"Where there is no vision, the people perish."
- - Proverbs 29:18

ELECTRIC POWER RESEARCH INSTITUTE

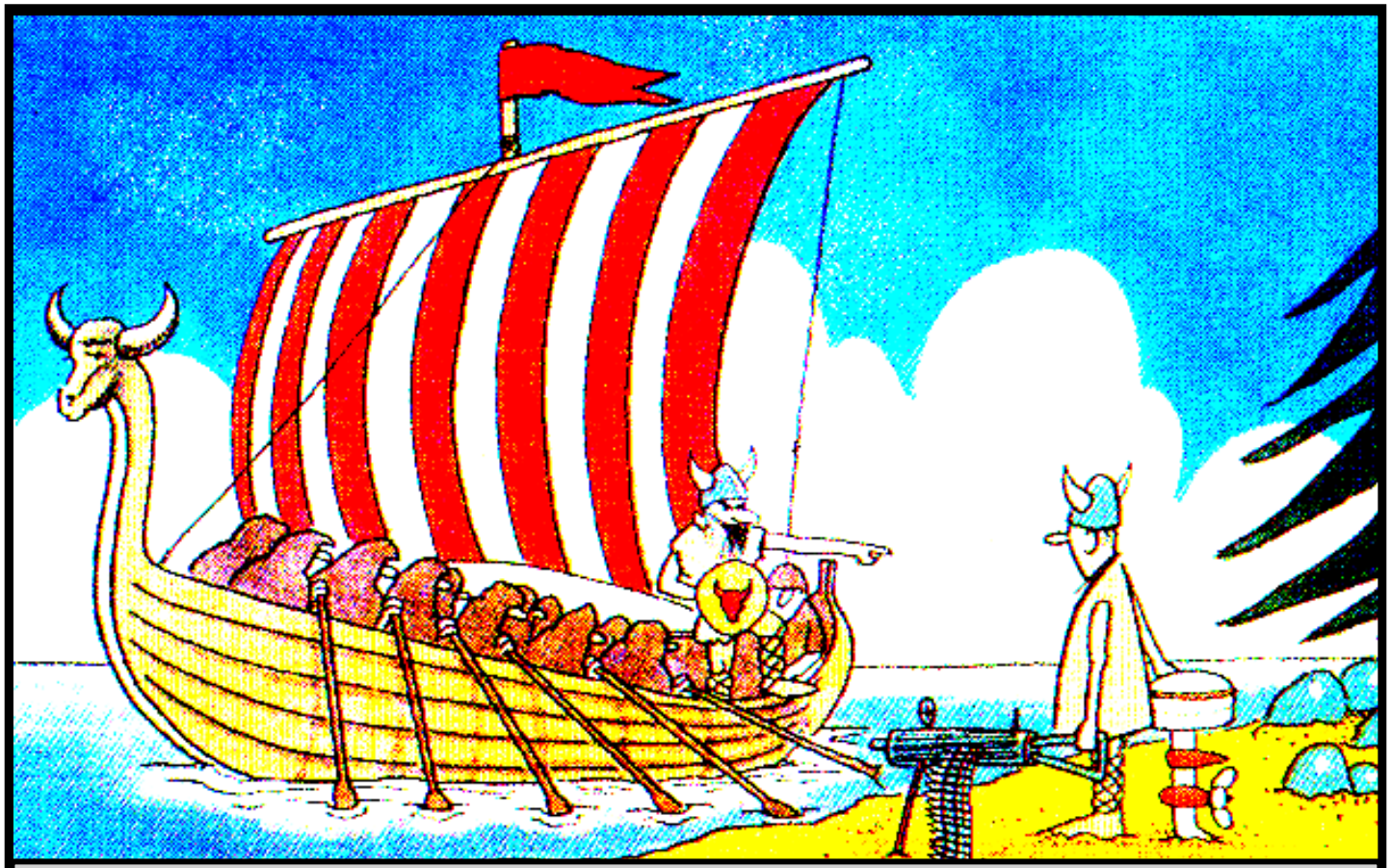
Exciting R&D Activities at the Electric Power Research Institute (EPRI)

Robert Schainker,
Technical Executive, Strategic Planning
Electric Power Research Institute
rschaink@epri.com

February 21, 2007

"We can't solve problems by using the same kind of thinking we used when they were created."

-- Albert Einstein

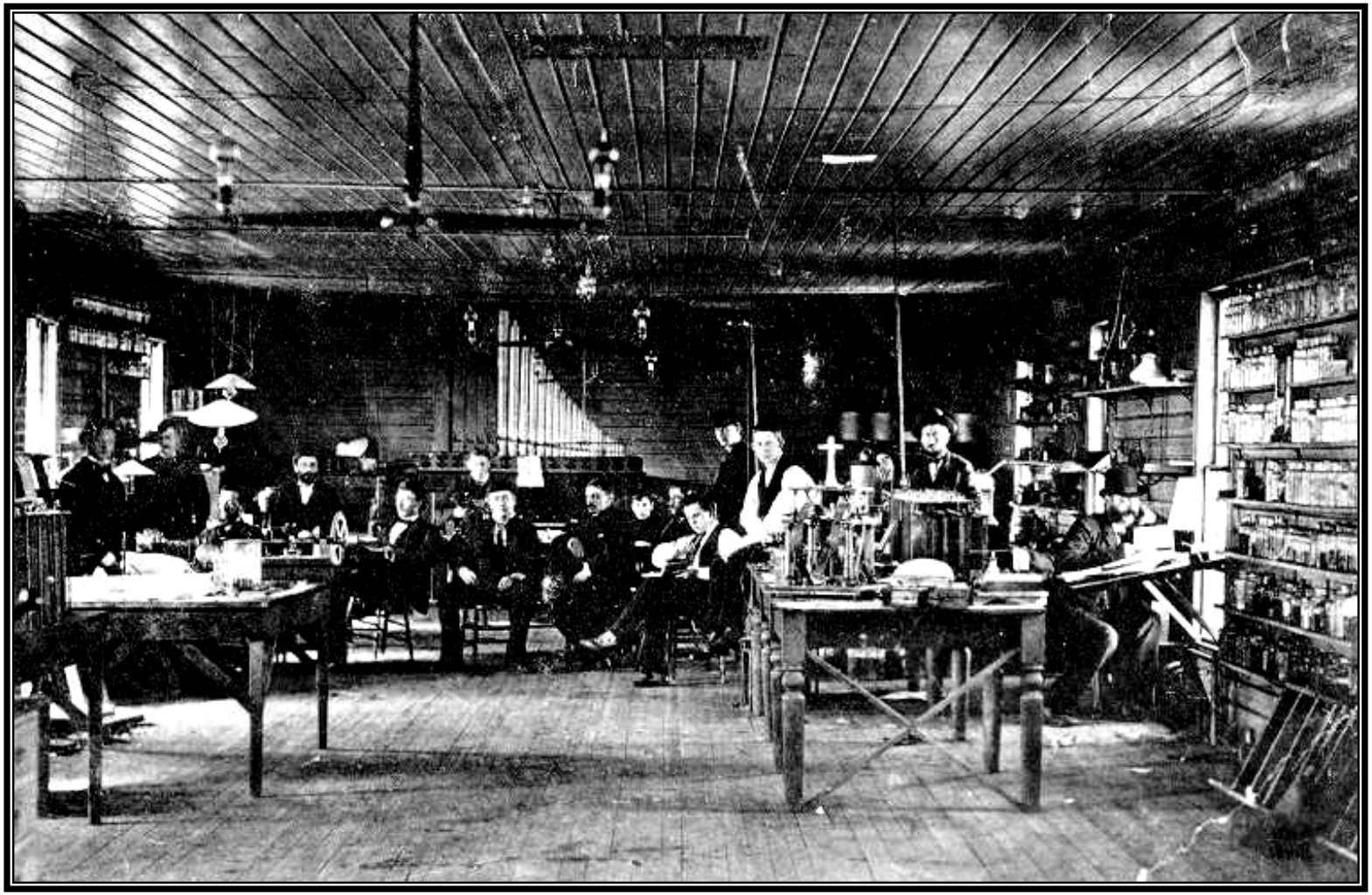


“ Do not bother me with your fancy new products and strategic plans – I have a war to fight! ”

Topics

- *Electric Power System Overview*
- *The Role of EPRI in Electric Utility R&D*
- *Key Drivers of R&D*
- *Scenario-Based Approach for R&D Planning*
- *Key R&D Opportunities*
- *Example of Recent R&D Results*
- *EPRI R&D Employment Opportunities*

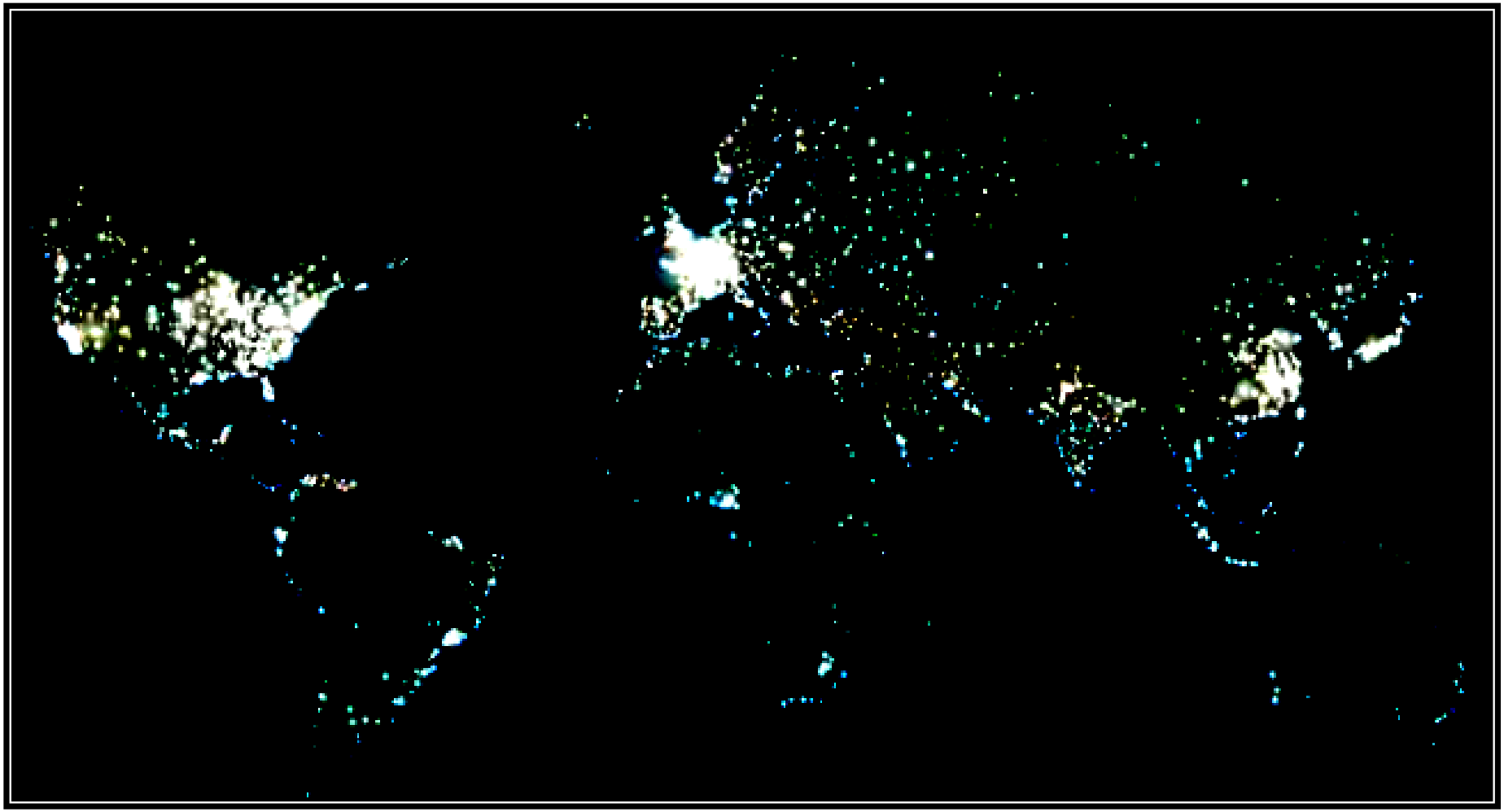
Thomas Edison (Front Left, Dark Cap) and His Menlo Park, NJ Team In The Second Story Of His Menlo Park R&D Laboratory



