

## Smart Grids: Opportunities and Pathways

Toward Stronger, Smarter, and More Secure  
North American Power & Energy Infrastructure

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umn.edu/~amin



Association of Minnesota Counties (AMC)  
Thursday, November 3, 2011

TECHNOLOGICAL  
LEADERSHIP INSTITUTE

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

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Driven to Discover™

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## Mega Cities with 10 Million People: Increasing demands/stress on lifeline Infrastructures



- By 2020, more than 30 mega cities\* in the now less-developed world
- By 2050, nearly 60 such cities
- World's electricity supply will need to triple by 2050 to keep up with demand, necessitating nearly 10,000 GW of new generating capacity

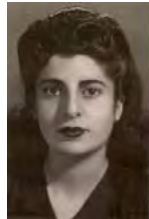
Note: \* Mega city 10 million population or greater

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## A personal observation on rural electrification and societal transformation



My father Dr. Mohammad Shafi Amin at the Mayo Clinic (pictured in Lake City, Minnesota on January 2, 1952)



My mother Mrs. Nahid Loghman-Adham's passport picture to study at the Sorbonne and Cambridge University, May 1946.



Maternal Grandparents, my grandfather was a Senator from Azerbaijan, first director of Red Cross and Minister of Health in Iran.



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## A personal observation on rural electrification and societal transformation



My Mom and me, Nov. 1961



Near Persepolis, Iran, age 8, March 1970



Rural electrification, June 1973



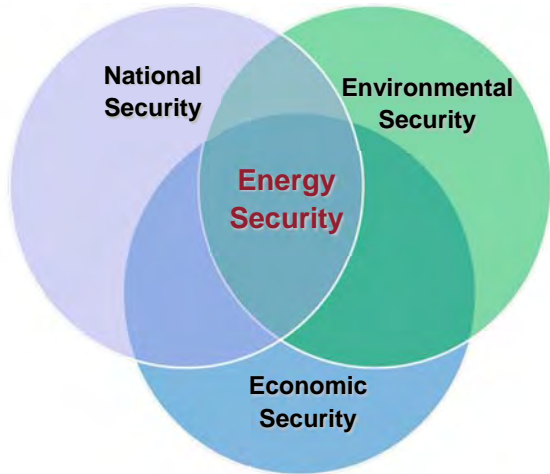
New York City, July 1977 blackout



Minnesota, January 2005

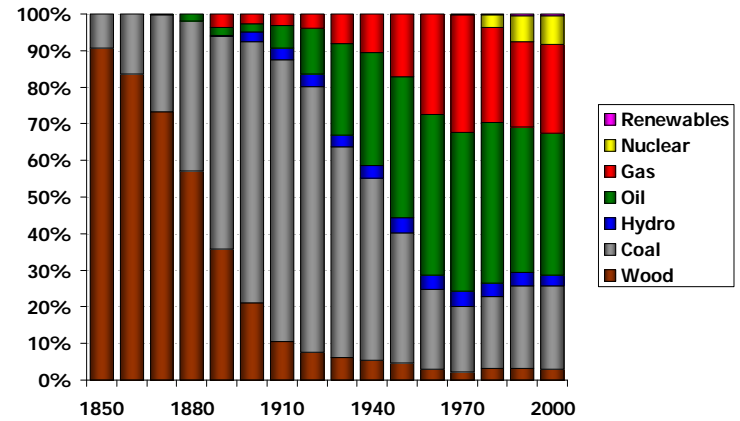
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**Energy Security: System of Systems**  
**The Energy Crises Taught Us Interdependency**



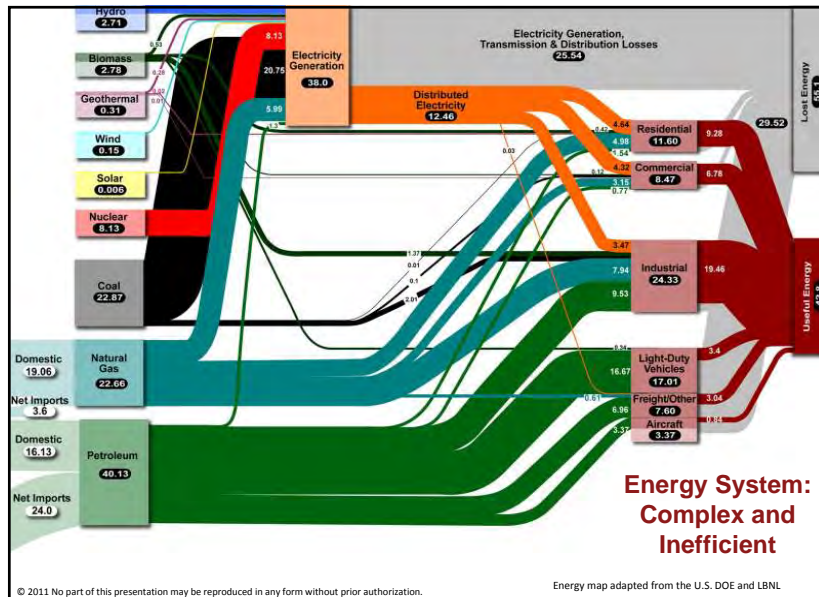
Source: Massoud Amin's Congressional briefings on March 26 and Oct. 15, 2009  
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**Focus: Energy Demand Growth and Fuel Substitution**  
**U.S. Energy Supply Since 1850**



Author: Koonin Source: EIA

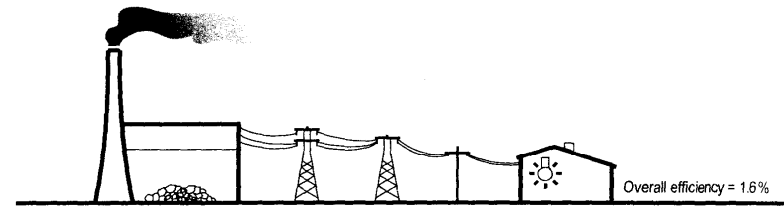
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Energy map adapted from the U.S. DOE and LBNL

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



Fuel = Coal  $E_0 = 1.00$     Power Plant  $E_1 = 0.35$     Transmission Lines  $E_2 = 0.90$     Light  $E_3 = 0.05$

