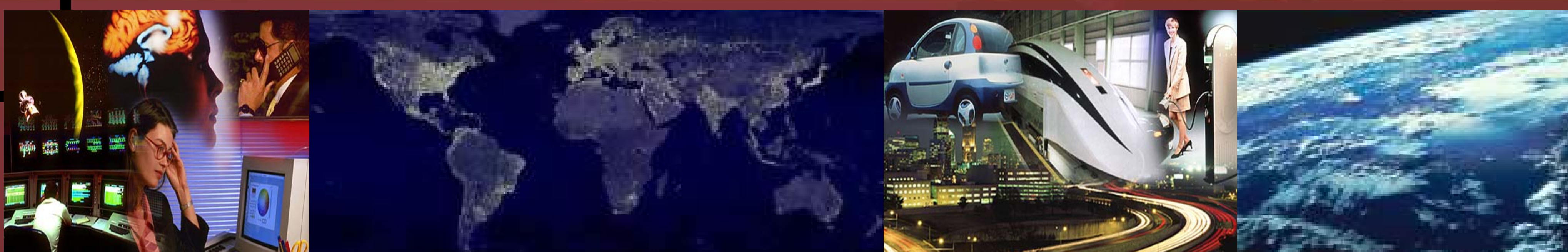
URBAN ENERGY & GREEN DESIGN - Smart Grid Cities

S. Massoud Amin, D.Sc.
Director, Technological Leadership Institute
Honeywell/H.W. Sweatt Chair in Technological Leadership
Professor, Electrical & Computer Engineering
University Distinguished Teaching Professor



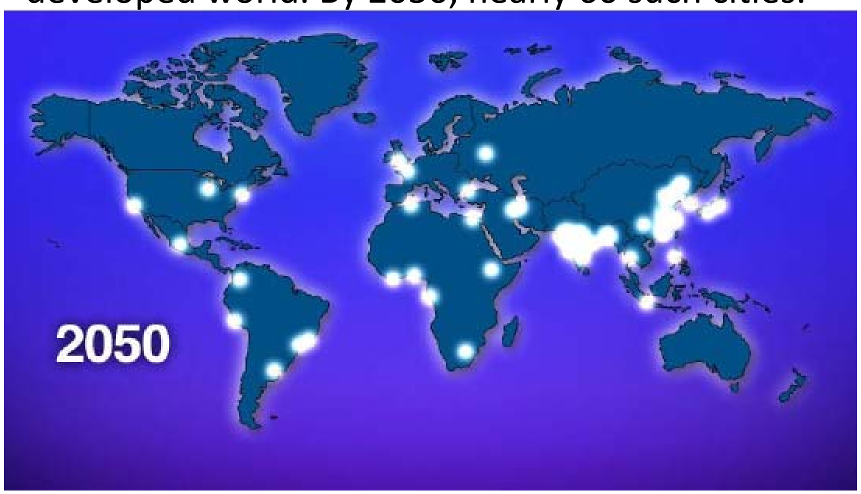
TUFTS ENERGY CONFERENCE
April 16-17, 2010 | THE EVOLUTION OF ENERGY