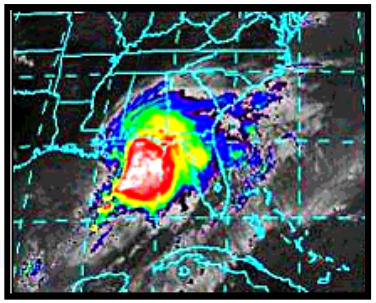
Picture Taken Soon After New Electric Lights Were Installed February, 1880)

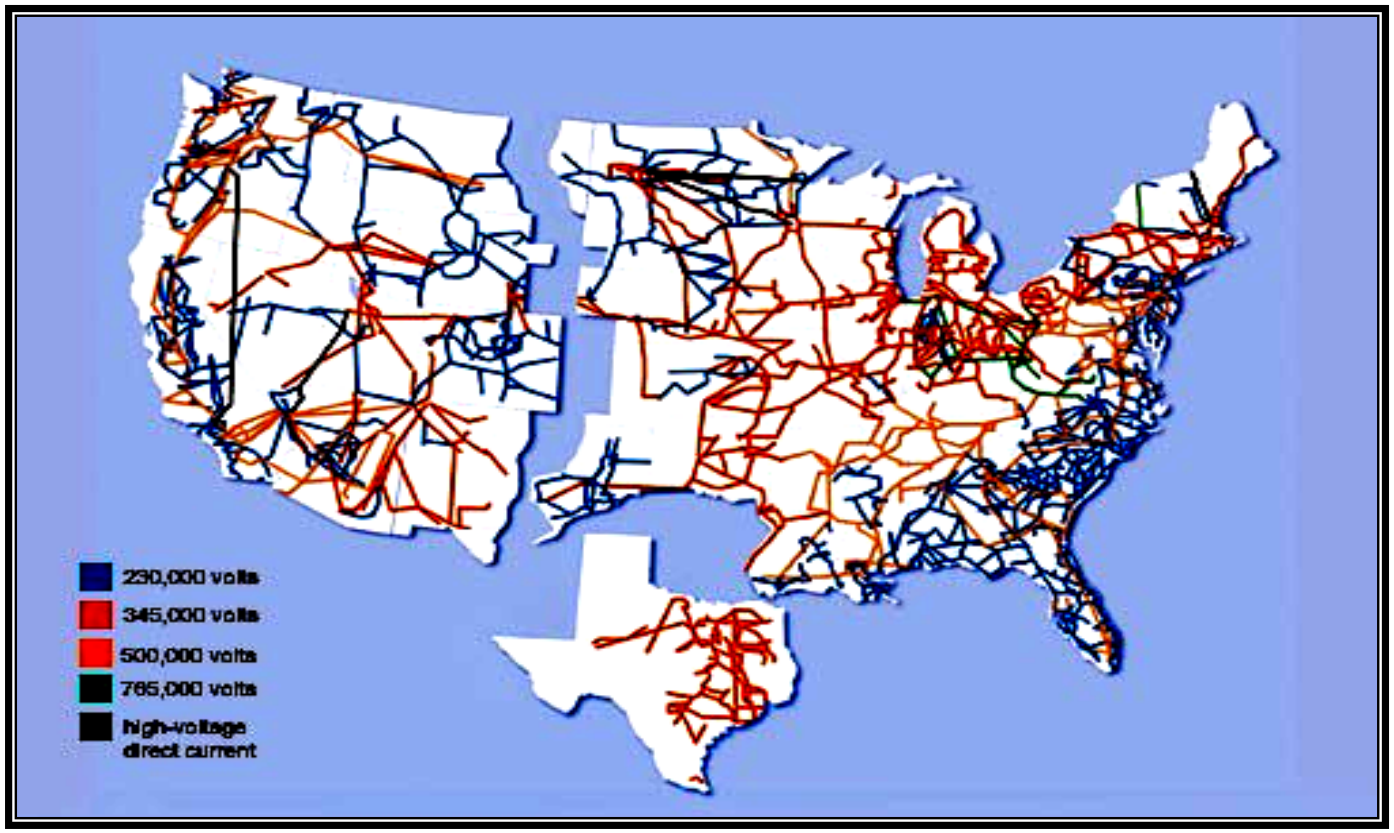
The vast networks of electrification are the greatest engineering achievement of the 20th century – U.S. National Academy of Engineering

The Electric Benefit Light Show Is On Every Night



The Scale and Complexity of the US Electricity Infrastructure

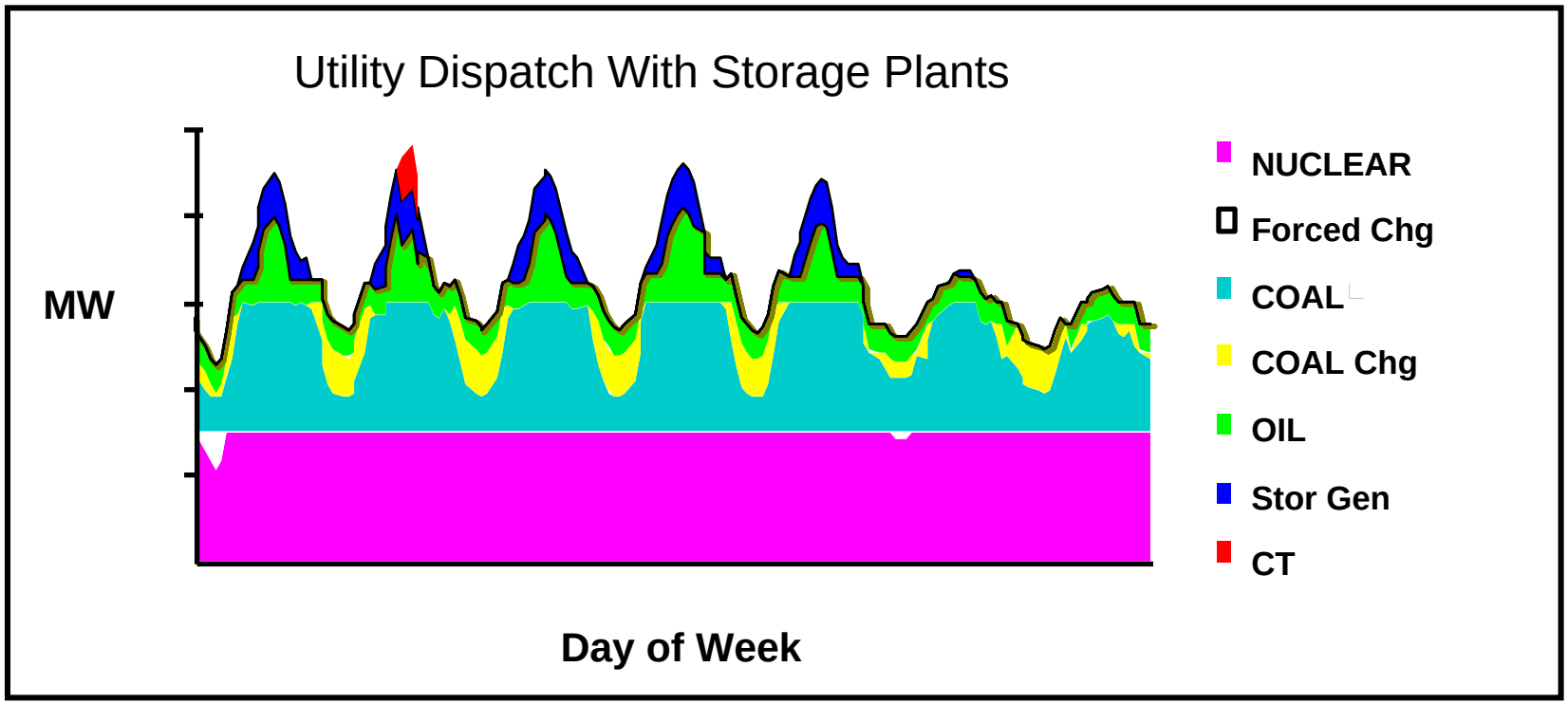




- **The US grid is composed of three separate alternating current (AC) 60 cycle / second synchronous systems connected together by a few AC-DC-AC links**
- **There are four types of electric utility owners: investor, federal, municipal, and rural cooperatives**

US Electric Sector

- **5,000 Power Plants; 800,000 Megawatts (MW)**
- **158,00 Miles of Electrical Transmission lines (230KV and above)**
- **Generation must follow customer diurnal MW power demand**



“Drivers” into the Future

- Load growth = 35% in last decade
- Capacity growth = 18% in last decade
- Peak demand expected to grow 1.8%/yr for next decade
- Wholesale transaction growth = 400% in last decade
- New rights-of-way difficult to obtain
- Focus is on transferring more power over existing rights-of-way and building more lines when and where possible
- Climate issue will transform generation mix and efficiency requirements throughout electric infrastructure

How is the Industry Changing? - - Institutional Considerations

- States are deregulating generation
- States are continuing to regulate distribution
- Transmission has been re-regulated to the federal level
- Operation of the grid is controlled by regional authorities that must meet federal requirements

EPRI is One of the World's Largest and Most Successful R&D Organizations

- Over 700 North American members
  - Over 90% of North American electricity generated
- Over 130 international participants
- Independent not-for-profit collaborative research
  - Generation
  - Power Delivery
  - Environment
  - Consumer