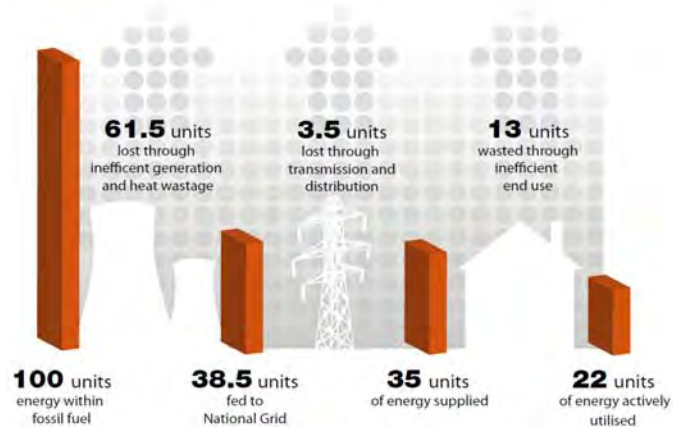
Overall Efficiency for Converting Chemical Energy To Light Energy =  $E_1 \times E_2 \times E_3 = 0.35 \times 0.90 \times 0.05 = 0.016$

**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)

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## End-to-end Energy Infrastructure System Inefficiency



Source: M. King and R. Shaw, "Community energy: planning, development and delivery," Town and Country Planning Association, Gosport, United Kingdom, 2010 © 2011 No part of this presentation may be reproduced in any form without prior authorization.

Smart Grid: Technological Innovations

## End-to-end Electric Power System



Generation

Delivery

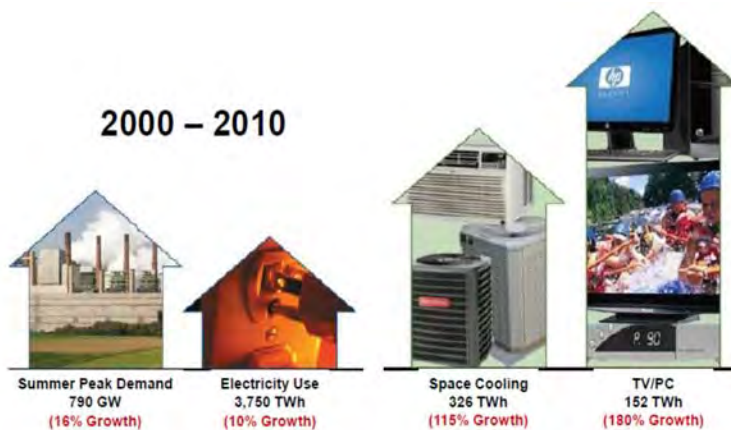
Customer

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Trends in Electricity Use (2000-2010)

## Electronics and Continued Electrification Drive the Growth

2000 – 2010



Source: EPRI, 2011

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Consumer Technology's Next Trend?

## Digitization of Society...in its infancy

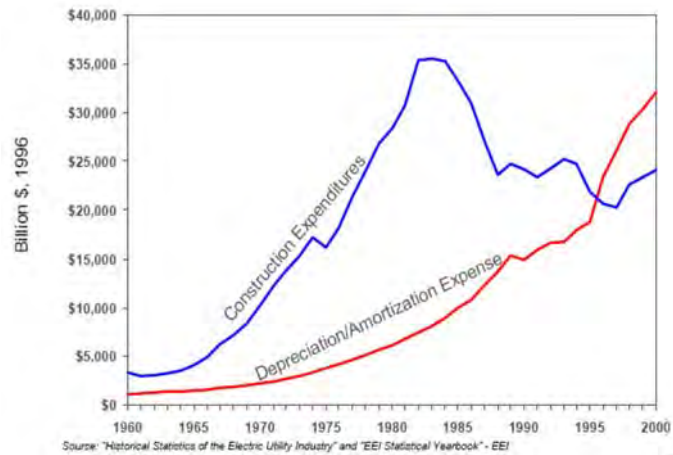
2011...one billion tweets sent every week!  
At 0.025 watt-hours per tweet >>> 2500MWh



- **The Next "Industrial Revolution"...Data Centers**
  - Electric load expected to Double Every 5 Years...
  - By 2030 Could Reach 20% of Total U.S. Electricity Use
- How many watts used per iPhone, Smart Phone & Blackberry device?
- What infrastructure quality of service and security do we expect?

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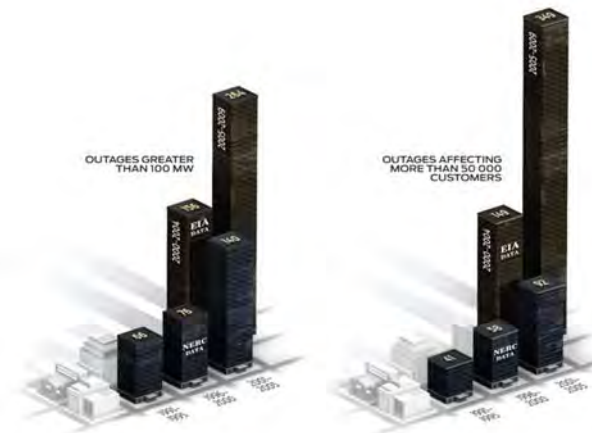
## Utility Construction: Overharvesting



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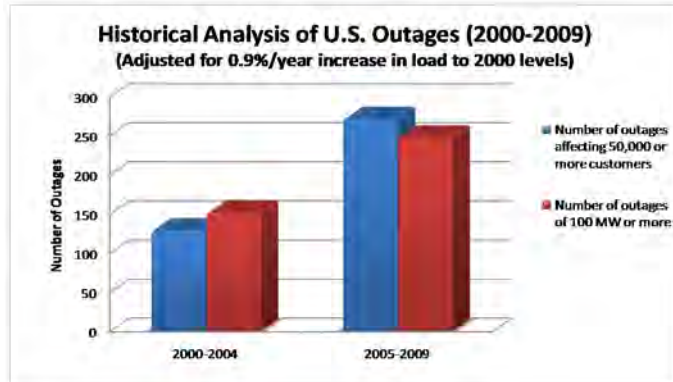
## Less Reliable Grid

