Transparency and knowledge
A legacy opportunity for the nation's electric infrastructure

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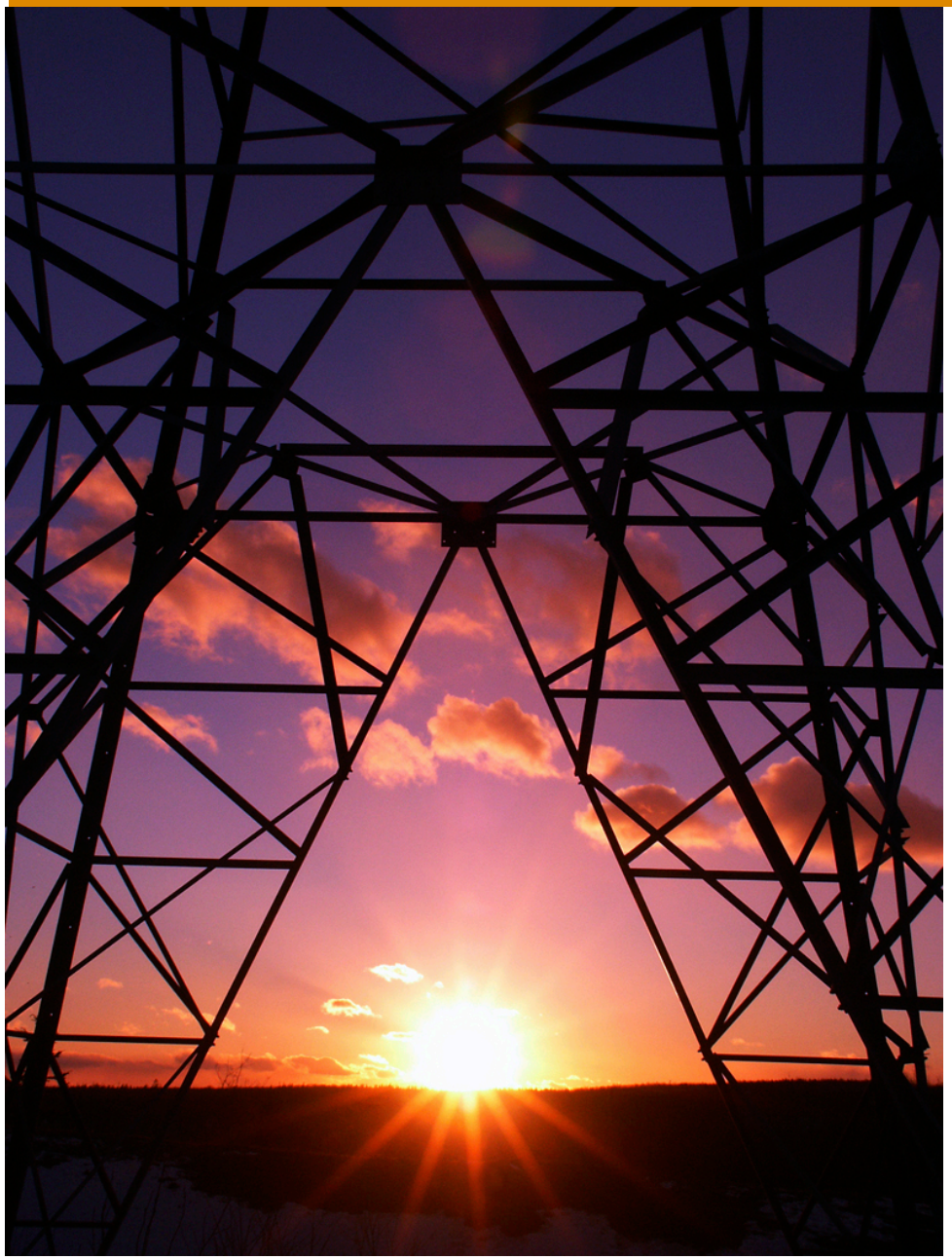
An overview of the nation's energy system



For more than 100 years, the nation's energy infrastructure has served us well, providing electricity that is:

- Abundant
- Affordable
- Reliable
- Secure
- Critical to our economic growth and success
- Essential to our quality of life