EPRI's Role in the Technology Development Process

National Laboratories

Universities

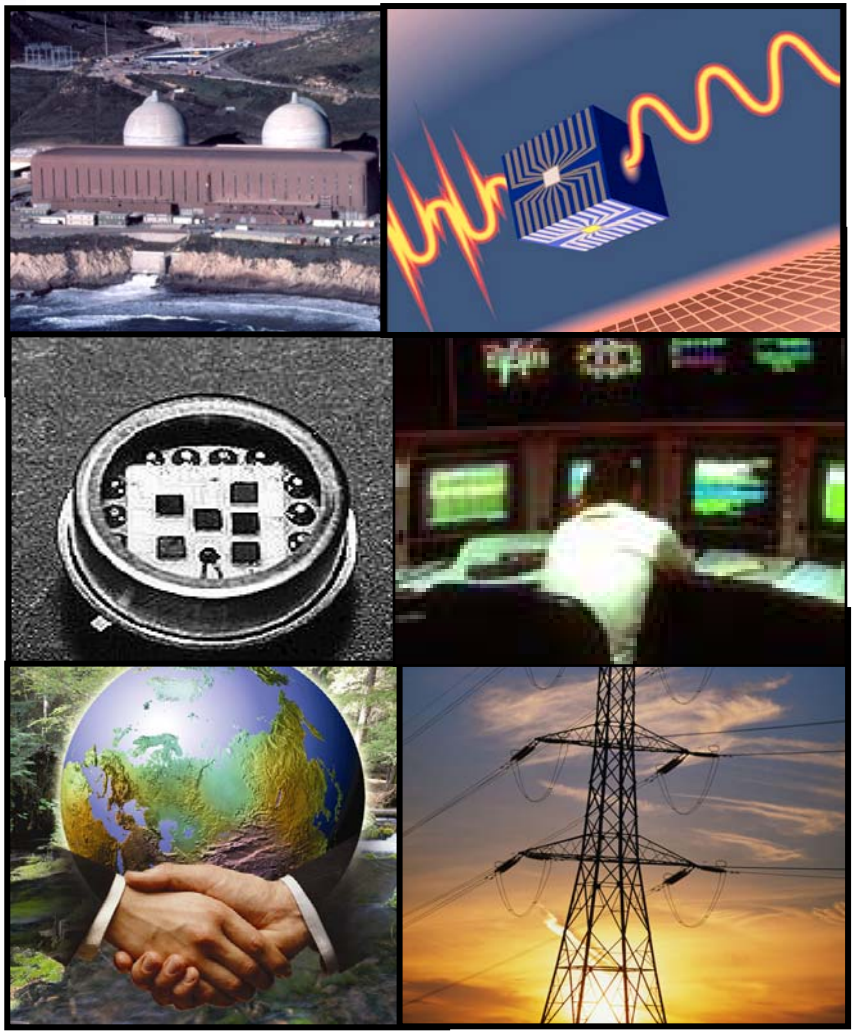
EPRI

Suppliers

Vendors

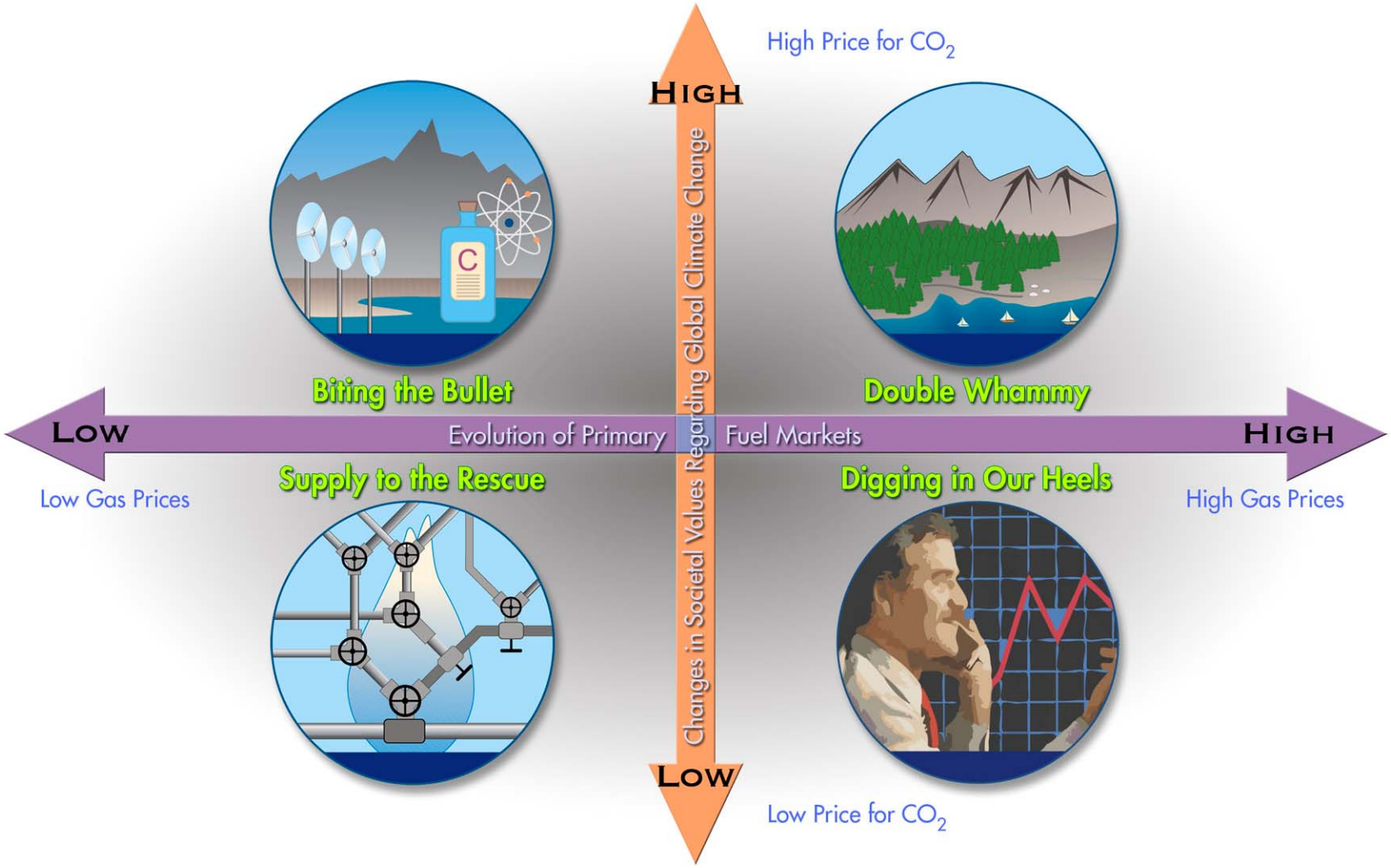
EPRI's Role Depends Upon The Specific Technology Under Consideration

R&D Challenges

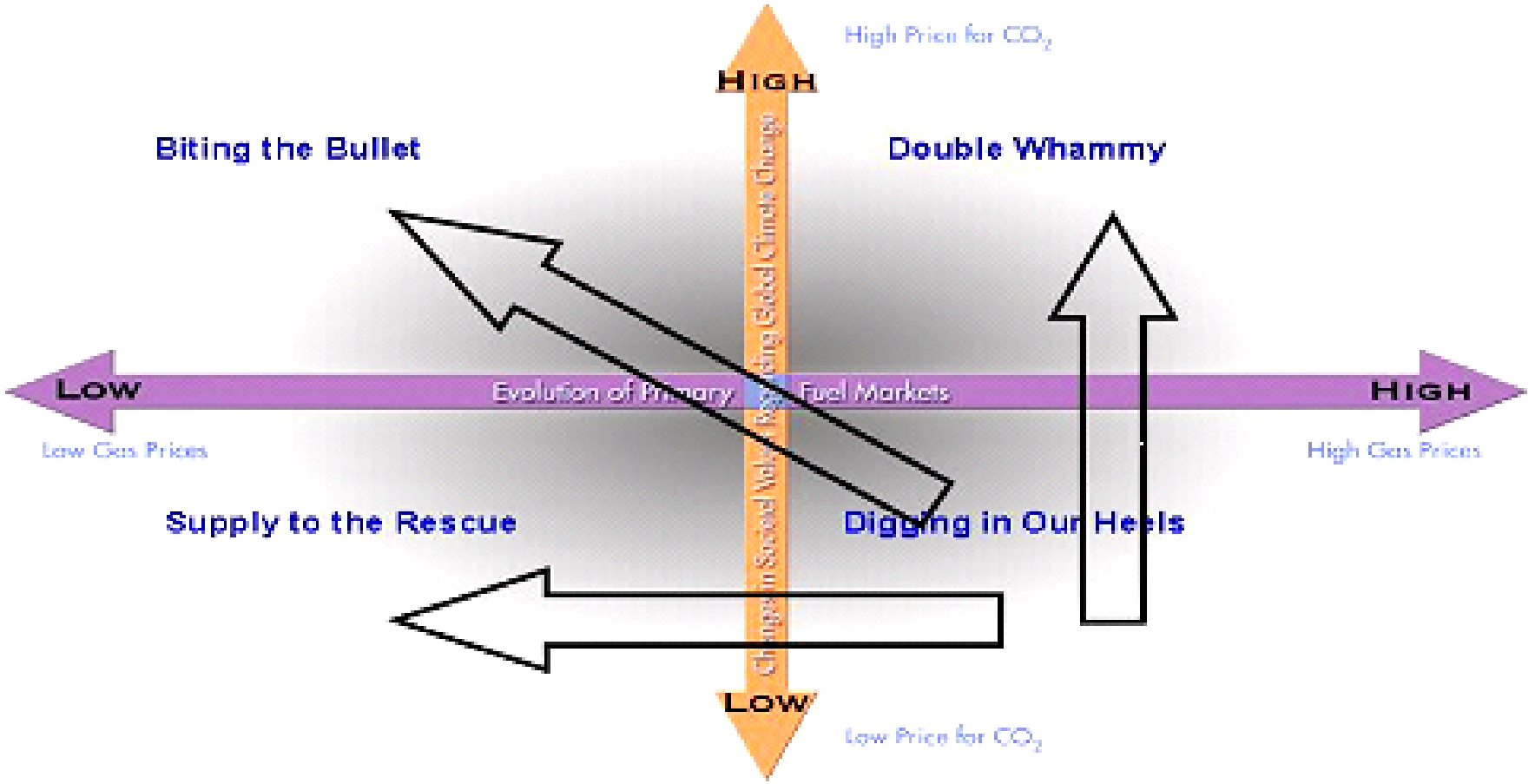


- Reduce CO_2 and Environmental Impacts
- Enable Self Healing Grid
- Relieve Transmission Bottlenecks
- Develop Consumer Communication Portal
- Provide Digital Grade Reliability
- Enable Plug-In Hybrid Vehicles and Distributed Generation and Storage Resources
- Deploy Integrated Electric and Communications “Superhighway”

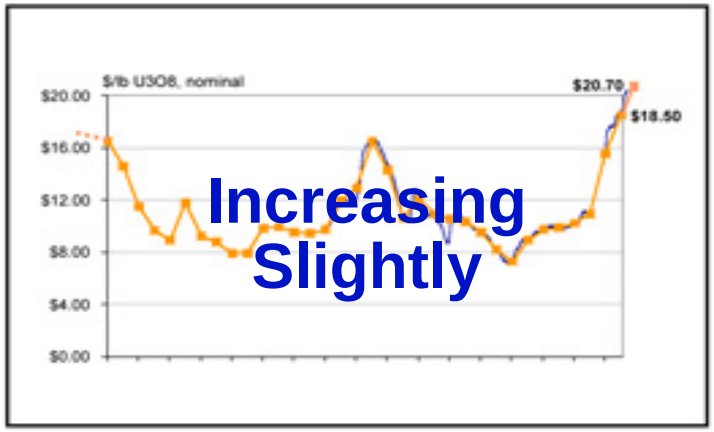
"What If" Scenario's Illuminate R&D Investment Opportunities