Power Outages have steadily increased



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

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## Stronger Grid

## Emerging Supply and Demand Patterns

What is the most efficient carrier of energy? ... electrons

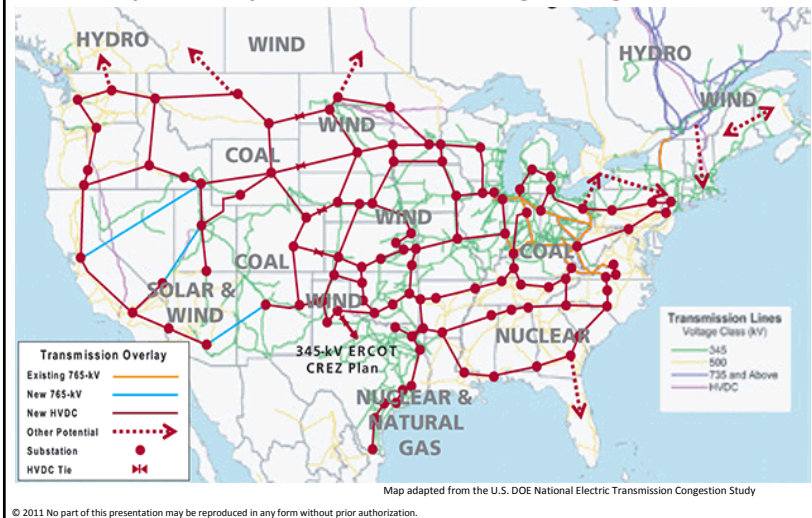


Map adapted from the U.S. DOE National Electric Transmission Congestion Study

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## Stronger Grid

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



## Stronger Grid

### 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.

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Sources: AEP 2007; DOE 2008

## Smart Grid: 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

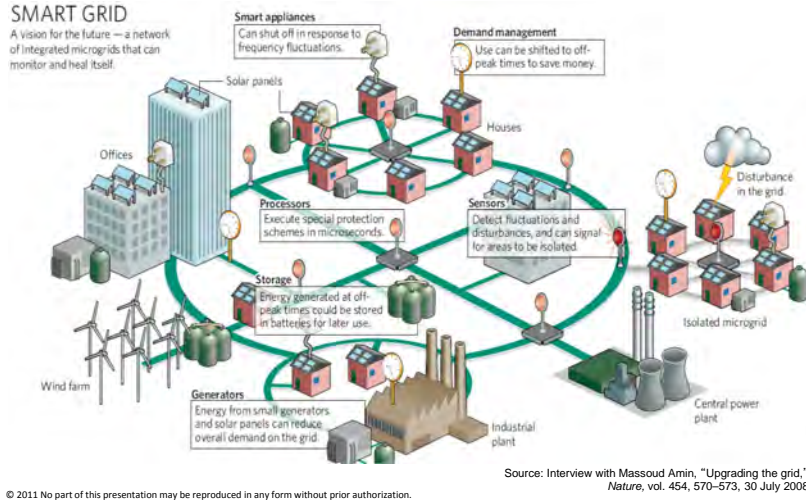
- **Increase energy efficiency**

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## Energy Independence and Security Act

- Passed by U.S. Congress in 2007.
- “It is the policy of the United States to support the modernization of the Nation's electricity transmission and distribution system ... that can meet future demand growth and to achieve each of the following, which together characterize a Smart Grid:
  1. Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid.
  2. Dynamic optimization of grid operations and resources, with full cyber-security...”

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



## 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."

**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."

**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..."

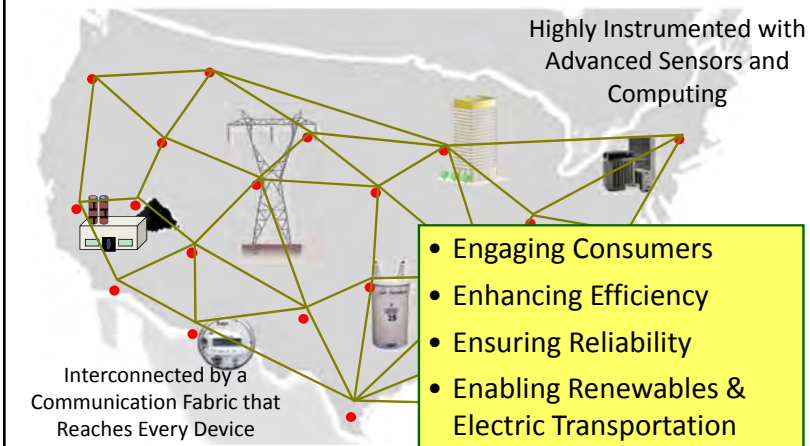
**Wikipedia:** "A Smart Grid delivers electricity from suppliers to consumers using digital technology to save energy, reduce cost, and increase reliability."

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

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

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## Many Definitions – But One VISION Visualizing the Smart Grid



## Smart Grid: Technological Innovations

### Customer

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



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## Smart Grid: Technological Innovations

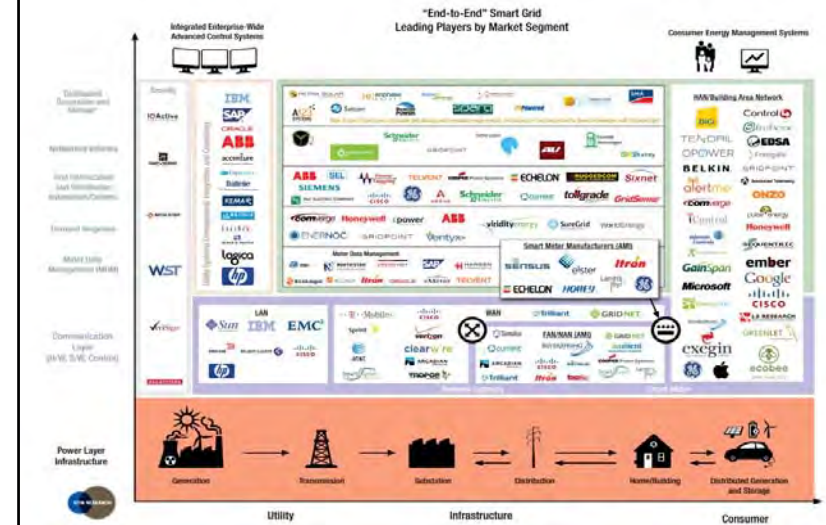
### Smart Grid and Power Delivery



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

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## End-to-End Smart Grid Players/Opportunities



## Smart Grids: Awareness, Costs and Benefits

### Awareness:

- Electricity outages cost over \$150 billion/year
- ~68% of consumers in the U.S. don't know what "Smart Grid" is...

