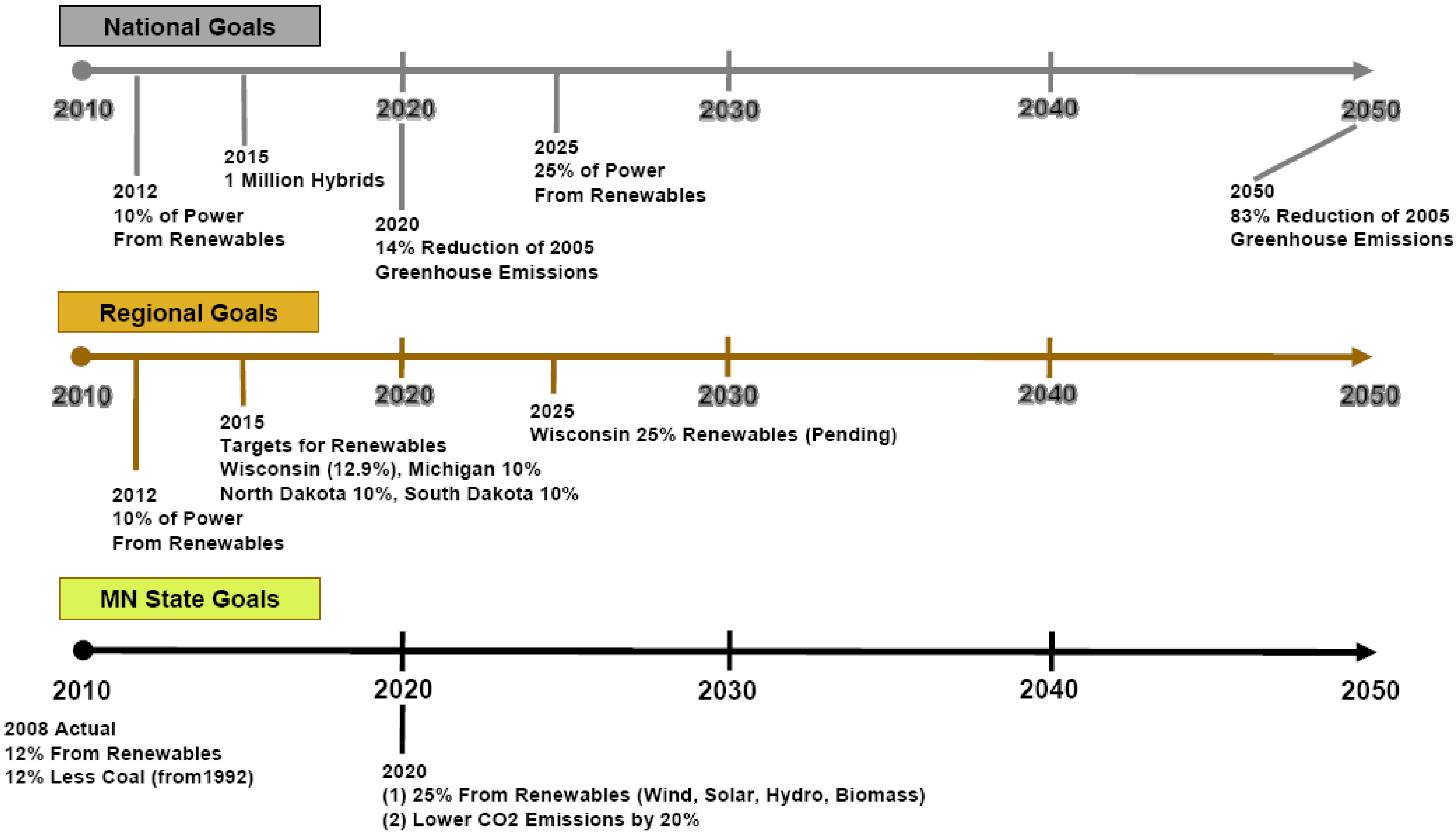
Technological Leadership Institute

University of Minnesota
Driven to Discover℠

Source: Bill Bushnell

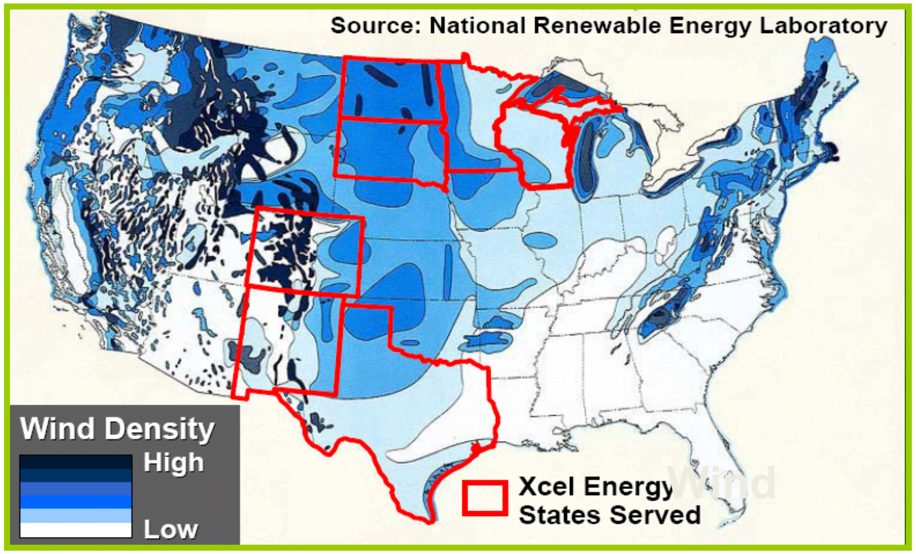
