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Superconductivity and Electric Power: Several Future Scenarios

Paul M. Grant

EPRI

DOE Peer Review Workshop

23 July 1997

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What is Electricity?

Electricity is the most efficient and convenient means mankind has found to transport energy throughout his habitat….

Electricity and the Quality of Life

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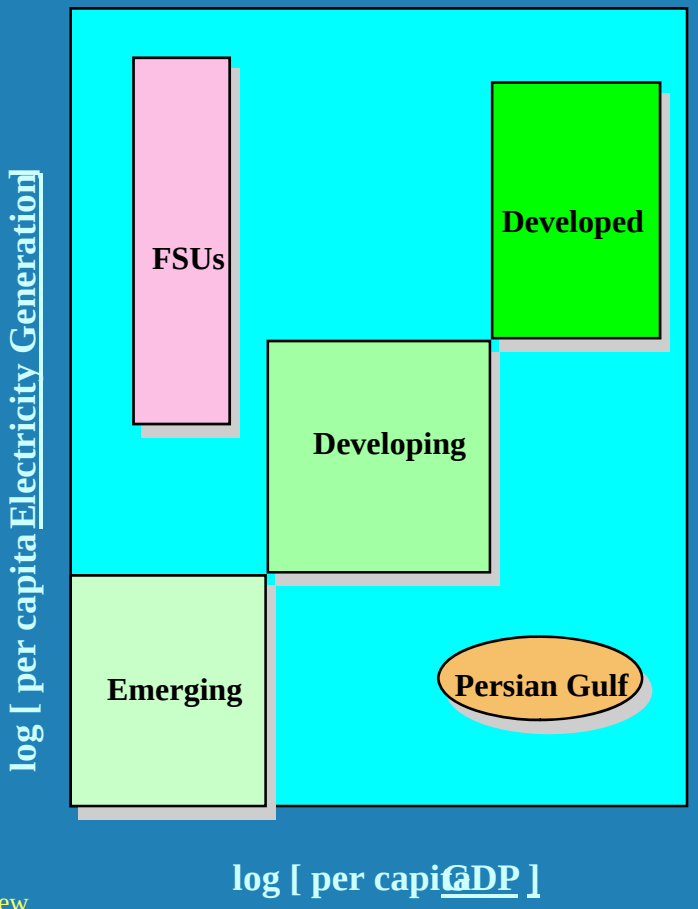

- Electricity directly related to standard of living in most of the world
- Enormous increase in electricity usage seen for the 21st century

Electricity & QoL: Asian Scene

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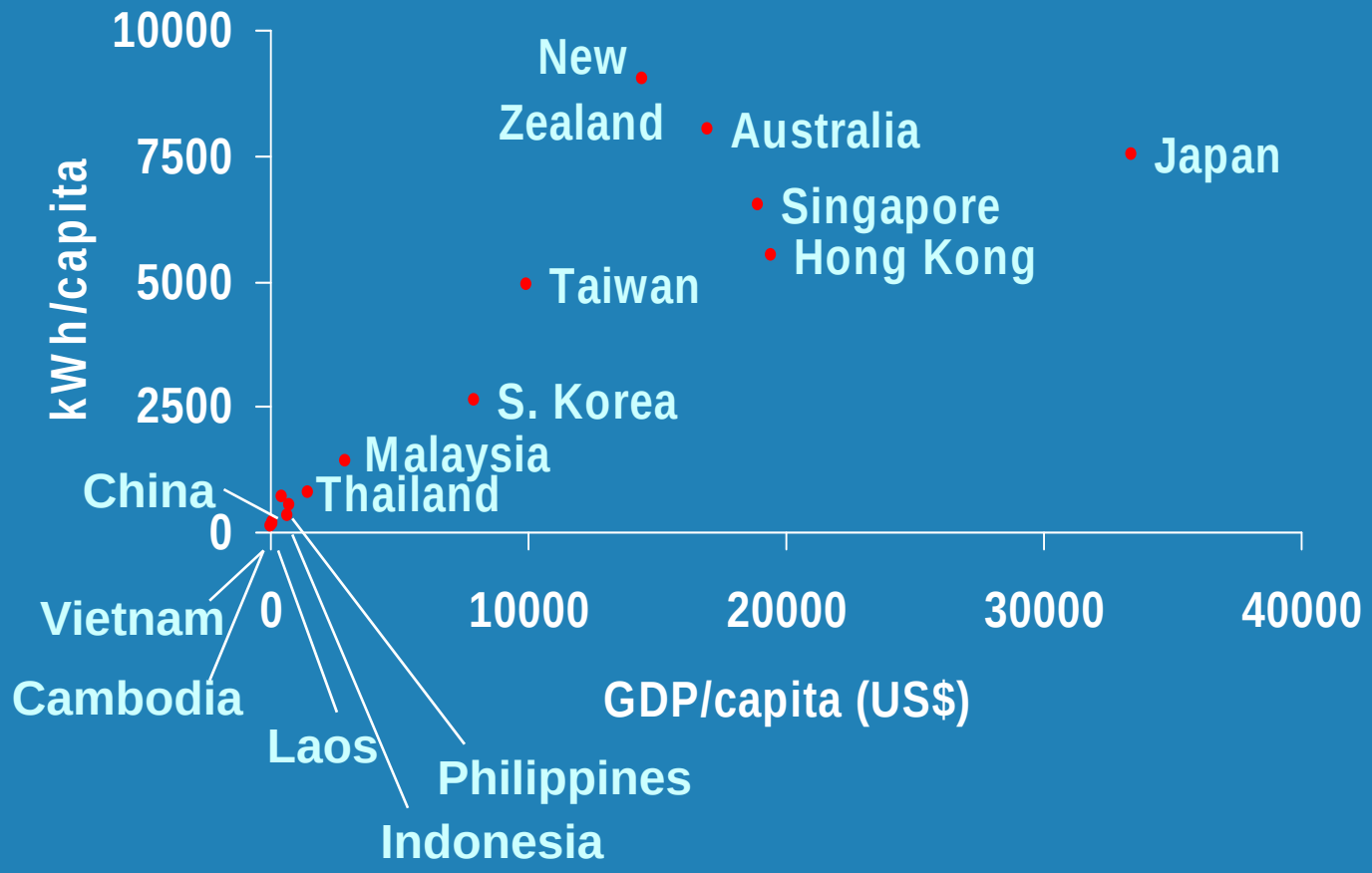