### Costs:

- \$17-\$24 billion/yr (\$338 and \$476 billion)

### Benefits:

- Increases efficiency by 5% (\$20.4 billion in savings annually)
- Reduces costs of outages by about \$49 billion/year
- Reduces emissions by 12-18% by 2030
- Decrease infrastructure investment costs by \$46-117 billion
- Economic growth:
  - Adds \$1.8 trillion in annual revenue to the U.S. economy by 2020. Benefits could be as high as \$2.3 trillion for the U.S.
- Our \$14 trillion economy depends on reliable, disturbance-free electricity

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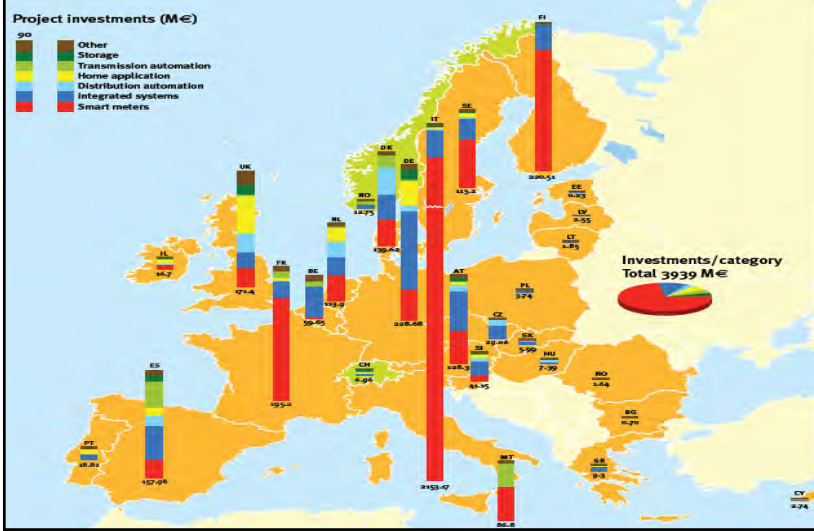
## Smart Grid: Options, Costs and Benefits

### Investments in Smart Grid Technologies

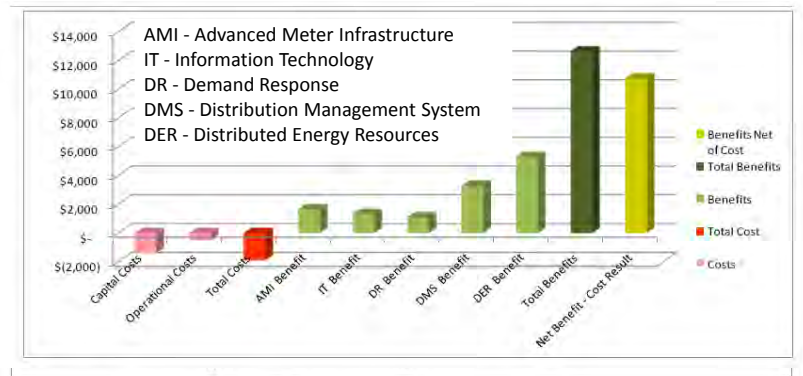
- Factors that boost SG investment and technology in the short term:
  - Analytics: Mining data to increase understanding
  - Standards consolidation
  - Increasing penetration of solar and electric vehicles: Demand shifts, integrate new tools and technologies.
- Emerging markets could leapfrog other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

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## Example: Smart Grid projects in Europe



## West Virginia Business Case



Source: National Energy Technology Laboratory

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## University Campuses & Cities are just the right scale for smart technologies to enable diverse value creation

"A highly original treat of human history... Incomparably readable as well as eminently instructive." - The Wall Street Journal

**NONZERO**

THE LOGIC OF HUMAN DESTINY

ROBERT WRIGHT

AUTHOR OF THE MORAL ANIMAL

**MORALS and MARKETS**

An Evolutionary Account of the Modern World

DANIEL FRIEDMAN

Villages = Too Small

Nations = Too Big

Cities = Just Right

Source: IBM, please also see Paul Romer's Charter Cities Video: [http://www.ted.com/talks/paul\\_romer.html](http://www.ted.com/talks/paul_romer.html)

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# What are we doing at the UofM?

## What are we working on at the U of Minnesota ?

- Integrating PHEVs into the grid for Minnesota and major cities
- Grid agents as smart, secure and distributed sensors and controls
- Fast power grid simulation and risk assessment (12-15 times speedup)
- More Secure and Smarter Grid
- Security of cyber-physical infrastructure
- Integration of Wind and Smart Grid Overlay into UofM-Morris
- Assessment of Smart Grid for UMore Park (30,000 homes and Commercial Bldgs)

University of Minnesota Center for Smart Grid Technologies (2003-present)  
 PI: M. Amin (support from EPRI, NSF, Honeywell, Sandia Nat'l Labs, ORNL, and UofM funding)  
 Dept. of Electrical & Computer Engineering  
 Faculty: Professors Massoud Amin and Bruce Wollenberg  
 PhD Candidates/Research Assistants: Anthony Giacomoni, Jessie Gantz, Laurie Miller, and Sara Mullen (PhD received 9/9, EPRI-Knoxville).

