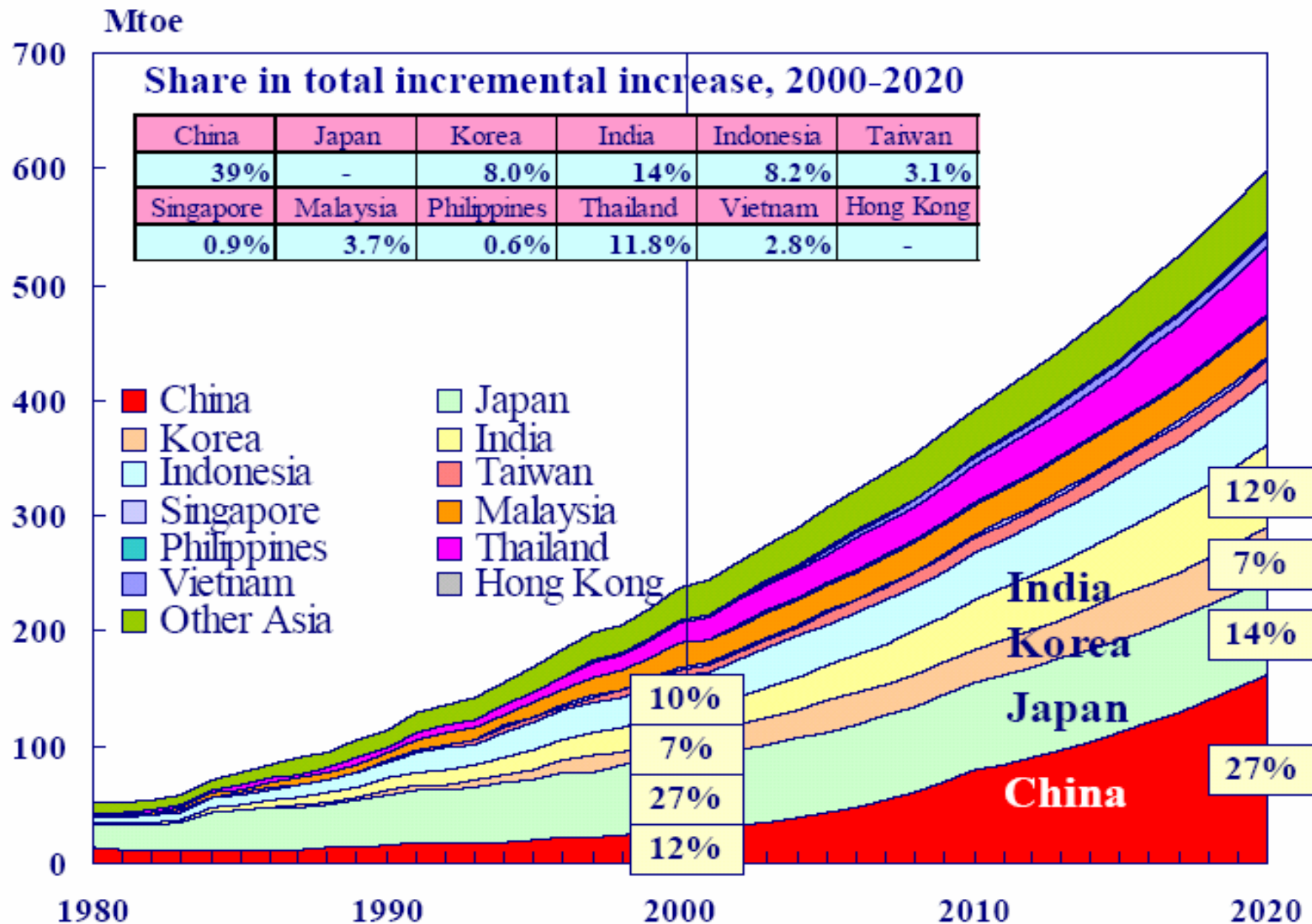


**From a Natural-gas-based to a Hydrogen-based Society:
Proposal for a Northeast Asian Hydrogen Highway**

**23rd World Gas Conference
Amsterdam, 6 June 06**

	Natural Gas Field
	Planned Pipeline Routes*
	Possible Pipeline Routes
	Gas Flow

Predicted demand for natural gas in Asia



Northeast Asia

- Asian Pipeline Research Society of Japan (APRSJ)
- Northeast Asian Natural Gas Pipeline Forum (NAGPF)

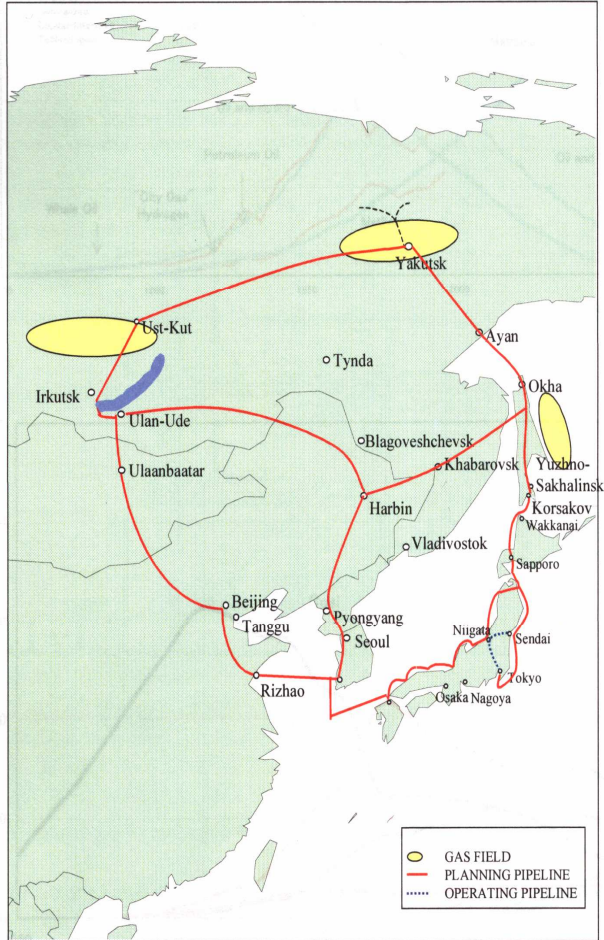
“ Proposal for a Northeast Asian Hydrogen Highway:

From a Natural-gas-based to a Hydrogen-based Society ”

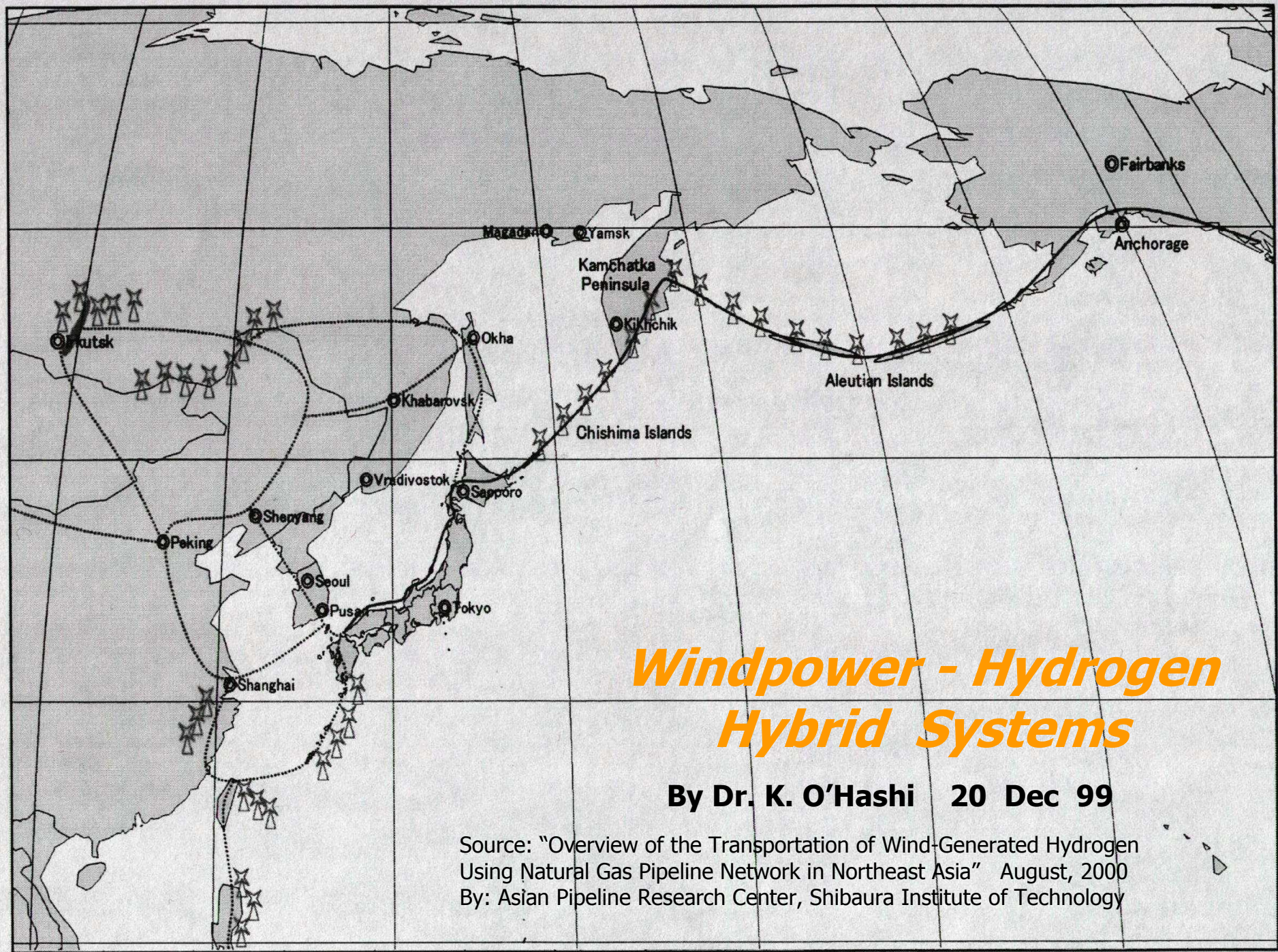
- 9th NAGPF meeting Sep 05, Seoul
- Windpower 06, June 06, Pittsburgh
- 23rd World Gas Conference, June 06, Amsterdam
- 16th World Hydrogen Energy Conference, June 06, Lyon