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The challenge ahead is complex

Deliver these new benefits…

Accelerate integration of renewable energy sources

Maximize opportunities for end-use efficiency to reduce carbon footprint

Develop and deploy effective energy storage technologies to accommodate intermittent resources like wind and solar

Electrify transportation sector to reduce dependence on imported oil

…With a system not designed or operated to deliver them

….While continuing to provide the abundant, affordable, reliable and secure energy that is essential to our economy and quality of life

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A quick look at the situation

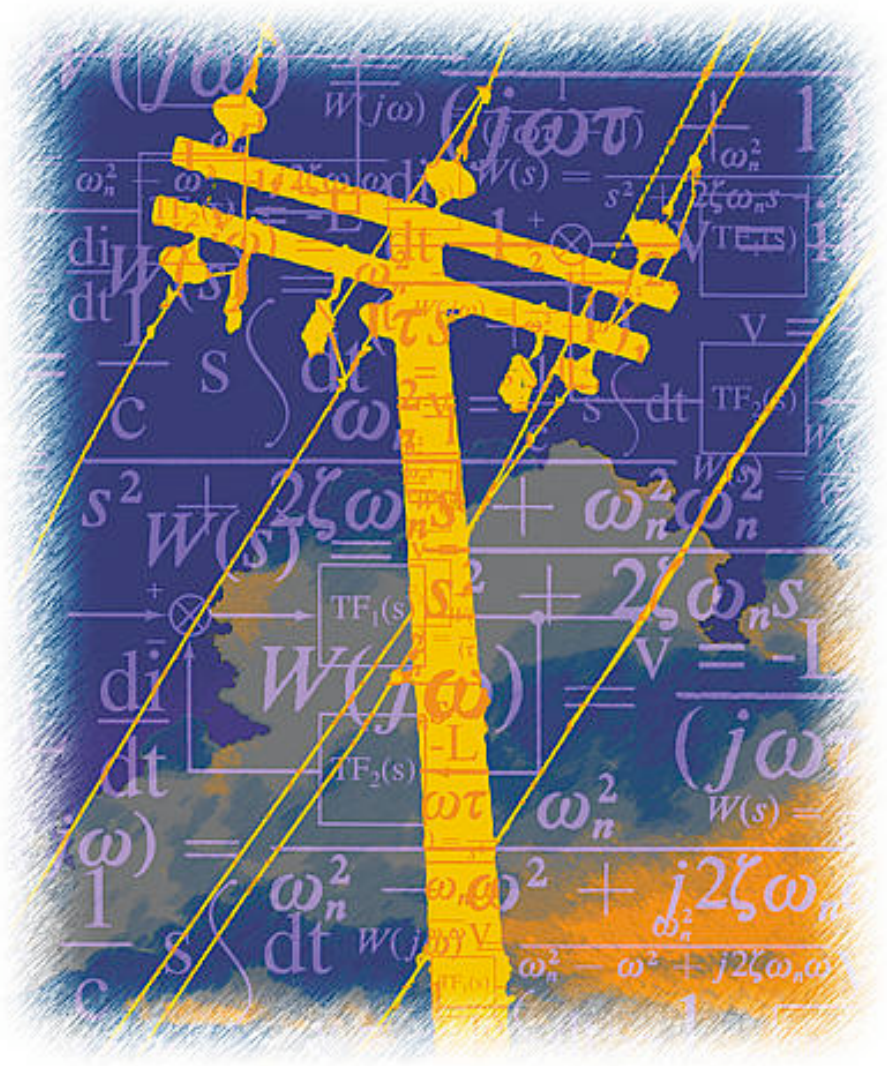
The electric infrastructure was created:

- Service territory by service territory
- With a market monopoly and a regulated return on investment in exchange for the obligation to serve

Service territories, though now connected, define the geographical, regulatory and balance sheet footprint for planning and operations

Are these footprints large enough to enable planning and operations that continue to serve us well?