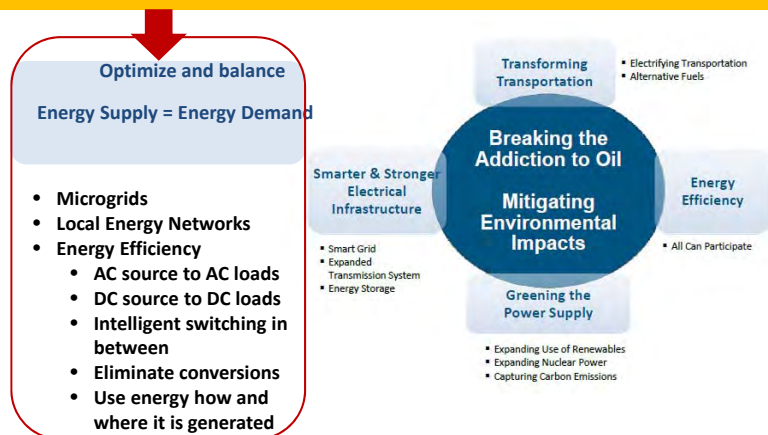


## Smart Grid U™

- 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.**



## Interface of Smart Grid and Buildings



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## Smart Grid assessment for UMore Park

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



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## 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.**

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## Master of Science in the Management of Technology (MOT) Overview

- Designed to equip full-time working professionals with the tools to clearly navigate the “grey zone” between business and science/engineering
  - Year 1 – focused on teaching business fundamentals
  - Year 2 – focused on merging science/engineering and business fundamentals to develop successful business strategy
- Develops leaders with the foresight and vision to develop robust strategies for the

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### Smart Grid: Options, Costs and Benefits

## 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



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## 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
<b>Small Lot</b>	1,600	2,500	2,050	\$225,000	\$350,000	\$287,500
<b>Traditional</b>	1,800	2,800	2,300	\$225,000	\$410,000	\$317,500
<b>Large Lot</b>	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
<b>Small Lot</b>	\$244,920	\$379,920	\$312,420	\$19,920	\$29,920	\$24,920
<b>Traditional</b>	\$244,920	\$444,720	\$344,820	\$19,920	\$34,720	\$27,320
<b>Large Lot</b>	\$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**

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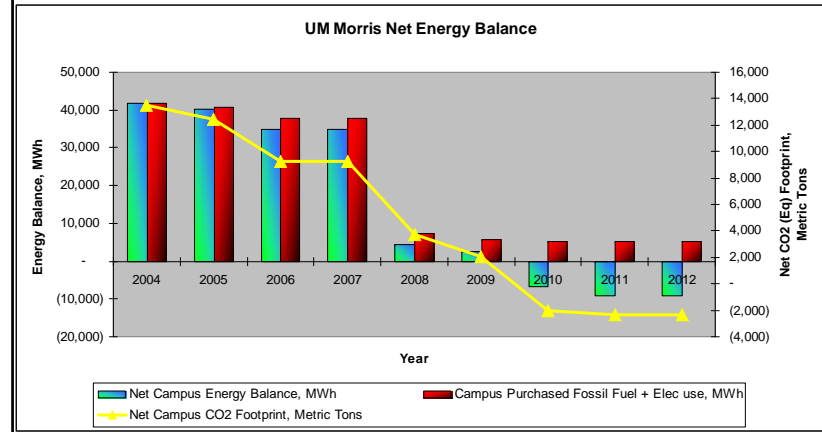
# UM-Morris Potential Smart Grid projects

- Location: Morris, MN
- Size: 1,800 student residential campus
- Energy Sources:
  - Biomass gasification plant
  - Solar thermal panels
  - Solar photovoltaic system
  - Two 1.65MW wind turbines (provides ~70% of campus's electricity needs)
- Load 300,000-750,000 kWh/month



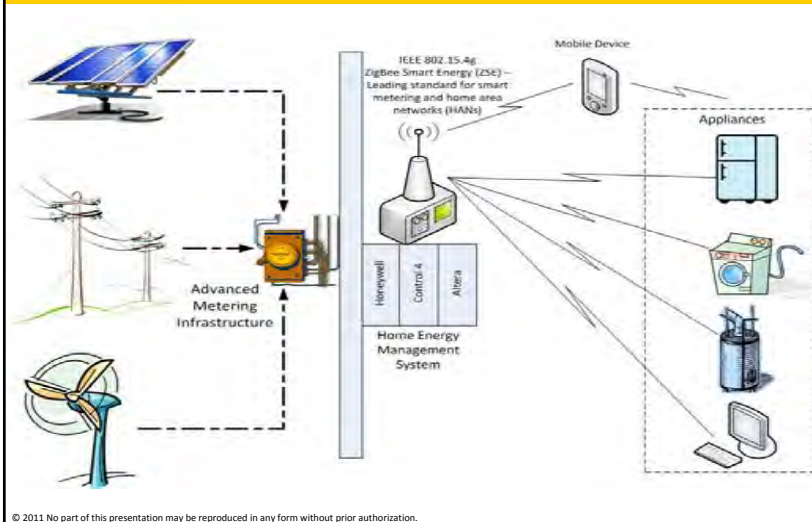
## Smart Grid: Options, Costs and Benefits

### Going Carbon Negative...



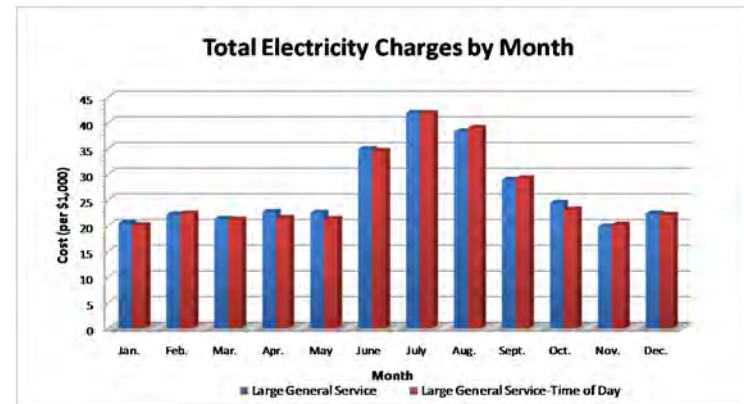
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## Local System Communication Overlay

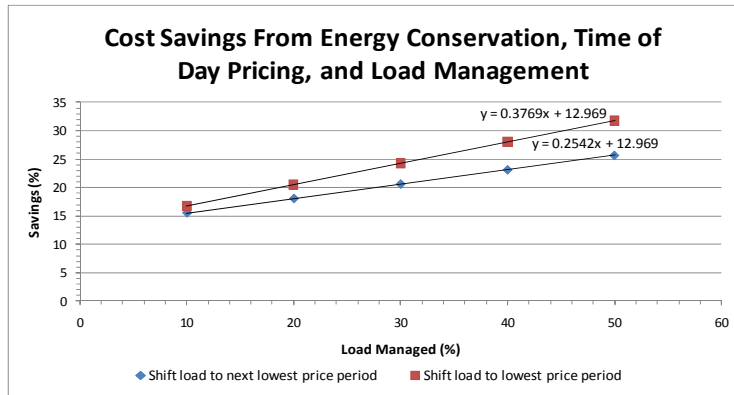


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## Rate Schedule Cost Comparison