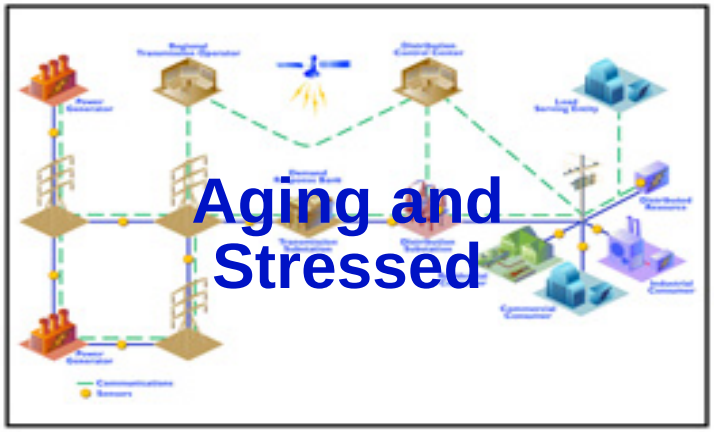
Important Consideration:
Don't "Bet" On Only One "Future" Occurring and Not Changing Into Another "Future"



Predetermined Elements



Uranium Prices

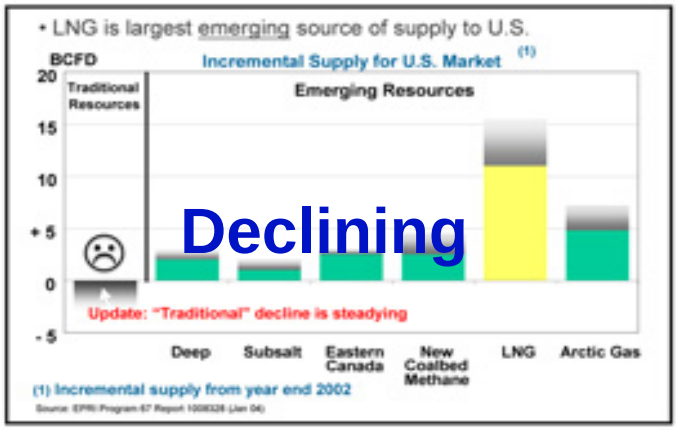


T&D Infrastructure

Coal Supply

Environmental Regulation

Predetermined Elements



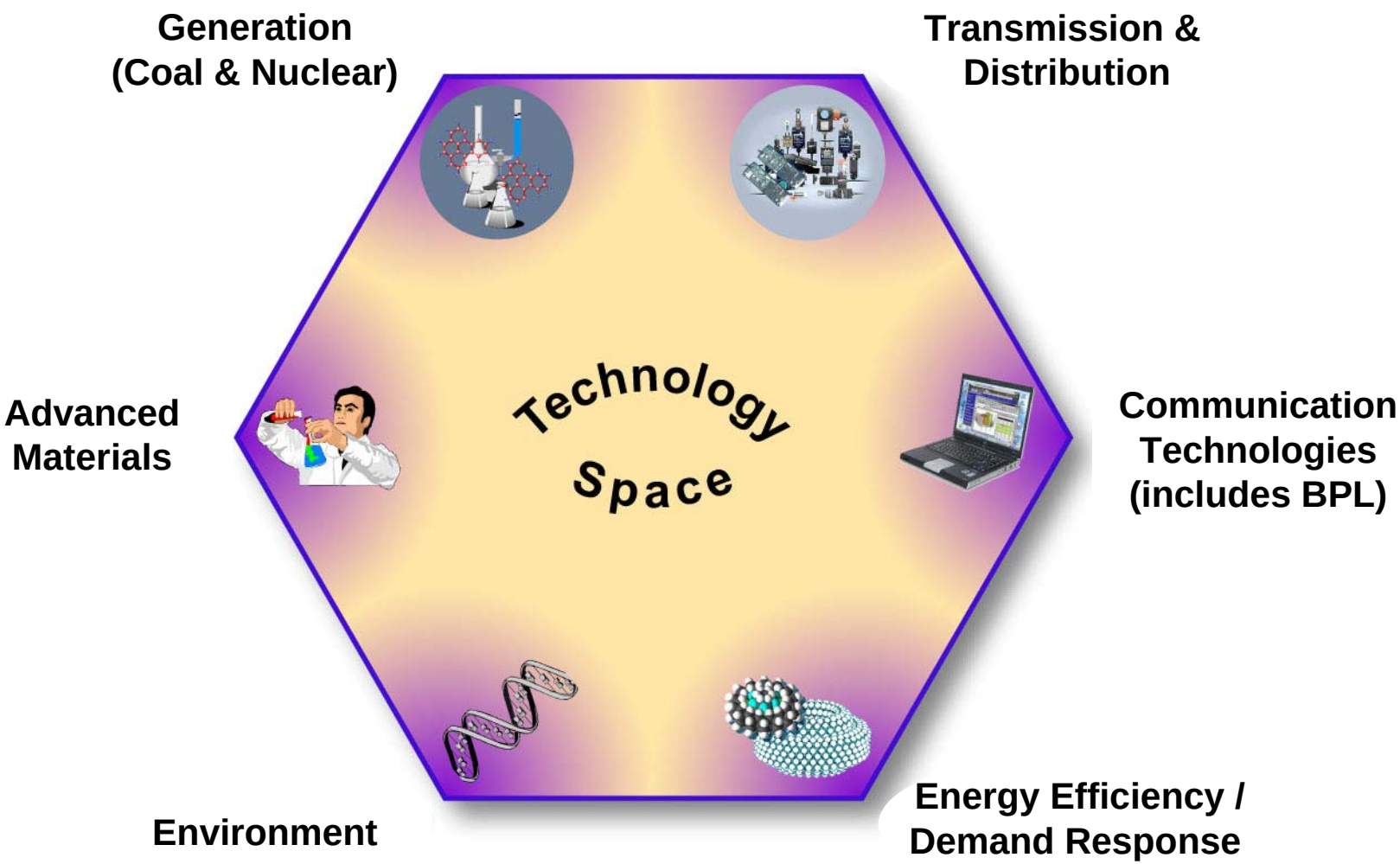
Domestic Gas Supply

Renewable Portfolio Standards

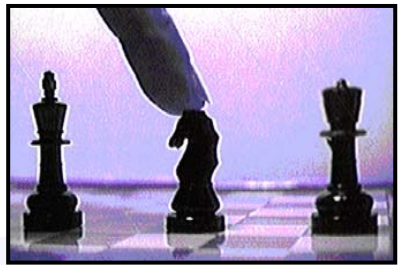
China & India

Local Distribution

Technology Space



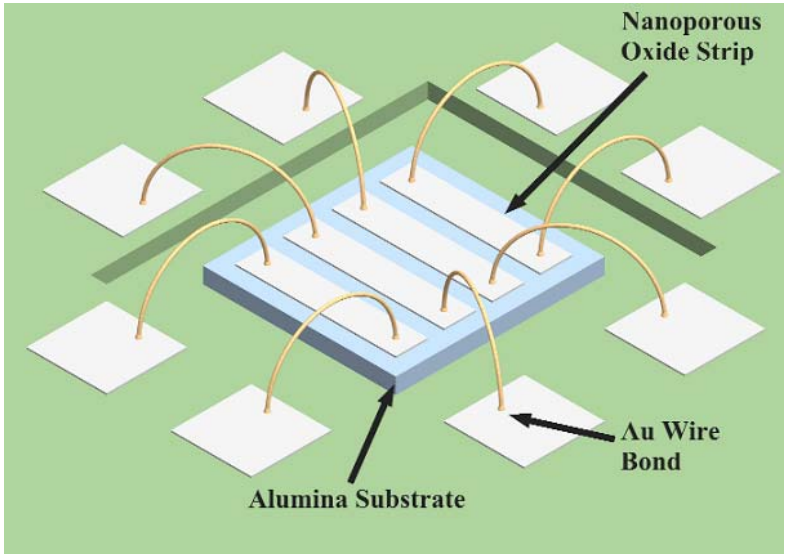
Key Technology/Application Challenges



Unranked

1. Clean Coal Power Generation
2. Natural Gas Fired Generation
3. Existing Nuclear Power Generation
4. Future Nuclear Power Generation
5. Renewable Resources
6. Distributed Energy Resources
7. Electric Energy Storage
8. Carbon Capture, Transport and Sequestration
9. Emissions Reduction and Control
10. Environmental Science & Technology
11. Transmission and Substations
12. Grid Operation and Planning
13. Distribution System
14. Power Quality
15. Physical and Cyber Security
16. Energy Service Portal
17. End-Use Energy Efficiency
18. Electricity Based Transportation
19. Power and Fuel Markets
20. Technology Innovation/Emerging Technologies

Example EPRI Results: Nanoporous Metal-Oxide Sensors

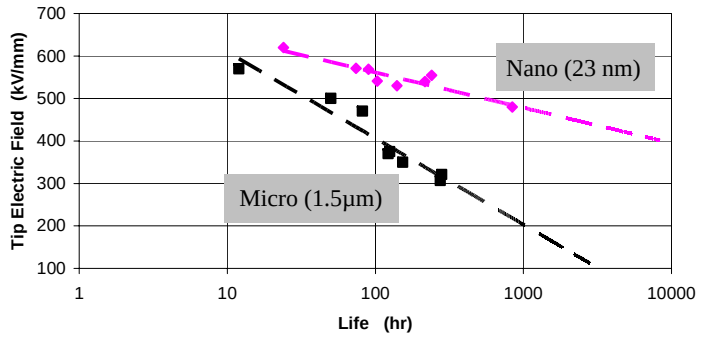


- Nanotubular/nanoporous metal-oxide sensors
  - Unique properties not found in bulk, thick or thin-film materials
  - Response is function of geometry, fabrication details
- Test case of hydrogen sensing in mineral oil through a variety of test conditions encouraging

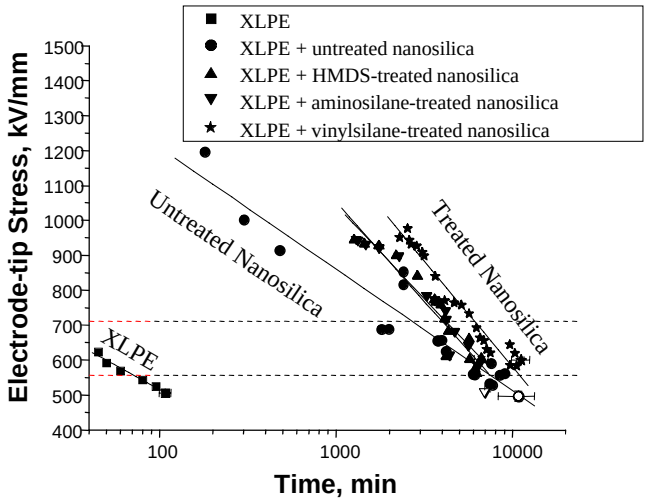
Example EPRI Results: Nano-Filled Polymers for Dielectric Applications