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

TECHNOLOGICAL LEADERSHIP INSTITUTE
UNIVERSITY OF MINNESOTA
Driven to Discover℠

Context: Cities with 10 million people

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

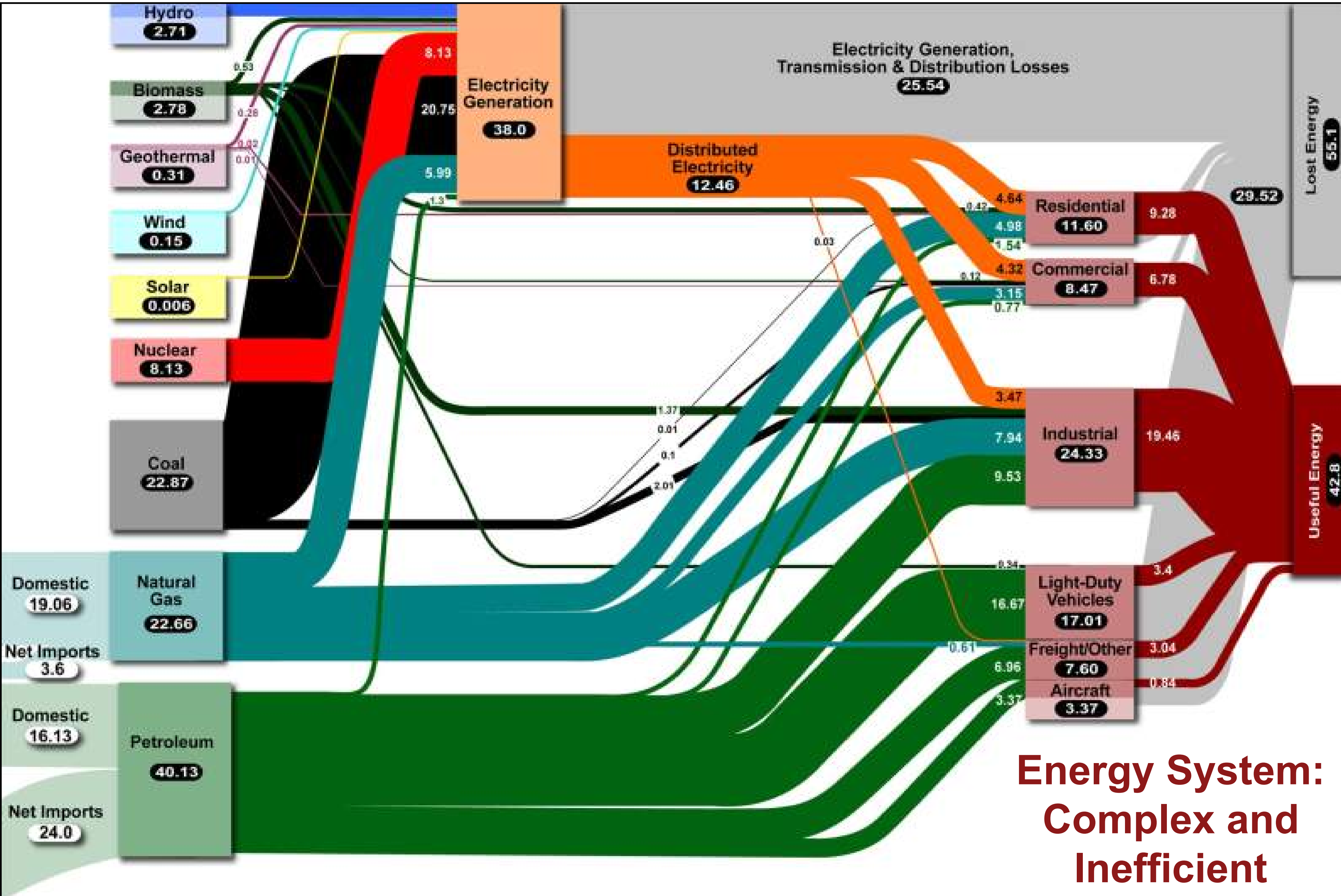


Note: * Mega city 10 million population or greater

- **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



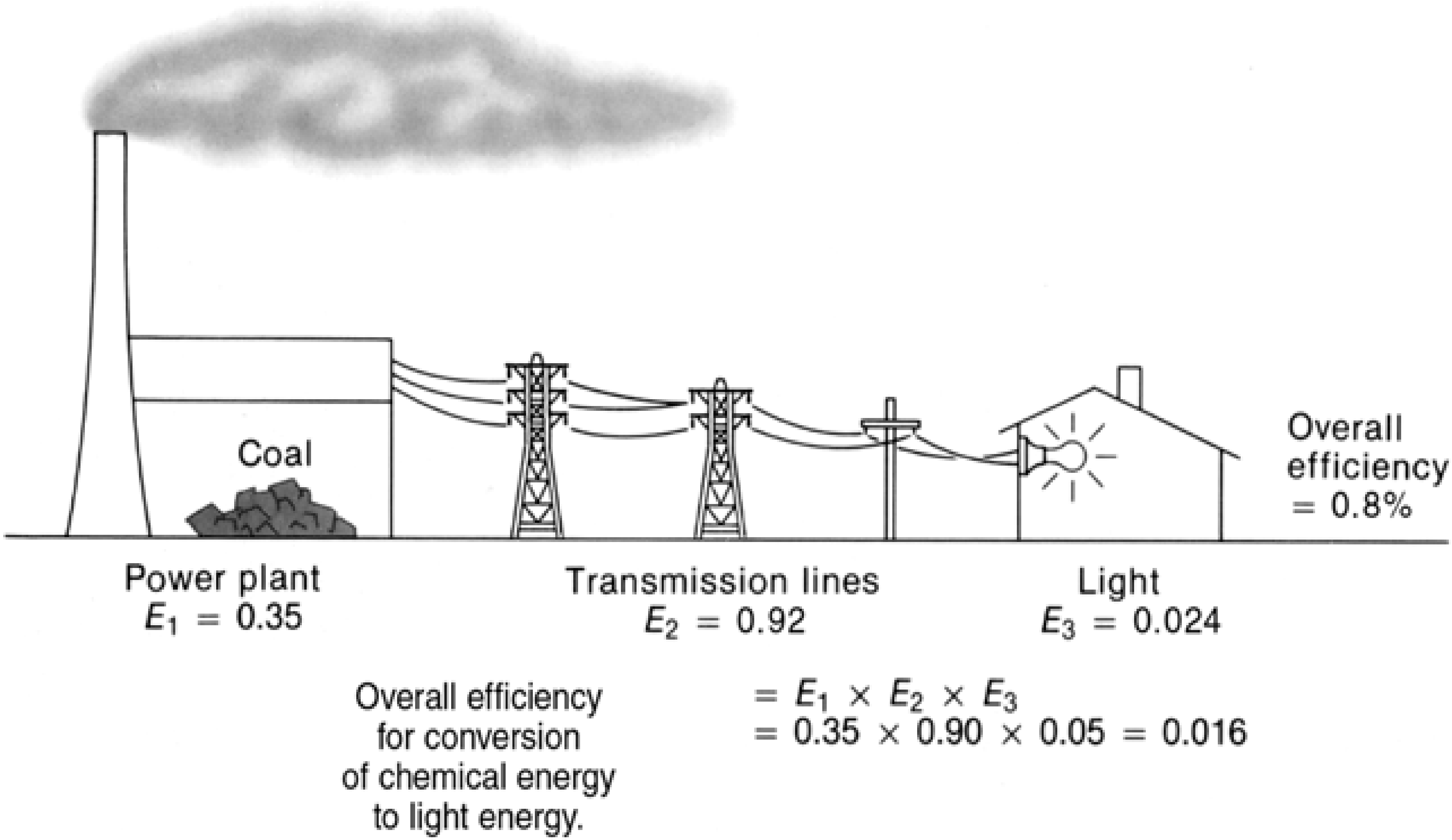
Energy System: Complex and Inefficient

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

Technological Leadership Institute

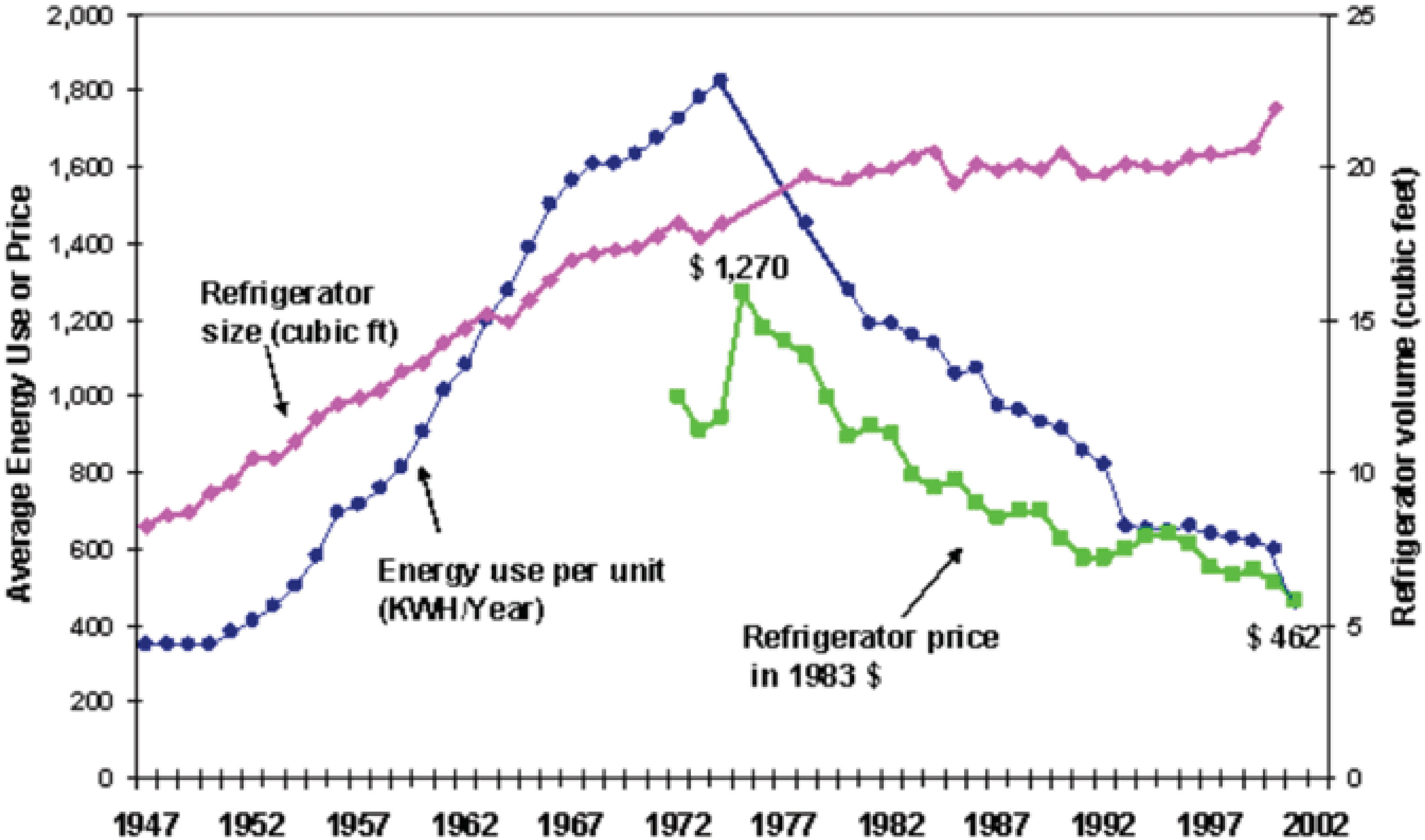
University of Minnesota
Driven to Discover℠

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



