Challenges for Solid Oxide Fuel Cells in the Future Energy System

Presented to the

Solid State Energy Conversion Alliance
Second Annual Conference

March 29, 2001
Arlington, Virginia

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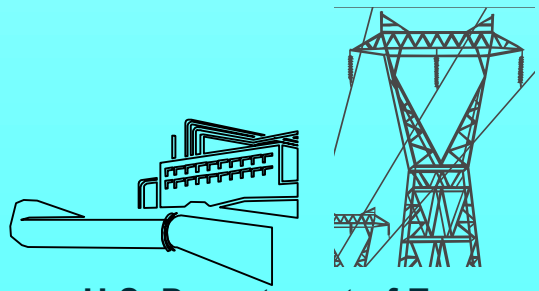

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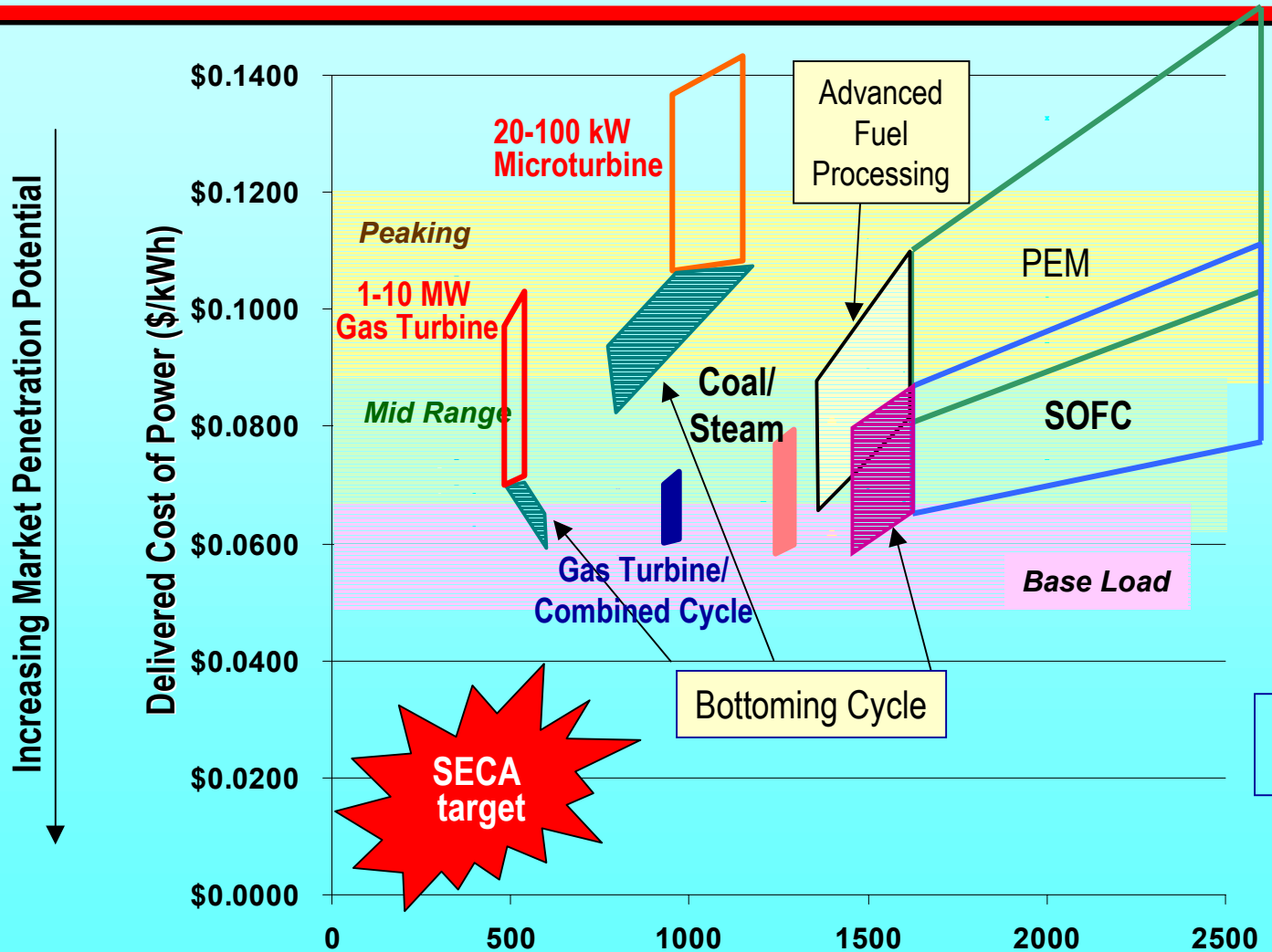
Competitive Cost Positioning for Alternative Power Concepts