- Nanoparticles have a very significant positive effect on the voltage endurance
- Significant improvement seen in widely differing materials – both epoxy thermosets and polyolefins

- The smaller the particle, the greater the surface area per unit volume
  - High breakdown strength of the polymer matrix
  - Superior voltage endurance



(a)



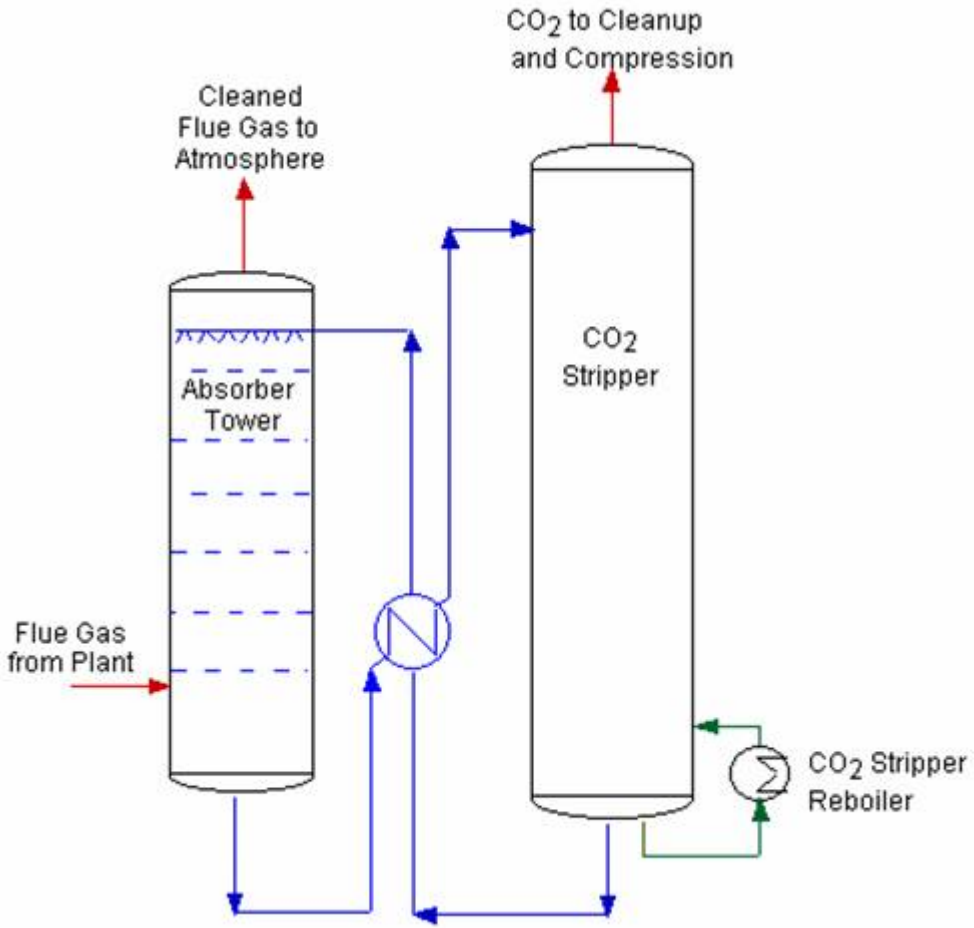
(b)

Voltage endurance characteristics for nanocomposites using 4 µm tip/plane electrodes. (a) Epoxy-TiO_2, (b) XLPE-SiO_2

Example EPRI Results: Superconducting Short-Circuit Current Limiter

- High reliability
- Fast response
- Improved power quality
- Successful test at 20 kV
- Technology is targeted to address fault current problems at transmission voltage level of 138kV and higher.

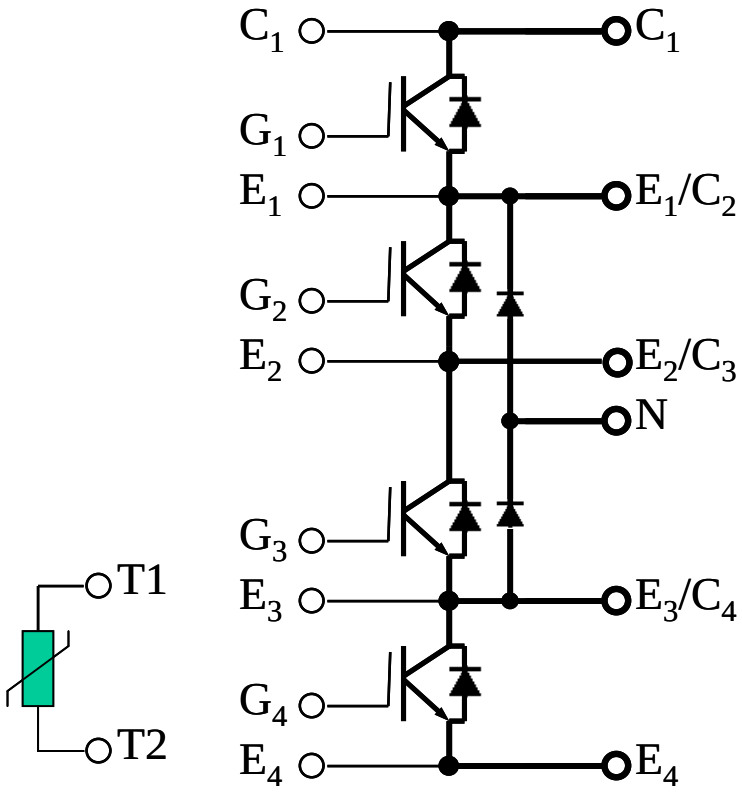
State of the Art for CO_2 Capture From Pulverized Coal Plants Produces 30% Loss of Power

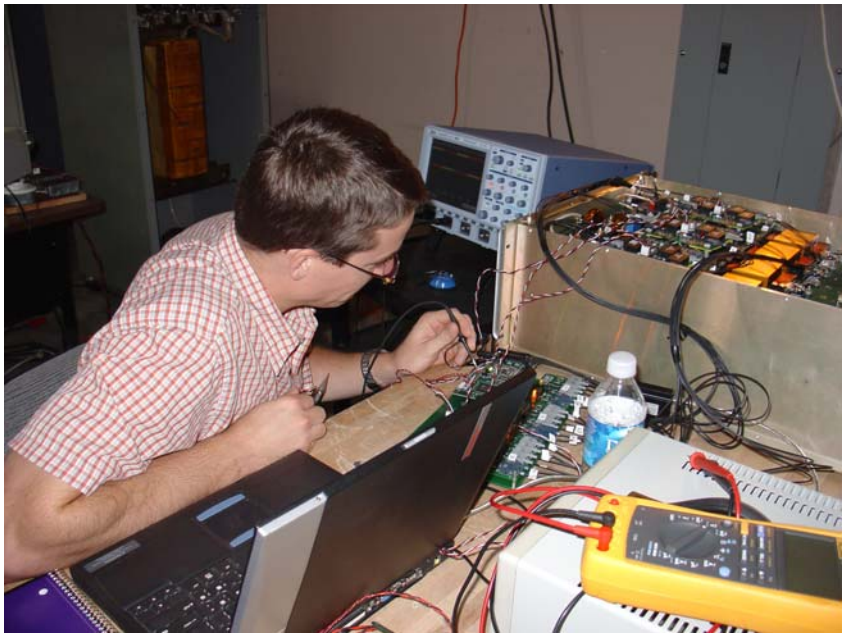


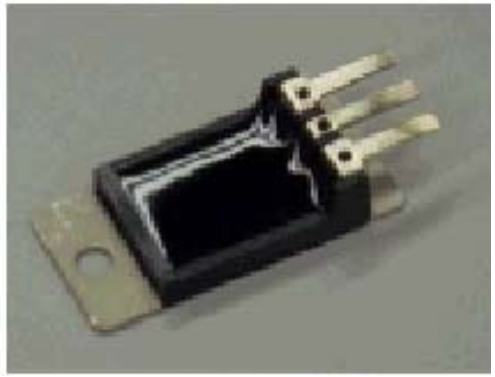
State of art uses MEA (MonoEthanolAmine). Two novel improved approaches are under investigation:

- **Use of 50/50 MEA/MDEA (MethylDiEthyanolamine)**
- **Use of Ammonia (NH_3) and the Ammonium Carbonate/Bicarbonate chemistry**