Source: NRC, 2009

Example: Energy Efficiency of refrigerator



Source: NRC, 2009

Example: Energy Use in Buildings

- 81 million single-family houses, 25 million multifamily residences, and 7 million mobile homes, together with 75 billion square feet of commercial floor space account for 73 percent of electricity use and 40 percent of total energy use in the United States.

- 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. Unfortunately, this potential is sensitive to price, especially for natural gas.

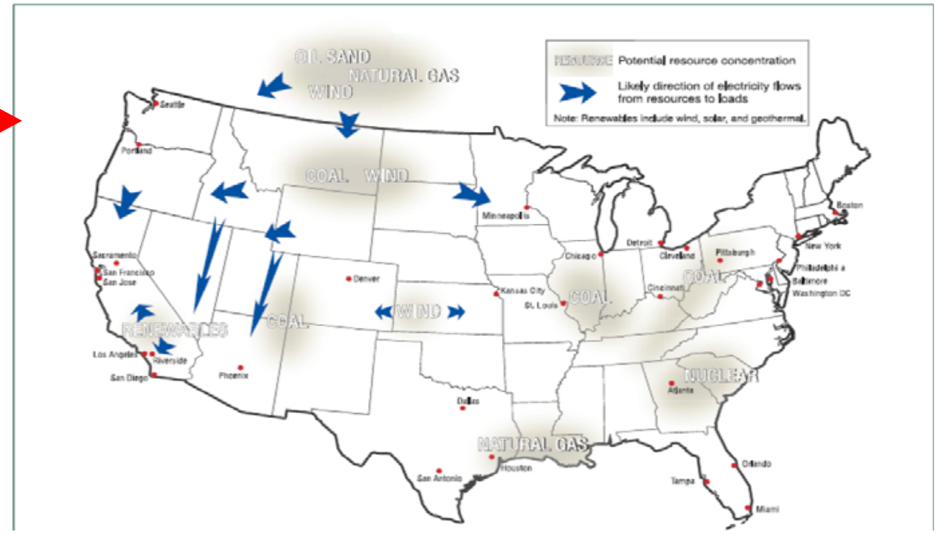
Smart Grid: Integrate Dispersed Energy Sources into a Modern Grid to Provide Energy to Centers of Demand