Smart Grid Systems View

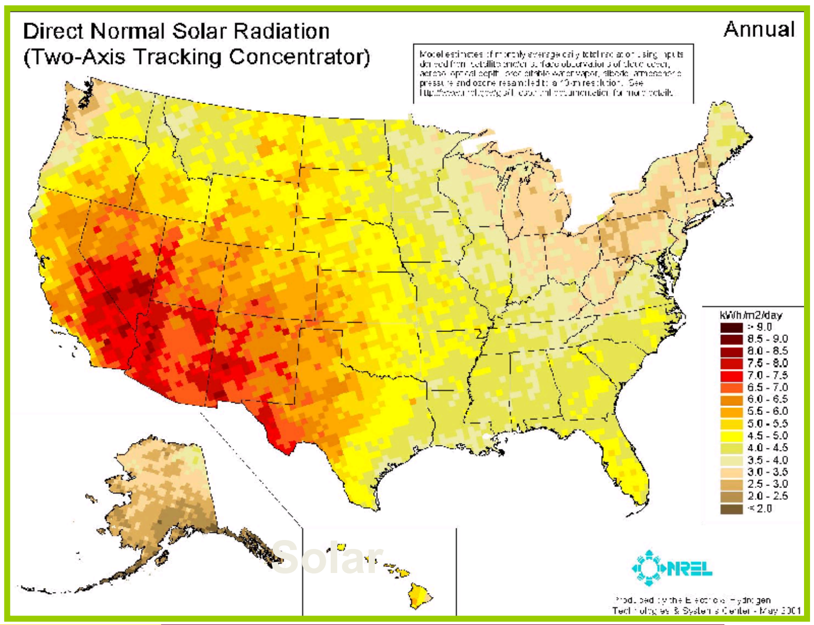
Goal Timelines by Level

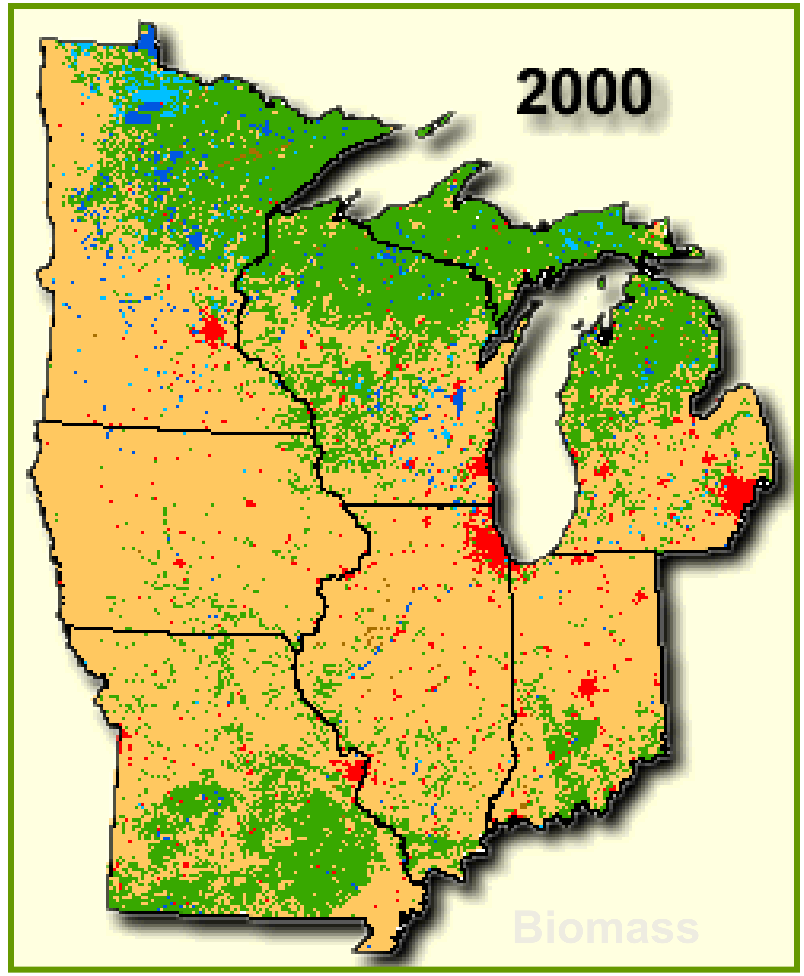


Source: Bill Bushnell

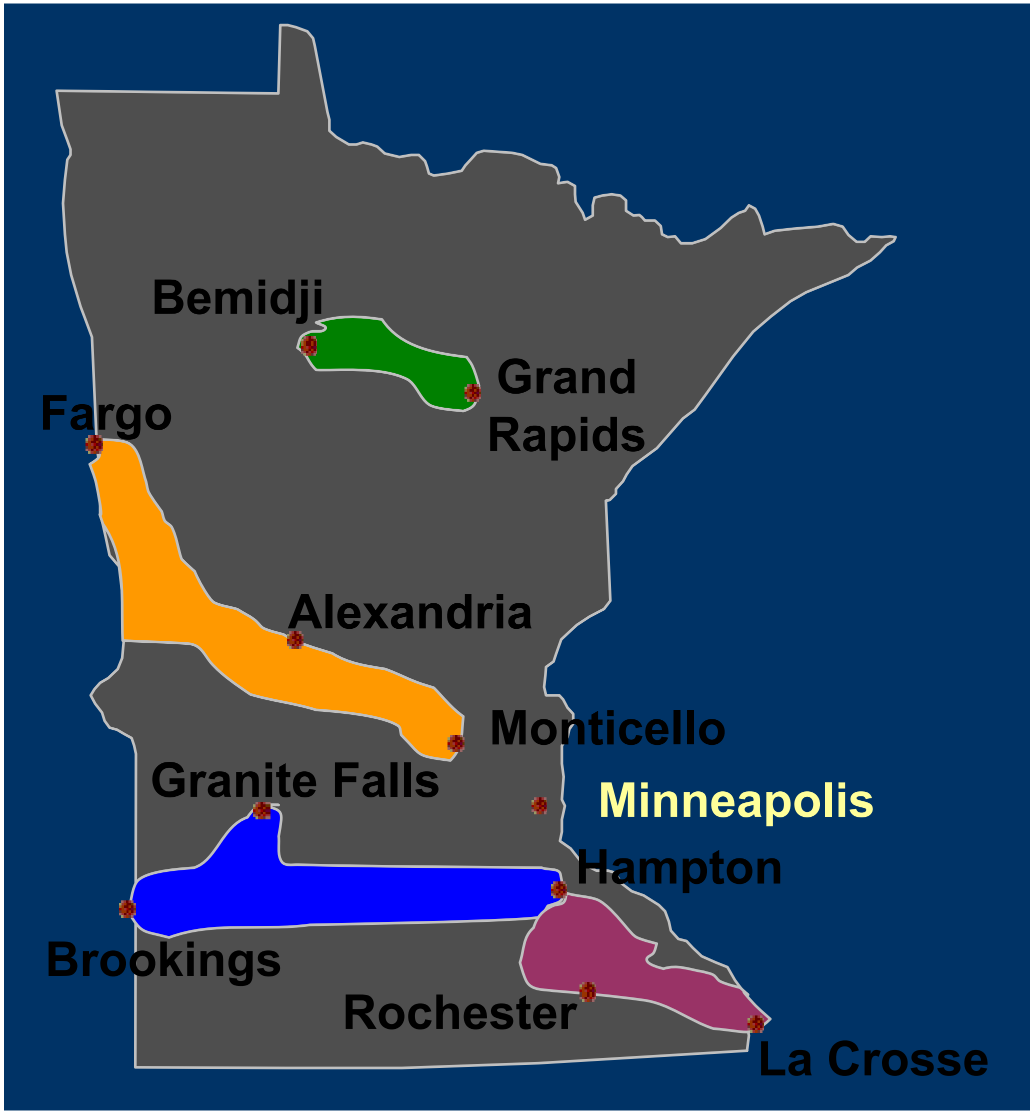
Renewables Highly Available







Building Transmission Is Essential



- CAPX 2020 approvals granted
- Route permits underway
- $1 billion Xcel Energy investment