Example EPRI Results: Solid-State Intelligent Transformer



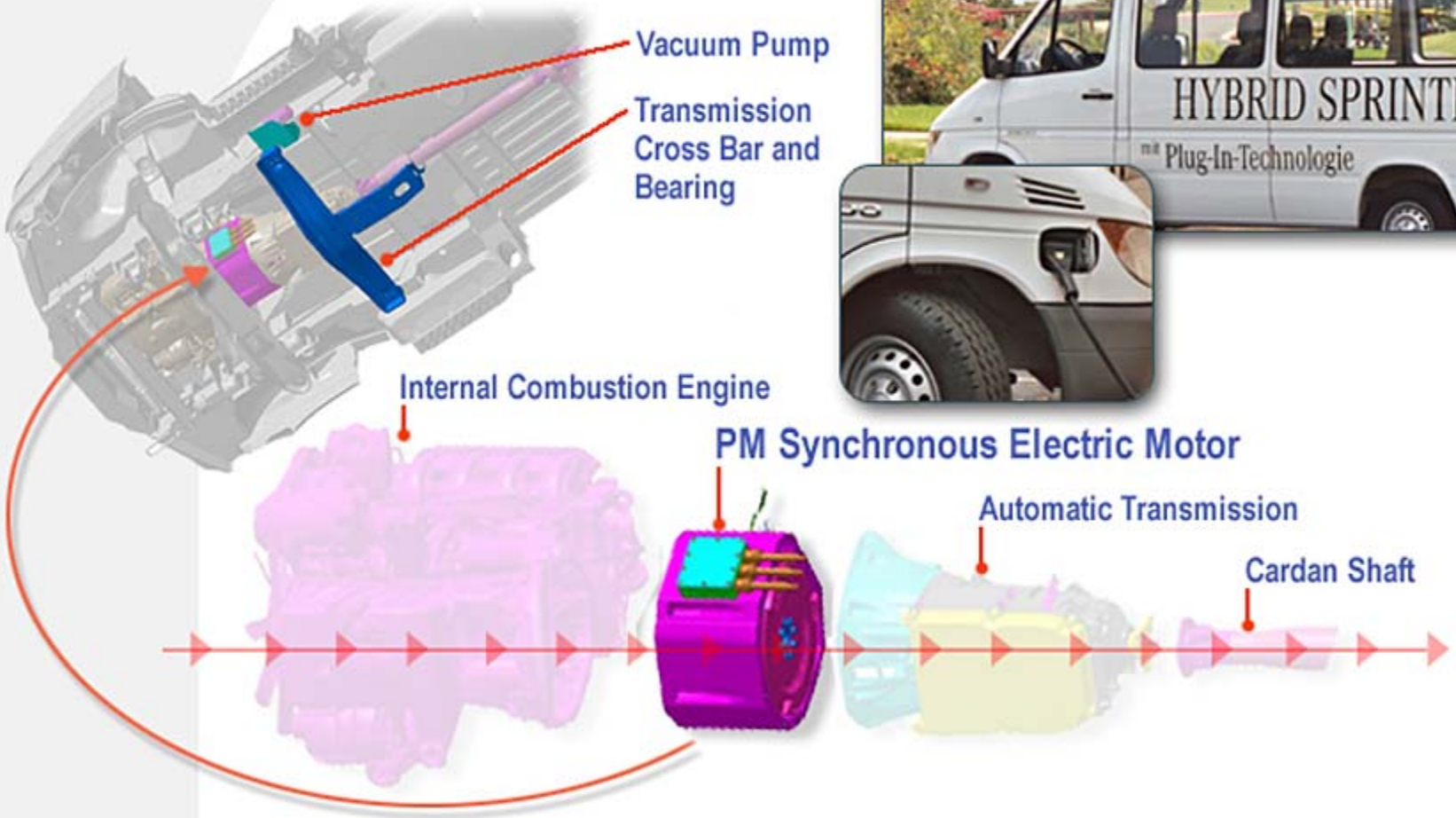




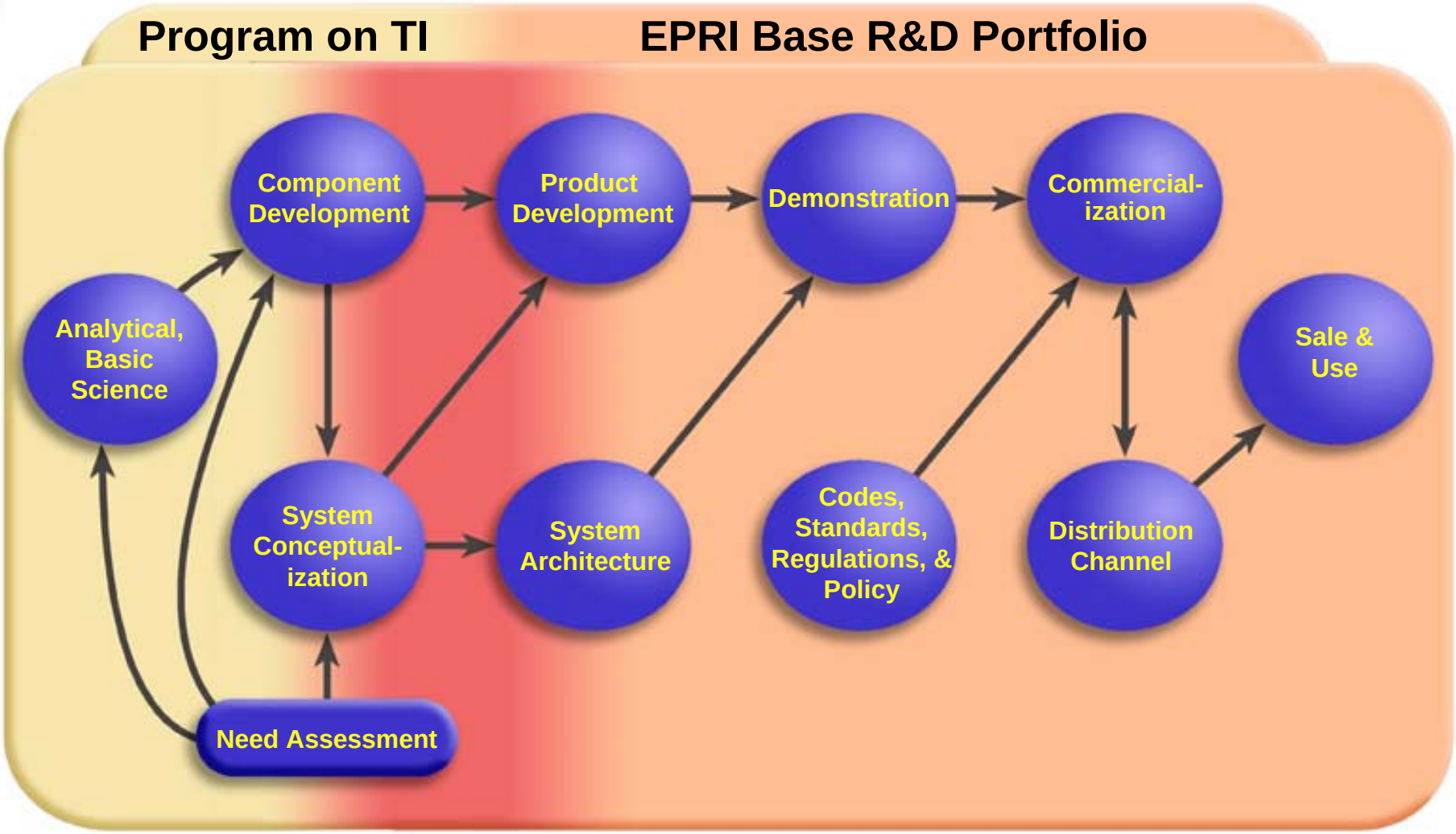
EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Example EPRI Results

Plug-In Hybrid Power Train

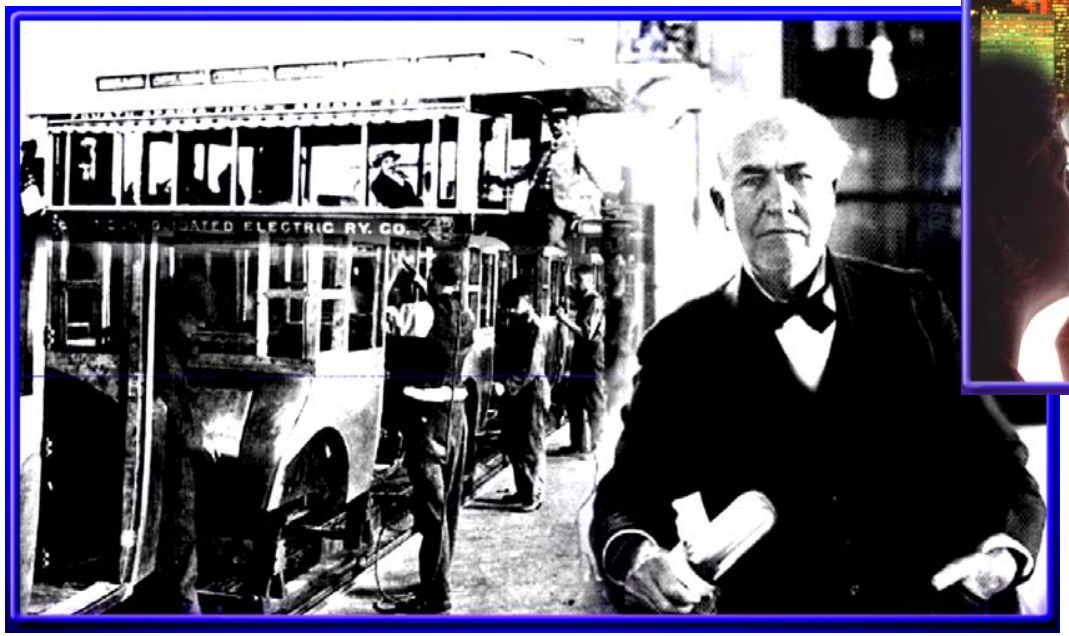


Stages of Technology Development



Conclusion: The future depends on deploying the trained minds of students to effectively utilize the past failures and accomplishments of technological giants.

Oct 3, 1908 Recording at NY Electric Show. He was 62 at the time.



"The best thing about the future is that it only comes one day at a time."

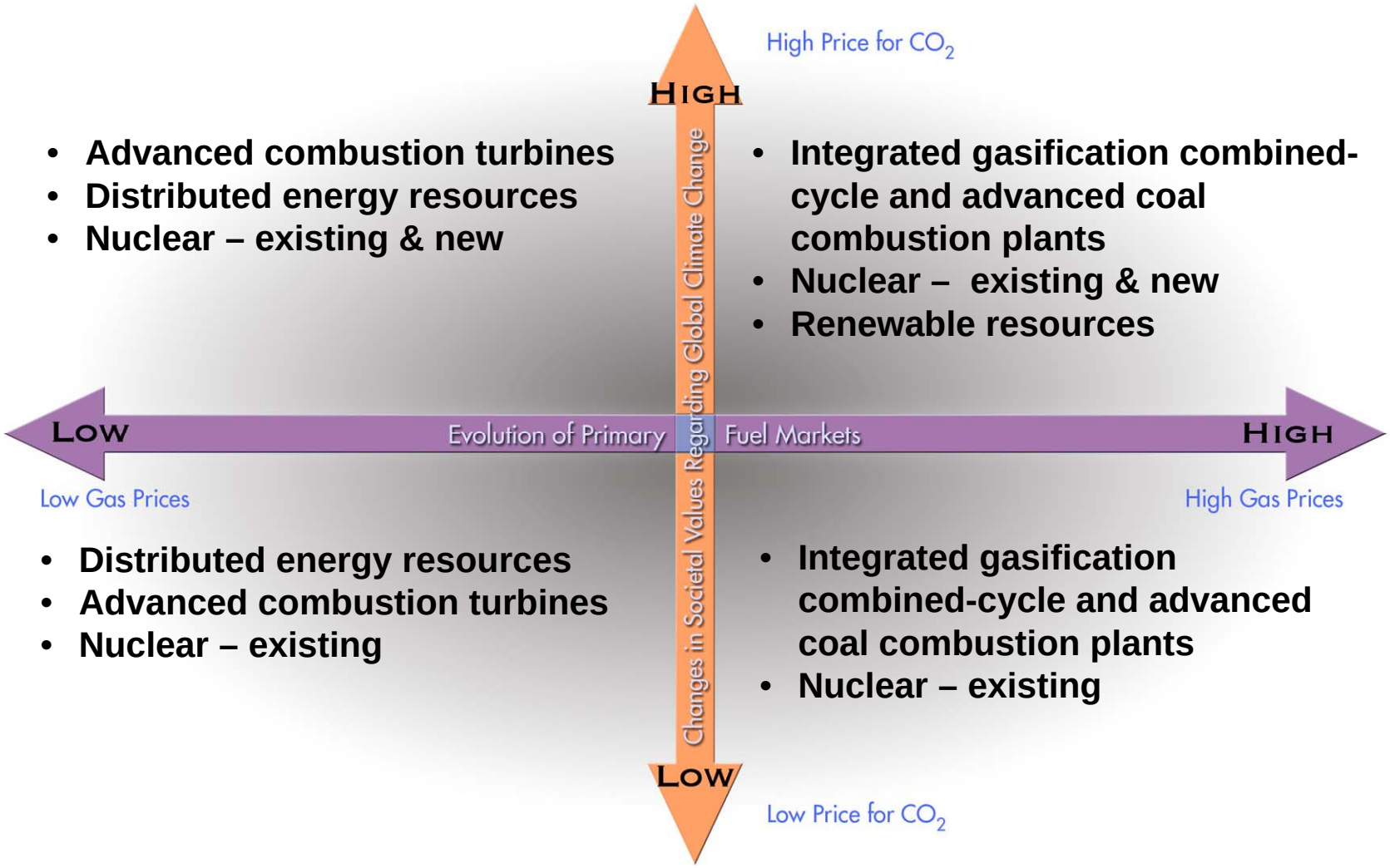
- - Abraham Lincoln

One of Edison's Most Famous Quotes:

"In periods of profound change, the most dangerous thing is to incrementalize yourself into the future."