The need for knowledge



- Models needed to:
  - accurately represent the existing and future infrastructure
  - understand the real-time dynamic operation of this infrastructure
- Combining models and real-time data will:
  - Create transparency
  - Enable decisions
  - Accelerate and broaden the ability to realize benefits

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Our vision for the evolution of power grid operations

Today	Near term	Long term
▶ Slow, static, slow operating tools, multiple data sources and analyses, each taking minutes	▶ Fast, static operating tools, some processes done in real-time	▶ Fast, dynamic operating tools, with online, real-time processes
▶ Existing assets are managed conservatively and underutilized	▶ Improved asset utilization	▶ Optimized asset utilization
▶ Limited marketing opportunities	▶ Enabled market opportunities	▶ Enabled regular and ancillary markets
▶ Emergency operations – blackouts and cascading failures	▶ Anticipate emergencies	▶ Predict emergencies
	▶ Emergency operations focused on preventing and mitigating failures	▶ Emergency operations prevent and mitigate failures

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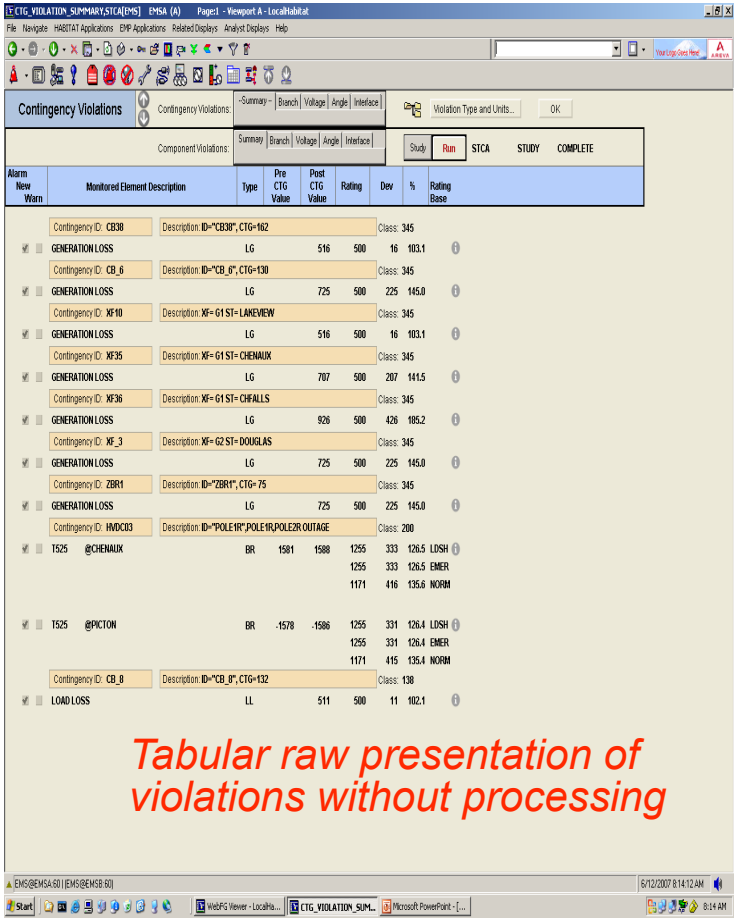
An example of today's grid operation tools

- Tabular representation
- Operators not adequately armed with timely, useful data
- No support for real-time decision making
- Technical gap between data and actionable information
- Need for visual analytics to aid decision support



