

# Energy Storage

## Why so few pay attention (and what we can do about it)

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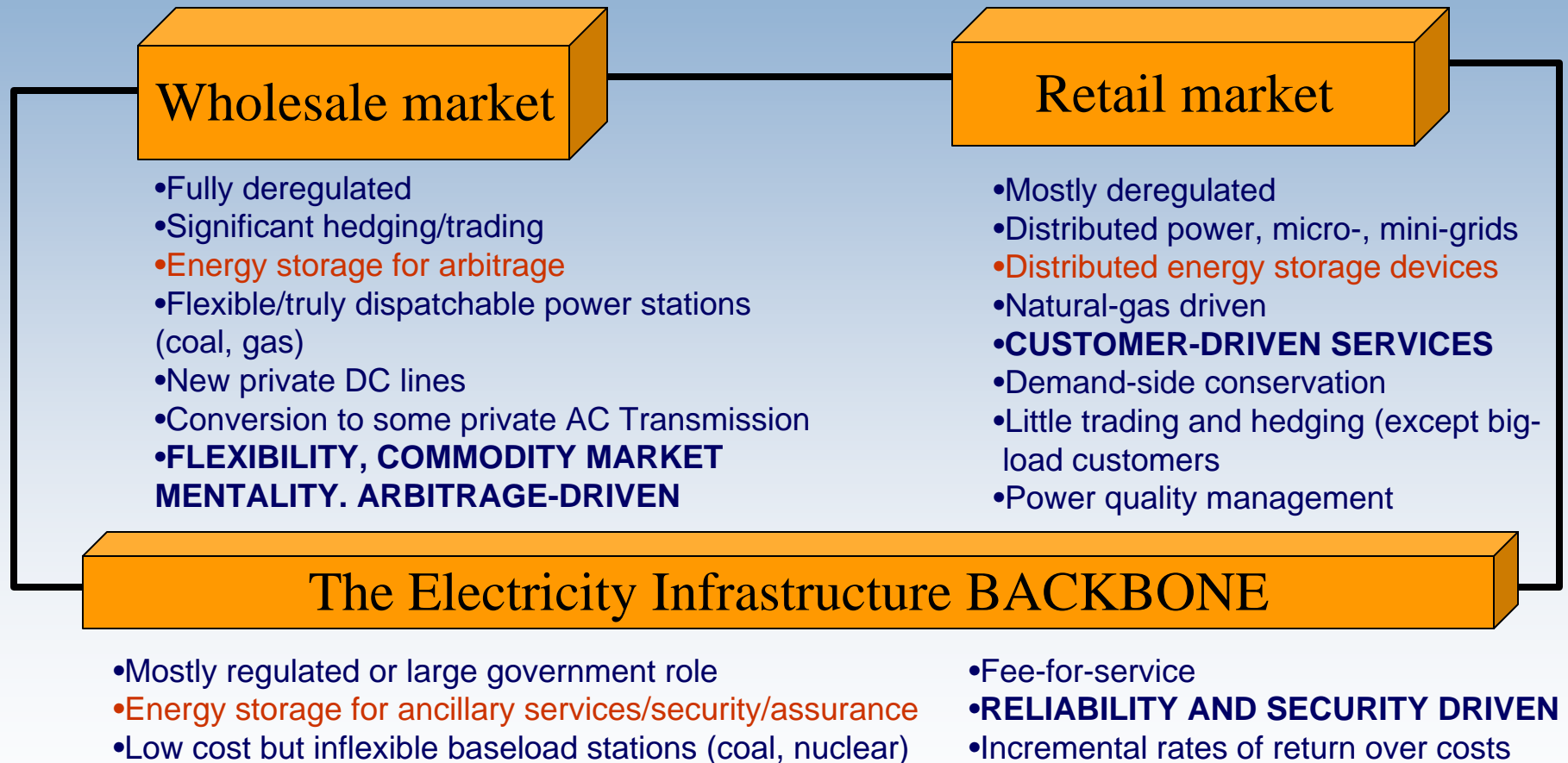
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# First, a step back: A New U.S. Order for Electricity