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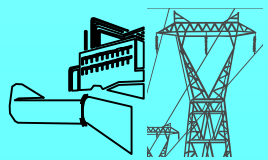

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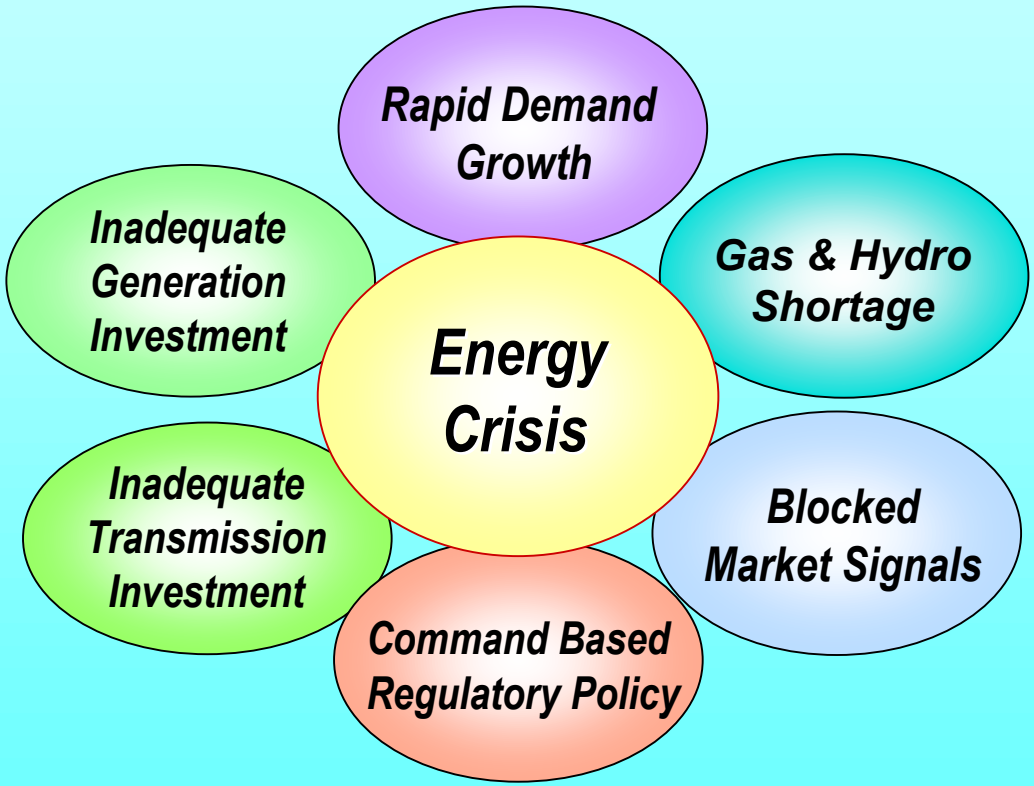
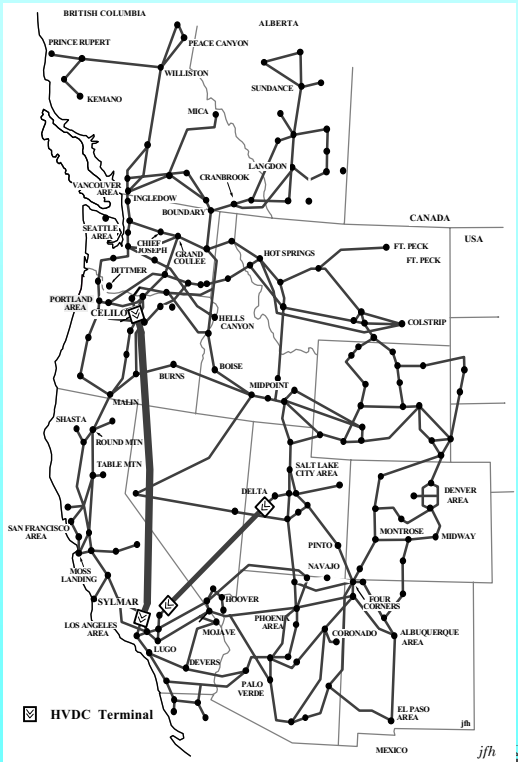
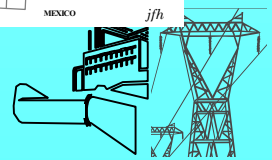
"We're facing, incredibly, another energy crisis!"