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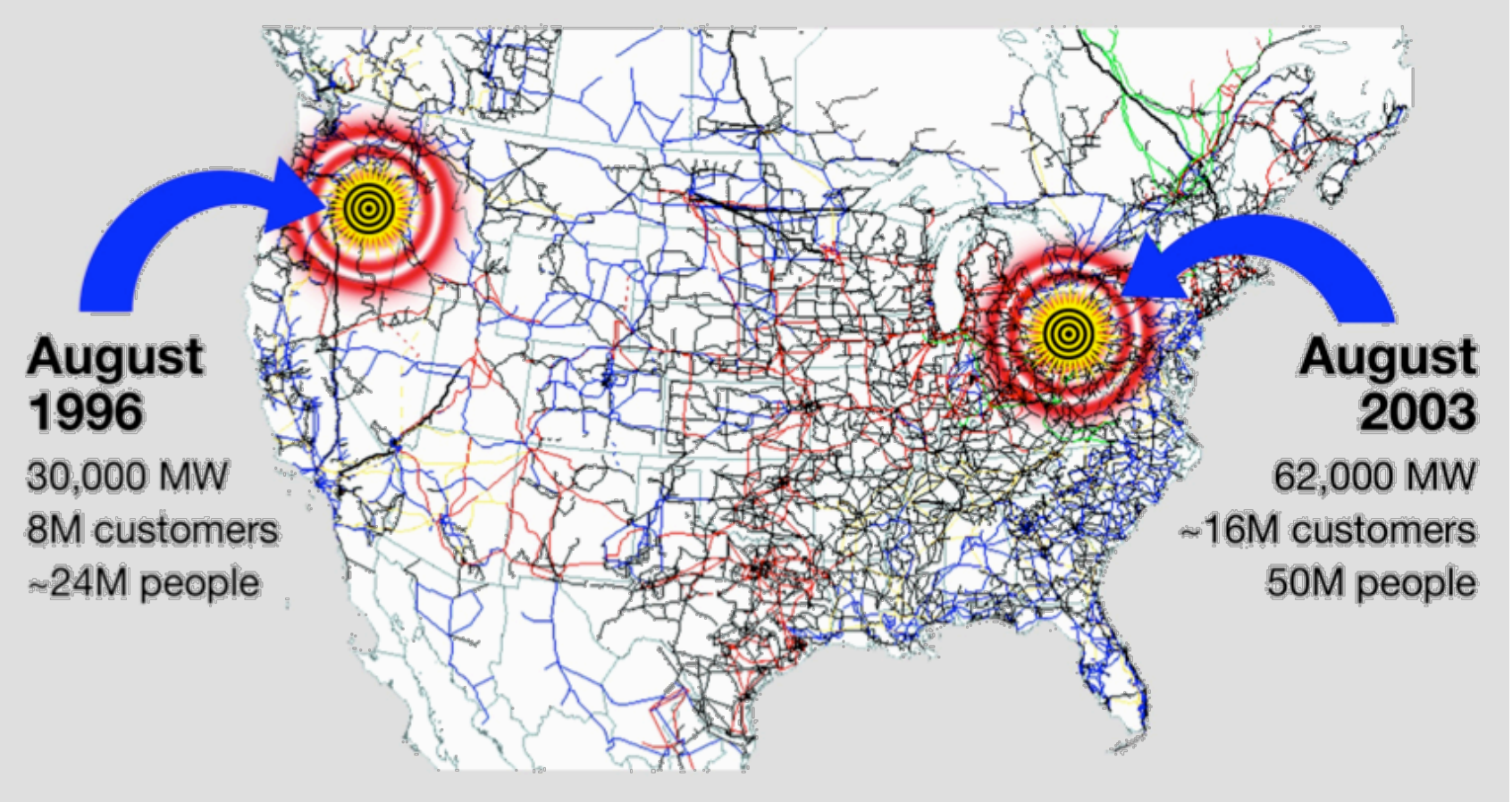
Current tools don't always cut it