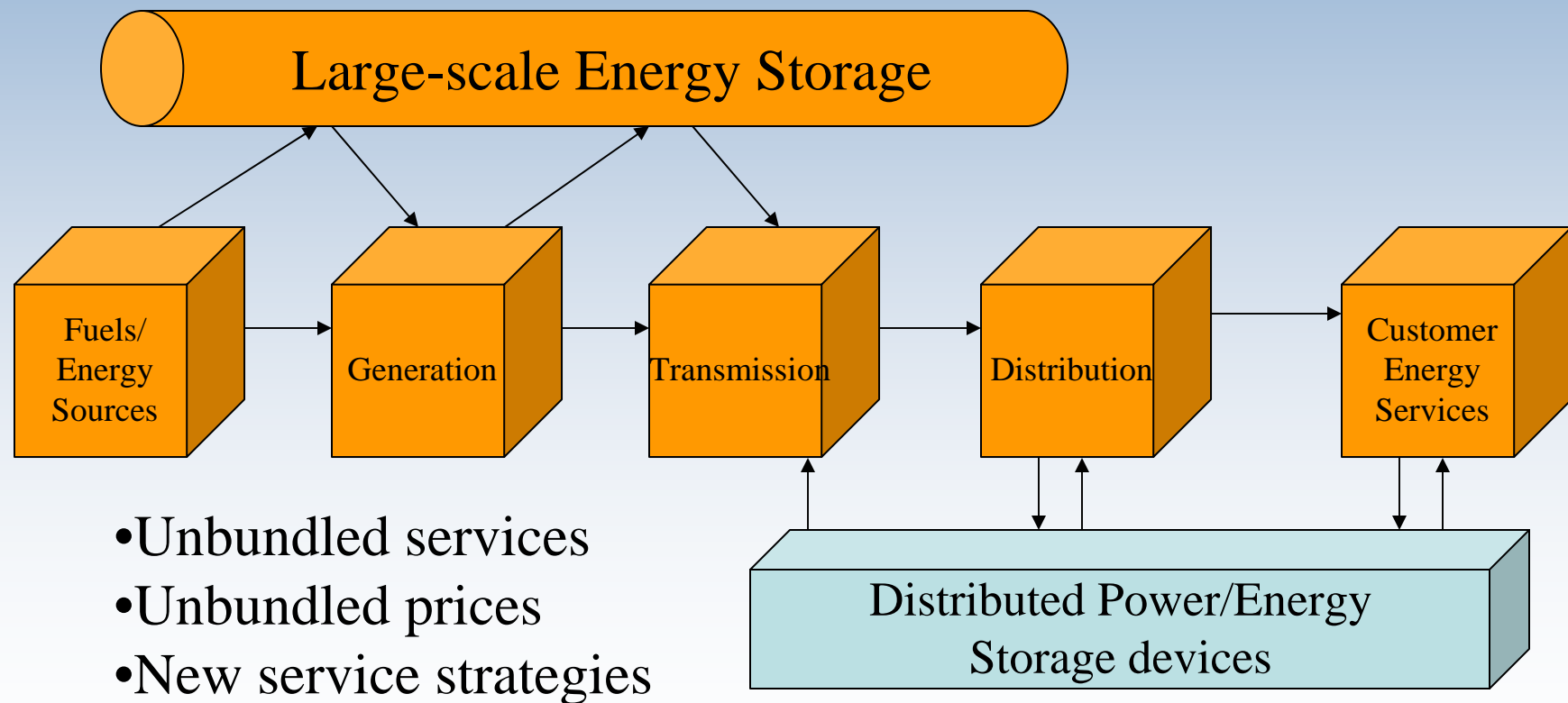


# The Issues: Tectonic Shifts in our Industry--and a Solution

- Consumers and elected officials are demanding renewables, but costs of highly variable resources not being properly accounted for
- National Security is jeopardized because electricity is fundamental to all other infrastructure
- Generation, transmission, and distribution are being disaggregated
  - More than 30% of generating assets are “non-utility,” merchant, or IPP
  - Transmission is being reorganized into regional grids and markets with private development emerging
  - Distributed generation is rising as distribution utilities seek new opportunities and customers with critical needs protect themselves against what they see as deteriorating grid service.

ENERGY STORAGE CAN BRIDGE GAPS BEING CREATED!

# Six Dimensions of the “New” Electricity Value Chain



# Energy Storage Value Buckets

- **Arbitrage**-storing and moving low-cost power into higher price markets, reducing peak power prices.
- **Security and assurance**-voltage regulation, black start, frequency control, emergency power.
- **Asset optimization**—reducing the cycling and dispatch of large fossil units meant for baseload.
- **Enhancing renewables** —transforming “take it when you can get it” into scheduled power. A fuel-free electricity source in the peak markets! (Also, daily wind resource curves are often opposite the daily load demand curves)
- **Transmission asset deferrals** —postpone the need for new transmission assets depending on where storage assets are placed.
- **Support distributed generation** —Micro- mini-grids and on-site power systems must become at least as reliable as traditional grid-supplied electricity. Today’s digital society/economy demands power quality several orders of magnitude higher. Storage assets placed at distribution-voltage substations and integrated into advanced DG devices and uninterruptible power systems