Recommendations for moving to energy system's to meet demand of tomorrow

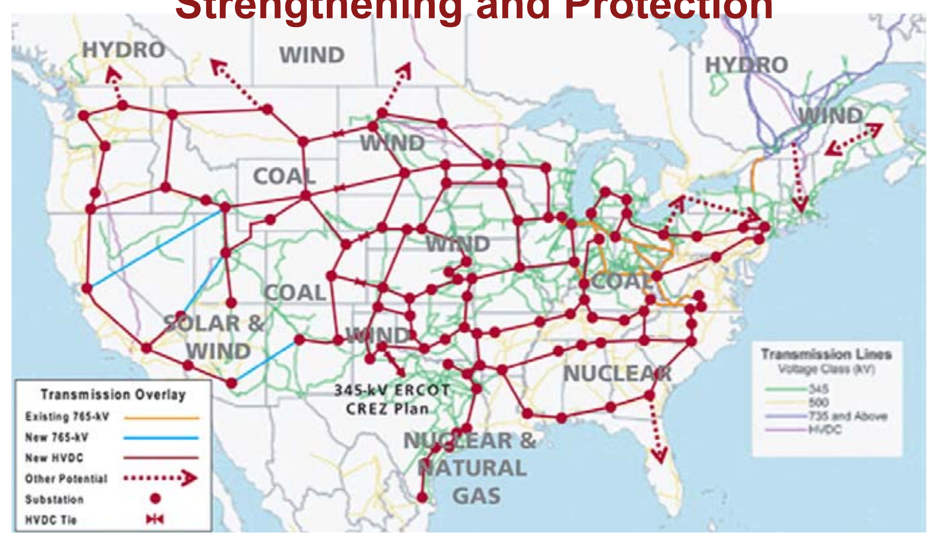
- **Build a stronger and smarter electrical energy infrastructure**
  - Transform the Network into a Smart Grid
  - Develop an Expanded Transmission System
  - Develop Massive Electricity Storage Systems
- **Break our addiction to oil by transforming transportation**
  - Electrify Transportation: Plug-In 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: M. Amin's Congressional briefings March 26, and Oct. 15, 2009