Electricity & Energy Conservation

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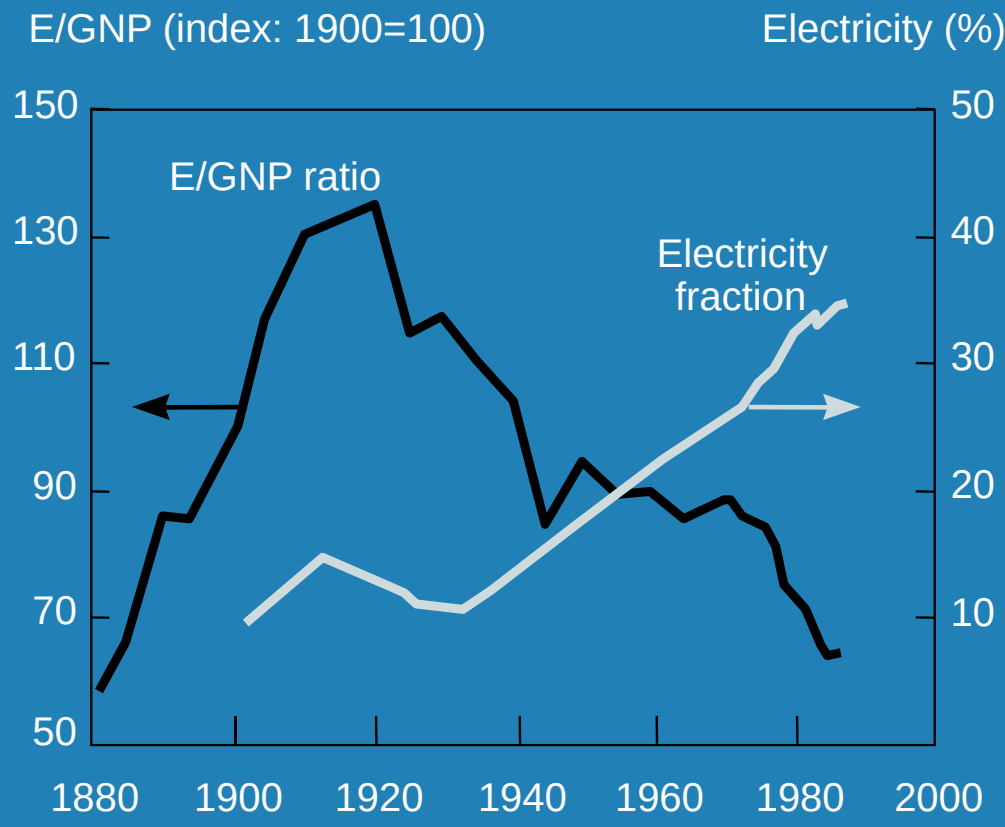

Electricity is the most efficient and convenient means mankind has found to transport energy throughout his habitat….

Source: Electricity in the American Economy, Sam H. Schurr, et al., 1990

Electricity - The Bottom Line

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Sunday, August 11, 1996

Millions lose power

Half of PG&E's customers in Northern California affected; blackouts in 9 states

THE POWER PROBLEM

PG&E Firms wonder: Is this the future?

U.S. says power will be bolstered

Substation explosion cuts PG&E service in South San Jose

Outage raises serious worries

Investigations planned after power grid falters

More Outages Expected for Power Network

Increased demand strains regional transmission lines

ELECTRICITY USERS FEELING POWERLESS

Shutoffs fray nerves in South San Jose

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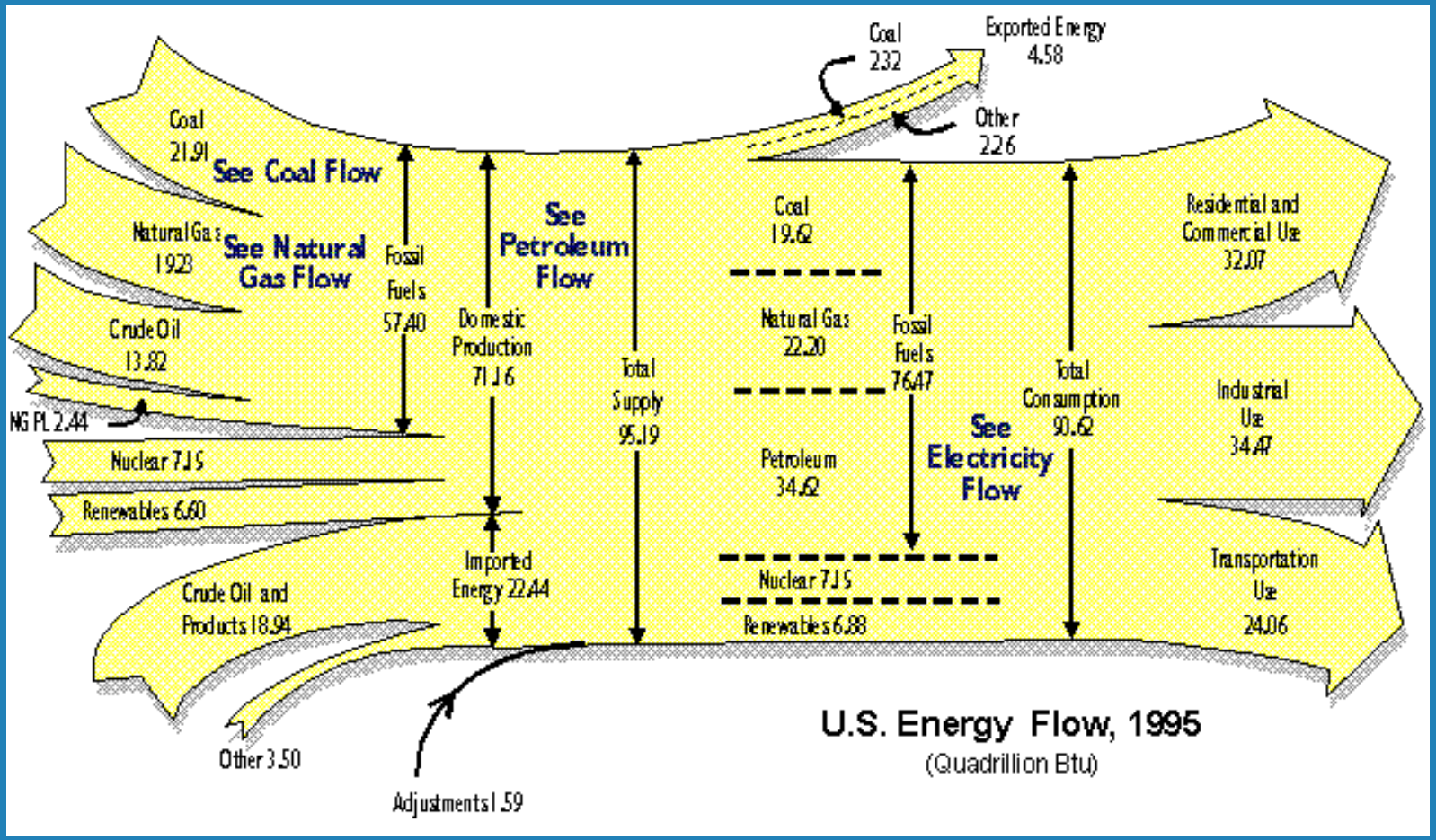
US Energy Flow - 1995