# The little appreciated “security” dimension to energy storage

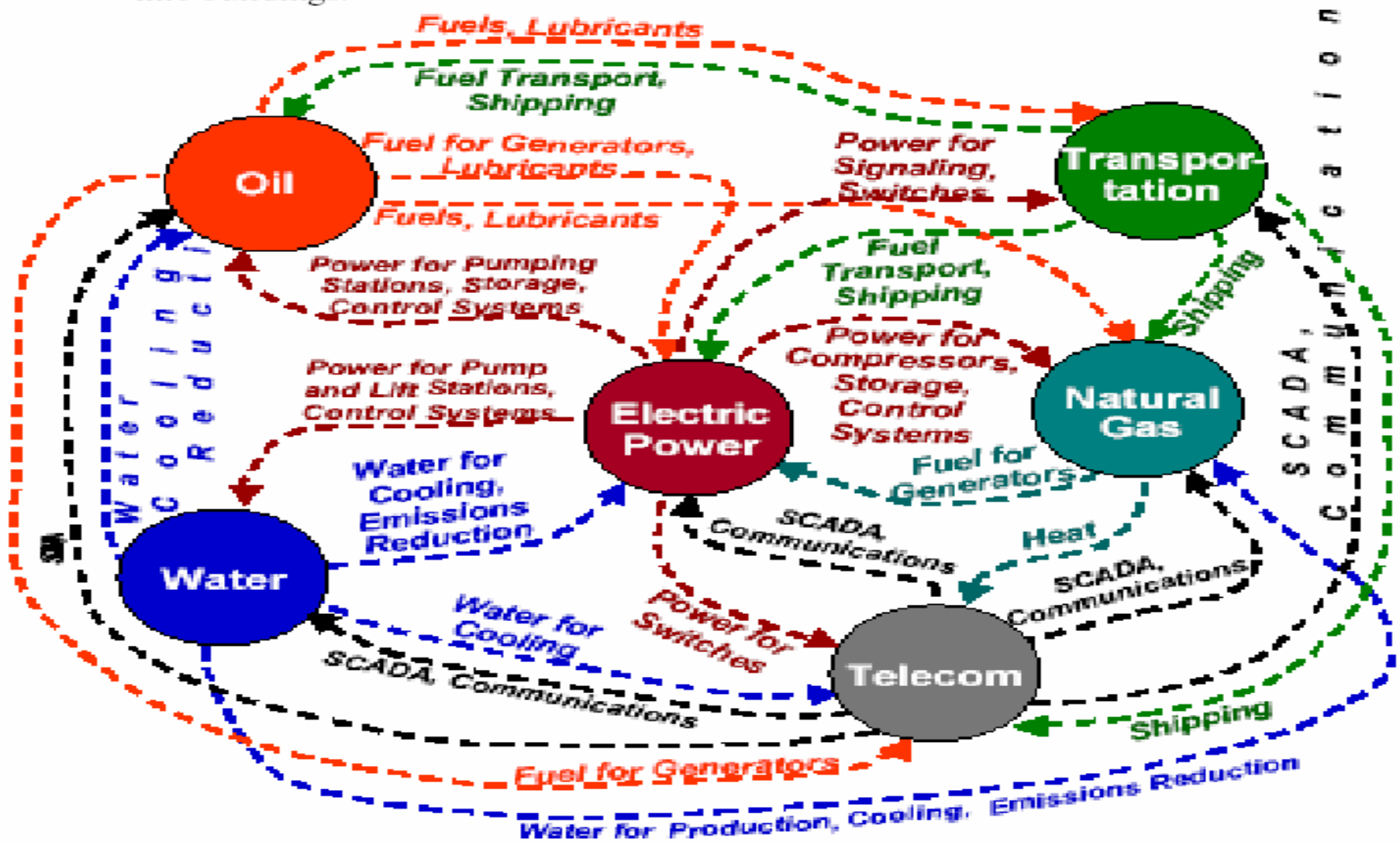


Figure 4: From a national security perspective, all critical infrastructures are inter-related and highly dependent on the electricity grid.

# Start with the answer...

- Large-scale wind energy
  - Low capacity factors
  - Seasonal and daily wind resource curves opposite to electricity demand curves
  - Transmission interface instability
  - Inadequate transmission capacity
  - High cost of electricity (COE)
  - Dependence on production tax credit (PTC)
  - Lack of firm capacity payments
  - Distance from good wind sites to electricity demand/population centers
  - High growth rate (and possibly higher with renewable portfolio standards-RPS) and larger percentages on grid



# ...then work backwards...

- Energy storage
  - Improves capacity factors
  - Smooths daily and seasonal load fluctuations
  - Uses existing transmission assets more productively
  - Allows firm capacity payments
  - Manages high percentage of wind on grid
  - Reduces dependence on PTC??
  - Reduces overall COE??
  - Substitutes for transmission capacity??



## ...then work backwards *to the questions*

- How can storage make wind energy the *best* new capacity option available, not just a subsidized resource forced on utilities?
- How can storage liquidate the typical arguments against renewable energy?
- How can storage enhance the support of renewable energy?
- How does storage fit into the world we see in 2020, and in 2006?



# ...then work backwards *to the questions...*

- The U.S. in the world in 2020
  - High fossil fuel costs?
  - Significant carbon constraints?
  - Global turmoil roiling premium fuel markets
  - Lack of domestic subsidies because of federal budget crisis and indebtedness?
  - Population growth in rural areas?
  - Terrorism and domestic security number one priority of Americans?
  - LNG imports similar to petroleum imports today?
- The world in 2006
  - Much like the world in 2005



...then work backwards *to the questions...*

- Wind + Storage

- Can it achieve 90% capacity factors typical of a base-load nuclear unit?
- Can it provide the flexibility of an intermediate-duty gas-fired combined cycle plant?
- Can it start up reliably like a peaking gas turbine?
- Does it help resolve transmission issues?
- Does it make us more secure in the world?



# ...and monetize the benefits

- The real or estimated value of...
  - A base-load-capable power plant operating at 90% capacity factor with “free” fuel
  - Avoiding LNG importation on the scale of our petroleum imports
  - CO<sub>2</sub>-free (or very low) power station
  - SO<sub>2</sub>, NO<sub>x</sub> emissions free power station
  - An intermediate load power station specifically designed for this purpose