Brief overview of the

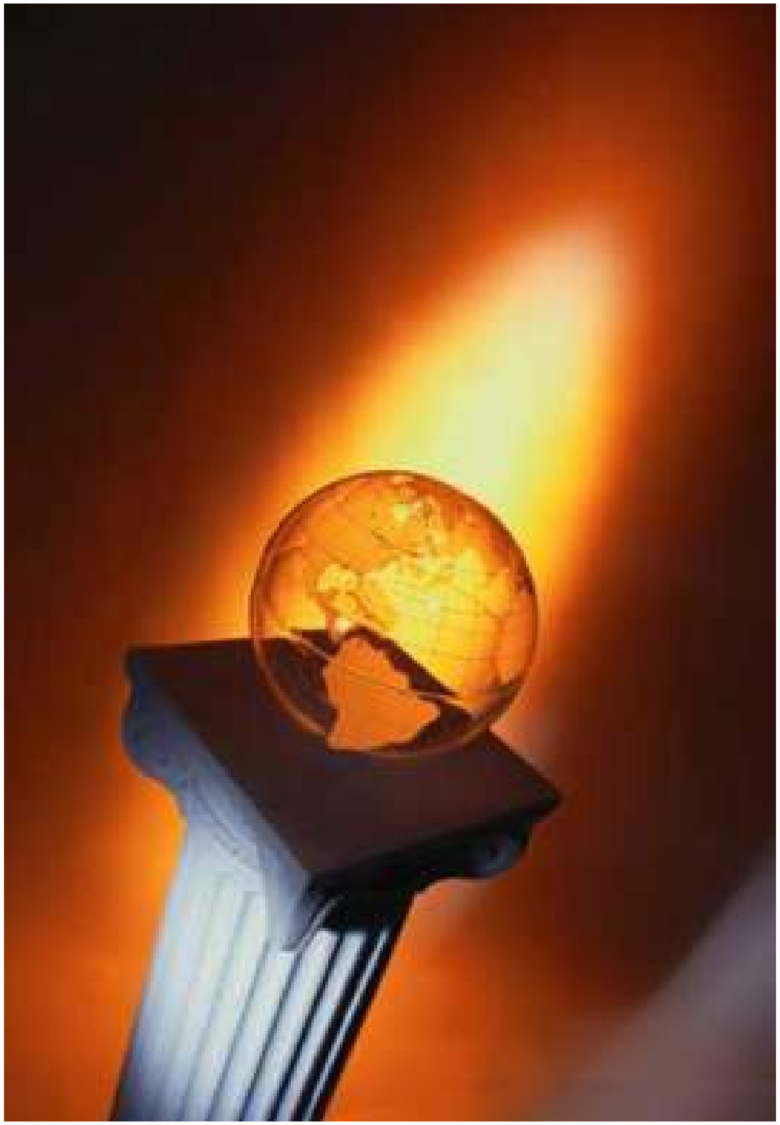
Technological Leadership Institute (TLI)

at the University of Minnesota

(tli.umn.edu)

Technological Leadership Institute (TLI) at the University of Minnesota

- Established in 1987 with an endowment from Honeywell Foundation.
- An interdisciplinary center housed in the Institute of Technology (engineering, mathematics, and physical sciences college)
- TLI has five endowed chairs, and has an additional 47 top-notch faculty from across the eight University of Minnesota colleges, government, and industry
- Expertise in the interface of critical infrastructure, engineering, science, technology, business, strategy, innovation, leadership, and policy
- *Developing Local and Global Leaders for Technology Enterprises*



What Does TLI Do?