Proposed Natural Gas Pipeline Network in North East Asia



**Large
Renewable
Resources ?**

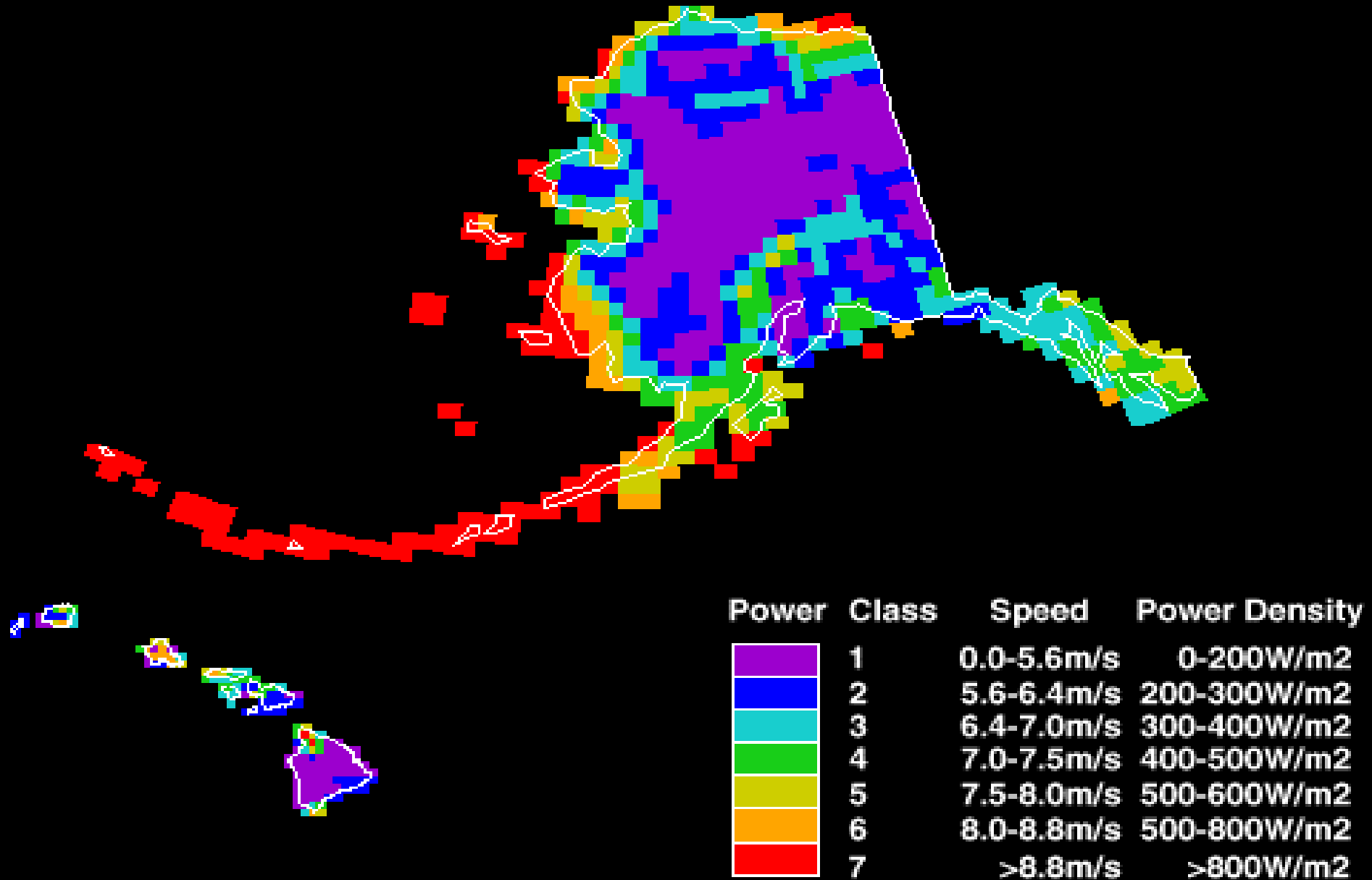


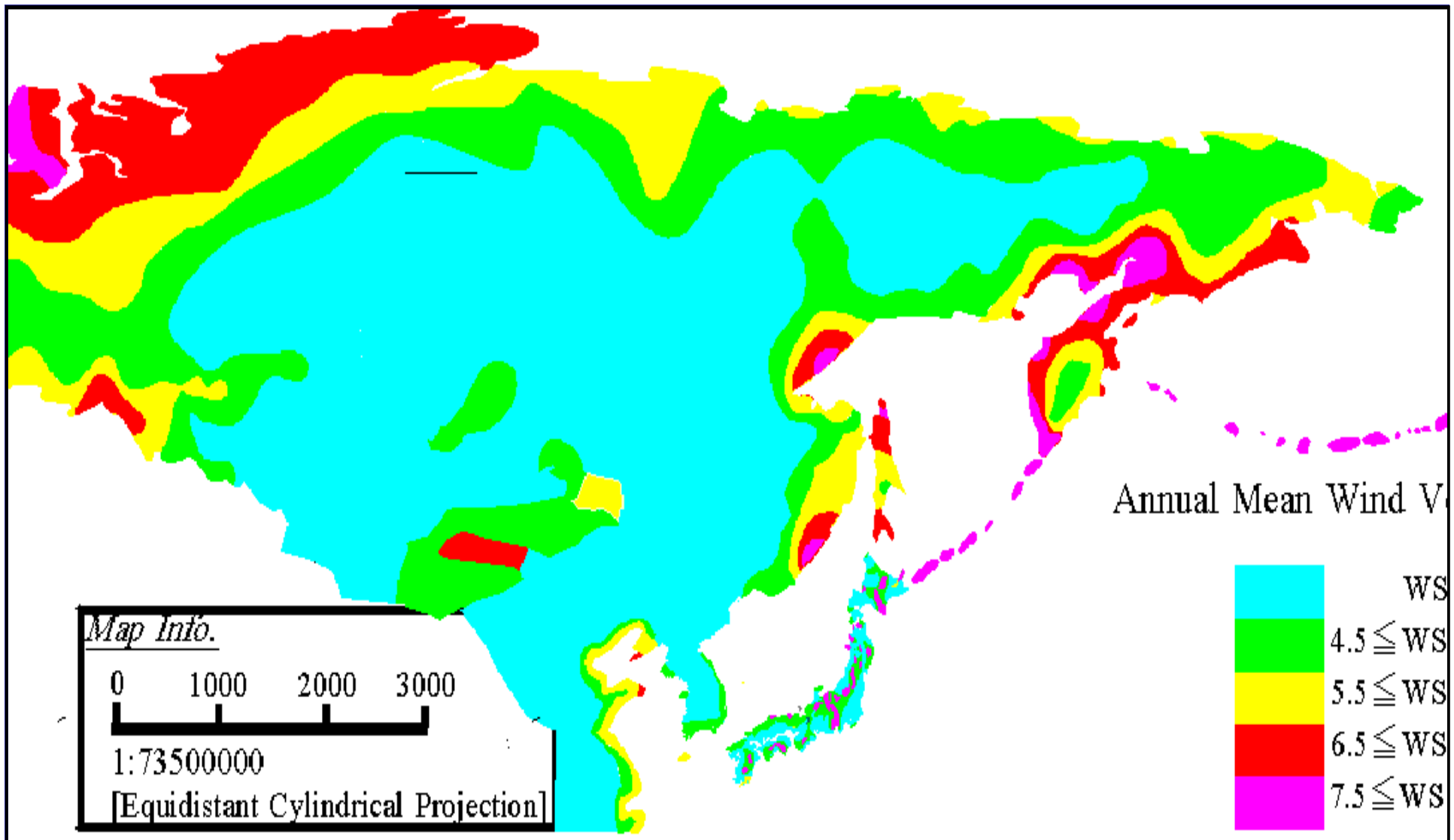
Windpower - Hydrogen Hybrid Systems

By Dr. K. O'Hashi 20 Dec 99

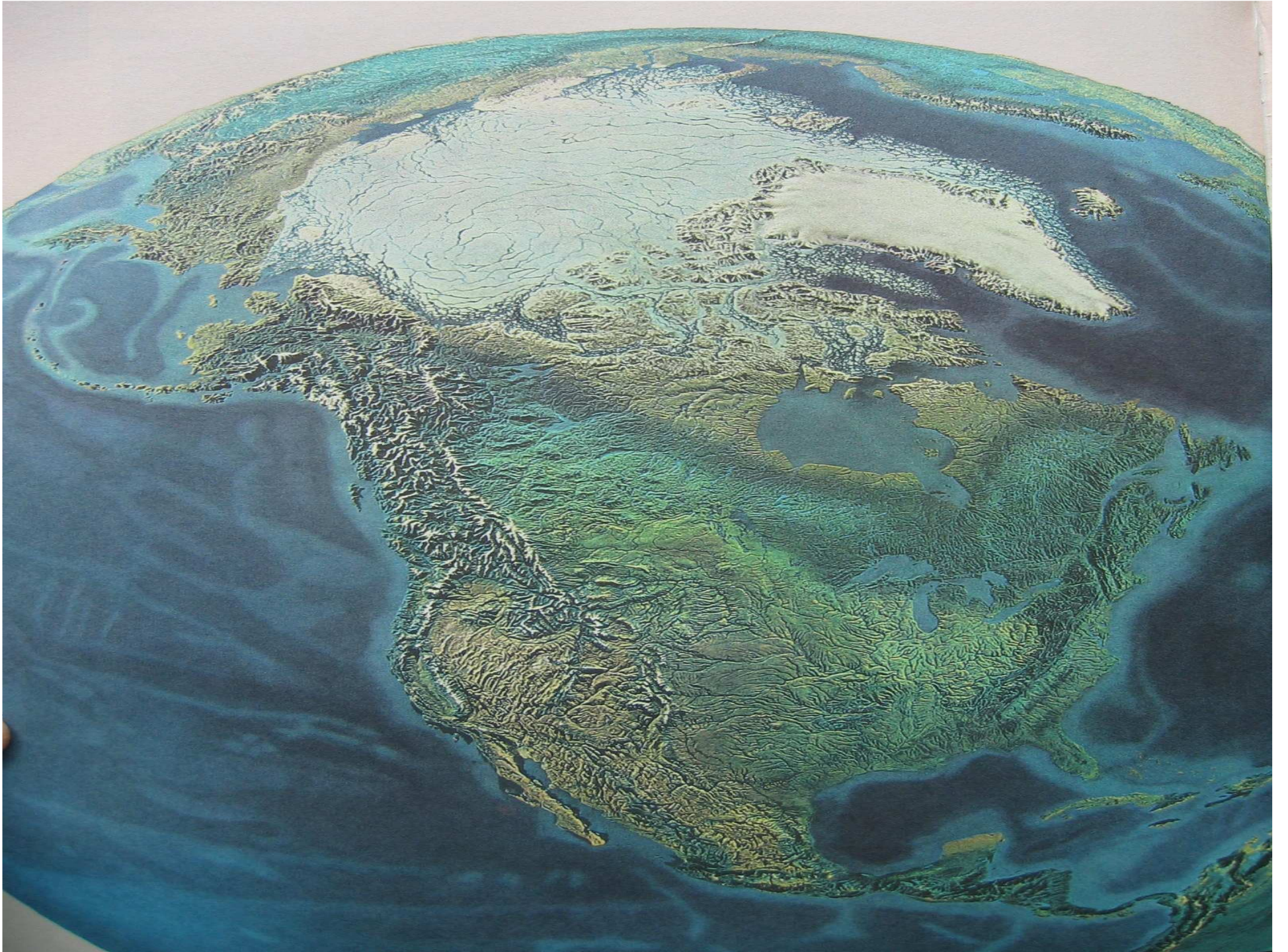
Source: "Overview of the Transportation of Wind-Generated Hydrogen Using Natural Gas Pipeline Network in Northeast Asia" August, 2000