Emerging Supply and Demand Patterns



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

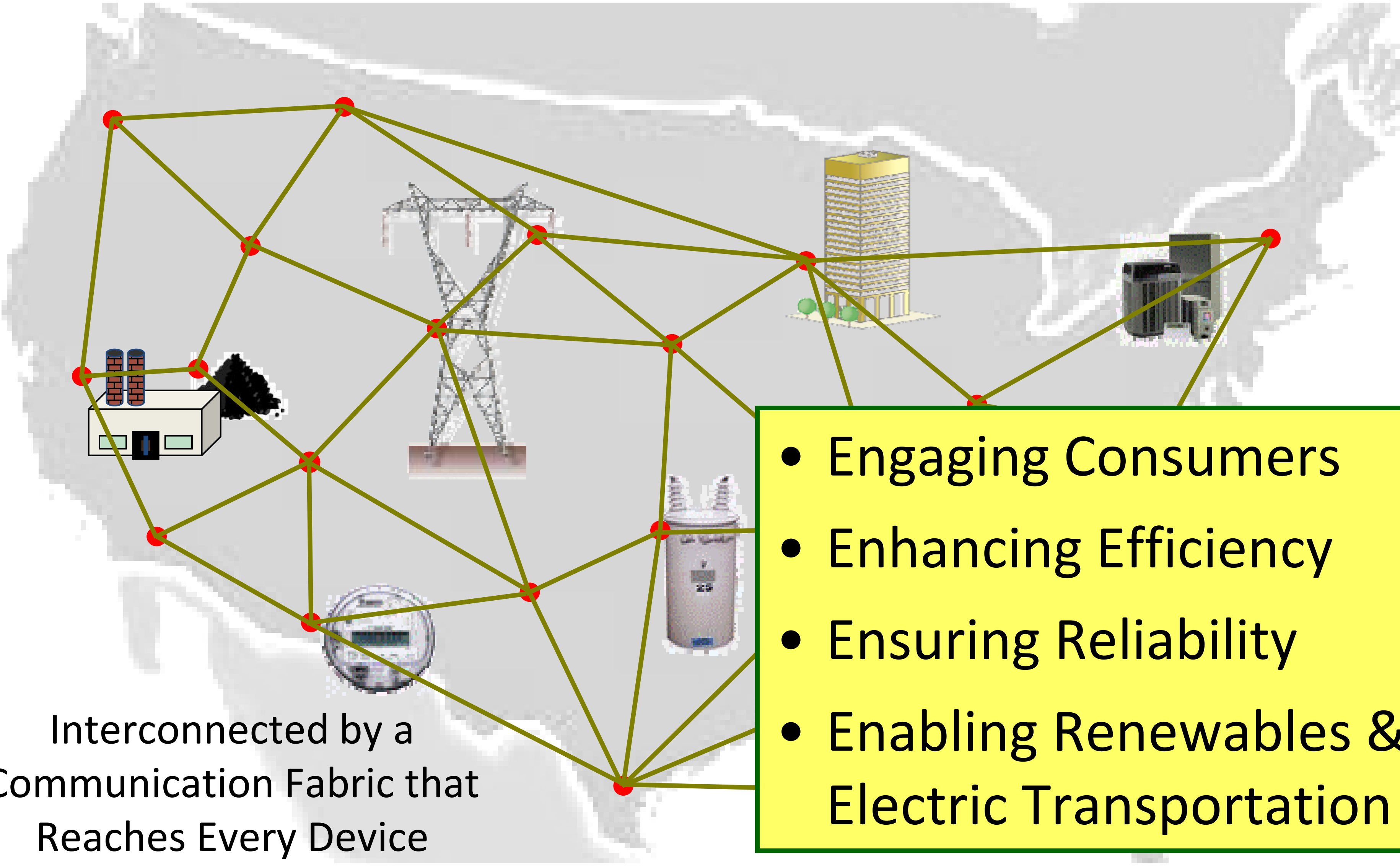


Smart Grid

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

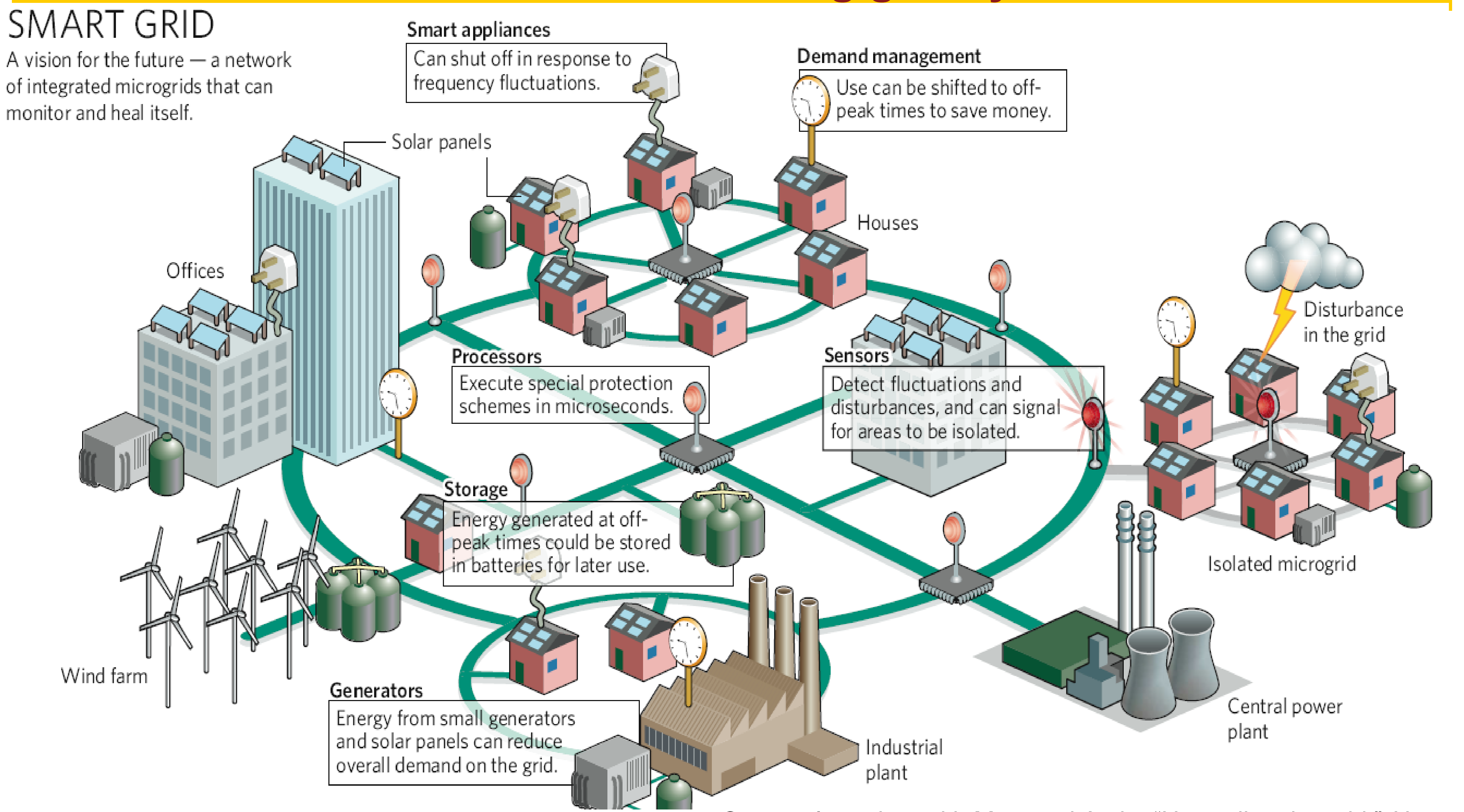
Interconnected by a Communication Fabric that Reaches Every Device