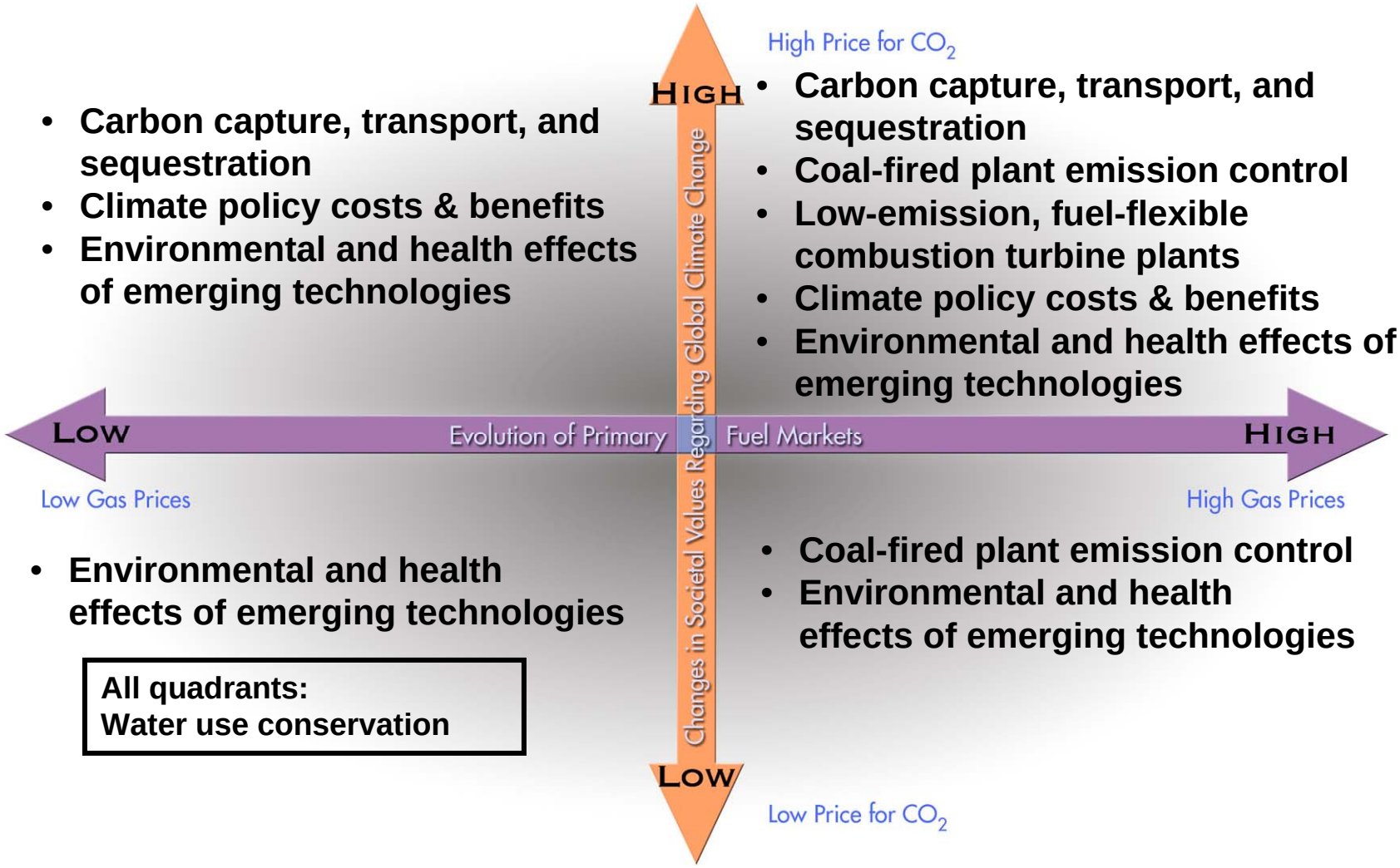
EPRI Critical R&D Needs: Power Generation Technologies

Appendix



EPRI Critical R&D Needs: Environmental Science and Technology

Appendix



- Carbon capture, transport, and sequestration
- Climate policy costs & benefits
- Environmental and health effects of emerging technologies

- Carbon capture, transport, and sequestration
- Coal-fired plant emission control
- Low-emission, fuel-flexible combustion turbine plants
- Climate policy costs & benefits
- Environmental and health effects of emerging technologies

- Environmental and health effects of emerging technologies

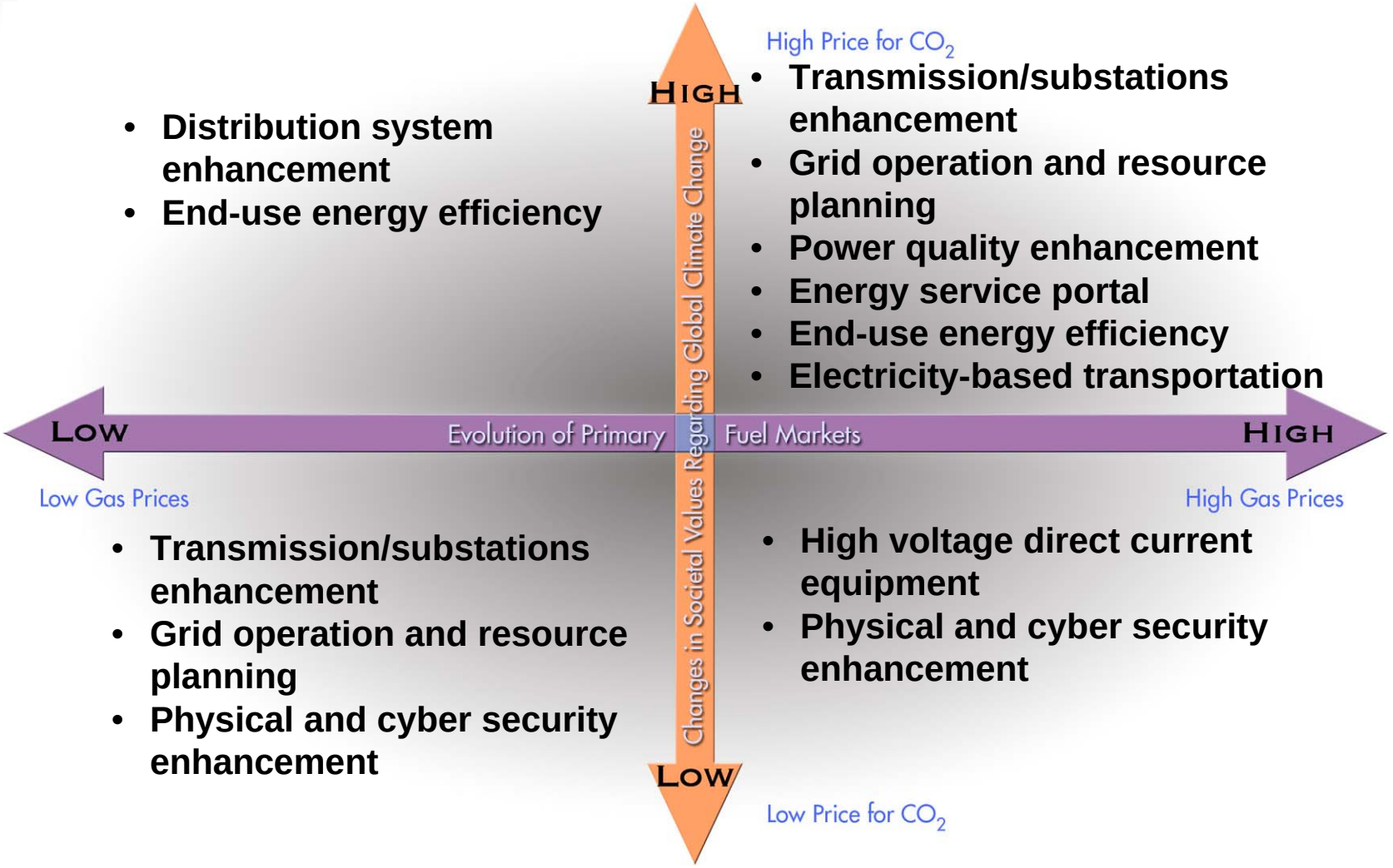
- Coal-fired plant emission control
- Environmental and health effects of emerging technologies

All quadrants:
Water use conservation

EPRI ELECTRIC POWER RESEARCH INSTITUTE

EPRI Critical R&D Needs: T&D and End Use Technology

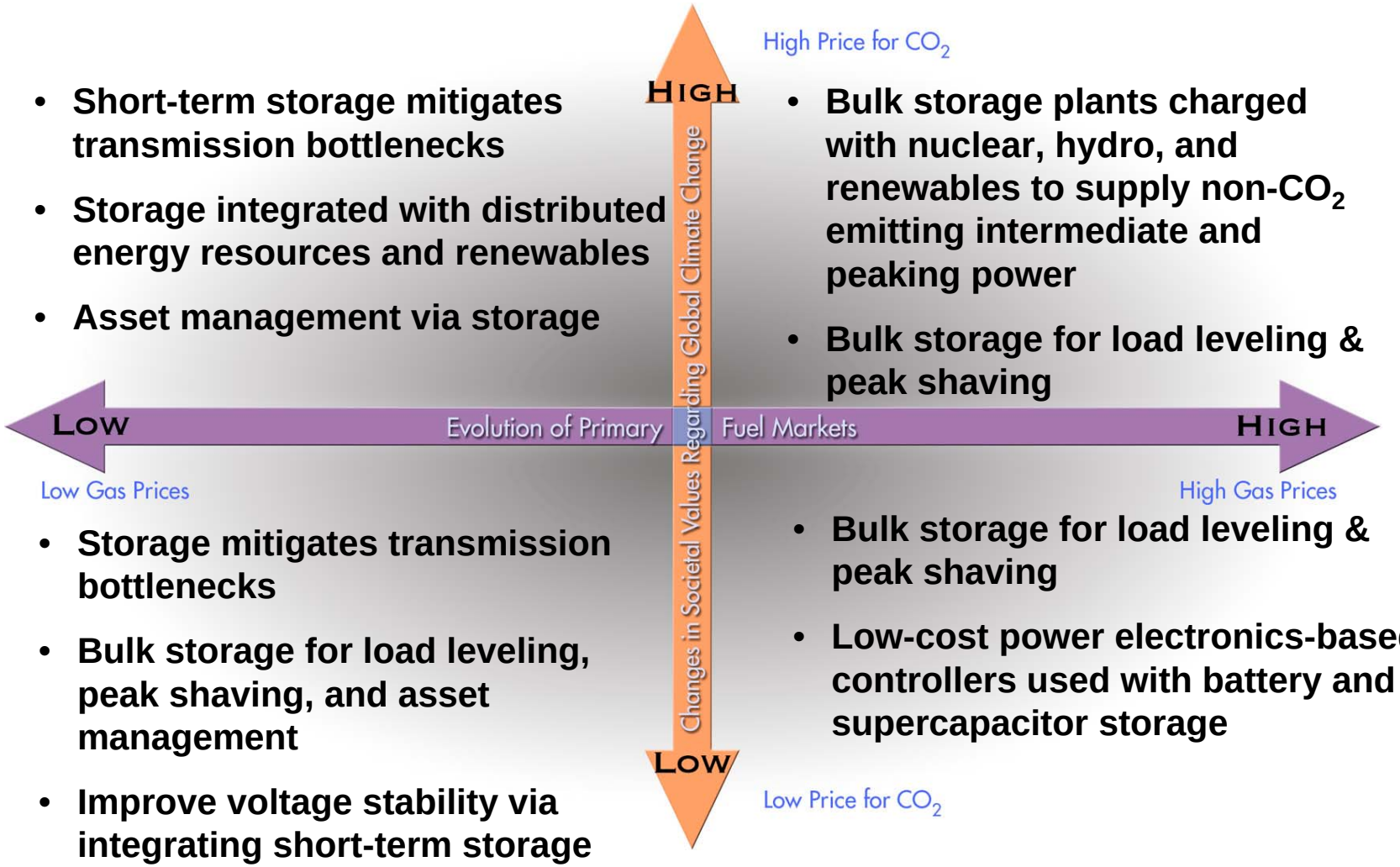
Appendix



EPRI ELECTRIC POWER RESEARCH INSTITUTE

EPRI Critical R&D Needs: Electric Energy Storage Technology

Appendix



- **Short-term storage mitigates transmission bottlenecks**
- **Storage integrated with distributed energy resources and renewables**
- **Asset management via storage**