# What LNG importation looks like...

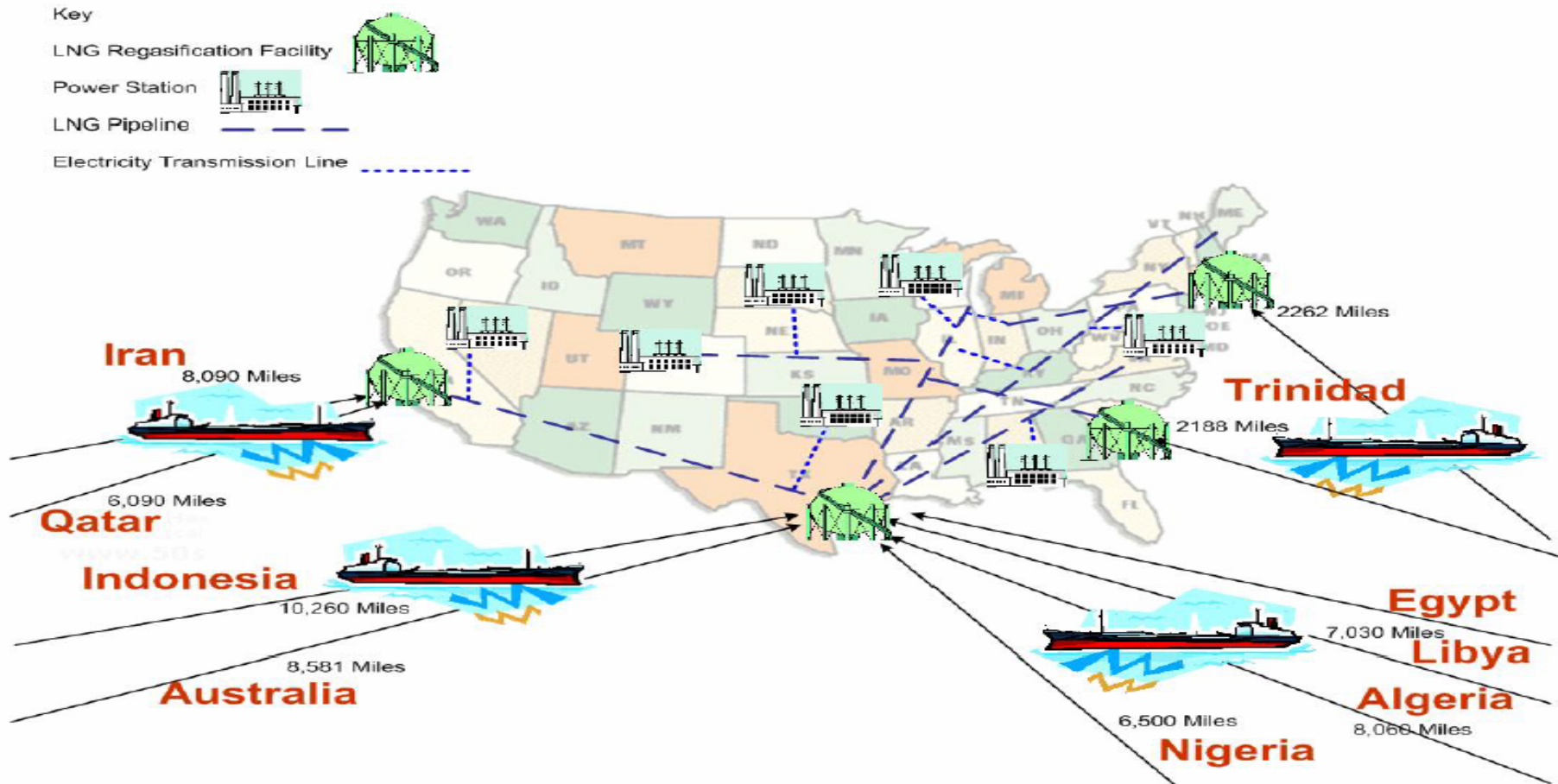


Fig 1: Importing LNG increases our “supply lines” for electricity production infrastructure by five- to ten-fold.

# Some intriguing questions...

- As a public policy issue, are we as a nation better off subsidizing wind energy with the PTC or channeling that money into the development, construction, and operation of large-scale storage facilities to capture the benefits just identified?
- Should electric energy storage be *the centerpiece* of DOE's efforts to modernize and secure the nation's electricity production and delivery infrastructure?
- On the commercial side, is the money that will be spent adding 2-3x wind turbines (to compensate for low capacity factor) better allocated to storage facilities coupled to wind farms?
- Why isn't energy storage R&DD funded as if it is a national imperative?
  - Look at the relative emphasis among coal, nuclear, transmission, and oil/gas, then storage, in the recently passed energy bill!



# Is our collective head in the sand?

- The European perspective suggests “YES”
  - Wind Energy has “exploded” in Europe
  - Germany leads with over 14,000 MW installed. Denmark has more than 10% of its generating capacity as wind
  - The issue of grid stability and base-load plant cycling has been fully manifested
  - DENA (German energy agency) organized a recent conference in Berlin on the subject of CAES (storage) and wind energy
  - Invited were large grid operators, power companies, wind farm operators & government officials



# Is our collective head in the sand?

- The European perspective
  - There was a broad agreement that storage is and will be needed
  - Ideas were requested to modify energy feed-in law to reward energy storage

What is being done here to bring utilities, wind project developers, technologists, OEMs, regulators and legislators, and electricity industry leaders together?

Can we get ahead of the curve instead of playing catch-up once a significant percentage of renewables is on-line here?

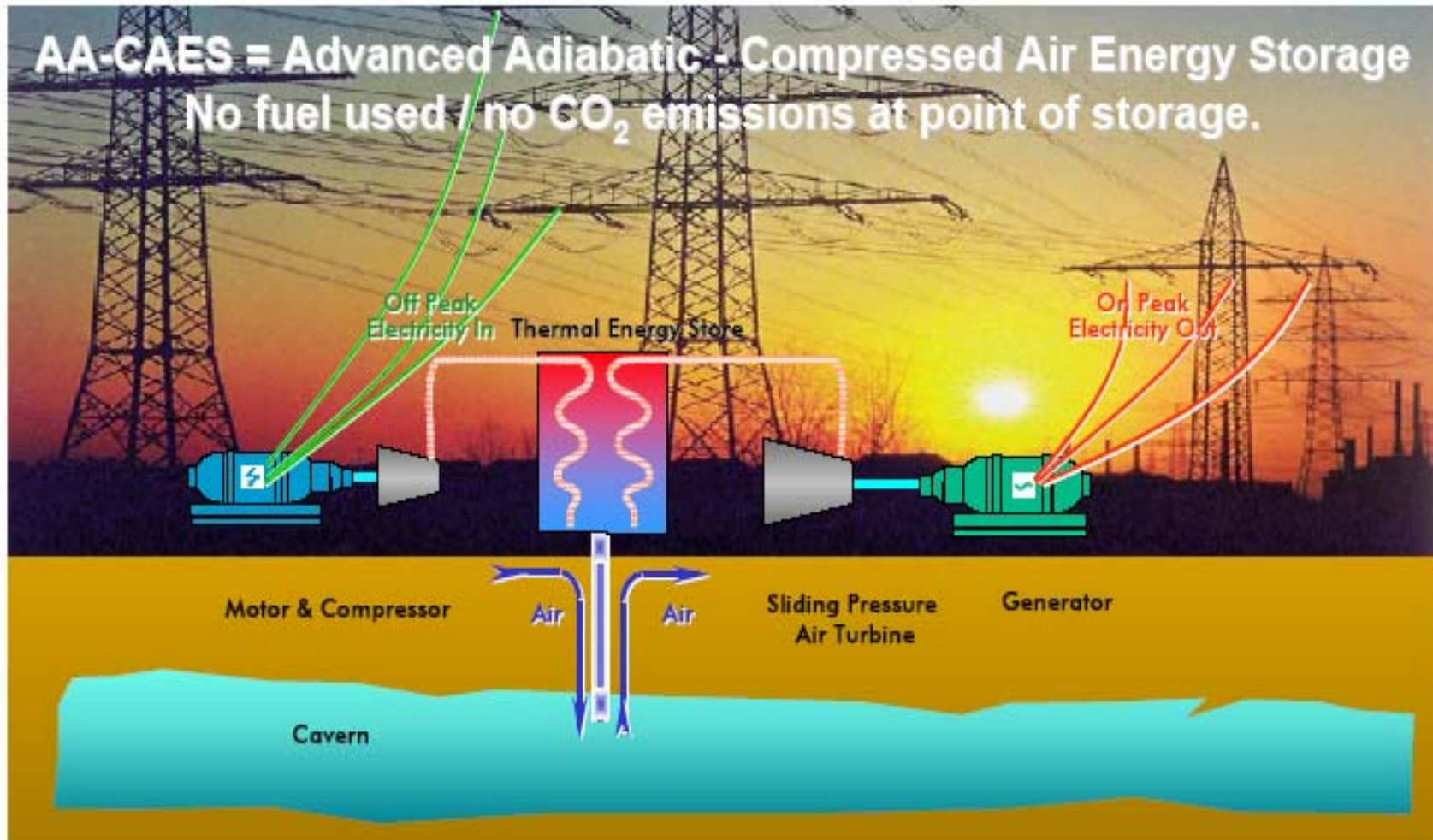
# Is our collective head in the sand?