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

Albert Einstein

Enable the Future

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

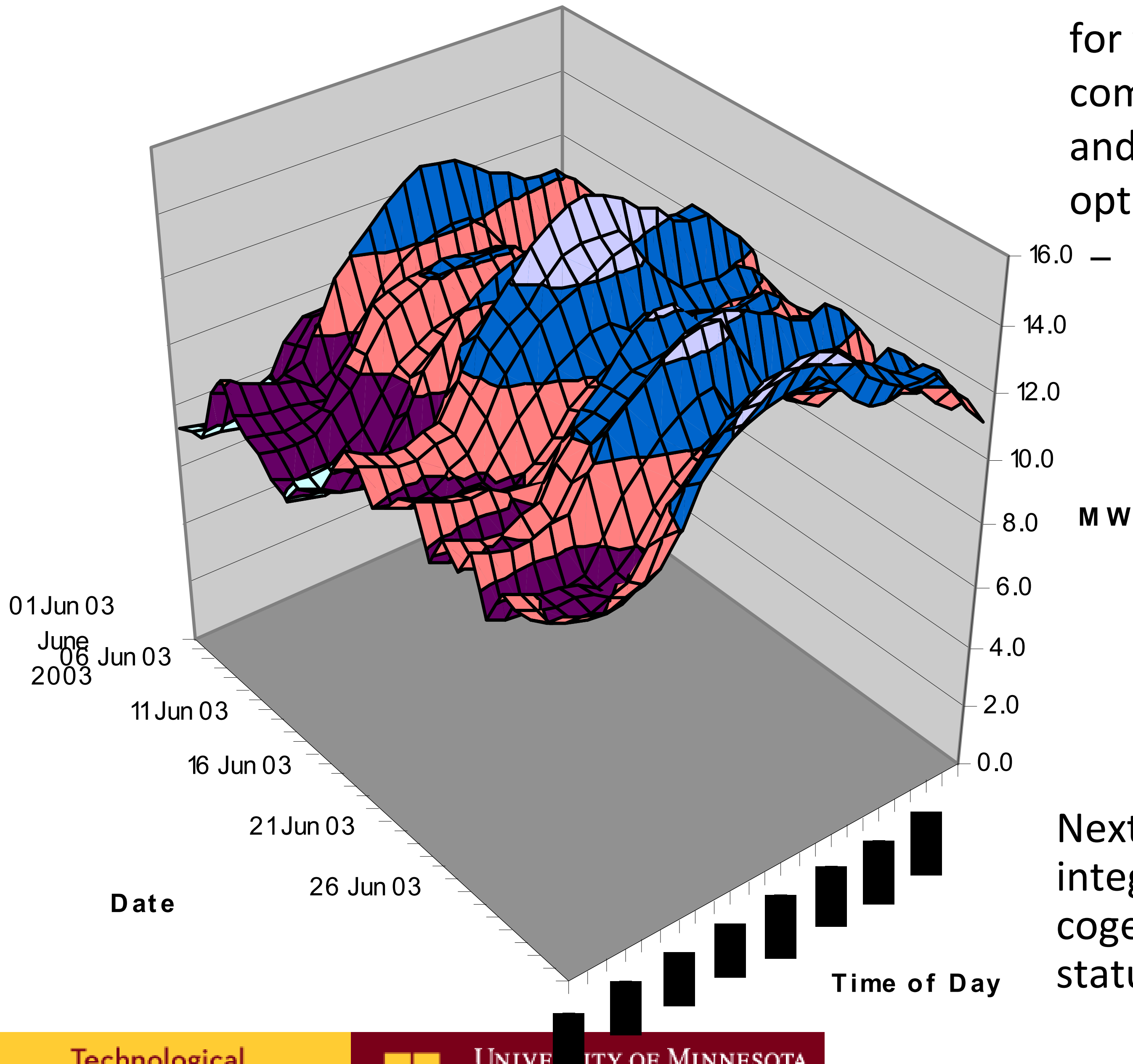


Source: Interview with Massoud Amin, "Upgrading the grid," *Nature*, vol. 454, pp. 570–573, 30 July 2008

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™



- Control algorithms and interfaces for turning individual energy components (storage, generation and loads) into an integrated, optimized energy system.
  - E.g., demand surface plots of raw data for demands, emissions, & efficiency

Next steps: demonstrate ability to integrate renewables/storage, cogeneration and achieve NZE status.

Smart Grid U™

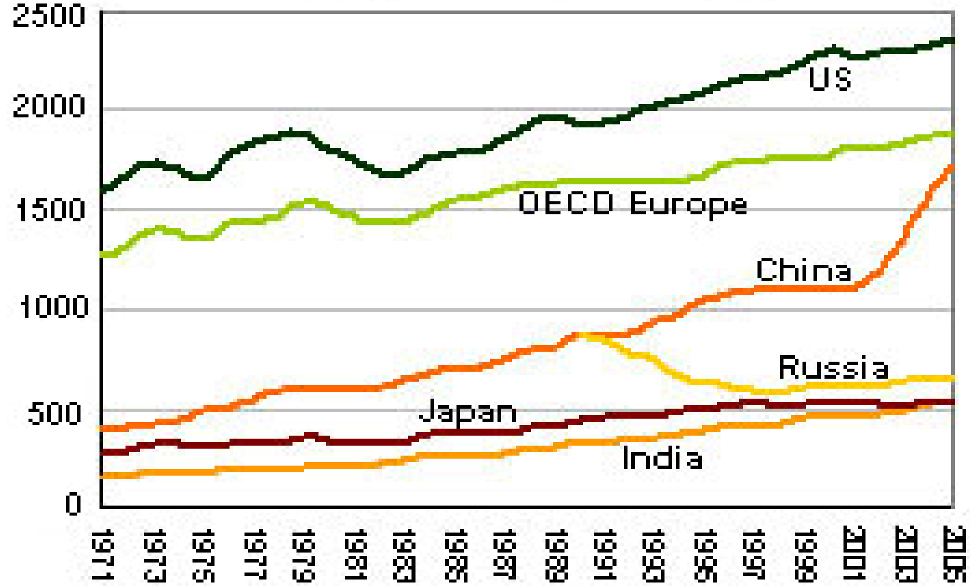
- Lessons learned and key messages:
  - Consider all parts together (Holistic Systems approach)
  - Focus on Benefits to Cost Payback
  - Remove deficiencies in foundations
  - The University as a Living laboratory
  - Education and Research → Implement new solutions
- **Consumer engagement critical 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"**