Rep. Billy Tauzin, Chairman, House Energy and Commerce Committee







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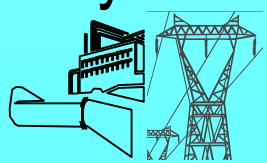
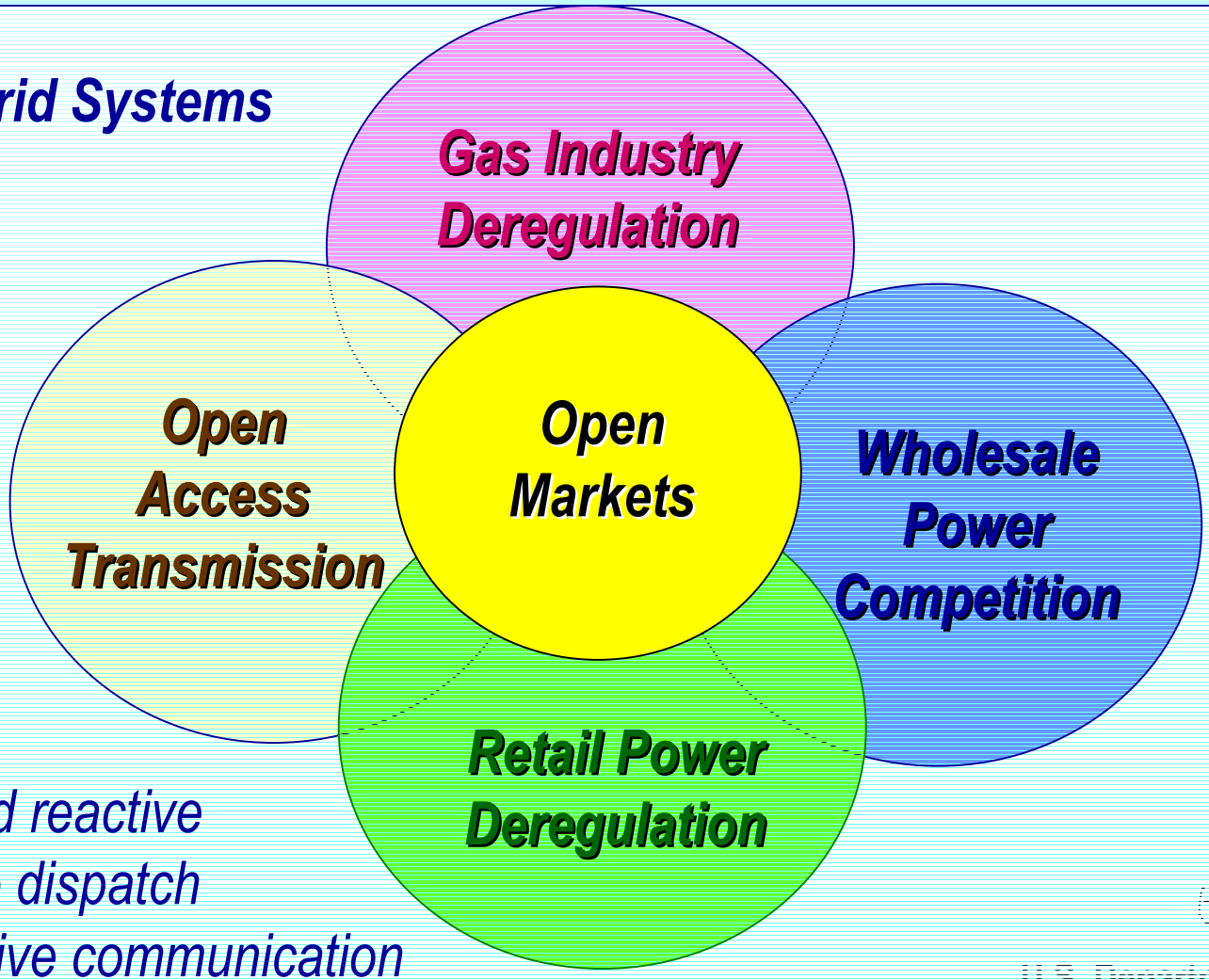
Efficiencies from markets are not automatic…