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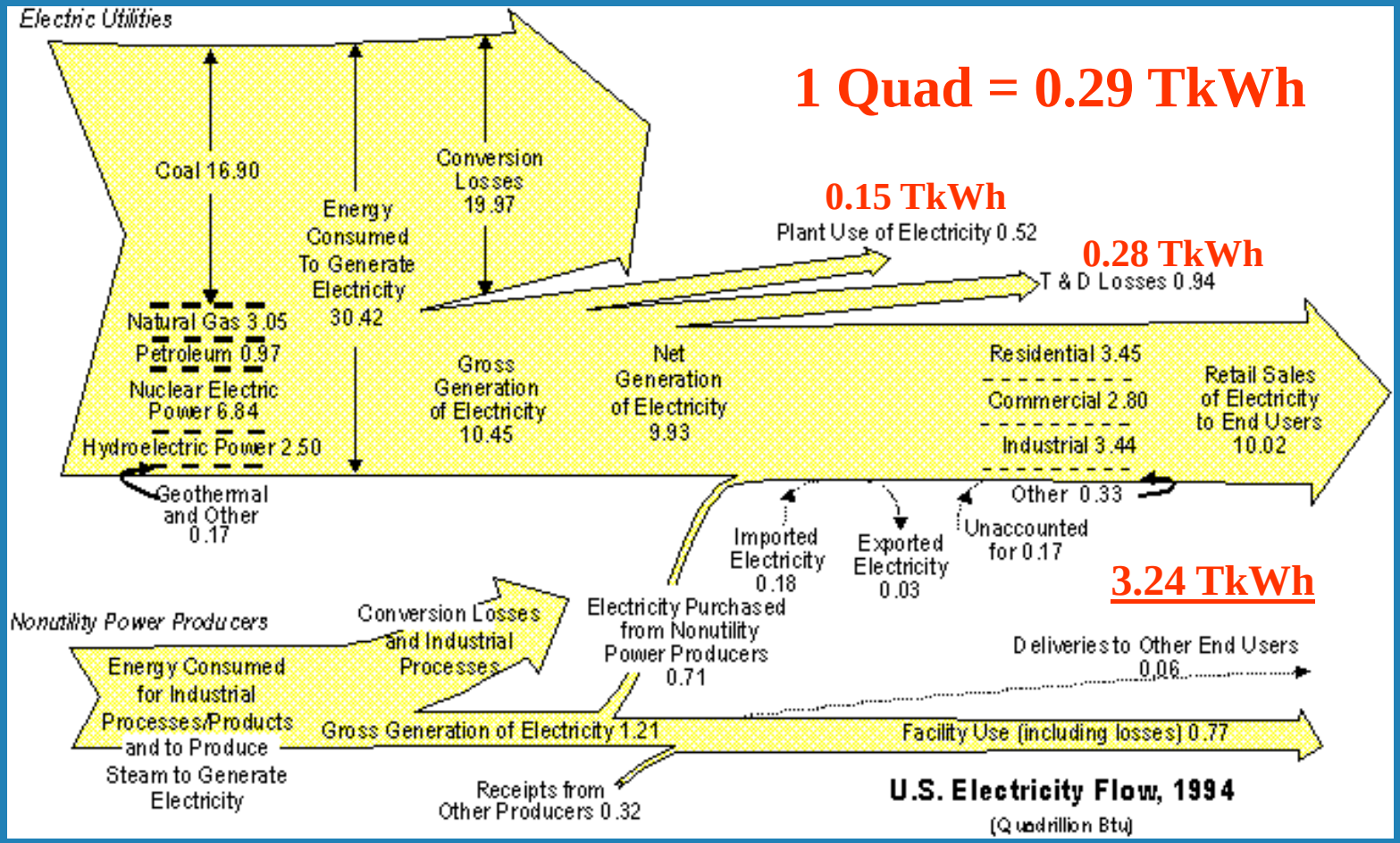
US Electricity Flow - 1994



Electricity Prices: 1995 US & Asia (¢US/kWh)

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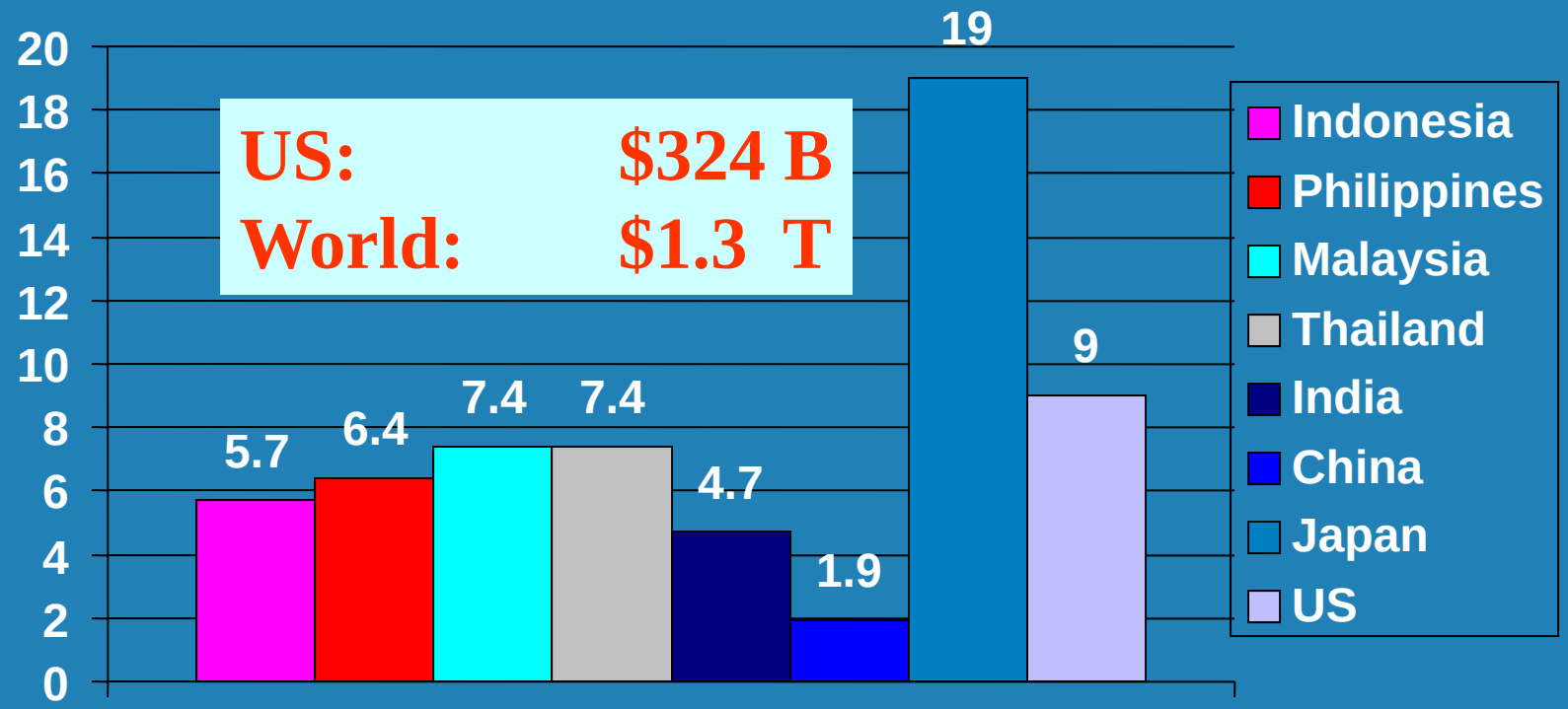