- The European perspective
  - Advanced Adiabatic CAES (AA-CAES) development progressing in Europe—Integration of Wind Energy
  - Wind energy or excess power generation stored as compressed air
  - AA-CAES compress & expands stored air adiabatically
  - Heat of compression is stored thermally (TES) & preheats the air prior to expansion in a power turbine
  - No added fuel—no emissions—every 100 MW/hrs captured from wind represents 90,000 tons of CO<sub>2</sub>!
  - Plant Sizes of 300 MW-150 MW & 30 MW are proposed
  - Demonstration Projects starting at 30 MW under consideration

**Is Europe where the US must go to obtain this technology?**

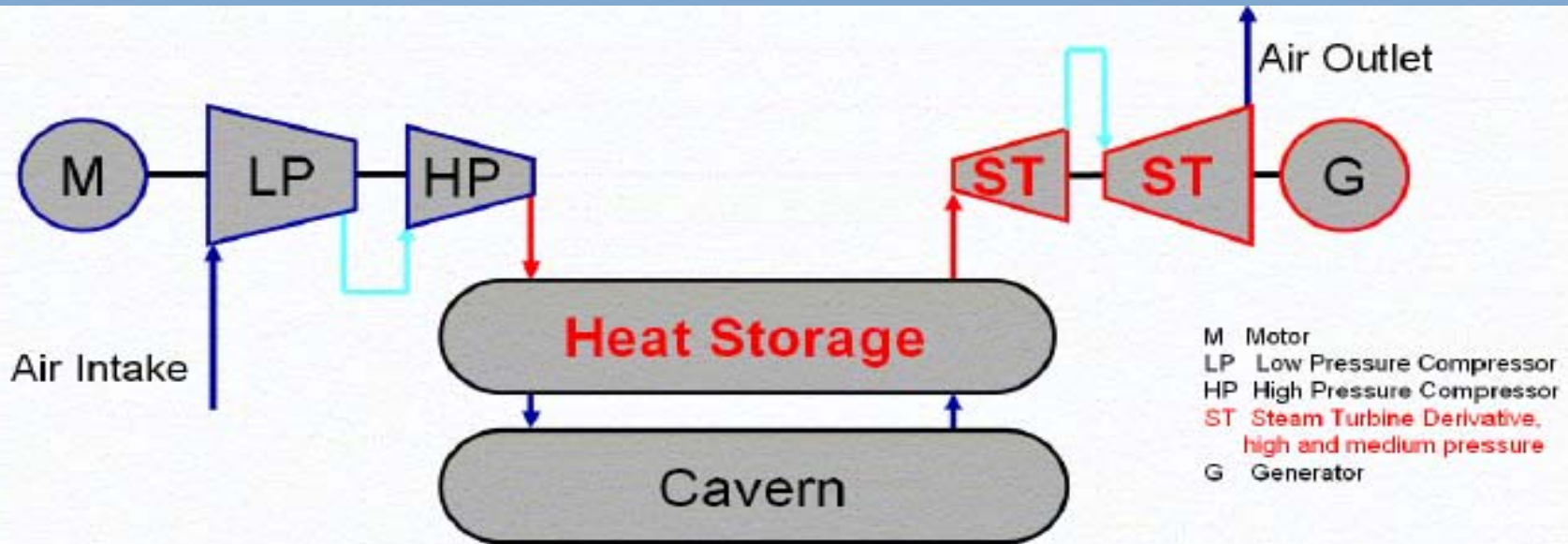
**Why not initiate & drive such technology efforts here in the USA?**

# Europeans considering...AA-CAES



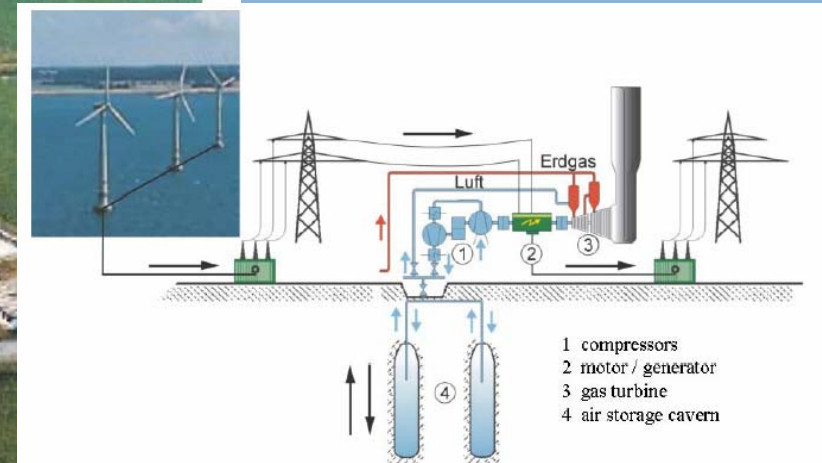
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# AA-CAES



Modus	Strategy of Operation	Size
Central Device	Revenues from Spot Market Price Spreads and System Services	300 MW
Decentral Device	Large windfarms Increase of Full Load Hours of WEG Ancillary Services Peak Price sales	150 MW
Remote Island Solution	Combined Wind/CAES System on autonomous Island; savings of grid connection costs or Gas Turbine Increase of Full Load Hours of WEG	30 MW

# Technologies are ready...CAES



# CAES Attributes\*

- Significant storage capacity at relatively low cost (\$400-600/kW)
- Proven technology, supplied competitively, easily optimized for site-specific conditions
- Black start, fast startup (seconds from hot spinning reserve condition, 5-12 minutes from cold metal), ramp rates of 30% MCR per minute
- Nominal heat rate 2.5 times better than combustion turbine, much better part load efficiency
- Ability to operate as synchronous condenser
- Project lead times less than three years