- FERC Report on Market Power (11/00)
- Price caps in the New England and California markets
- Immaturity of retail markets in all states
- Failures among retail marketers and e-commerce sites
- Lack of effective market signals and transparency
- Lack of consumer response options
- Lack of market based incentives for higher efficiency, cleaner energy conversion sources
- Bottlenecks in distribution resulting in imbalanced availability
- Incentives drive inefficiencies: focus on “islands of standby power” rather than overall power system reliability



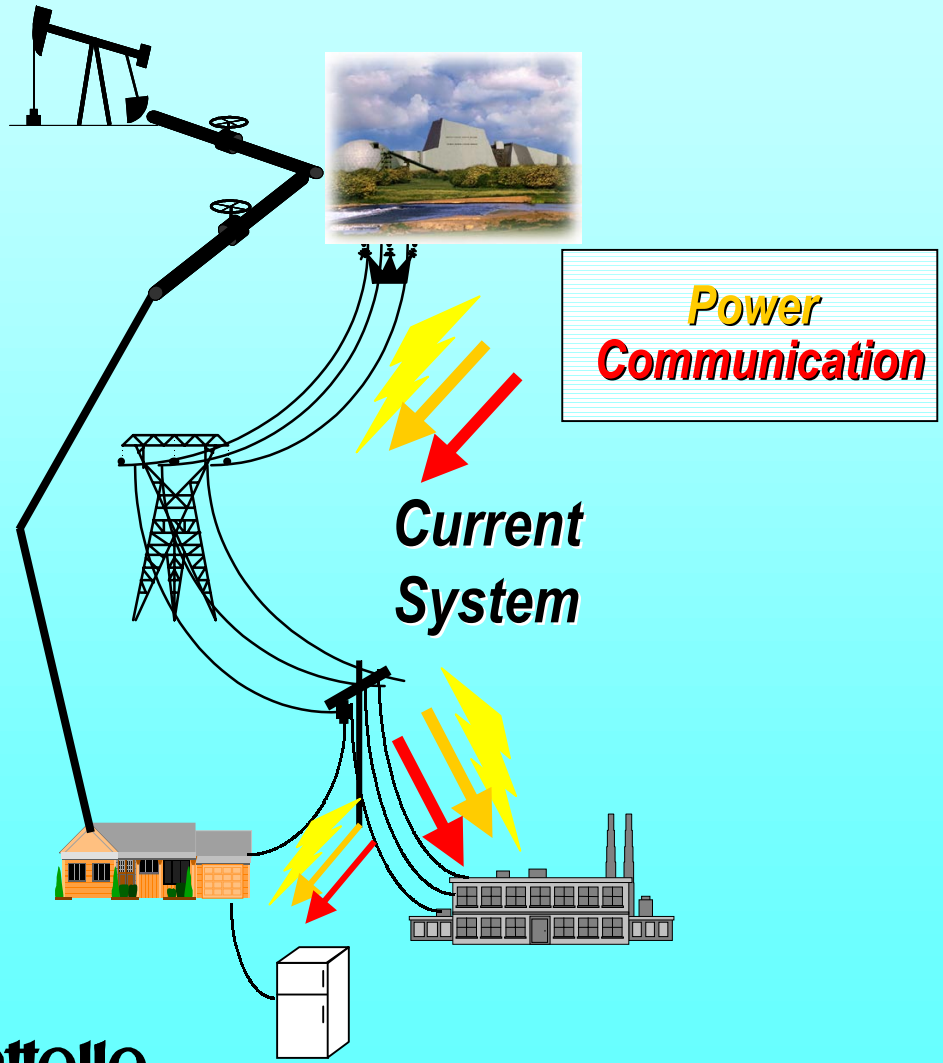
Open Energy Markets: In Theory…
Increased Access and Competition Will Improve Efficiency, Reduce Overall Costs and Incentivize Investment