Integrated Systems Science for Understanding of Full Impacts of Decision Pathways: **Global Transition Dynamics**

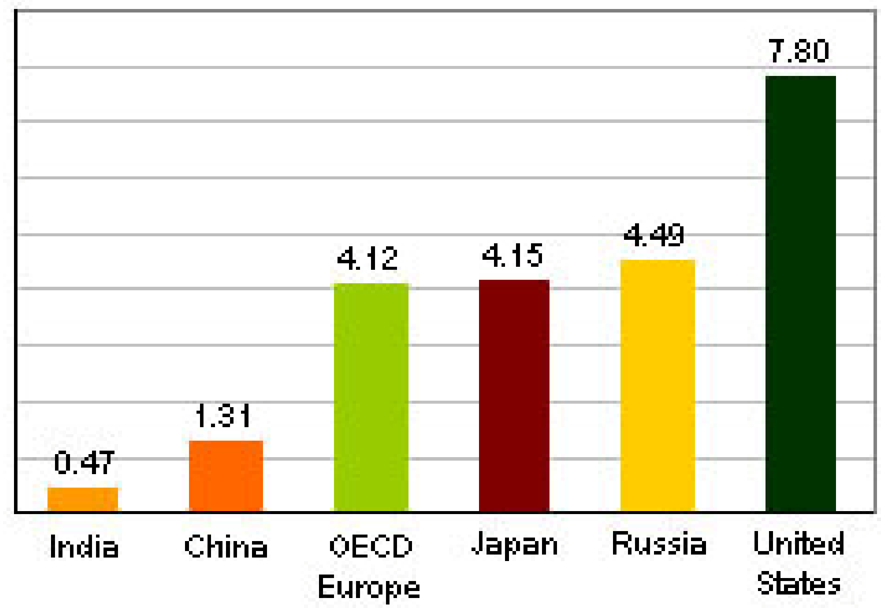
Electrification provides the **essential foundation** to transform global economies for sustainable development.

Energy Demand

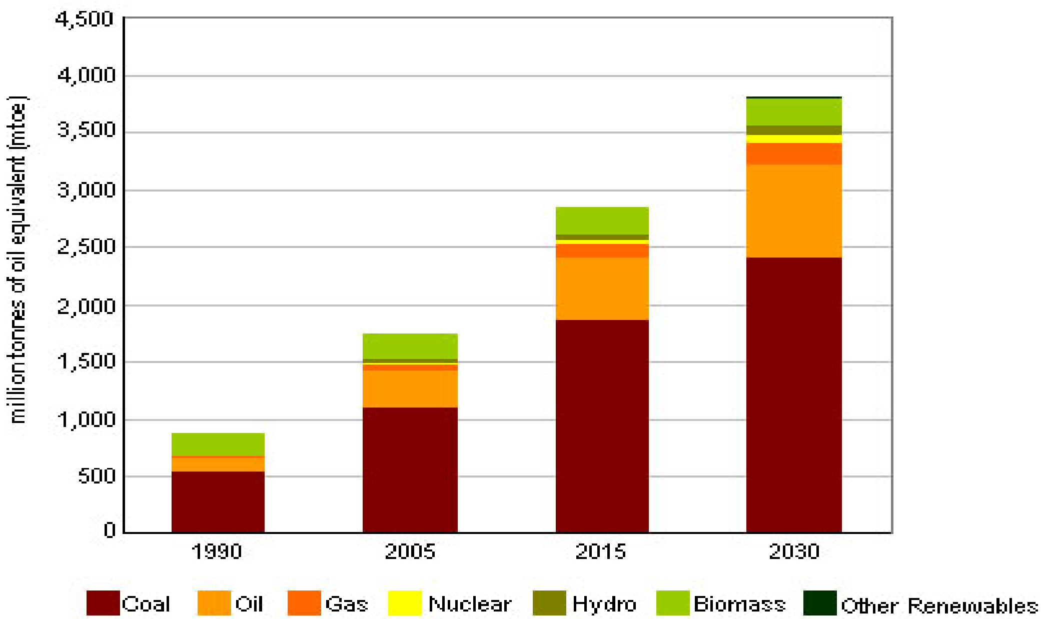
Total Energy Demand
(million tonnes of oil equivalent)



Per Capita Energy Demand
(tonnes of oil equivalent in 2005)



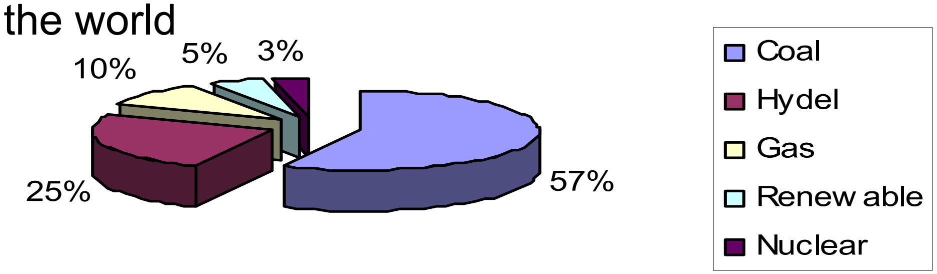
China's Energy Growth



India's installed Capacity

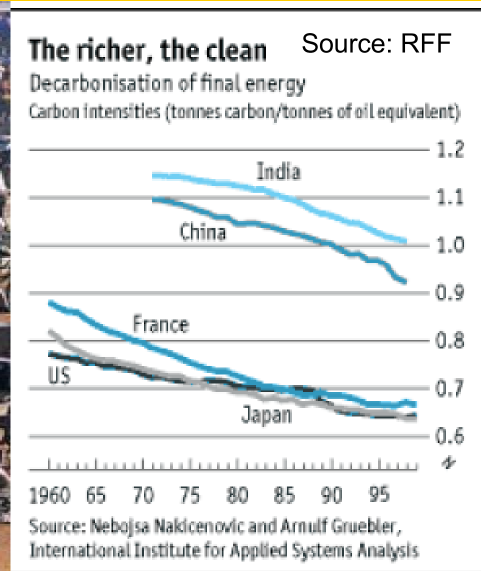
122 GW; 5th largest generation capacity in world