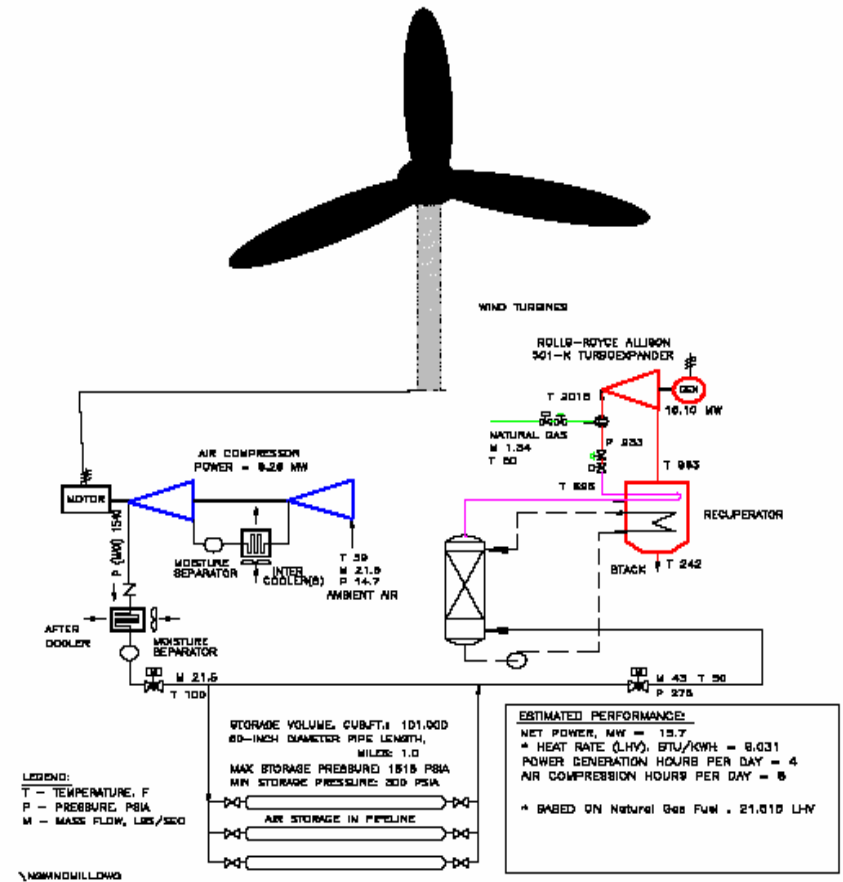
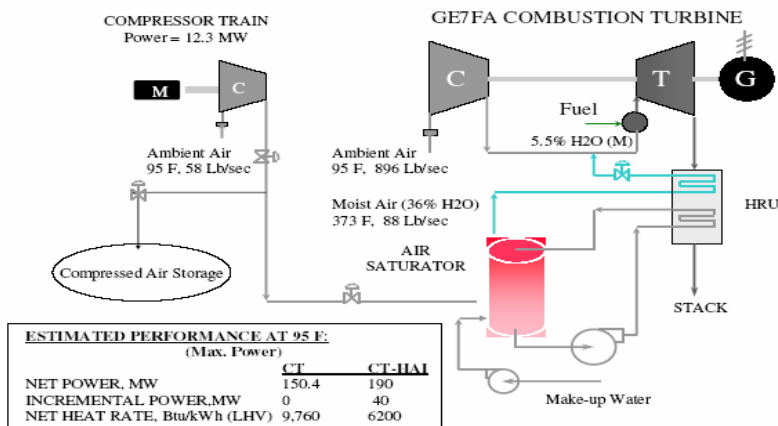
\*Source: EPRI T&D Handbook, Chapter on CAES

# New CAES Technologies--SSCAES



Existing storage technology  
Buried gas storage near Zurich, Switzerland  
Operating pressure 1000 PSI

## CAES-CT Concept with Humidification based on GE 7FA CT



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# ...Small-scale storage with wind

- On-going analytical studies on transmission benefits of deploying hybrid wind and advanced battery storage systems.
- Numerous schematics to couple wind turbine generators with power electronics and UPS-like devices for ride-through, and advanced batteries and flywheels for renewable storage

KEY REQUIREMENT: DEVICES MUST FIT UTILITY PERFORMANCE PROFILE, ESPECIALLY FOR RELIABILITY. Otherwise, firm capacity benefit is lost



# Flywheels for grid frequency regulation

- Regulation, or fine-tuning of grid frequency, does *not* require generation
- Required time to full capacity- <5 minutes
- Flywheel “Smart Energy Matrix”
  - Ten 25-kWh flywheels
  - 1-2.5 MW for five to 15 minutes
  - Quick connection, highly mobile
  - Delivers both real and reactive power
  - Excellent deep discharge and cycling
  - Sub-second response time



ANCILLARY SERVICE	GRID STATUS	TIME TO FULL CAPACITY	PURPOSE
REGULATION	On-line	< 5 min.	Fine -tune frequency
SPINNING RESERVE	On-line	10 - 15 min.	Fill in big energy holes
SUPPLEMENTAL RESERVE	Off-line	10 - 15 min.	Fill in big energy holes
REPLACEMENT RESERVE	Off-line	30 - 60 min.	Fill in big energy holes