Future Grid Systems

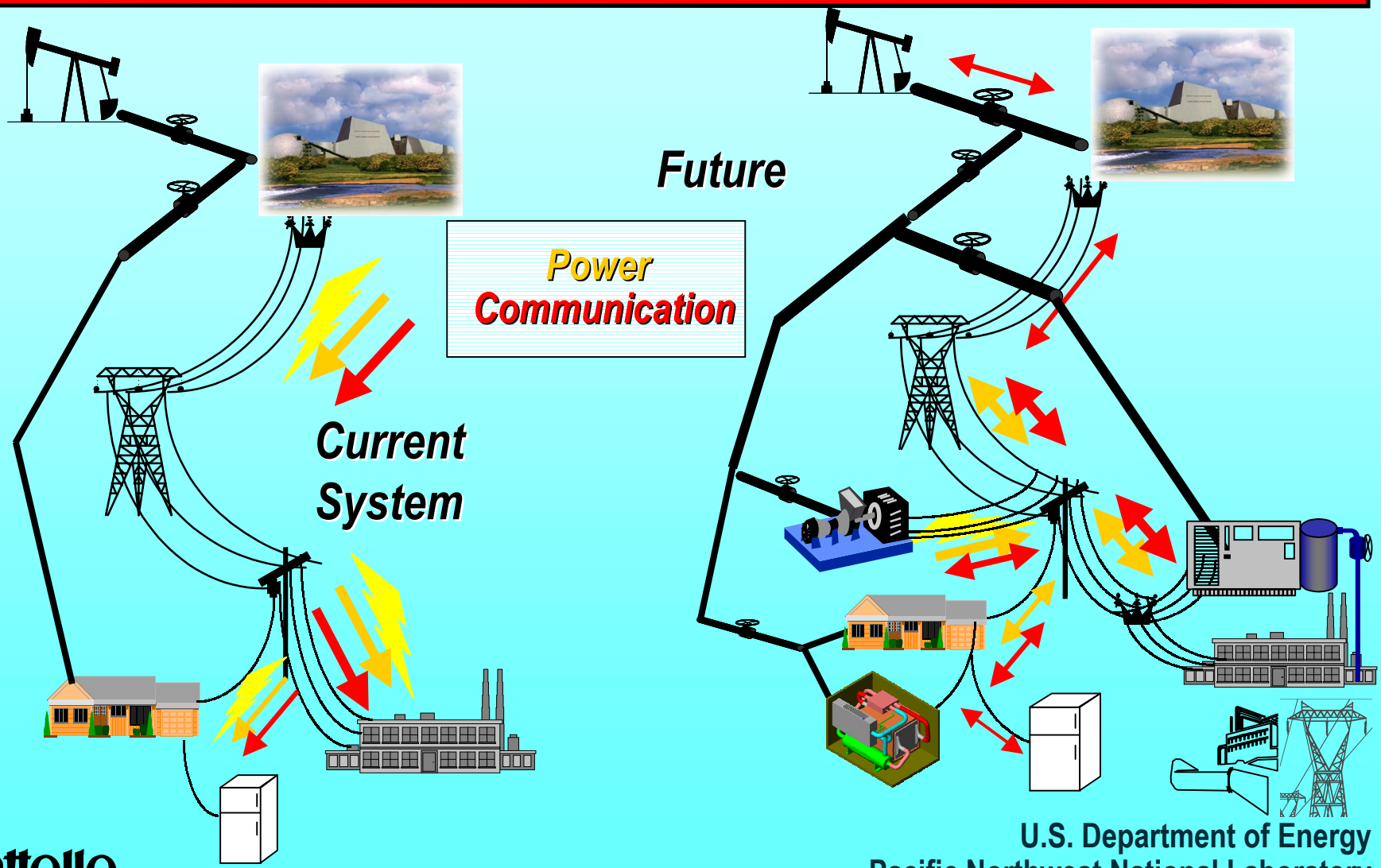


- Demand reactive
- Remote dispatch
- Interactive communication

The current energy system has inherent limitations that impede distributed generation



The Future Energy System Will Evolve to Facilitate Open Markets …



This new energy system embodies the features of a robust, reliable and efficient energy supply.

CURRENT

- Blackouts used to manage market and component failures
- Centralized, top-down control and planning is required
- Unidirectional control frustrates consumer responses and deployment of new technology
- Lack of resiliency can result in cascading system failure
- Layered and serial processes frustrate coordination and real-time responsiveness
- Top-down solutions, with regulatory checks, results in either over- or under-building
- Current system is not environmentally optimized
- Retards market based, efficient system solutions

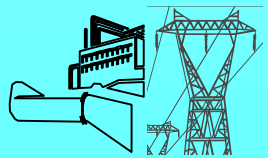
FUTURE

- Stable, reliable, predictable, controllable, manageable, fails gracefully, quality power
- Fuel flexible, resilient, demand responsive, decentralized (markets, generation, control, etc.)
- Expands and contract with markets, distributed vs. central power, absorbs new technologies/ markets/market instruments
- Withstands natural and deliberate threats to infrastructure
- Auditable, builds links between markets and institutions, dynamic system optimization, holistic
- 2nd law efficient, promotes and rewards efficiency, faster, easier to manage and maintain
- Environmentally friendly, incorporates externalities, responds to environmental dispatch
- Higher asset utilization, lower first cost, lower life-cycle cost
- Compatible with existing system, can evolve over time to new paradigm

Demands of the New Energy System on SECA Products

While application specific, typical applications will require:

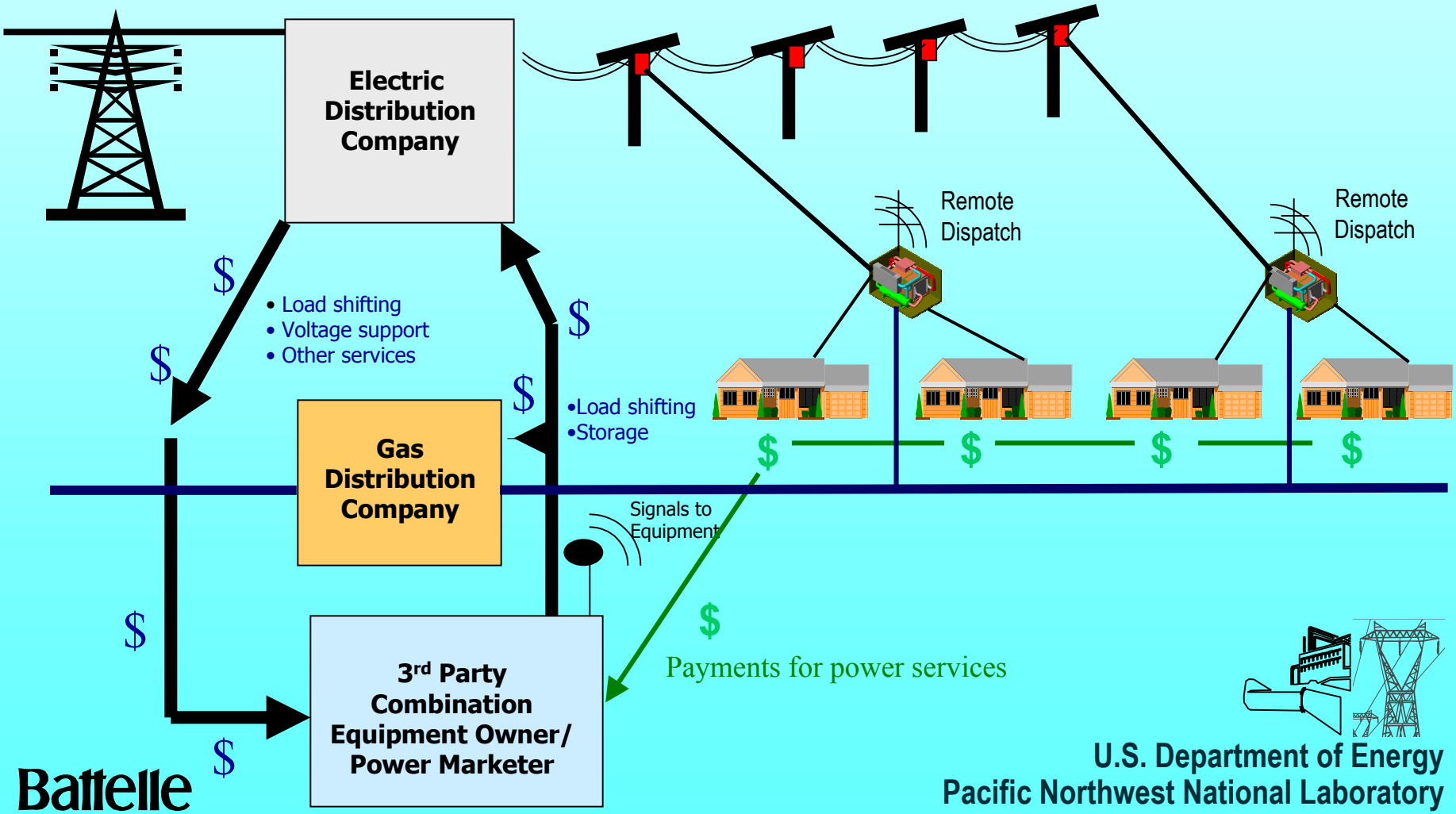
- Interactive control and telecommunication systems:
  - Dispatch controllers
  - Transaction-based controls
  - Plug and play controls
- Multiple power outputs (AC, DC Mixed)
- Waste heat utilization (CHP)
- Broad range turn down capability
- Remote monitoring, diagnosis and prognosis



Reducing Demand: Commercial AC/DC Building Bus

- **Scenario**---Office bldg. with grid-connected fuel cell; 1 W/ft^2 DC-plug loads (computers, printers), 2 W/ft^2 fluorescent light ballasts @ 108V 20kHz AC
- **Currently**---expensive, 90% eff. synchronous inverter; 50% eff. DC converters; 90% eff. ballasts
- **Future**---Multiple power outputs provides DC at several voltages, frequencies; direct conversion for lights saves 15%; DC used directly saves 50%; downsized fuel cell & inverter; ballasts and DC converters eliminated
- **Opportunities**---integrated system design (supply, distribution, end-use); conversion technologies; appliances; fuel cell balance-of-plant

Taking advantage of the "Spark Gap": Remotely Dispatched, Fuel Cell Load Balancing



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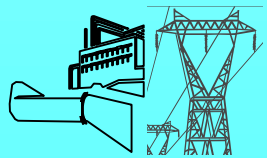
Crosscutting Science & Technology R&D Areas

- Complex, adaptive systems theory & applications
- Genetic (and other adaptation) algorithms applied to markets, regulations, controls
- Network topologies and stability
- Control theory for large-scale, dispersed, hierarchical networks
- Simulation of massive, complex, coupled economic/engineering hierarchical networks
- Microtechnology applications in sensors, controls, equipment



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