Production/Loss Summary

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	TkWh	% in T&D Loss and In-Plant Use	Revenue @ $0.10/kWh (B$)	No. of 500 MW Power Plant Equivalents	Capital Cost @ $800/kW (B$)
Total	3.24		324	740	296
T&D Losses	0.28	8%	28	63	25
In-Plant Used	0.15	5%	15	35	14

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The Electricity Paradigm

- Generation/Storage
- Transmission/Distribution
- Delivery/End Use

The Electricity Paradigm *and Superconductivity*

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- **Generation/Storage**
  - **Generators, SMES, Flywheels**
- **Transmission/Distribution**
  - **Cables, Transformers, FCLs**
- **Delivery/End Use**
  - **Motors, Electromagnets**

Superconductivity and Efficiency

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	1994	2014 @ 2%/yr	2014 Plants Saved 0.2% Penetration 4× Efficiency
Total	740	360	
T&D Losses	63	31	11
In-House Use	35	17	6

The Electricity Paradigm *and Deregulation*

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- Generation/Storage
  - GenCo
    - Deregulated, Open Market, Commodity Bidding
- Transmission/Distribution
  - TranCo
    - Regulated, ISOs, Stewardship?
- Delivery/End Use
  - ServCo
    - Deregulated, MultiUtility (Elec, Gas, Telecom,...)

Electricity-Transportation Analogy

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Electricity	Transportation
• Fuel	• Natural Resources
• Generation	• Manufacturing/Agriculture
• Transmission *Electrons* • Distribution	• Interstate Highways *Trucks* • Regional Freeways
• End Uses • Lighting • Rotating Machinery • Appliandes	• Retail Sales • Home Depot • Sears • Safeway

Electricity Transmission *and Deregulation*

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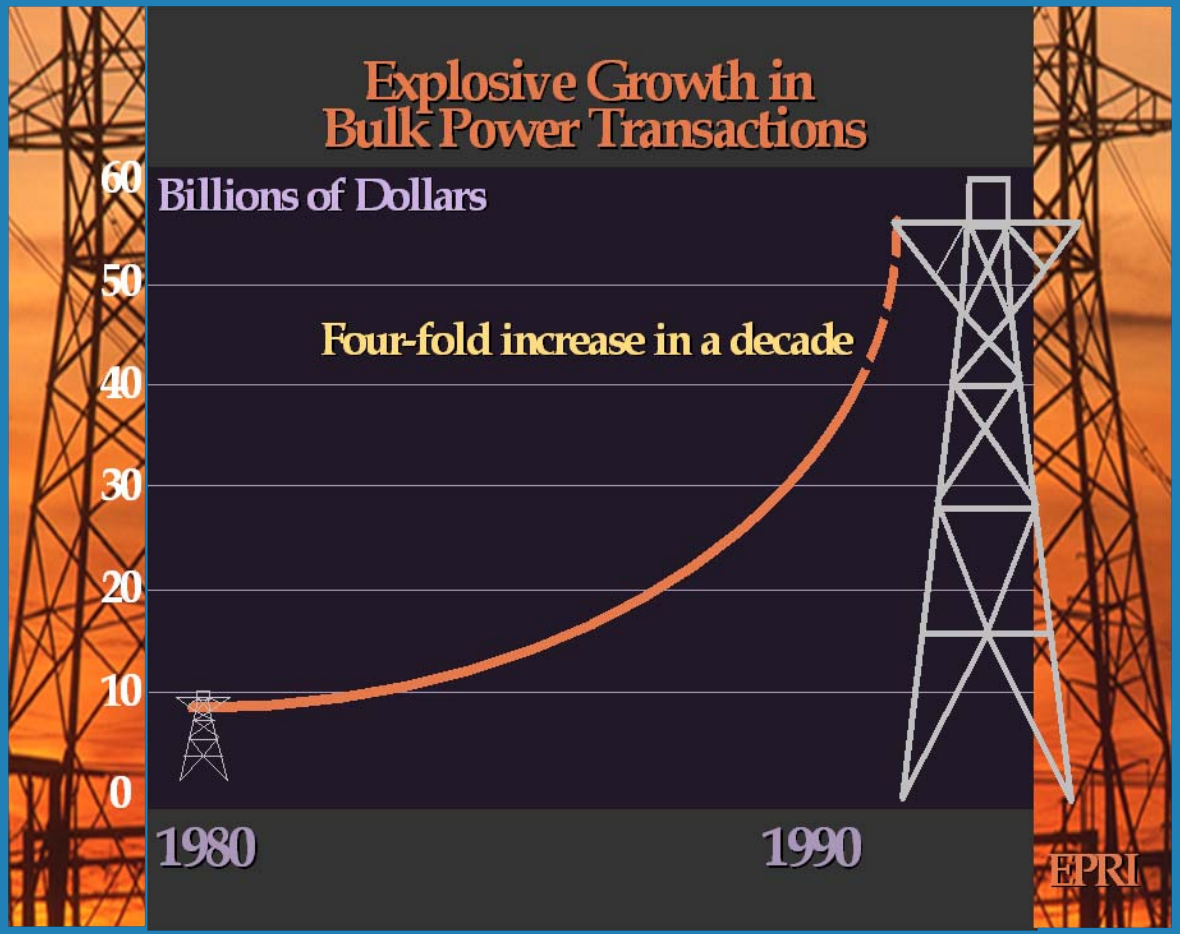

- Public Stake in Viable Grid
- Freeway System Analogy
- Who's in Charge?