By: Asian Pipeline Research Center, Shibaura Institute of Technology

Wind Power Class





Estimated Asian Wind Energy Resources





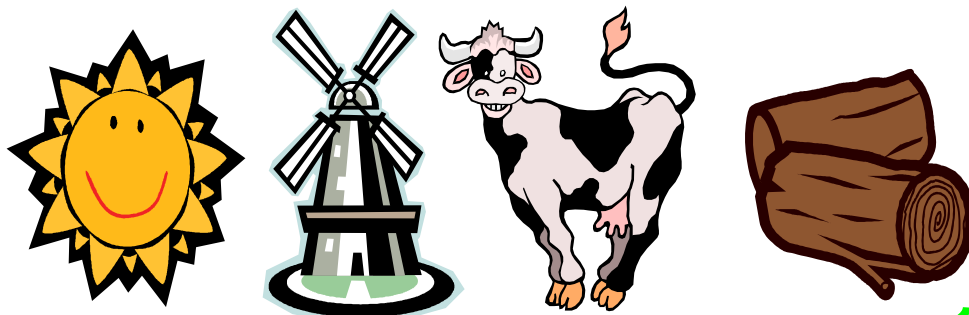
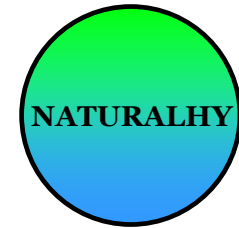




The Great Plains Wind Resource



The NATURALHY approach



H₂

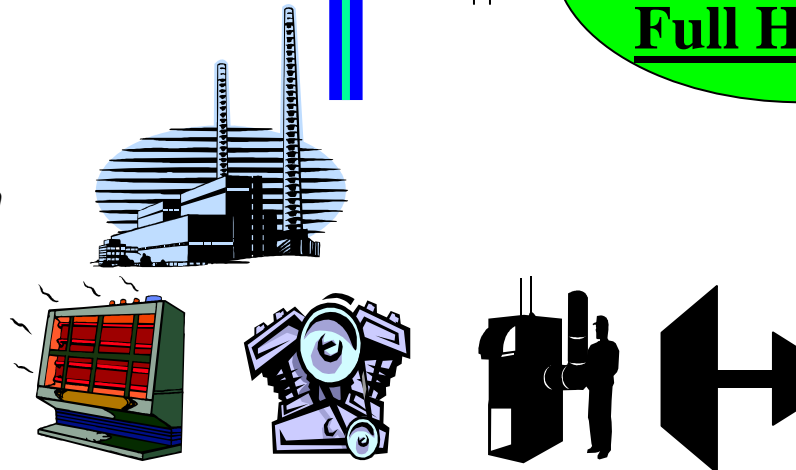


N.G.