- **Master of Science degrees**
  - Management of Technology (1990)
  - Infrastructure Systems Engineering (2000)
  - Security Technologies (2010), with options for the M and MS/PhD minors

- **Short Courses, Seminars, and Certificates**
  - Certificate Programs and *Summit Certification*
  - Fall *Signature Series* “Best of Technology Management”
  - Customized Leadership Training and Courses
  - *Foresight After Four*

- **Research and Consulting**
- **Web site: <www.tli.umn.edu>**

Leadership and Management at the Interface:

Developing Local and Global Leaders for Technology Enterprises

HUBERT H. HUMPHREY

Science & Technology Policy/Gov't & Business

CARLSON SCHOOL OF MANAGEMENT
UNIVERSITY OF MINNESOTA

-Management
-Marketing
-Accounting
-Finance
-Entrepreneurship
-Operations
-Economics

TLI

TLI and MOT "DNA":

-Technology Foresight & Forecasting
-Strategic Technology Analysis
-Innovation Management
-Strategic Management of Technology
-Technological Leadership

INSTITUTE OF TECHNOLOGY
ENGINEERING | PHYSICAL SCIENCES | MATHEMATICS

-Engineering
-Science
-Technology

LAW
Rigorous. Relevant. Ready.

IP Management & Protection

Industry: Applied to technological work and marketplace

Technology at TLI and in MOT Is…

- **Any application of science**
  - Broader than software or hardware
- **Areas**
  - Research, processes, or products
- **Examples**
  - Gene therapy/bio tech, pharma, security and privacy technologies, sensors, fuel cells, new composites, nanotech, etc.

The MOT Students

- Experienced
  - 12-13 yrs work experience, on average
  - 36 yrs old, on average
- Diverse expertise
  - R&D, operations, consulting, quality, engineering, information systems, intellectual property
- Varied responsibilities
  - Directors, managers, project or team leaders, senior engineers, consultants, business or science/technical unit liaisons, chief officers, entrepreneurs
- Represent tech-intensive industries, companies, and organizations

The Alumni >>

	Before MOT	5-8 years After MOT
Management	32%	42%
Executive	1%	27%
R&D	28%	12%
Marketing	1%	6%
Design	18%	4%
Manufacturing	6%	4%
Business owners	0%	3%
"Other"	15%	2%

→ Out of the 531 MOT alumni, over 33% are executives and over 50% of the remaining alumni report that they hold management positions or have management responsibilities.

An Engine for Economic Growth

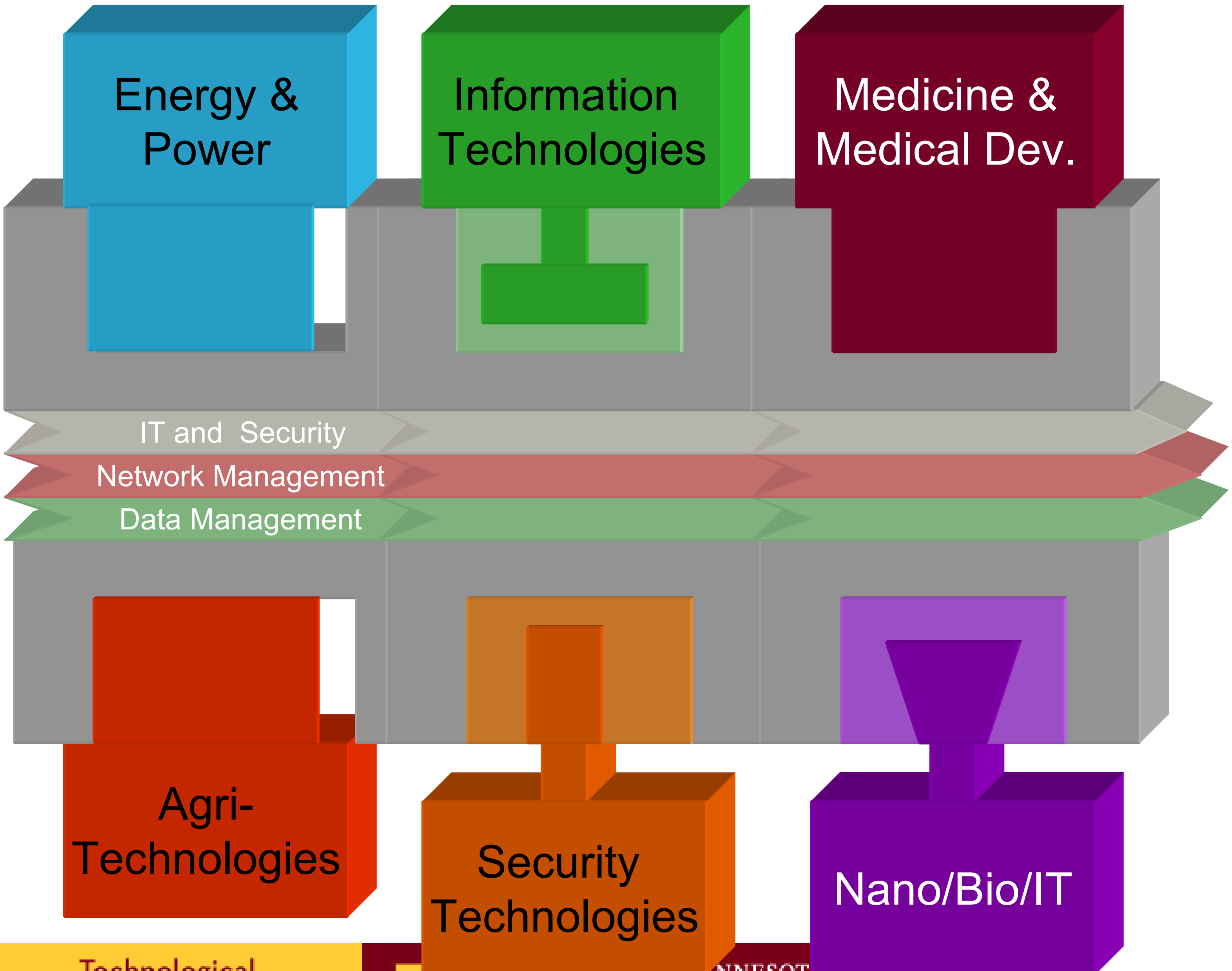
Entrepreneurship:

- Institute of Technology (College of Engineering, Physical Sciences and Mathematics at the U) Founders2005 Survey of alumni who have started businesses:
  – 15,000 alumni responded
  – 3,024 have founded one or more companies
  – 2,600 active companies in Minnesota (employing 175,000 in Minnesota), with annual global revenue of $90B ($46B in Minnesota)
  – with Faculty also active in start-ups, often with former graduate students.

A Minnesota Engine for Economic Growth

Minnesota's Technological Leadership Role:

Enabling Economic Growth→ First Build the Right Foundation



Build The Right Foundation

Security

Network Management

Data Management

Interoperability

Macroeconomic Rationale

Endogenous growth models –

Y = f(R, K, H), where:

Y = GDP

R = R&D

K = physical capital

H = human capital

GDP growth: a) Velocity and proportion of R, K, H, and b) available and affordable energy: determinants of success

The (Economic) Ages of Humankind

•Hunter/Gatherers	(~1 Million - ~5K BC)
•Agriculture	(~5K BC - ~1850 AD)
•Industrial	(~1850 AD - ~1950 AD)
•Information	(~1950 AD - ~2040 AD)
•Bio/Nano	(~1995 - ~2040)
•Virtual	(~2015 - ?)

Technology MATTERS

Noble-prized economist Robert Solow (MIT)
→Quantitative power of technology in the economy
→ "Technology drives 60% of US economy!"

What are the Technologies of the Future?

- IT (comms/computing/sensors/electronics/machine intelligence)
- Bio (genomics/molecular biology/designer life forms)
- Nano (coatings/barriers/computers/sensors/materials/ “assemblers”)
- Energetics (solar/biomass/storage)
- Quantum (crypto/computing/sensors/optics/Electronics)
- Societal Technological Systems (motivational asynchronous “distance learning,” immersive/virtual presence, “tele-everything,” “robotic everything,” digital earth/digital airspace)