California AB 1890 *Summary*

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- Implements electricity deregulation and mandates CEC to set up RD&D program
- CEC RD&D Program Mission
  - "Public interest RD&D activities to advance energy science or technology not adequately provided by competitive and regulated markets"
- Funded by utilities and access rate levy
  - $62 M/yr

California AB 1890 *RD&D Focus Areas*

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- Renewable Energy
- Energy Efficiency
  - Superconductivity?
- Environmental Protection
- Strategic Energy Research
  - Superconductivity?

Gas or Electricity?
Pipes or Wires?

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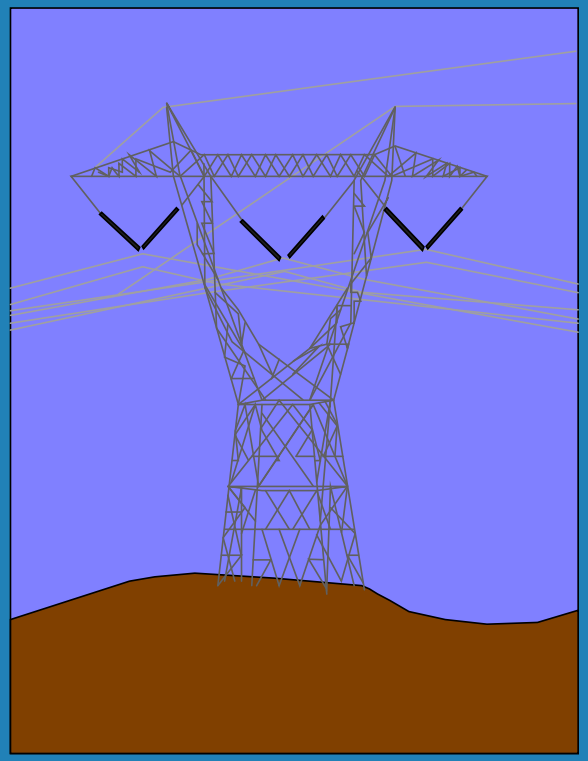

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North American CH_4 *There's Lots of It*

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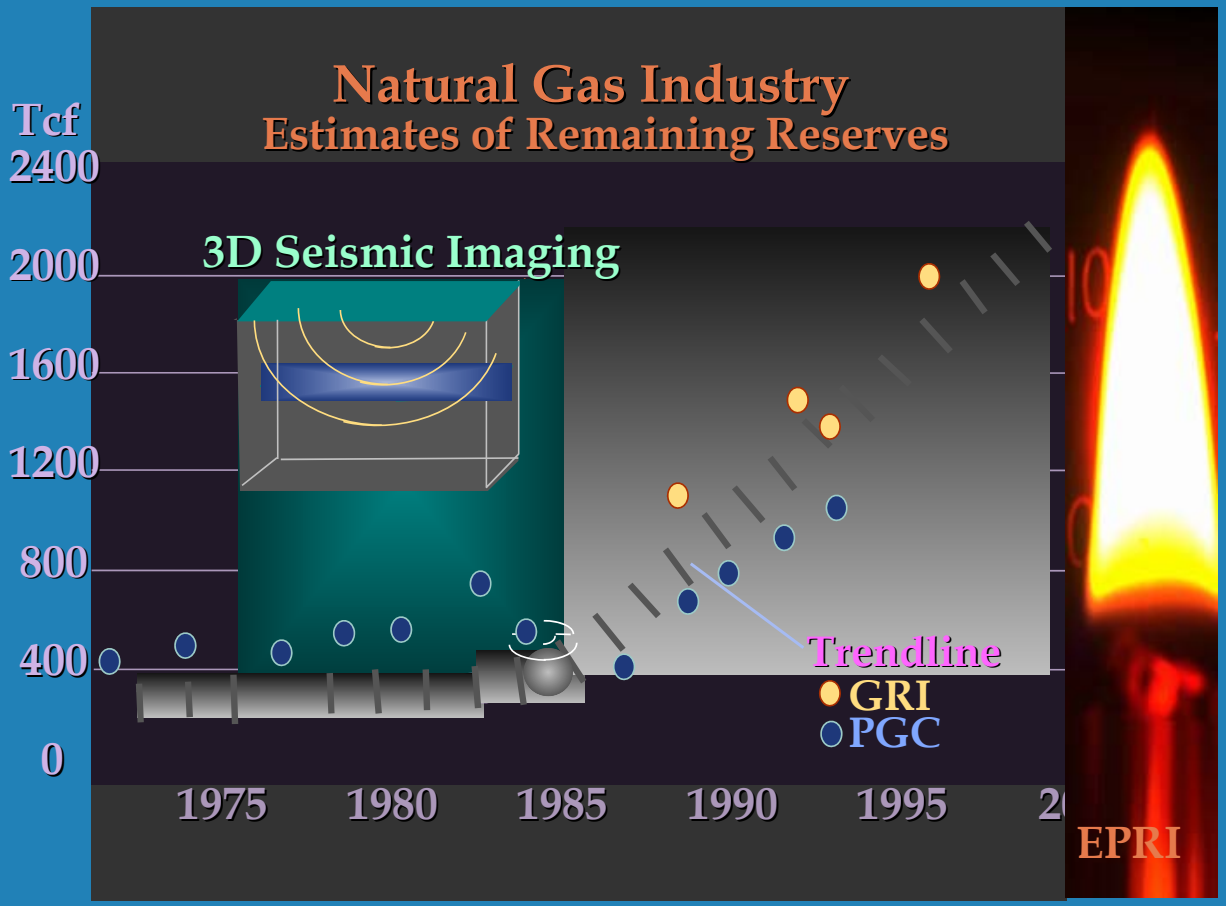