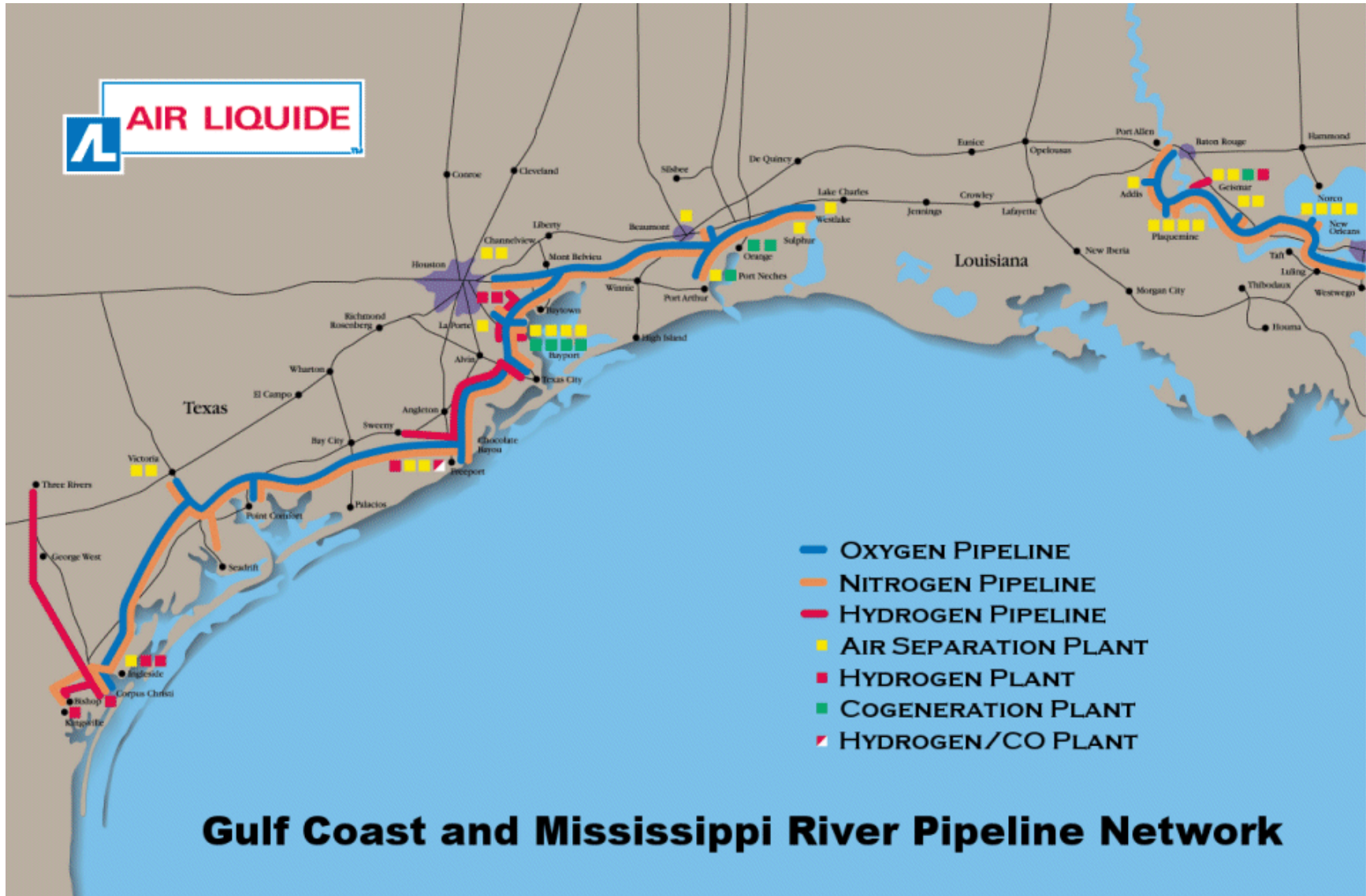
NATURALHY:

- *Breaks “chicken-egg” dilemma*
- *Bridge to sustainable future*



Hydrogen's principal value

- NOT fuel cell cars
- Gather, transmit, store:
 - Large-scale, diverse, stranded renewables
 - FIRM time-varying-output renewables
 - Pipeline transmission, storage
 - Geologic storage
- Benign, if from renewables
- Global opportunity
- Hydrogen “sector”, not “economy”
 - Transportation fuel: ground, air
 - DG electricity, CHP, retail value



Gulf Coast and Mississippi River Pipeline Network

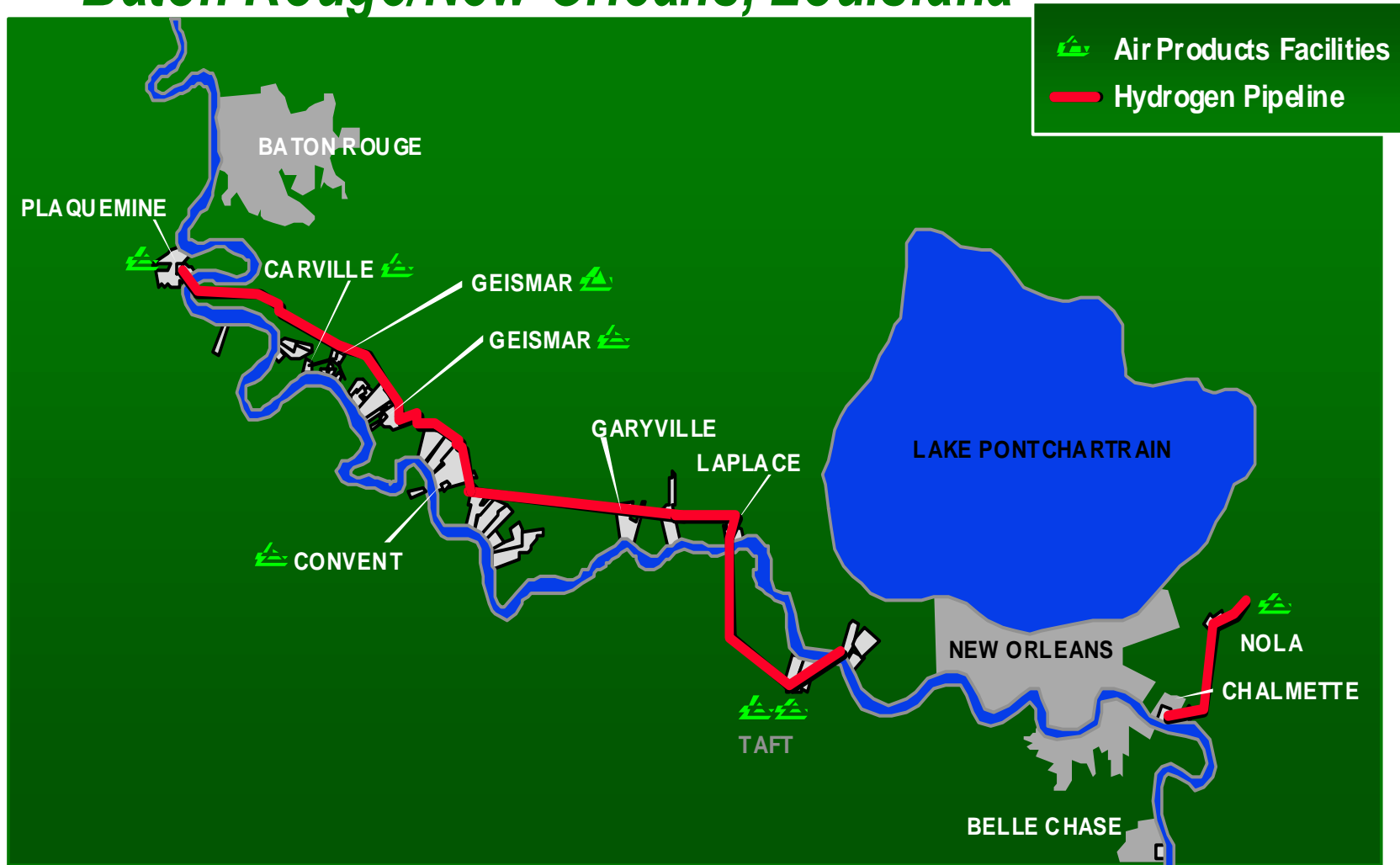
“We know how to pipeline hydrogen” Air Products
~ 10,000 miles of GH2 pipeline, worldwide