## Total Cost Savings



## Total Cost Savings (cont.)

Load Managed (%)	Savings (\$)	Savings (%)
<b>Load Shifted to Next Lowest Price Period</b>		
10	51,398	15.5
20	59,823	18.1
30	68,247	20.6
40	76,671	23.1
50	85,096	25.7
<b>Load Shifted to Lowest Price Period</b>		
10	55,463	16.7
20	67,952	20.5
30	80,442	24.3
40	92,931	28.0
50	105,420	31.8

## Building a MN Smart Grid Coalition

- The Smart Grid Working Group foci:
  - Consumer preferences
  - Systems
  - Duluth Demonstration
  - SmartGrid U Demonstration\*
- Key elements of Smart Grid Roadmap and potential timetable for implementation:
  - Identified appropriate smart grid pilot projects/demonstrations
  - Develop the generation/transmission/utility/customer model
  - Develop a portfolio for Minnesota Smart Grid capabilities
  - Articulate the story for stakeholders
  - Develop state regulatory model to support this market

- \* - Phase 0: "Smart Room"
- Phase I: "SmartGrid School"
- Phase II: "SmartGrid U"
- Phase III: "SmartGrid City"

Evolve from "Smart Room" to "Smart Building" to "Smart Campus"

Create a "Smart Grid Sandbox" at the U of M where companies could contribute their SG technologies and expertise to see what works - and what works together - a CoLab and "skunkworks" projects.



## Key Findings - Smart Grid Minnesota Existing Resources

- Minnesota Wind Power Generation**
  - 4th in Nation in Total Installed Capacity - 2,192 MW
  - 297.9 additional MW currently under construction

(Source - American Wind Energy Projects, January 2011)

State	Total Installed Capacity (MW)
Texas	10,085
Iowa	3,675
California	3,177
Minnesota	2,192
Washington	2,104
- 700 Mhz Licensed Wireless Grid Communication Network**
  - First implemented by Great River Energy, then adopted by over a dozen Minnesota Co-ops
  - High-Reliability 2-Way Communication for Grid Monitoring and Control
  - Gaining broader recognition as a national model for reliable Smart Grid communication

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## Key Findings - Smart Grid Minnesota

### Technology and Service Providers, Projects

- **Technology and Service Providers - with MN offices**
  - Cooper Power Systems - grid demand management systems
  - Digi International - technology to help utilities monitor and adjust end-user consumption during peak demand events
  - Ecologic Analytics - software for meter data management (MDM) and decision management
  - NorthWrite - web-based energy monitoring and analysis tools (received \$5 million ARRA for Idaho school efficiency project, Feb 2010)
  - Open Access Technology International (OATI) - software to track energy transmission and scheduling
  - Open Systems International (OSI) - software for energy management, communications, and cyber security
- **Smart Grid Projects - Existing**
  - Great River Energy/Arcadian Networks - 700 Mhz Licensed Wireless
  - Xcel Wind Storage Project - test of 1MW Battery Storage and grid integration at Luverne Wind Farm (with MinWind LLC)

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## Key Findings - Minnesota Energy Sector

- **Renewable Energy Research at UMN**
  - 3 ARPA-E National Finalists (only 80 National Finalists from 3,700 applicants) - Awarded 1 of only 37 ARPA-E grants
    - Bacteria for high-volume, hydrocarbon feedstock production (\*Grant Winner)
- **Combining carbon sequestration with geothermal energy use**
  - Reversing combustion by cycling CO2 and H2O back into higher energy density hydrocarbon fuels using only solar energy
  - IonE (IREE and NISE) - Renewable Energy and Sustainability Research
- **Resources**
  - UMN Wind Turbine Research Center - Received an \$8M DOE grant to install a Siemens 2.3MW turbine for experimentation
- **Emerging Technology - Energy Storage**
  - Silent Power sub transmission scale storage
  - iCel Systems Energy Lab (St Paul) - Production facility for Lithium Ion battery storage
  - EcoVoltz - developing a lower cost flow battery solution for grid-level storage (searching for potential wind farm pilot sites)

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## 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.**

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and rewarded on the value their thoughts bring to humanity  
powered workers in a corporation may power the economy  
itself. Change is accelerated by the fundamental ability  
to anticipate it. The time to prepare for the future  
and the future is now. The time to prepare for the future  
management, human capital, social development, energy  
virtual, competitor's new product will be a market per  
the rule of  
services, don't  
of goods and services, and the developed world  
they are than three offerings meaningful to the co  
value has migrated away from the p  
systems, don't  
global, cost-denominated, capital accessible. Overcapa  
growth, competition, and no pricing power based on  
product differentiation by a brand dominance. Org  
visibility, your networks, and your awareness of the  
comes with empowered and interconnected networks. The new

# An Engine for Economic Growth

## Global Technology Diffusion



June 2006

Guangdong  
Science Center --  
China  
Opened 2008



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## What Lies Ahead?

...to the age of Security?

...to the age of Energy?

...to the age of Global Competitiveness?

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## Macroeconomic Rationale

Endogenous growth models –

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

$Y = \text{GDP}$

$R = \text{R\&D}$

$K = \text{physical capital}$

$H = \text{human capital}$

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

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## 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 - ?)

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# Entrepreneurship:

- College of Science and Engineering 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.