The need for improved situational awareness became clear

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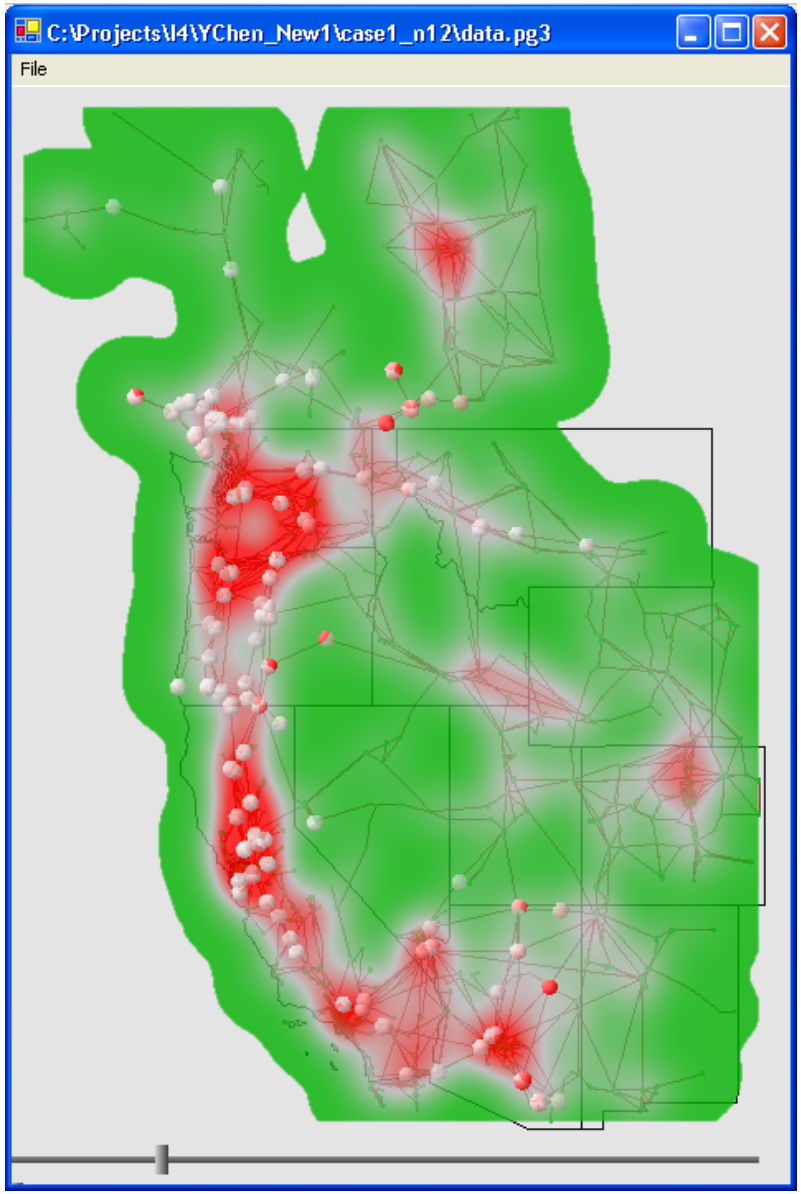
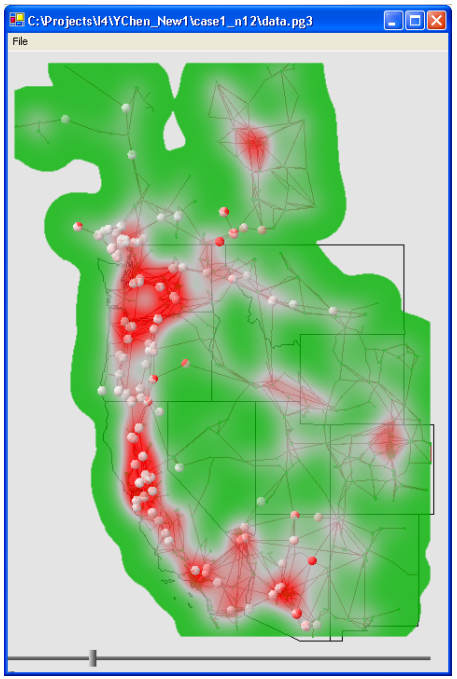
Visual analytics at work – helping identify risks



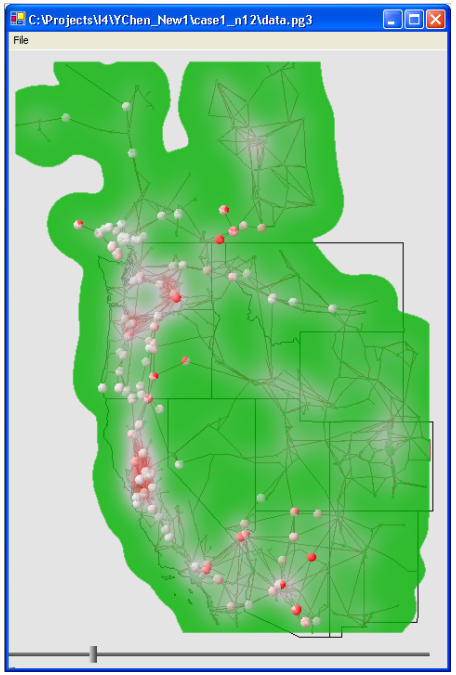
- Convert contingency analysis results to graphic domain
  - Determine the severity of individual network operation violations
  - Superimpose multiple contingencies by overlaying graphs
  - Perform statistical analysis to derive a risk index of grid stress
    - Overall and regional indices
- Predict imminent problems