Air Products H₂/ CO Pipeline - Texas Gulf Coast



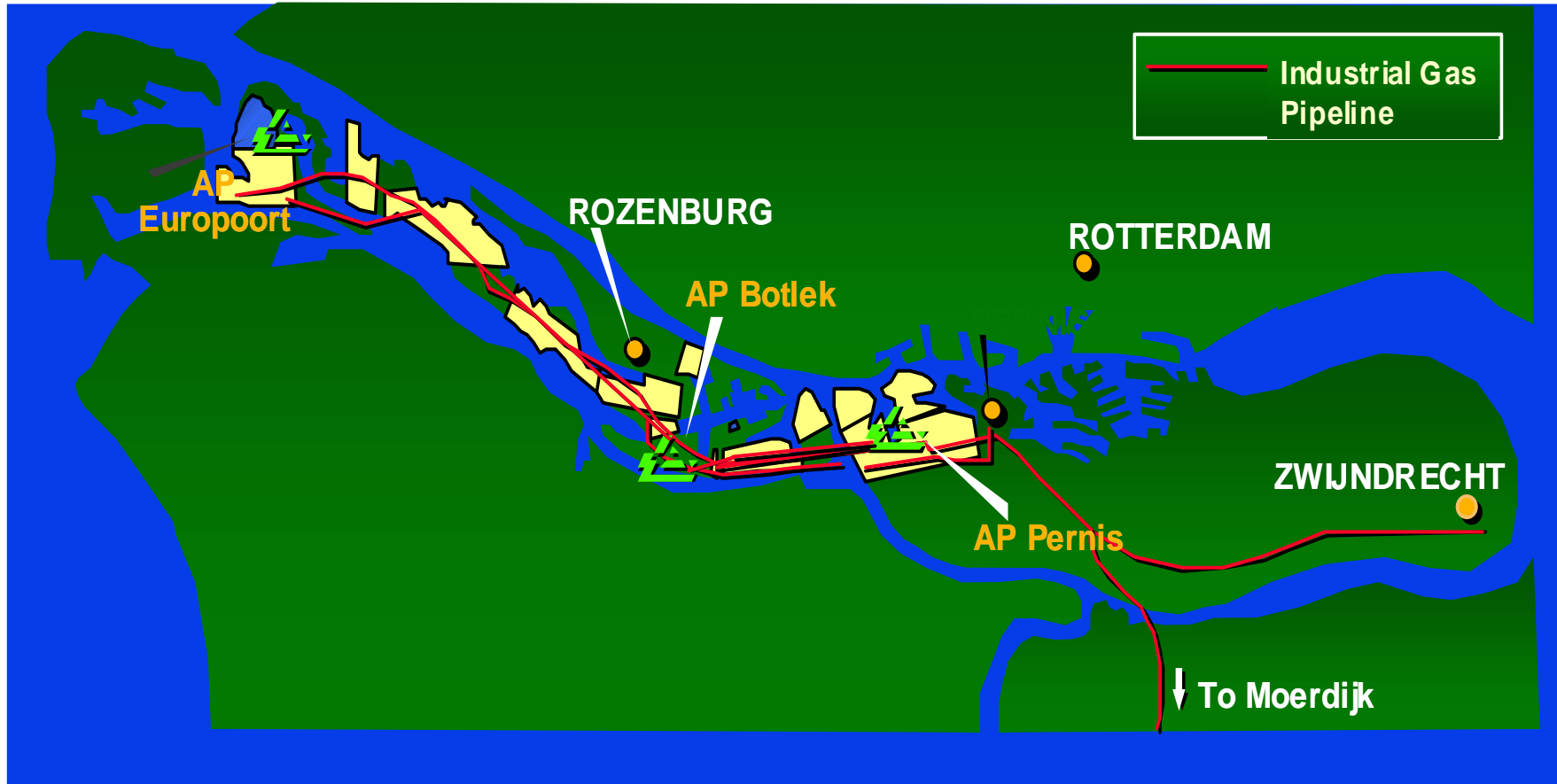
abc

Air Products H₂ Pipeline Baton Rouge/New Orleans, Louisiana



abc

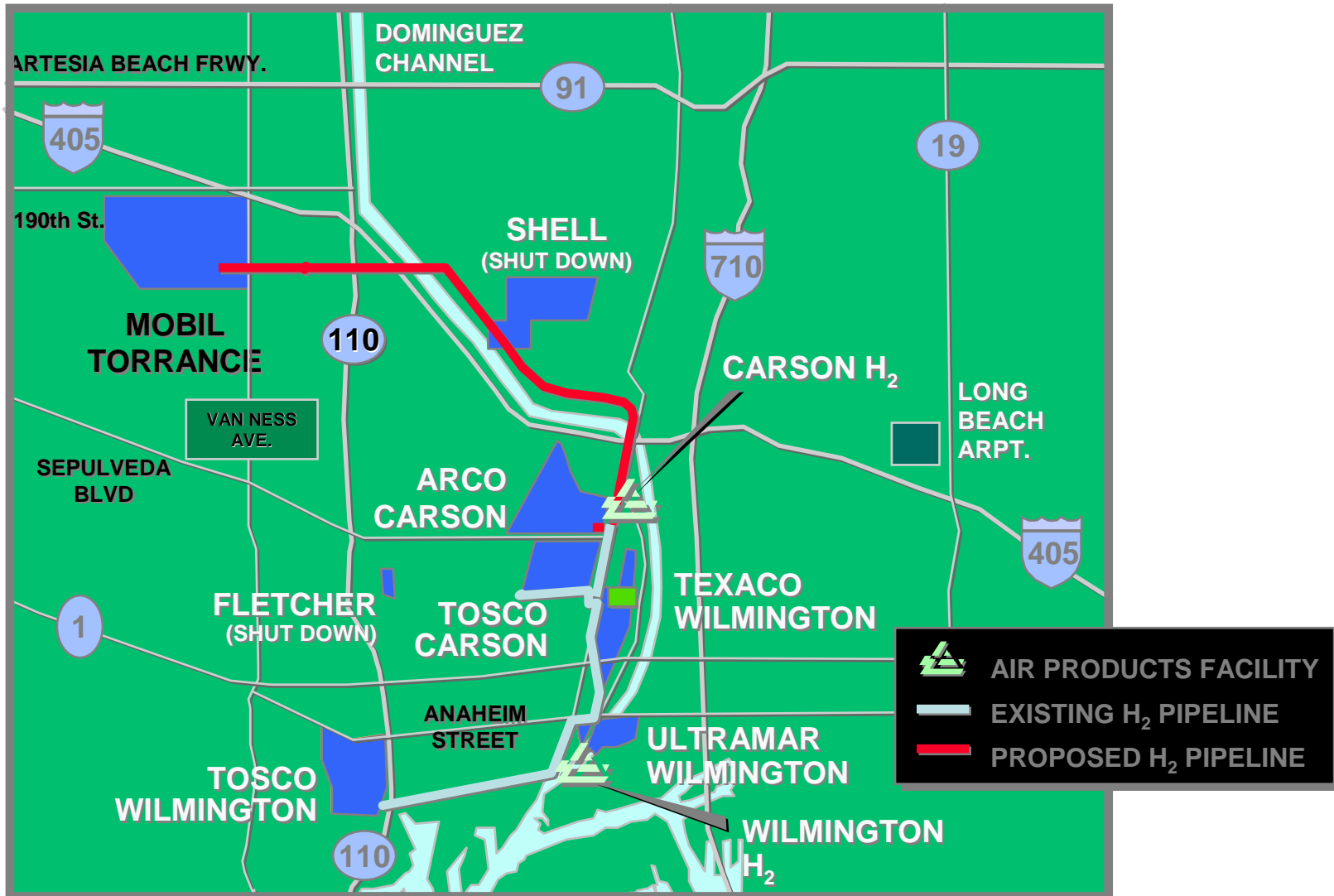
Rotterdam Pipeline System



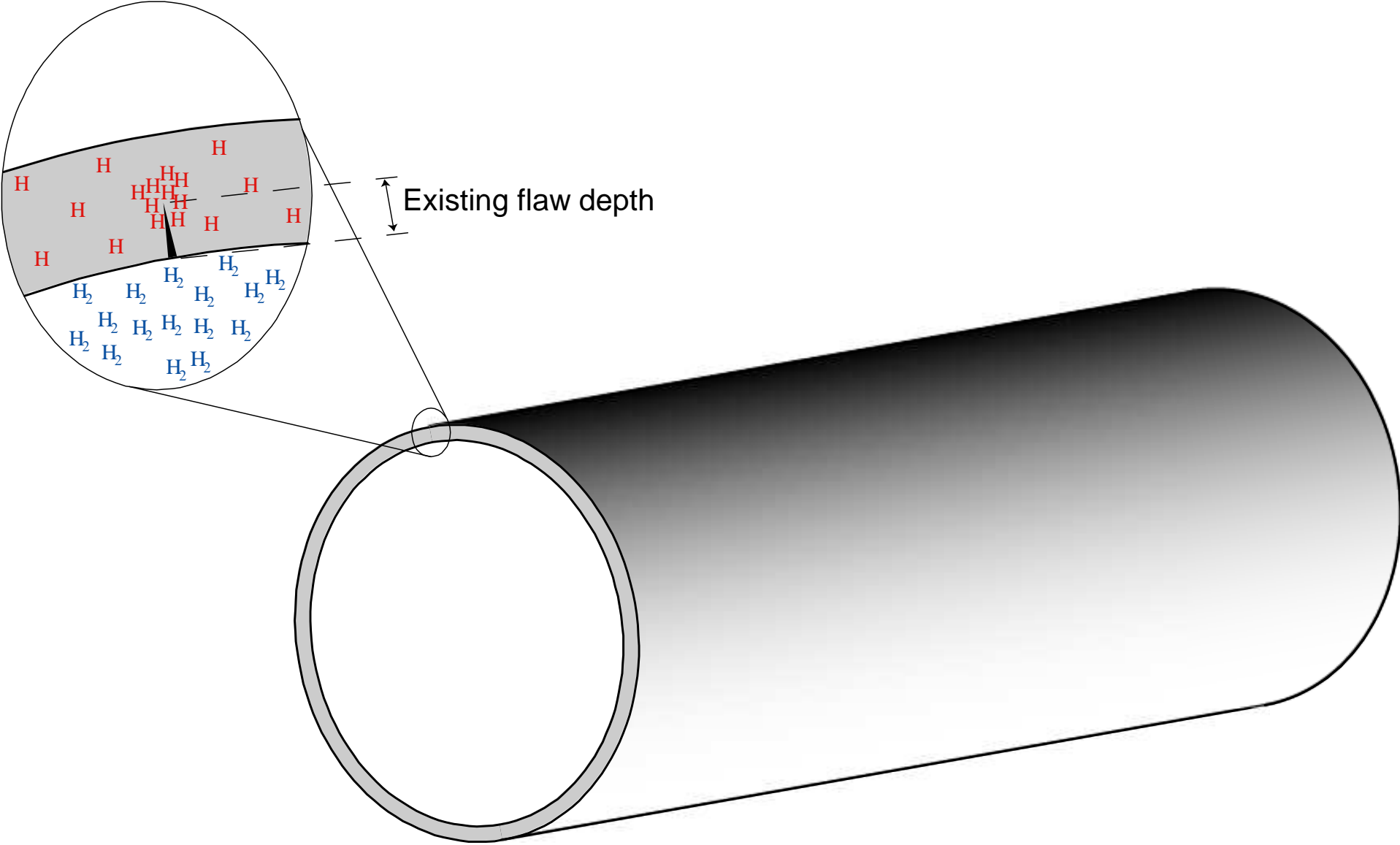
Air Products Company

REFINERY ACTIVITY

LOS ANGELES BASIN, CALIFORNIA



Hydrogen Embrittlement (HE) of Pipeline Steel



Industrial H₂ Pipelines

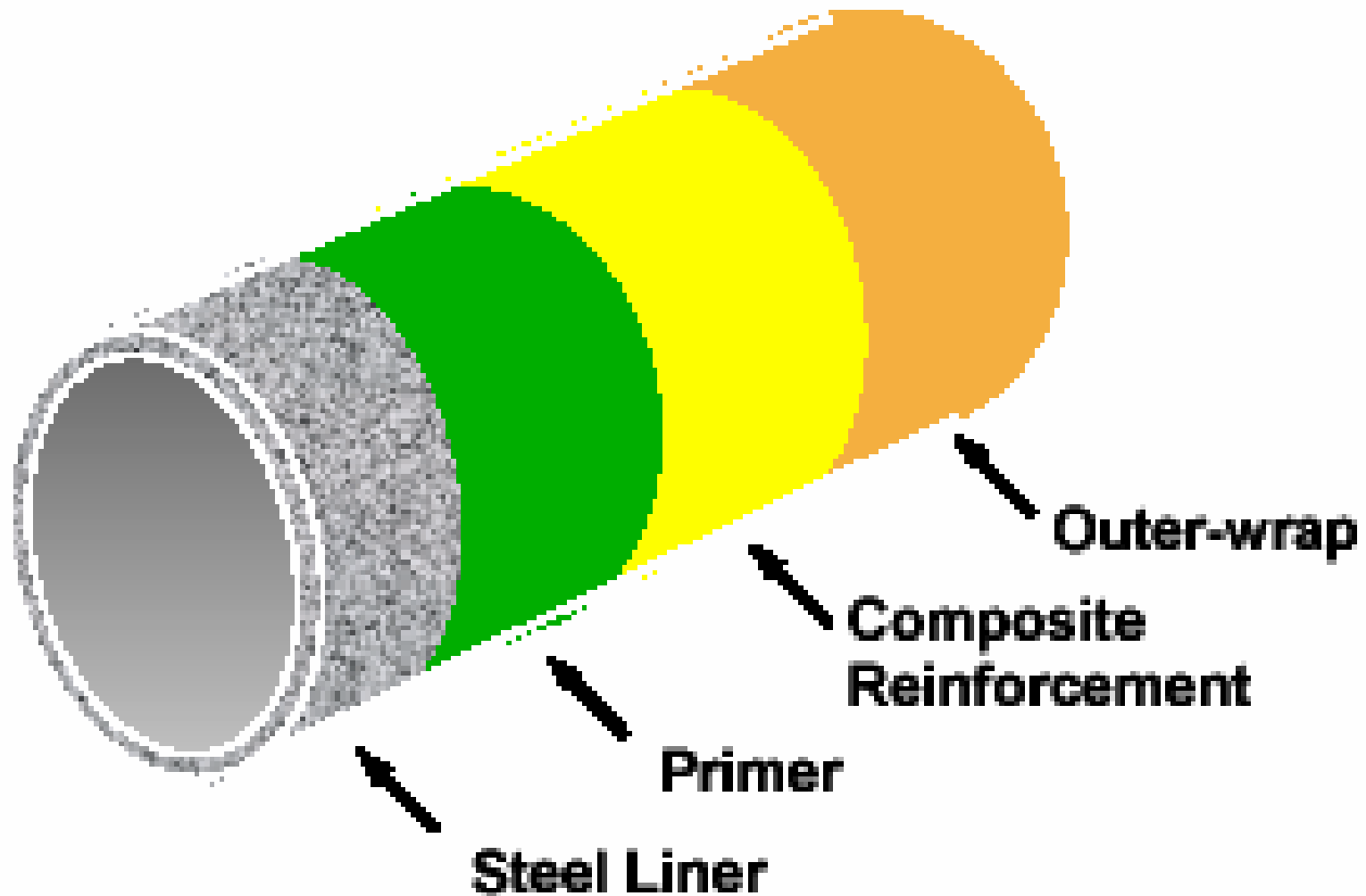
- 3,000 km worldwide
- Industrial corridors; on-site
- 30% SMYS typical *
- Constant pressure; low cyclic fatigue
- Low-alloy, low-strength steel
- Re-purposed oil pipelines

** Specified Minimum Yield Strength*

Line Pipe Material Options

- Control Hydrogen Embrittlement (HE)
- Minimize energy-distance cost (kg-km)
 - “Sour service” X65 steel
 - HTUFF microstructure by Nippon Steel
 - CRLP by TransCanada and NCF
 - New ?

Composite Reinforced Line Pipe (CRLP)