**WORLDWIDE**  
 ACTIVE COMPANIES  
 4,150  
 EMPLOYEES  
 551,000  
 ANNUAL REVENUE  
 \$90 BILLION

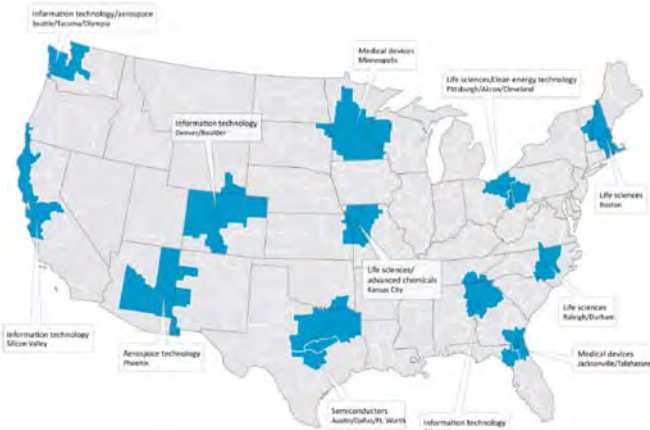
**IN MINNESOTA**  
 ACTIVE COMPANIES  
 2,600  
 EMPLOYEES  
 175,000  
 ANNUAL REVENUE  
 \$46 BILLION

[http://cse.umn.edu/prod/groups/cse/@pub/@cse/documents/content/2005\\_04\\_founders\\_survey\\_pdf.pdf](http://cse.umn.edu/prod/groups/cse/@pub/@cse/documents/content/2005_04_founders_survey_pdf.pdf)

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**A Minnesota Engine for Economic Growth**

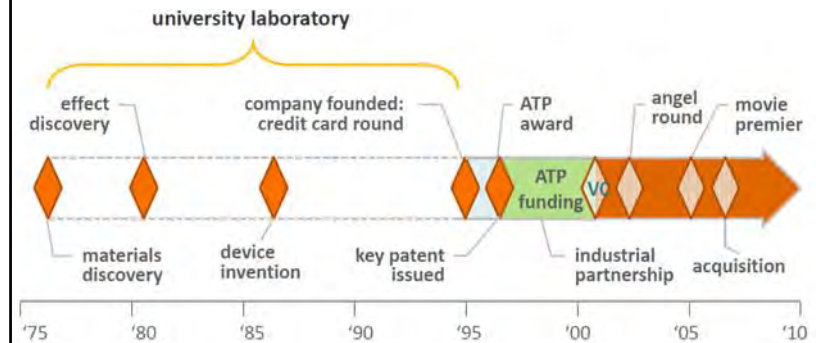
## “Geography of Innovation\*”



\*Source: Cluster Mapping Project, Institute for Strategy & Competitiveness, Harvard Business School

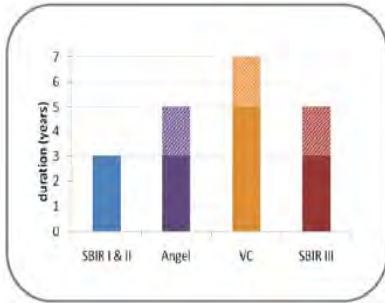
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## Staying Power: A Long Timeline...

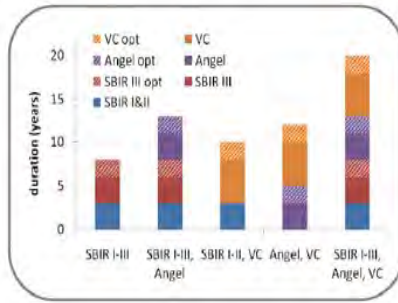


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# Small Companies need Staying Power...

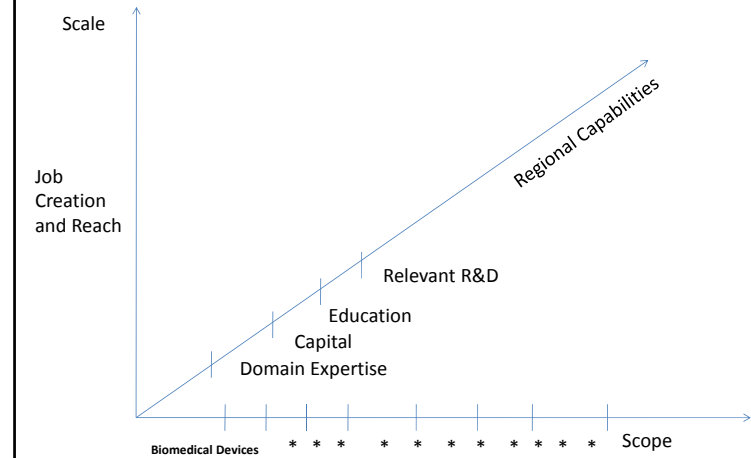


Durations of various innovation financing mechanisms

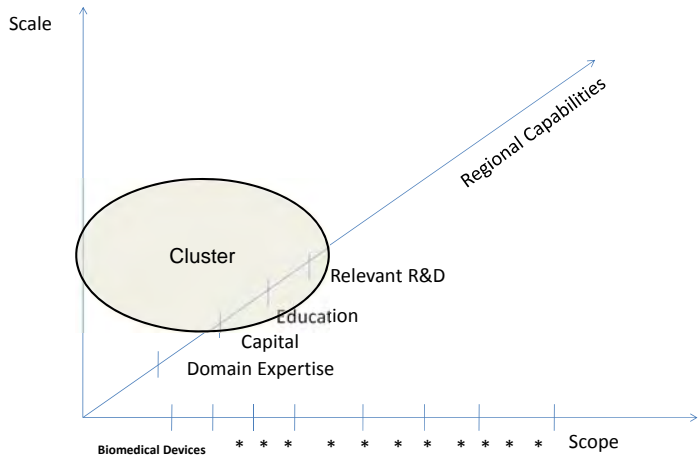


Combinations of financing types possibly applicable to companies pursuing fundamental innovation

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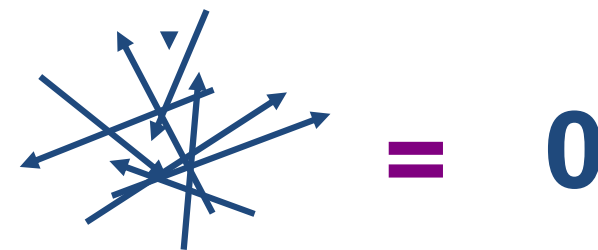


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# When Innovation *Doesn't* Matter Remember Your Vector Math Class!