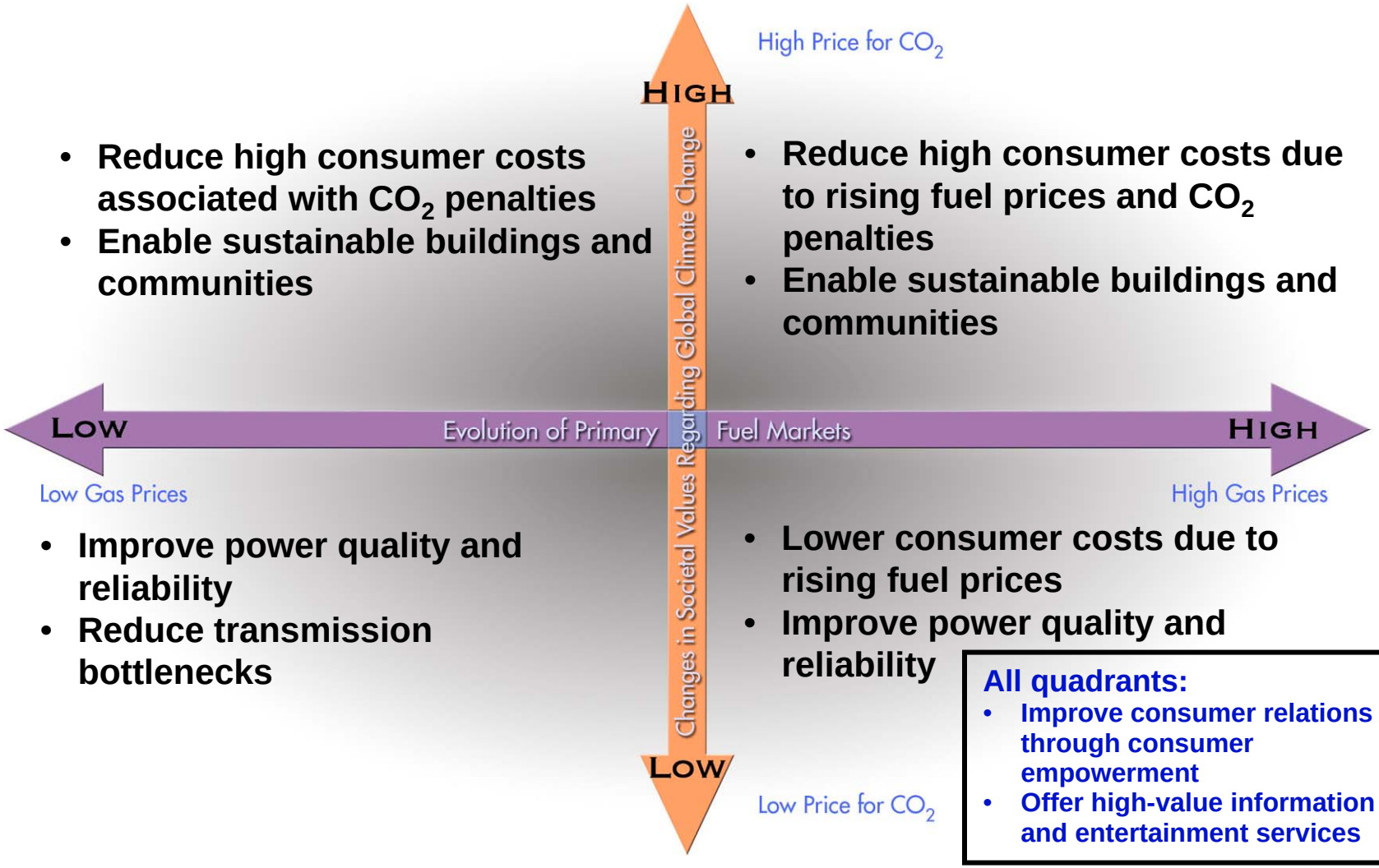
- **Bulk storage plants charged with nuclear, hydro, and renewables to supply non-CO_2 emitting intermediate and peaking power**
- **Bulk storage for load leveling & peak shaving**

- **Storage mitigates transmission bottlenecks**
- **Bulk storage for load leveling, peak shaving, and asset management**
- **Improve voltage stability via integrating short-term storage with ac-dc-ac converters**

- **Bulk storage for load leveling & peak shaving**
- **Low-cost power electronics-based controllers used with battery and supercapacitor storage**

EPRI Critical R&D Needs: Energy Service Portal

Appendix



- Reduce high consumer costs associated with CO_2 penalties
- Enable sustainable buildings and communities

- Reduce high consumer costs due to rising fuel prices and CO_2 penalties
- Enable sustainable buildings and communities

- Improve power quality and reliability
- Reduce transmission bottlenecks

- Lower consumer costs due to rising fuel prices
- Improve power quality and reliability

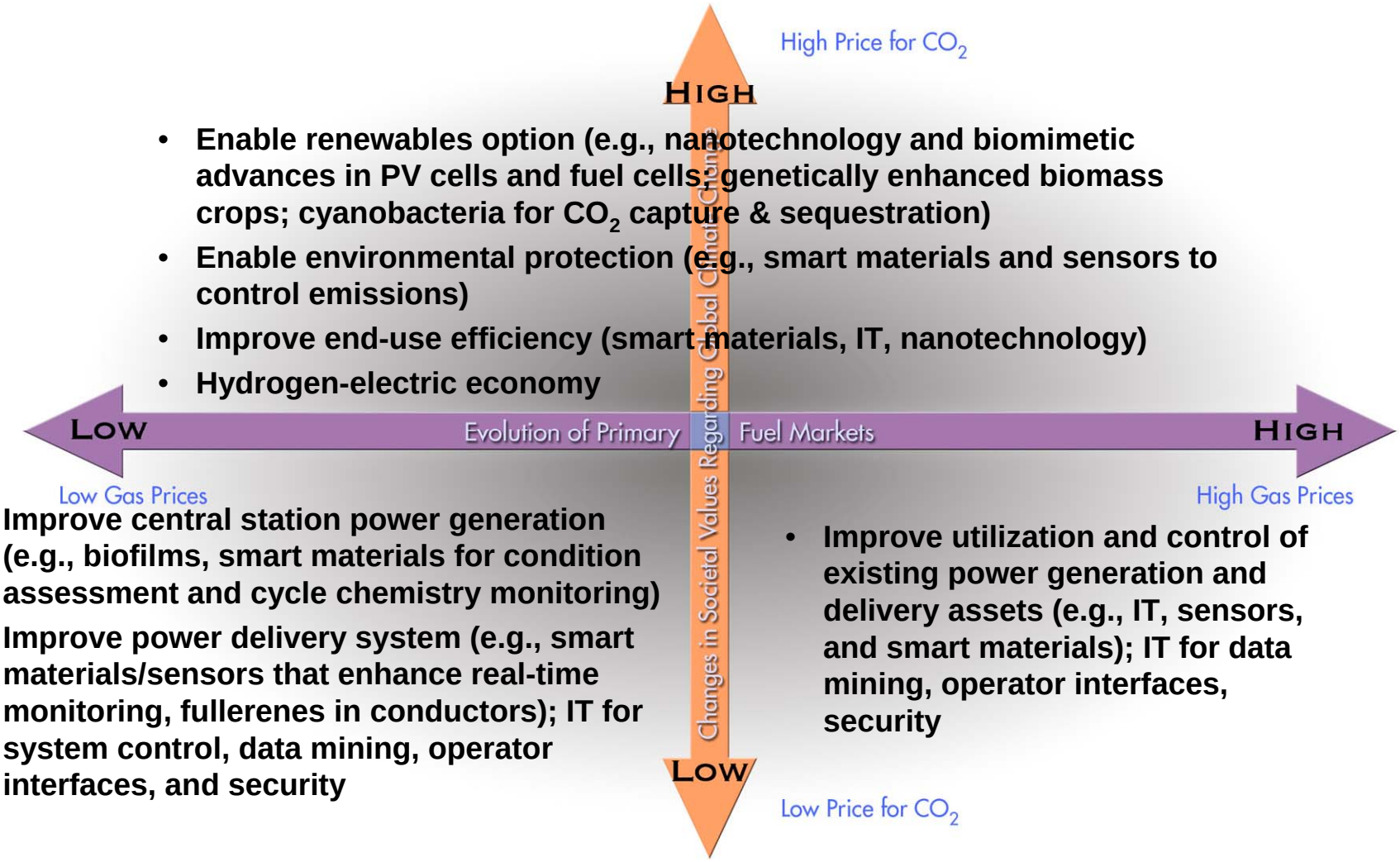
All quadrants:

- Improve consumer relations through consumer empowerment
- Offer high-value information and entertainment services

EPRI ELECTRIC POWER RESEARCH INSTITUTE

EPRI Critical R&D Needs: Technology Innovation/Emerging Technologies

Appendix



- Enable renewables option (e.g., nanotechnology and biomimetic advances in PV cells and fuel cells; genetically enhanced biomass crops; cyanobacteria for CO_2 capture & sequestration)
- Enable environmental protection (e.g., smart materials and sensors to control emissions)
- Improve end-use efficiency (smart materials, IT, nanotechnology)
- Hydrogen-electric economy

- Improve central station power generation (e.g., biofilms, smart materials for condition assessment and cycle chemistry monitoring)
- Improve power delivery system (e.g., smart materials/sensors that enhance real-time monitoring, fullerenes in conductors); IT for system control, data mining, operator interfaces, and security

- Improve utilization and control of existing power generation and delivery assets (e.g., IT, sensors, and smart materials); IT for data mining, operator interfaces, security

EPRI ELECTRIC POWER RESEARCH INSTITUTE