TransCanada Pipelines & NCF Industries





**Composite – Reinforced Line Pipe (CRLP)
3,400 psi, .75” X70 steel plus .75” composite**

**NCF Industries and TransCanada Pipelines
ASME International Pipeline Conference and Exposition,
Calgary, AB, Canada, October 02.**



Composite Reinforced Line Pipe (CRLP)

**42" diameter
3,400 psi
.75" X70 steel
.75" composite**

**NCF Industries and
TransCanada Pipelines**

**ASME International Pipeline
Conference and Exposition,
Calgary, AB, Canada,
October 02.**



CRLP™ is a trademark of NCF Industries, Inc.

CRLP™ is manufactured under license from NCF Industries, Inc. U.S. and Foreign patents have been issued and are pending.



Wrapper, composite splice

CRLP™ is a trademark of NCF Industries, Inc. CRLP™ is manufactured under license from NCF Industries, Inc.
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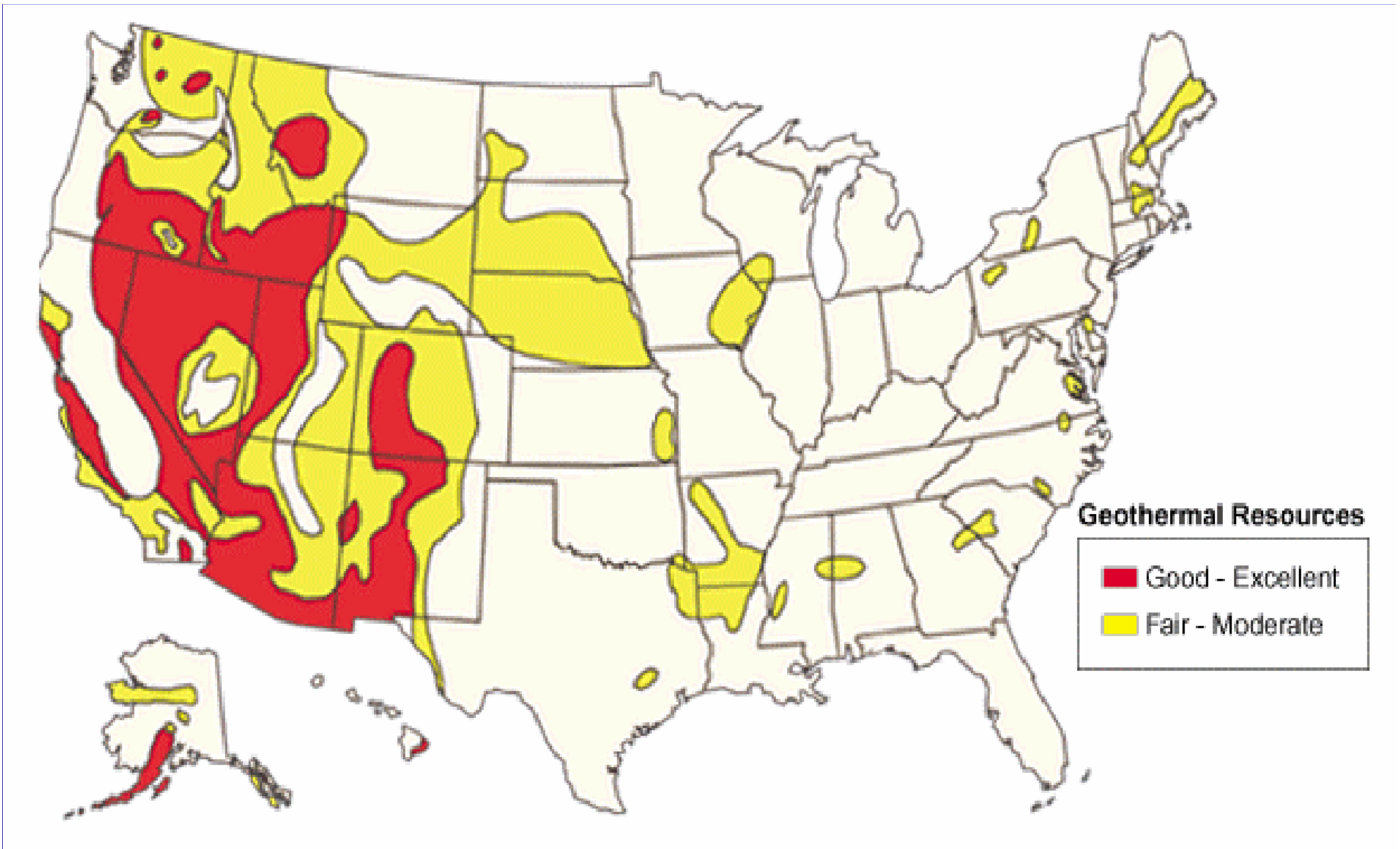
*Denmark: Middelgrunden,
13 x 1500 kW = 20 MW*