Visual analytics at work – mitigating risks

- Identify critical contingencies
- Interactively evaluate control actions
- Provide operation guidance



Operator Actions: reconfiguration, re-dispatch, load shedding, etc…



Demand-side management through the Smart Grid

- Today, the grid is managed solely on the supply side
- New tools can aggregate the demand side of the equation to the point of control
- If you can control demand then it can be dispatched—faster than any new resources could be on the supply side
- PNNL's Olympic Peninsula GridWise® project illustrated this concept
  - Real-time price signals
  - Smart devices

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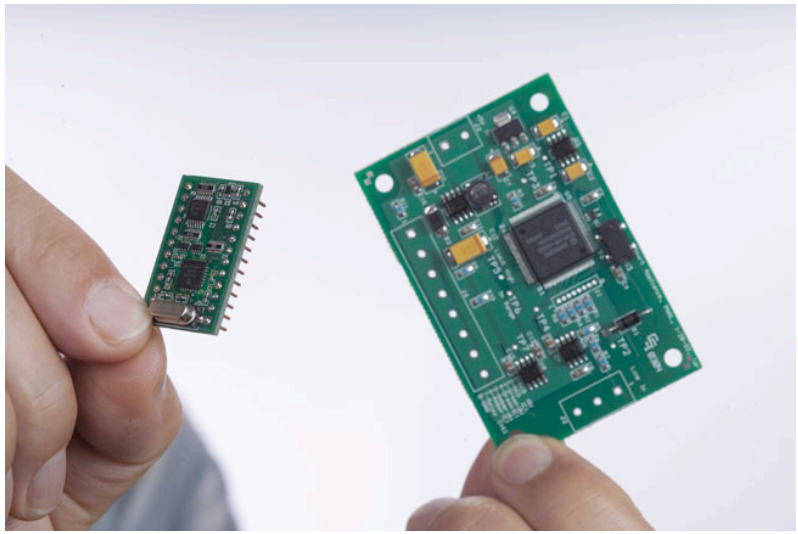
PNNL's Grid Friendly™ Appliances provide automatic safety net for the grid

- Autonomously detects stress on the grid and reacts by turning off the appliance
- Tested in 150 new Whirlpool clothes dryers, 50 retrofitted water heaters
- ***No one noticed in hundreds of curtailment events!***
- Can displace spinning reserves and increase reliability
- Reacts within 1/2 second
- Delays and randomizes service restoration to avoid grid shock
- Low cost: ***no communications required***



"When the inevitable occurs … people get stuck in elevators and high-value uses of power are shut off along with all the lowest priority uses of energy. It's the meat-ax approach to interrupting power flows."