3D Seismic Imaging Plus Directional Drilling

50 Years at '97 Prices!

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Monthly Price Fluctuations

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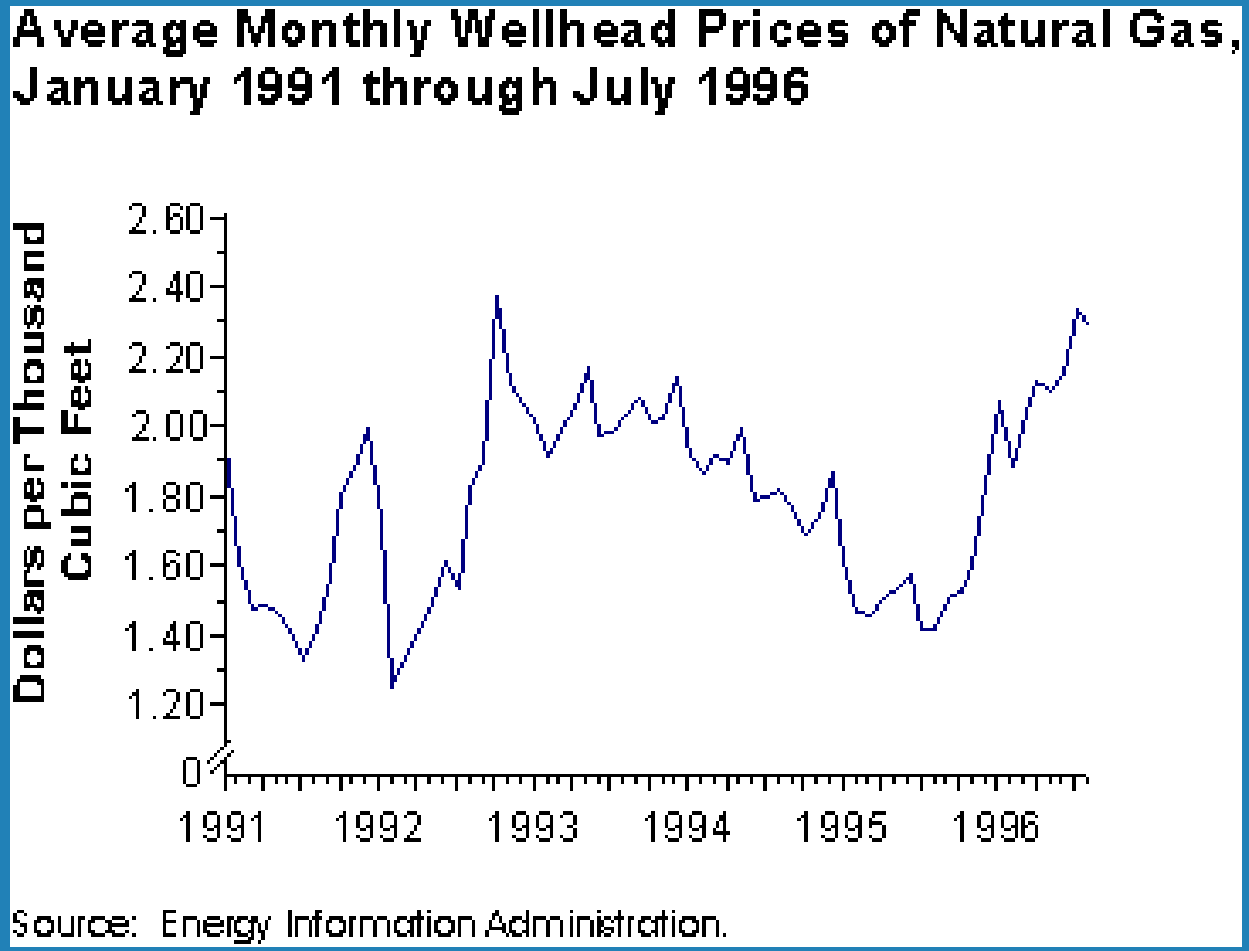

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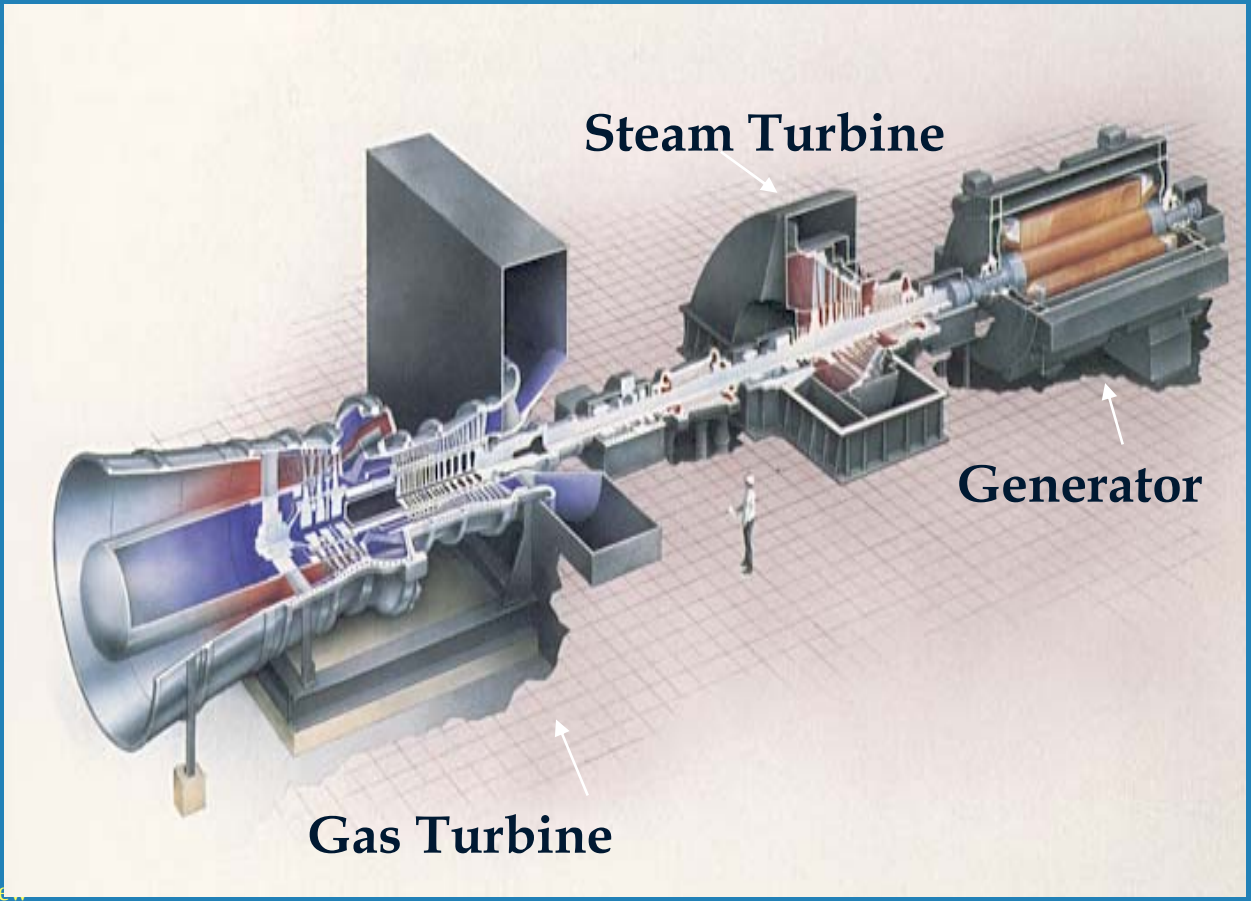
Electricity from Gas