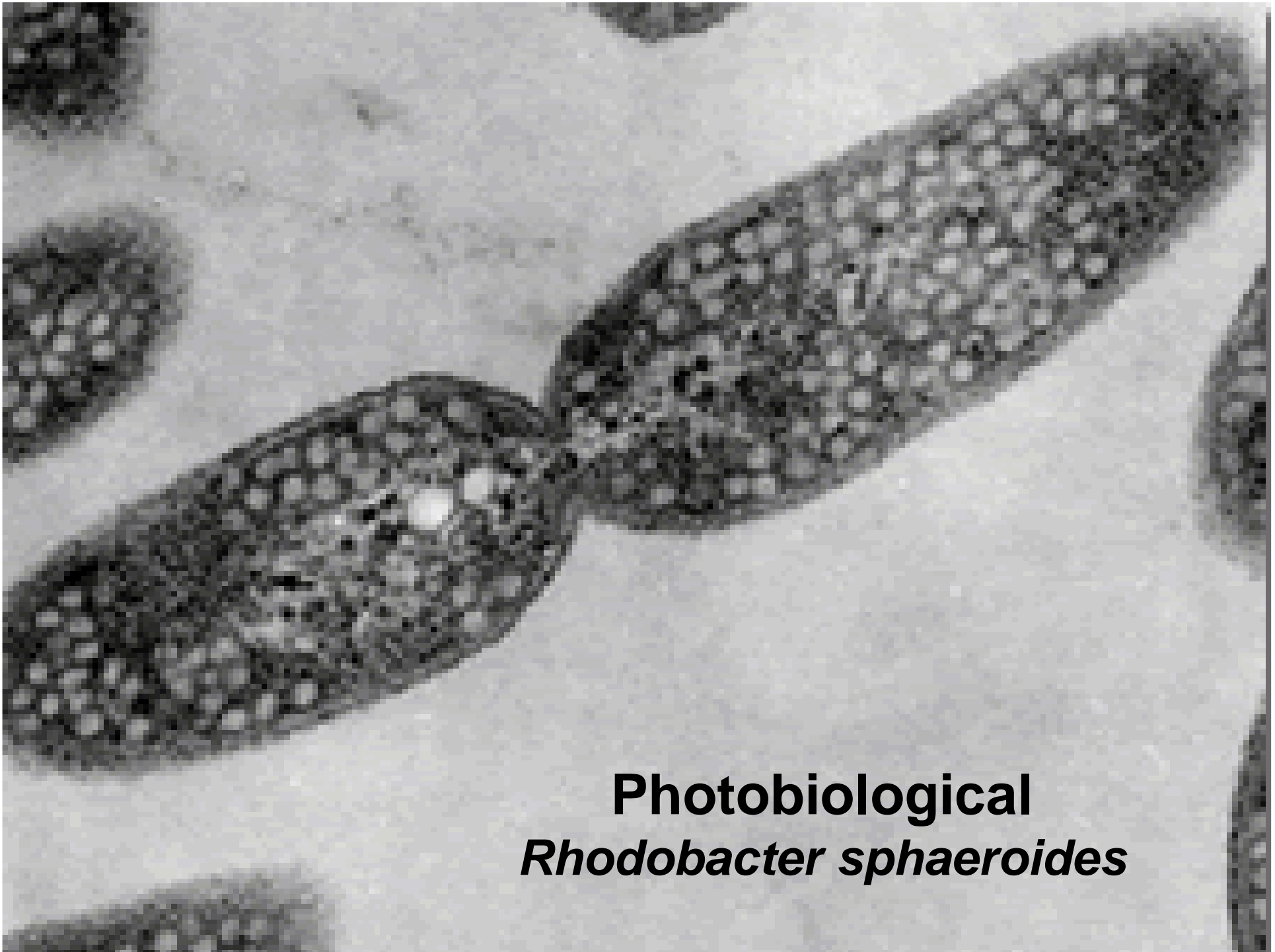


Hydro

Hoover Dam



Geothermal Resources

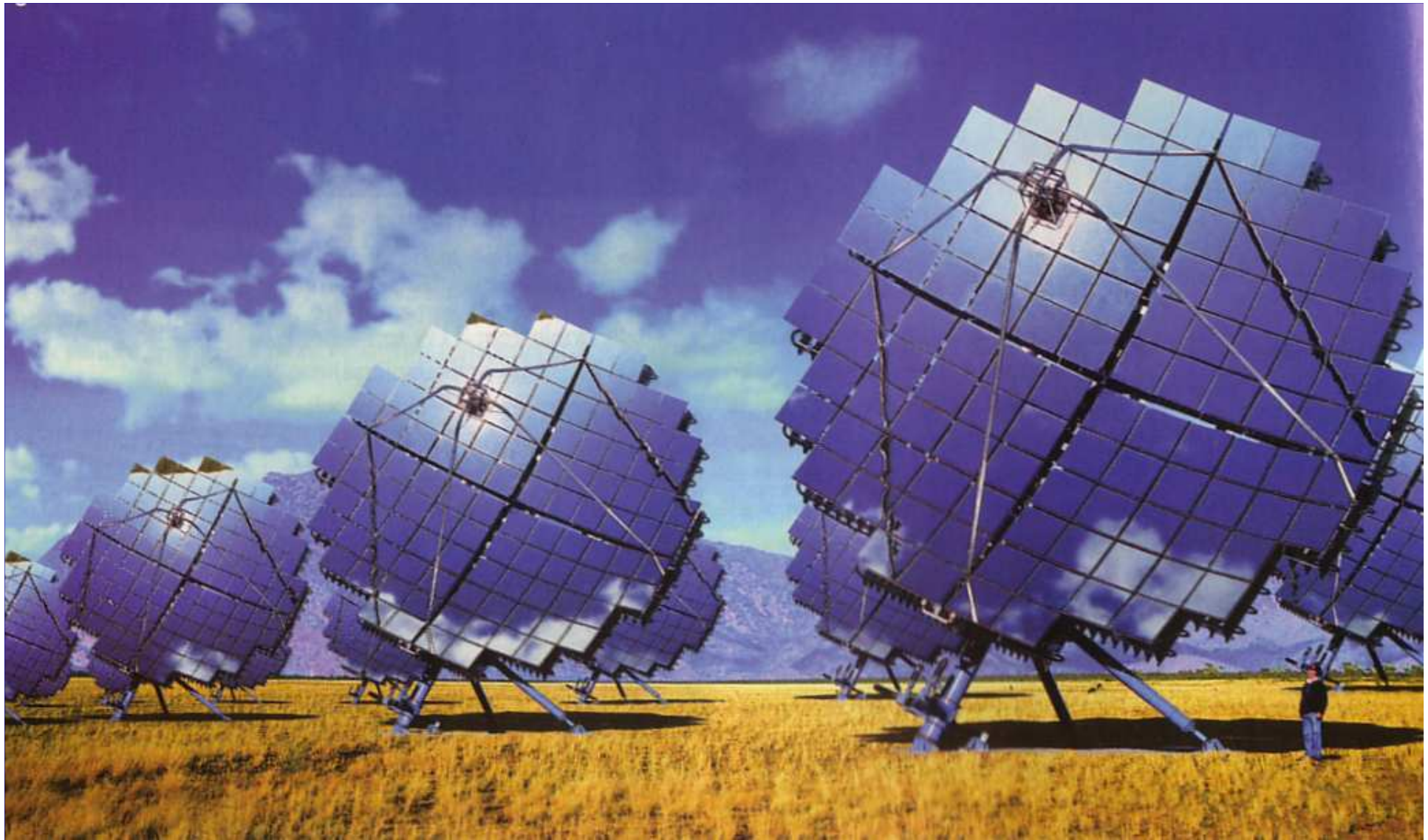


Photobiological
Rhodospirillum rubrum

Algae:
Chlamydomonas
reinhardtii

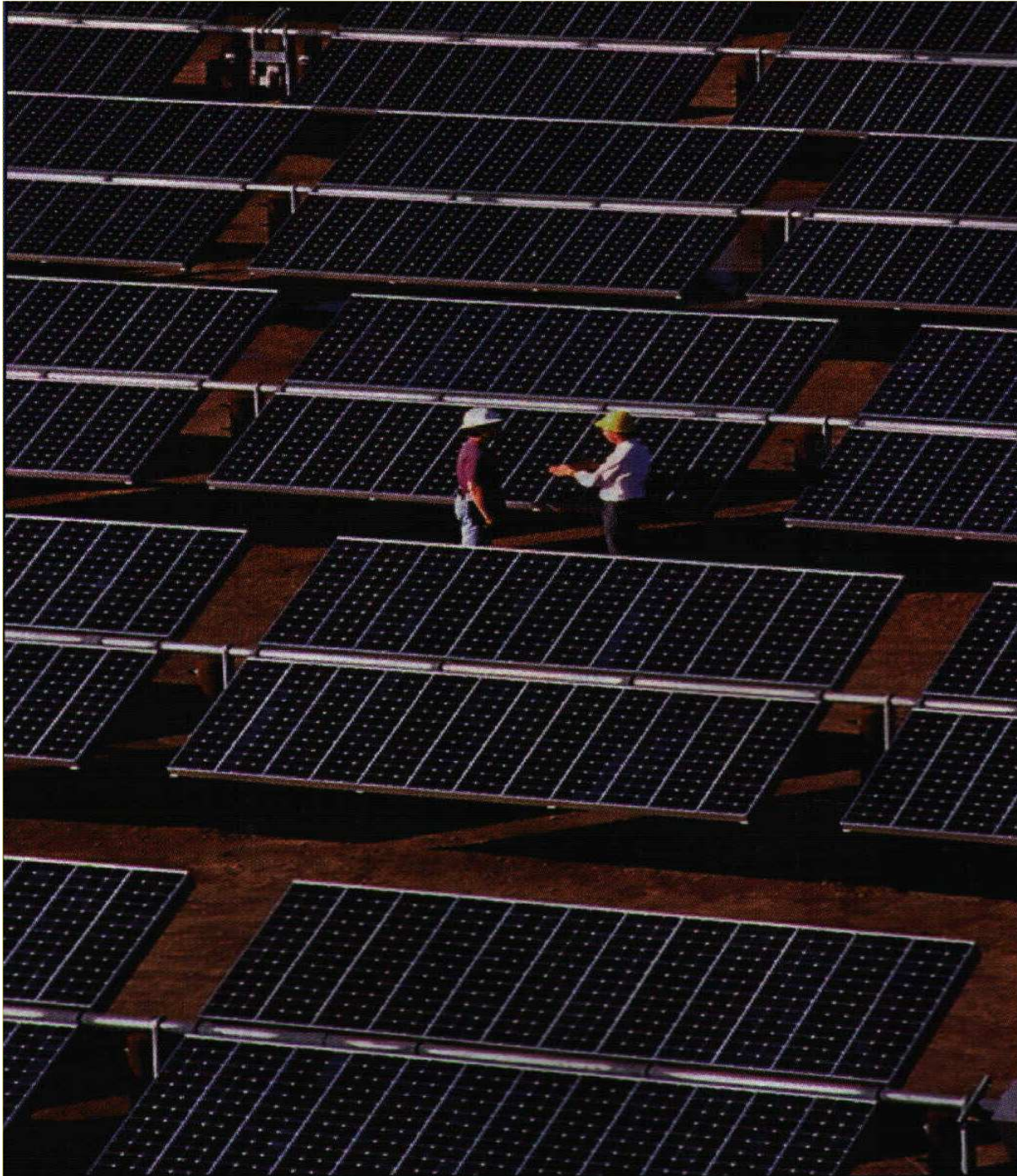
Photo: Tasio Melis, PhD,
UC Berkeley, USA





Concentrated Solar Power (CSP)