--Dr. Vernon Smith, 2002 Nobel Prize Winner, Economics

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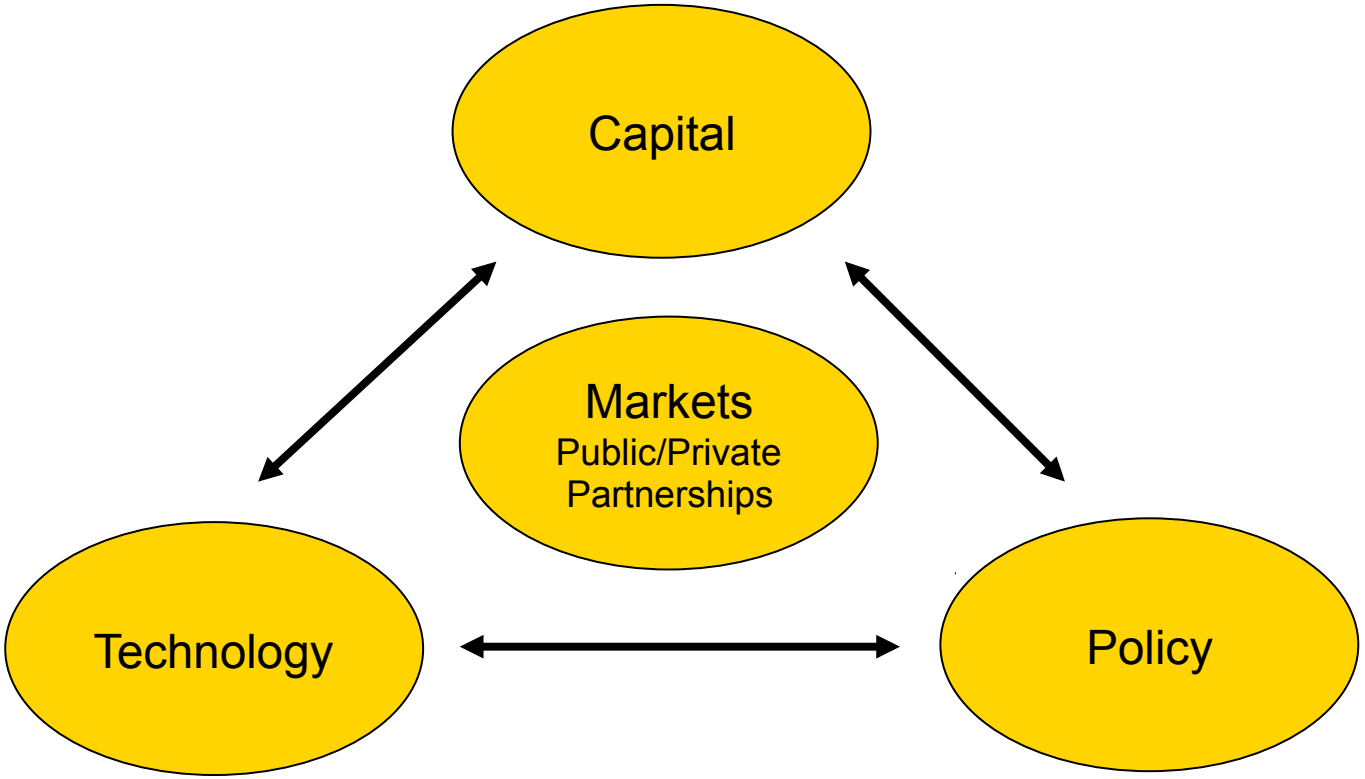
How to move these concepts forward in a changing landscape



Policy needs

Focus on national interests, not special interests

- Enable thinking beyond service territory boundaries and balance sheets
- Provide data to arm all participants with sufficient understanding beyond their service territory (footprint) to:
  - maximize asset utility
  - move from static and conservative management of assets
  - speed and broaden progress toward new grid objectives
- Enable regulatory structure that welcomes and rewards new technology

Technology needs

Establish computational and visualization capability to look beyond and deeper within current service territory footprints

- Models to accurately represent the built infrastructure at the interconnection level
- GPS information to understand real-time dynamic operation of infrastructure
- Use new knowledge to:
  - create transparency
  - enable decisions and sound policy
  - realize benefits more quickly and broadly

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Capital needs

Define and manage Smart Grid investments and business models

- Who gets the benefits and what does it cost?
- How are costs allocated and who pays?
- Who takes the risk?
- Who owns the assets?
- What policies will maximize benefits to all parties?
- How do we ensure fairness? (Transparency = no cheating)
- What regulations should be removed, changed or added?
- How do we realize the new expectations without losing sight of the benefits we have today?

Leadership needs

Leadership needed to build constituency and consensus necessary for change and progress

- Leaders help move from data → knowledge → action
- Greater understanding of system can move participants toward consensus on the best next steps
- Real-time knowledge of system at interconnection scale is necessary to optimize electricity system planning and operations, but can be equally important in approaches to carbon cap and trade
- Learn from others
  - China's national grid is deploying technology and business models that look at real-time dynamic system operations

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In closing

- New technologies for the grid exist, but are slow to be adopted
- Better tools needed to understand benefits and make decisions
- New infrastructure could provide opportunities for game changers
- Computational scientists can help shape the grid of the 21st century

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