Combined Cycle Gas Turbine (Aeroderived)

>60% TE, $500/kW

GE, ABB, Hitachi

Distributed Generation: US &Europe

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- Use widespread NG pipeline network
- Generation plants sited locally
  - Community of 60,000: 50-100 MW
  - Subdivision of 1-2000: 3-5 MW
  - Single Family Dwelling: 20-30 kW (100,000 btu/hr)
- Some level of storage required
- "Loosely" connected to grid

Distributed Generation: Approaches

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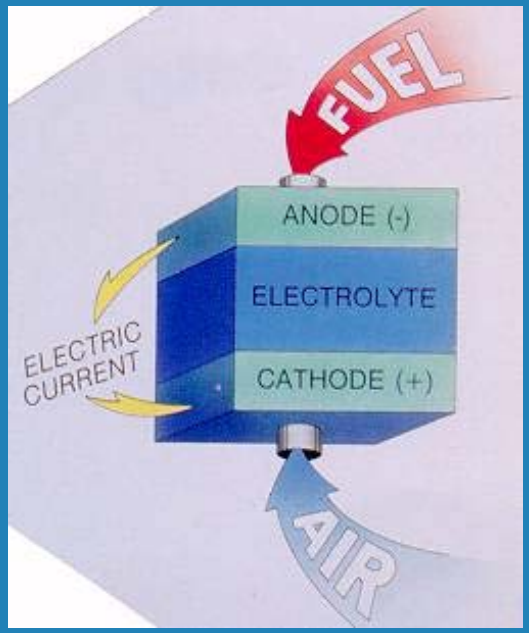
- Internal Combustion (GRI)
- "Micro-turbines" (EPRI)
- Solid Oxide Fuel Cells



Power by HTSC: Middle East

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Power by HTSC: North America

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- Two Wheeling Scenarios:
  - Hudson Bay Hydo Power into New England/New York
  - Vera Cruz Gas Fields to Texas

Power by HTSC: Asia

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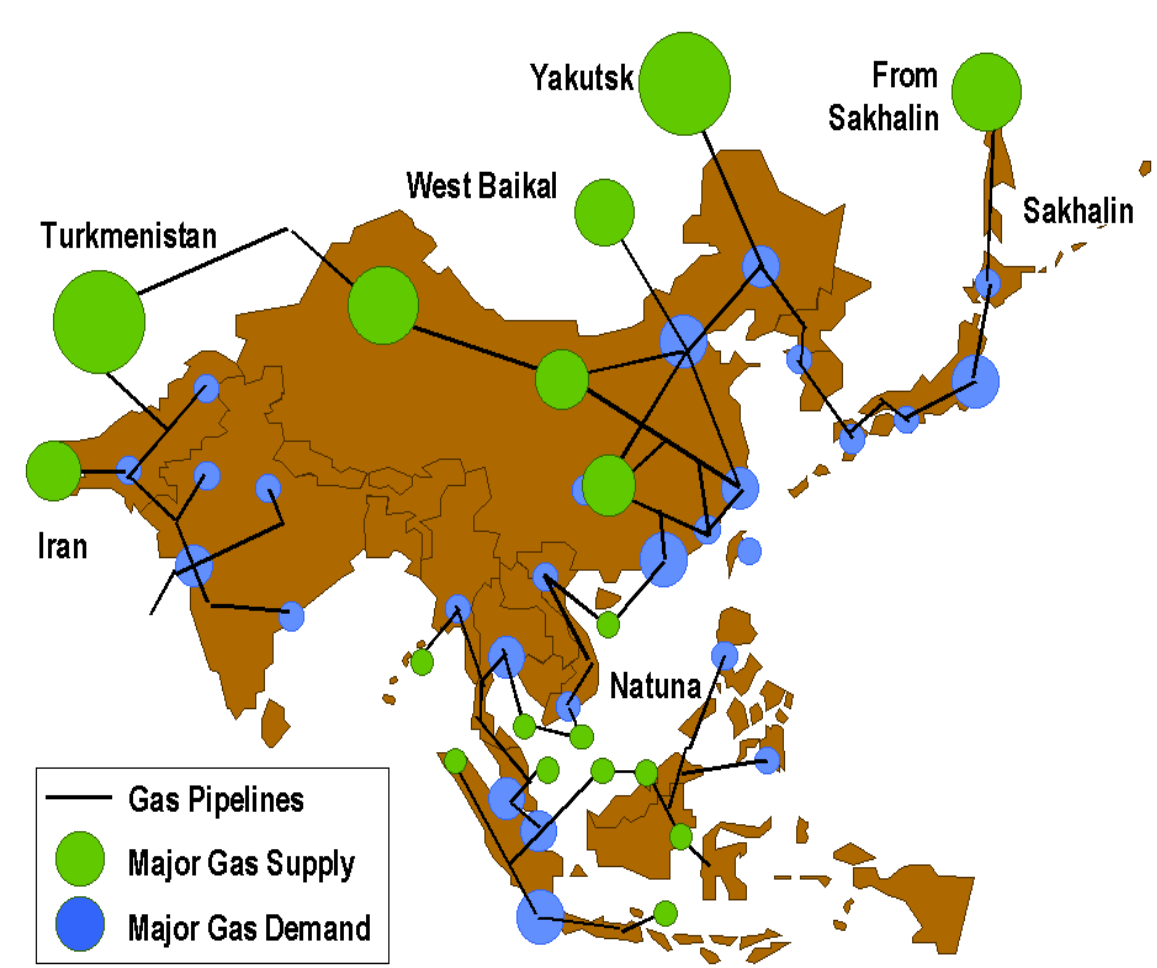