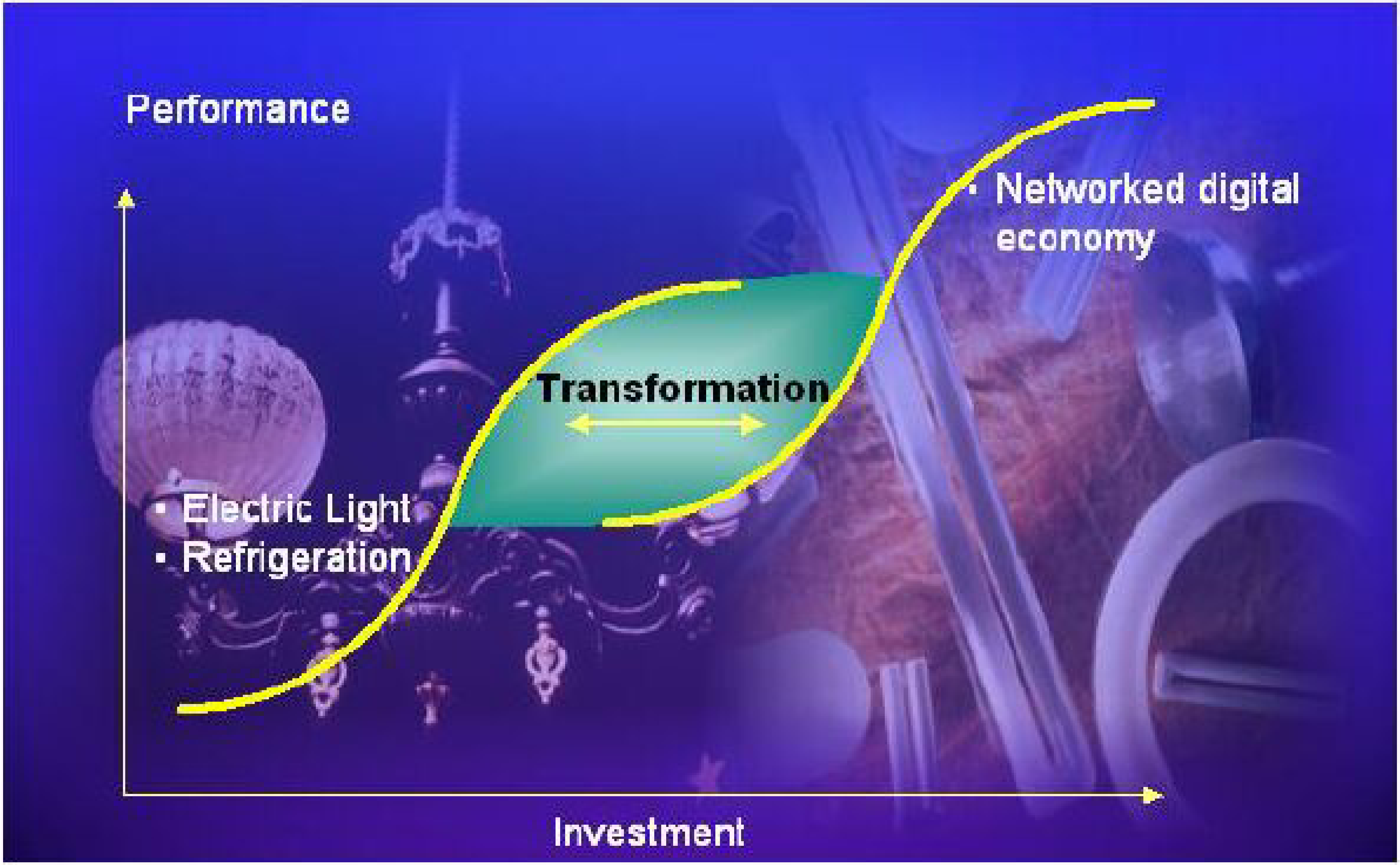
Impact of ongoing IT revolution on Society

1. Telecommuting ("tele-everything")
2. Shopping at home, web-based, robotic delivery
3. Entertainment/leisure (at home, immersive 3-D, interactive/multisensory via VR/holography)
4. Travel (3-D/interactive/multisensory tele-travel)
5. Education (at home, low-cost, web-based on-demand asynchronous, immersive/virtual presence, life-long distance learning, .edu)
6. Health (at home interactive tele-medicine)
7. Politics (increased real-time virtual involvement of the body politic)
8. Commerce (tele-commerce already ubiquitous)
9. Tele-socialization Tele-[onsite] Manufacturing

Key Technologies for Minnesota

1. Energy and Power
2. Information Technologies (IT)
3. Medicine and Medical Devices
4. Agricultural Technologies
5. Security Technologies
6. Nano/Bio/IT

Breaking the Limits on Electricity Value




LEADERSHIP

Bottom Line:

"Only three things happen naturally in organizations:
friction, confusion and underperformance.
Everything else requires leadership."

-- Peter Drucker

Policy, Science and Technology Must Support This Transformation: Recommendations

- Establish the "Smart Grid" and "self-healing" interdependent infrastructure security & protection as national priorities
- Authorize increased funding for R&D and demonstrations of the "Smart Grid", and interdependency R&D, resilience/security
- Revitalize the national public/private electricity infrastructure partnership needed to fund the "Smart Grid" deployment

M. Amin's Congressional briefings on March 26 and Oct. 15, 2009

Enabling a Stronger and Smarter Grid:

- Broad range of R&D including end-use and system efficiency, electrification of transportation, stronger and smarter grid with massive storage
- Sensing, Communications, Controls, Security, Energy Efficiency and Demand Response *if architected correctly* could assist the development of a smart grid
- Smart Grid Challenge/Opportunity areas include:
  - Distributed Control
  - Grid Architectures
  - Cyber Security