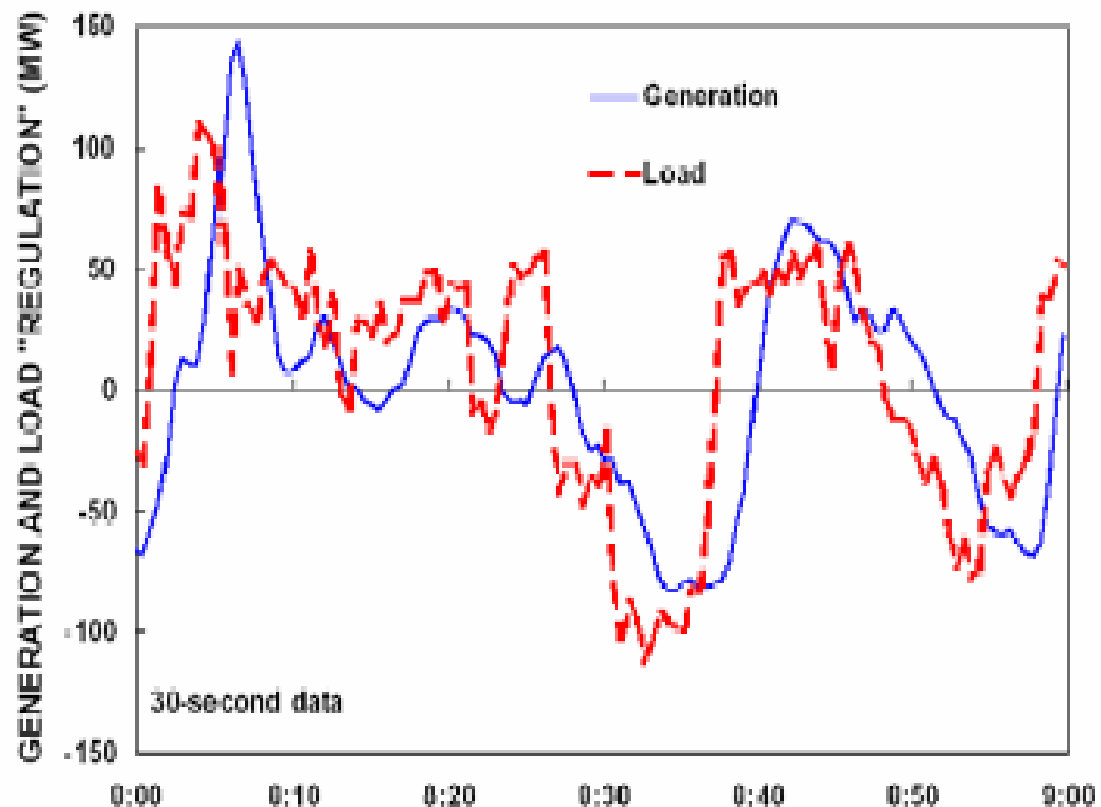
**Regulation does not require generation  
that the other services do**



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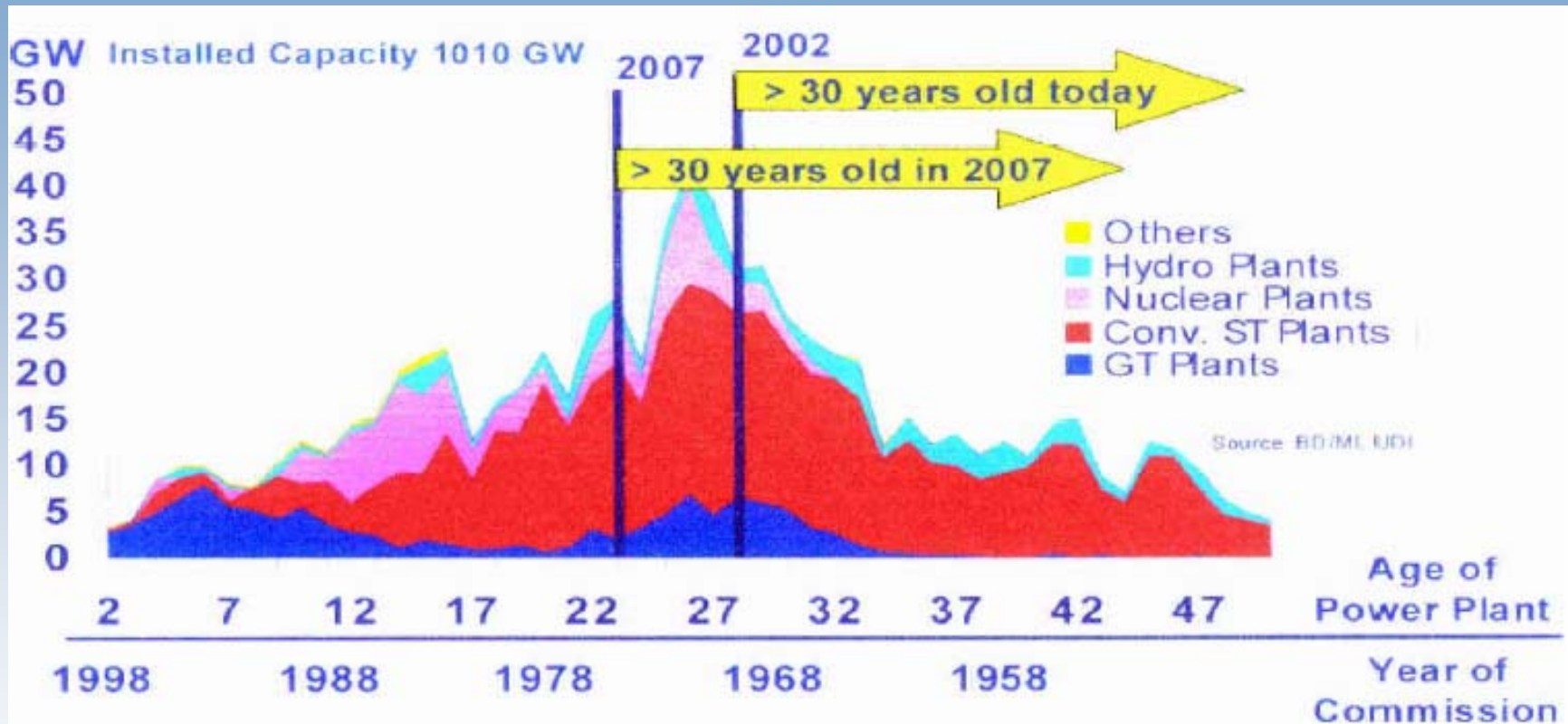
# Frequency Regulation from Fossil Fuel Plants

- Fossil systems follow load with a several minute time lag
- Slow Response leads to greater Area Control Error (ACE)