Location of Asian Gas Fields and Major Energy Use Centers

Power by HTSC: Southeast Asia

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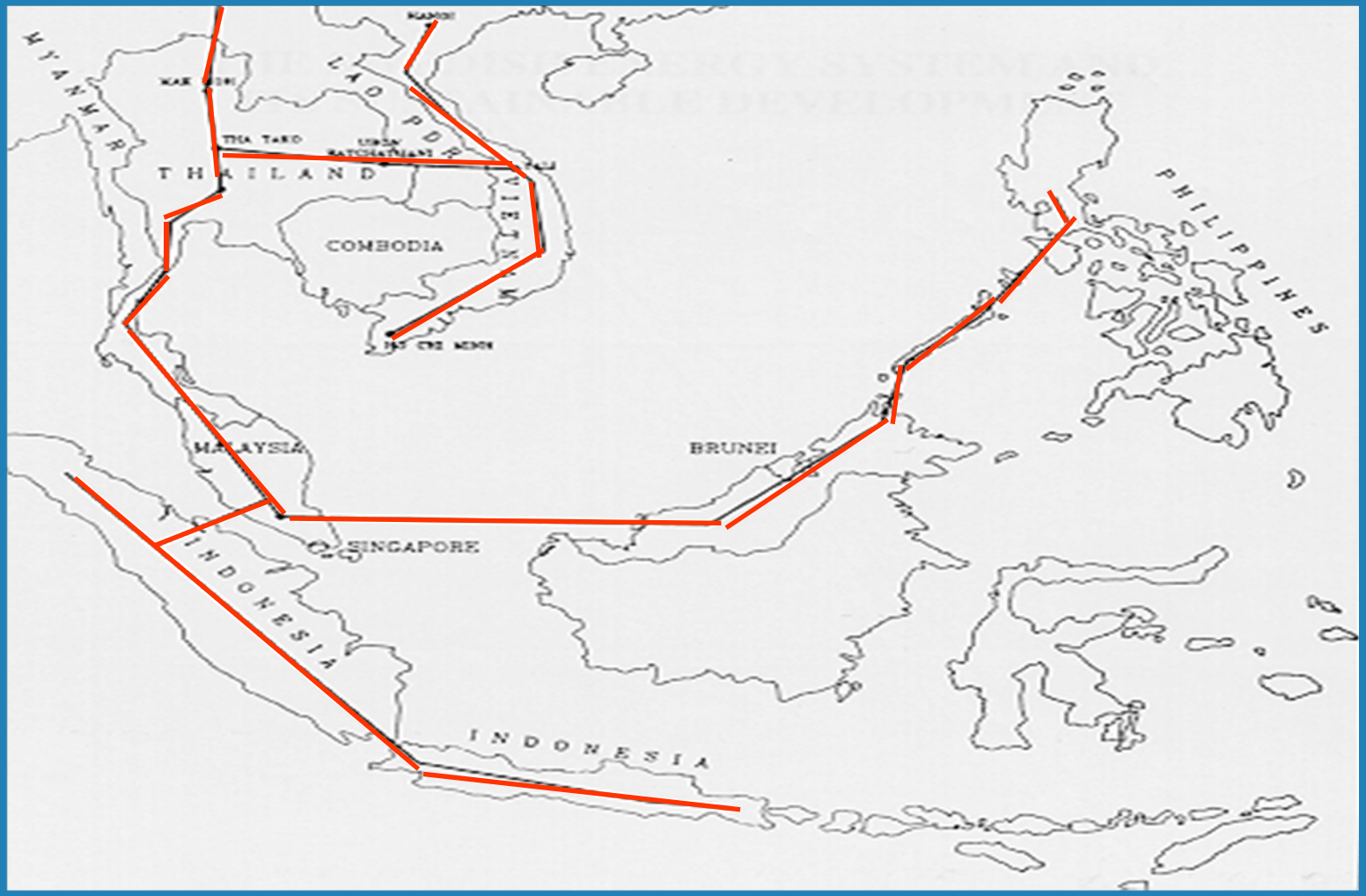

The Superconducting Electricity Pipe!

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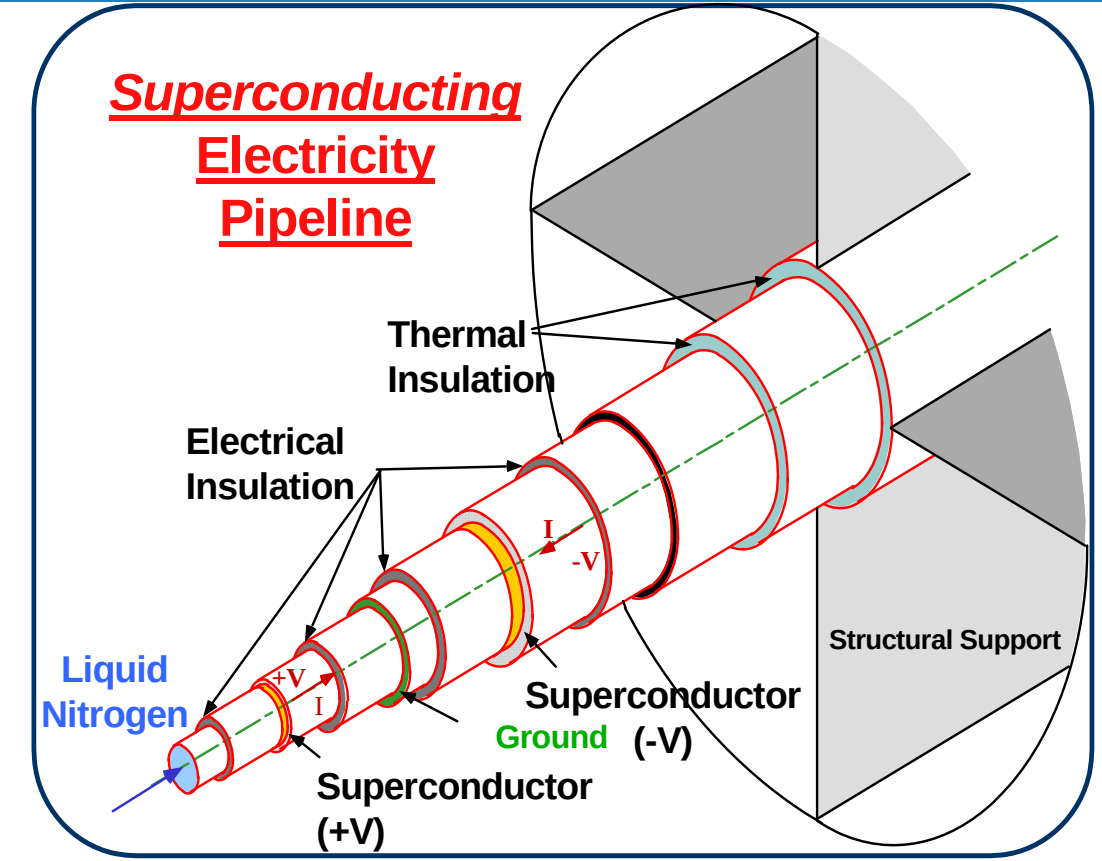

- Total Cryo System
- Power: 5 GW dc
- Cost: < Gas, HVDC > 500 Miles

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Operating Parameters

Capacity	50 kA, ±50 kV; %GMW
Length	1610 km
Temperature Rise, 1 K every 10 km, 65 K, 1 W/m heat input	21,600 liters LN_2/hr, 100 kW coolers, 120 gal/min
Vacuum 10^{-5}-10^{-4} torr	10 stations/10 km need 200 kW

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Gas/HVDC Comparison