T & D network of 5.7 million circuit km – 3rd largest in the world



Low per capita consumption at 606 units -- less than half of China

"Trilemma" of Interlocking Sustainability Issues: Economic Aspirations of Rapidly Expanding Populations, Environmental Quality, and Natural Resource Consumption… Population, Poverty and Pollution



Trilemma of Sustainability

Population, Poverty and Pollution:

Science and technology hold the key to managing this trilemma -- allowing prosperity to grow most efficiently, while reducing humankind's environmental footprint and resource demands.

Technological Leadership Institute

University of Minnesota
Driven to Discover℠

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%.

There will be at least 27 "megacities" of 10 million people, compared to 19 today.

'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

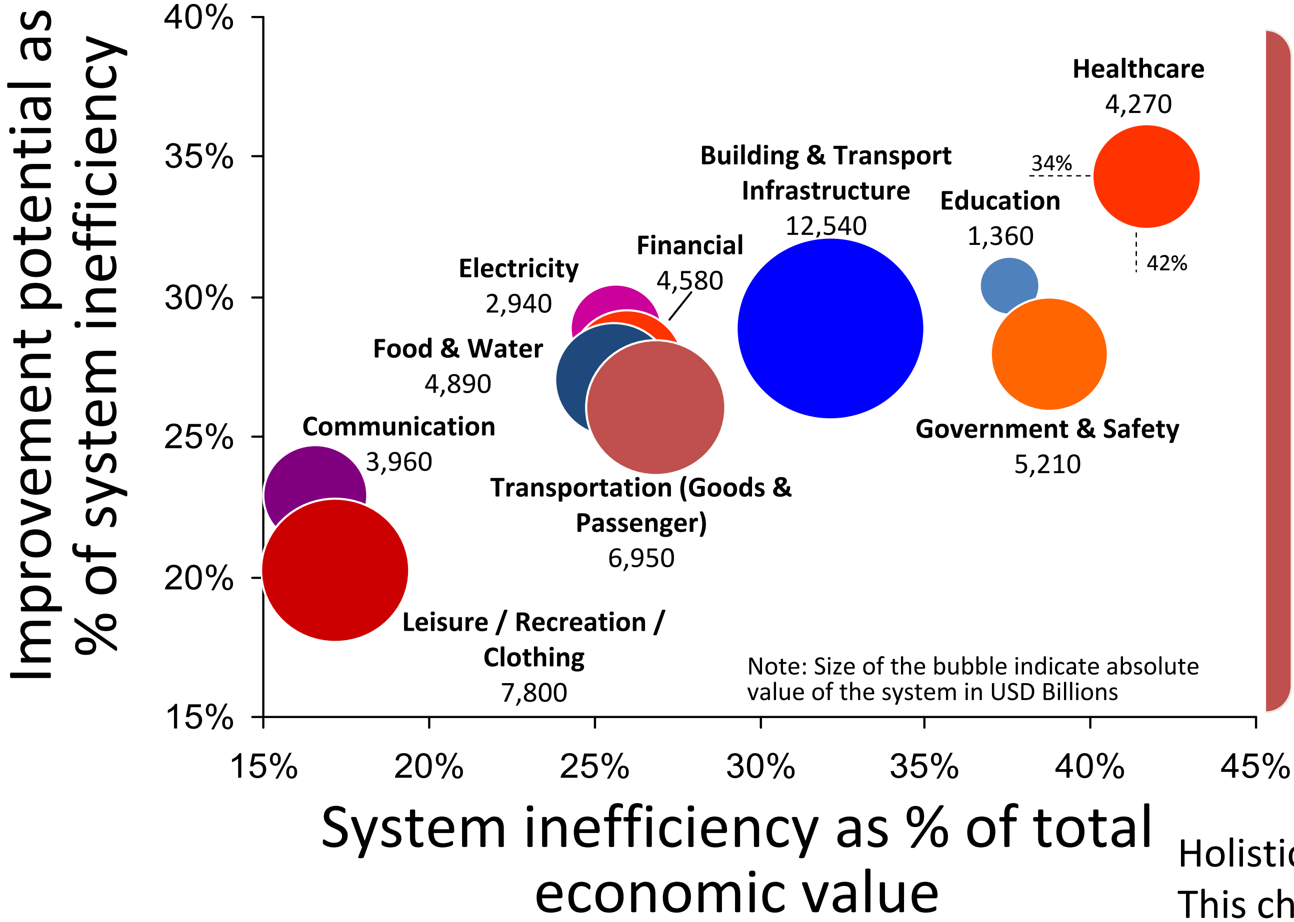
Top 10 cities

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

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

Technological Leadership Institute

University of Minnesota
Driven to Discover℠

A "Problem that Matters" in the 21st Century

"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

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


THANK YOU
MINNESOTA