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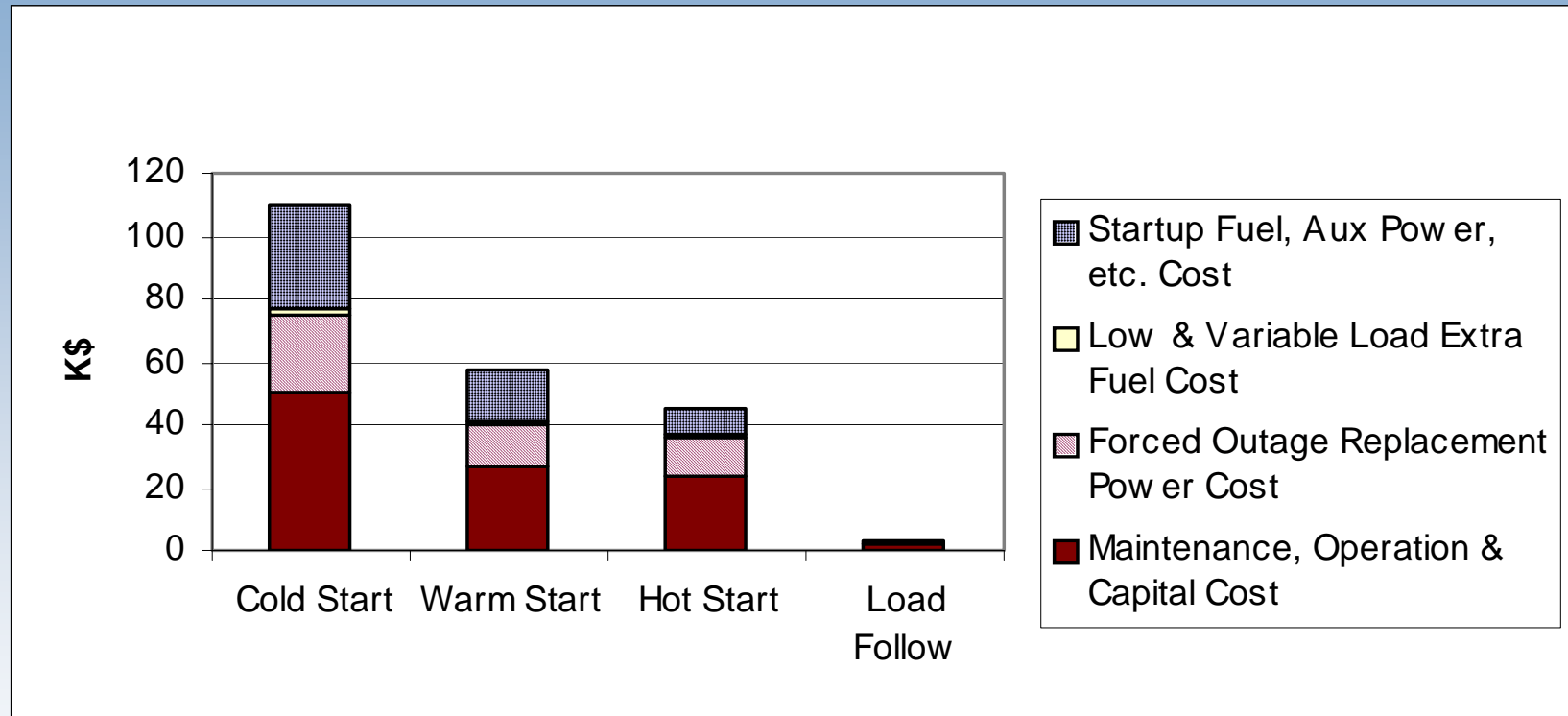
# ...And speaking of those *aging* fossil Plants



- Replacement with CAES will improve loading & efficiency of advanced coal plants, lower emissions per kW/hr
- Integrate Renewable power with more grid stability



# Cycling aging fossil plants is costly...



Source: Aptech Engineering Services Inc, Sunnyvale, CA

# The needs are apparent...

- Enhance the value of renewable energy
- Improve security of our domestic energy infrastructure
- Raise productivity of existing transmission assets
- Minimize O&M costs from cycling aging fossil power stations
- Provide cost-effective grid ancillary services
- Arbitrage low-cost power into higher cost regions

...The technologies are ready or under development...

- Ultra-capacitors
- Flywheels
- Advanced batteries and regenerative fuel cells
- CAES
  - **Conventional** (fully demonstrated-Huntorf 290 MW and McIntosh 110 MW)
  - **Advanced Adiabatic-CAES**
  - **Sub-Surface CAES**



# ...Where is the leadership?

- Energy Storage Council, DC-based policy organization, no longer funded by storage community
- EPRI-Information transfer (recently issued storage handbook) but leadership in this area, typical 20 years ago, is lacking
- ESA-technical community with members who are not allowed to lobby
- DOE-an almost insignificant piece of the overall R&D budget
- CA, NY have modestly funded storage R&D programs
- No power industry “major” (GE, Siemens) pushes energy storage in U.S.
- No significant deep-pocket developer is actively developing projects- “one-offs” typical to date
- No electric utility supports storage as integral to its business strategy-only as an R&D line item
- No RTOs or ISO (PJM, MISO, Ercot) see storage as integral to their business

Contrast this to: AWEA for wind, FPL in wind development, GE in wind turbines



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# Some interesting quotes...

- “The use of energy storage increases the net emissions and lowers the payback ratio due to conversion and transmission inefficiencies but the addition of storage to low-carbon generation from renewable sources can produce a completely dispatchable and relatively low carbon electricity infrastructure.” **Net Energy Balance and Greenhouse Gas Emissions from Renewable Energy Storage Systems,** Energy Center of Wisconsin, June 2003 ([www.ecw.org](http://www.ecw.org))
- “Storage strategies do not appear particularly useful. Even under the optimistic assumptions used here, we find that the rates of return for investment in storage are either negative or small.” **Improving the value of wind energy generation through backup generation and energy storage** (draft for review), California Wind Energy Collaborative, August 2003.

**What organization is out there ensuring that studies like these are validated, thoroughly vetted, and responded to?**

# What we can do about lack of U.S. attention to energy storage

- Identify and support bold leadership to ask the hard questions and address them with competent analysis and foresight.
- Support a consistent public policy and advocacy presence in Washington and the state houses.
- Make compelling arguments for cooperation with other industry groups. Make them work with us!
- Drive a “top-down” energy storage agenda with the C-level executives at utilities, major project developers, investment community, and equipment suppliers.
- Involve the European and global industry leads to participate more fully in activities here