Bubble-up Innovation  
Many Types

When organizations "peanut-butter" innovation,  
nothing of significance happens

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## An 'About FACE' is Required

- Focus
- Alignment
- Collaboration

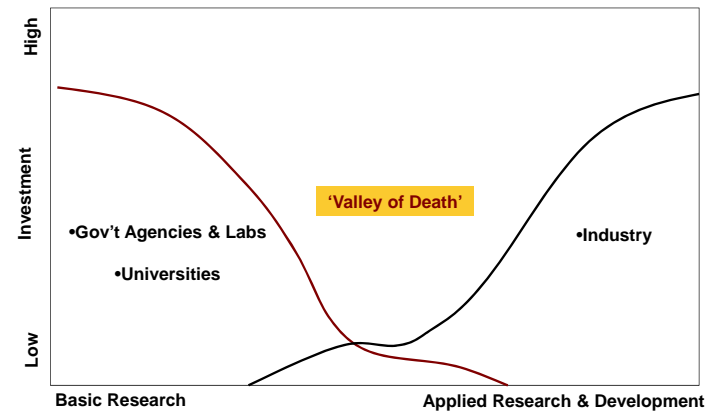
**Begin with a 360 Systems' Approach and the End Goal in Mind:**  
Focus on a few big 'problems that matter' to our nation and the world in the next half century



**Exploit Core Competencies to Address Strategic Areas:**  
Focus on the intersection of 3-5 problems that matter **AND** our core competencies (build and leverage expertise, Government/Industry/University relationships, to power economic growth).

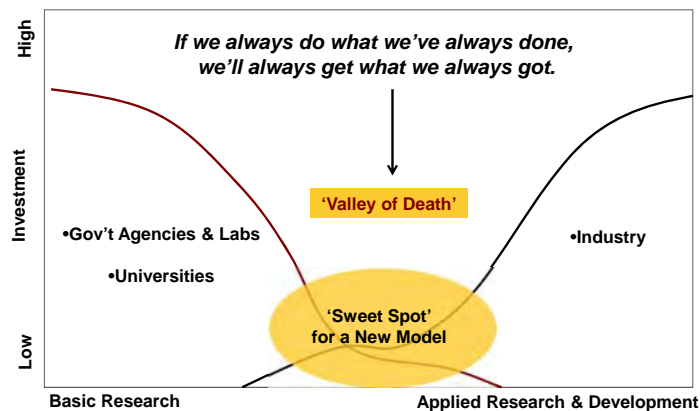
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## A 'Valley of Death' divides Research and Development



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## More of the Same is Not an Option (if long-term relevance matters)

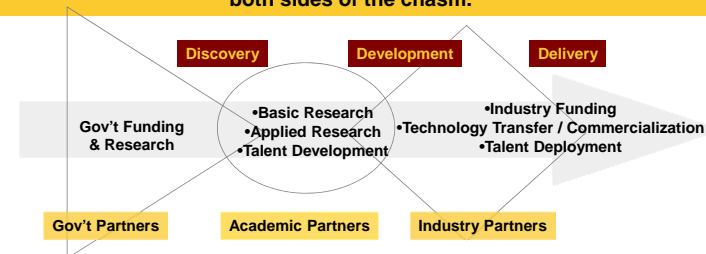


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## An 'About FACE' is Required

- Focus
- Alignment
- Collaboration
- Execution

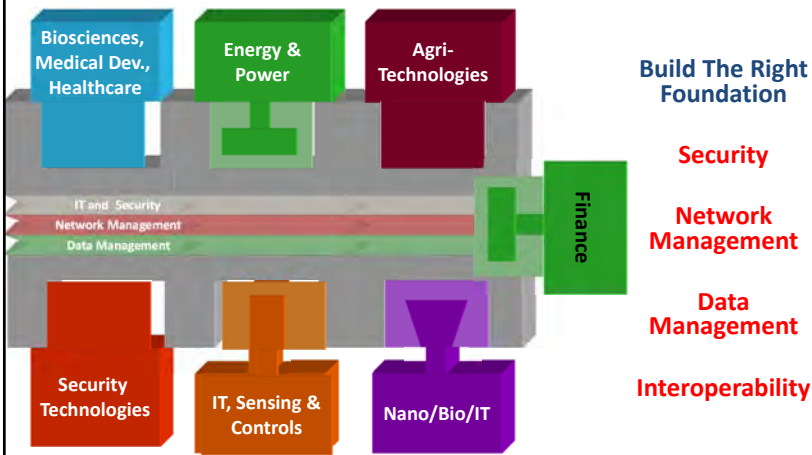
**Align and Conquer:**  
In the critical few areas of focus, develop a new 'value delivery system' to bridge the Valley of Death by forging strategic alliances with key stakeholders on both sides of the chasm.



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## Minnesota's Technological Leadership Role:

Enabling Economic Growth → First Build the Right Foundation



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## Example of Cluster Potential

- Nano Based Sensors
  - Bio, Electronic, Bio-chem, Medical, Bio-Mechanical
  - Agriculture
    - Bacterial, Time/Temperature, Tracking,
  - Power, Switching, Regulating
- Smart Grid Technologies
- Security
  - Software and Resilient Architectures
  - Anticipatory Modeling
  - Intelligent Layered Detection/Defense Systems
- Economic Modeling
  - Sensor impact
    - As scientists and engineers we learn **“if you measure it, you manage it”** a prerequisite to **if you price it, you manage it even better.**

Source: In collaboration with Mr. Michael Wright, TLI Sr. Fellow and author of *The New Business Normal*, 2005

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Smart Sensor Technology  
Smart Grid  
Smart Bio  
Smart Ag  
Smart Distribution  
Smart Networks

All with Security Built-in as a Part of Resilient Architectures

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

Albert Einstein

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# I-35W bridge

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, Reuters, 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 Ballarín, 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.



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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



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## 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>



## Smart Grid Goals

Develop Robust Electric Power Infrastructures

Increase Electric Power Energy Efficiency

Integrate Renewable & Distributed Power

Electrify Transportation

Promote New Customer Focused Energy Business Models

Sustainable Electrical Power

M. Amin, Chairman, IEEE Smart Grid Newsletter <http://smartergrid.ieee.org/publications/smart-grid-newsletter>

## Observations and the Road Ahead:

- What are the key energy, environmental and economic issues facing our campuses, communities, cities, our nation, and the world?
- Service Innovation/Business: “What are the range of new services enabled by smart grids?”
- Goal: transform our cities and counties into Smart Grid Communities, and the University of Minnesota’s campuses into *SmartGridU*
- Policy:
  - Smart grids, Smart buildings and “Smart Grid cities” included in all energy legislation
  - Smart grid’s potential as an “enabler in local, state and federal regulatory policies” to drive economic growth

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## Bottom Line:

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

*-- Peter Drucker*

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