Source: Massoud Amin, Congressional briefings, March 26 and October 15, 2009

Discussion and the Road Ahead:

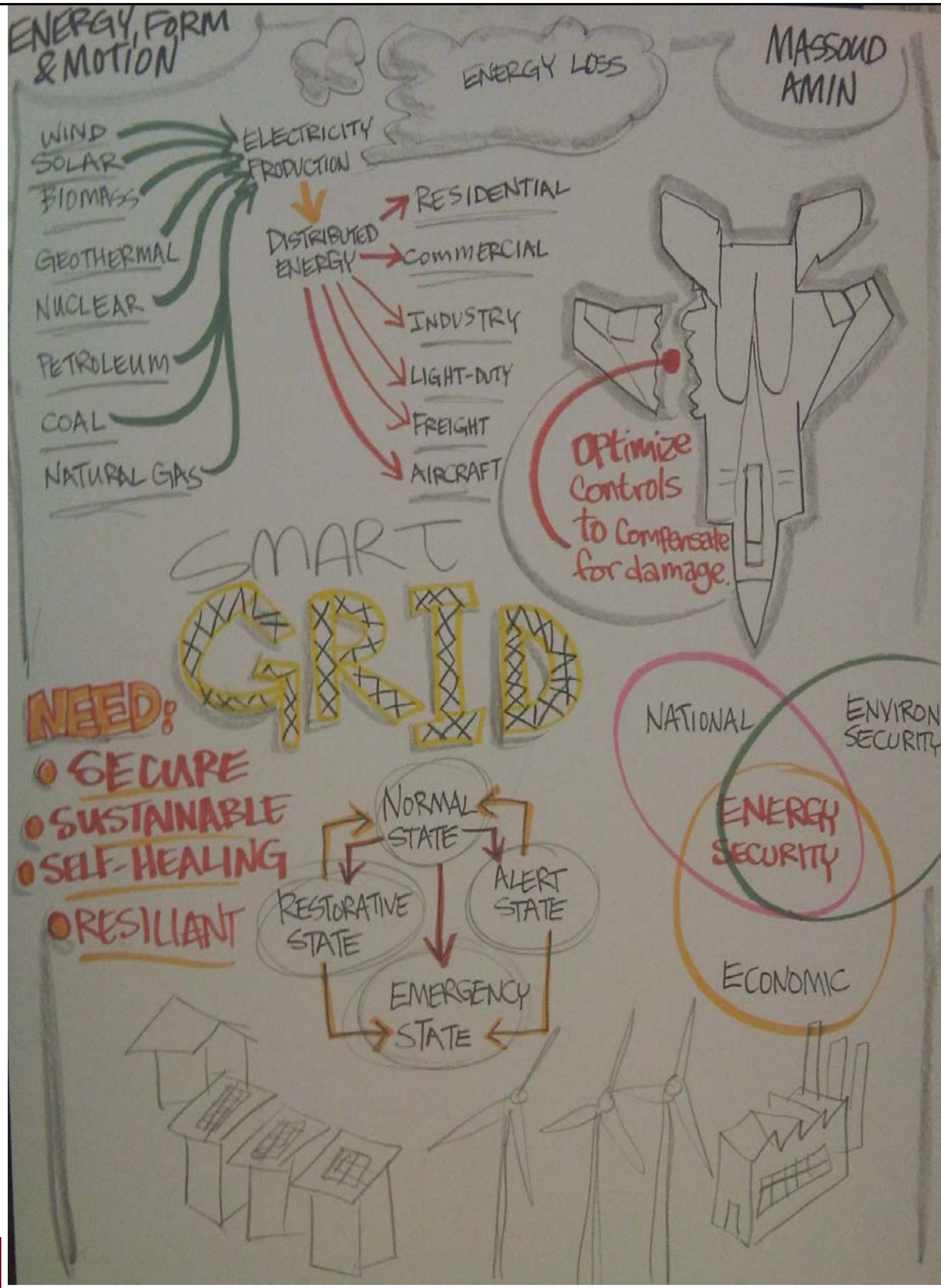
- What are the key energy, environmental and economic issues facing MN, our region, our nation, and the world?
- "What are the range of new services enabled by smart grids?"
- Smart grids included in all energy legislation
- Smart grid's potential as an "enabler in state and federal regulatory policies" to drive economic growth

"… 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



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