Thermal, Photovoltaic



Photovoltaic

(PV)

Example: Vision of a bright future

*The Silk Road Genesis Project**

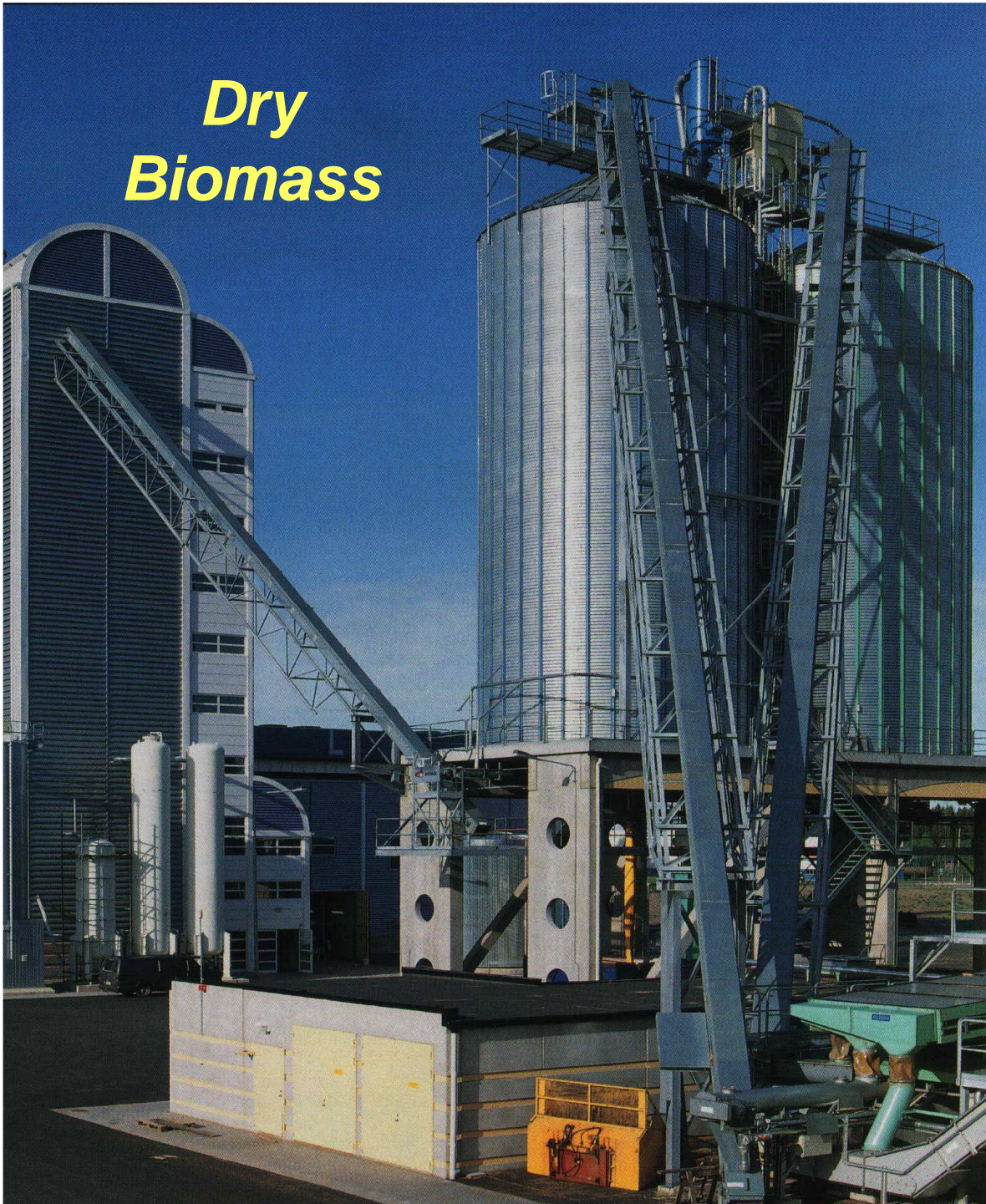
**proposed by Sanyo*



**Vision of solar farms in China along the historic silk road
to cover $\frac{1}{3}$ of China's energy demand in 2030**

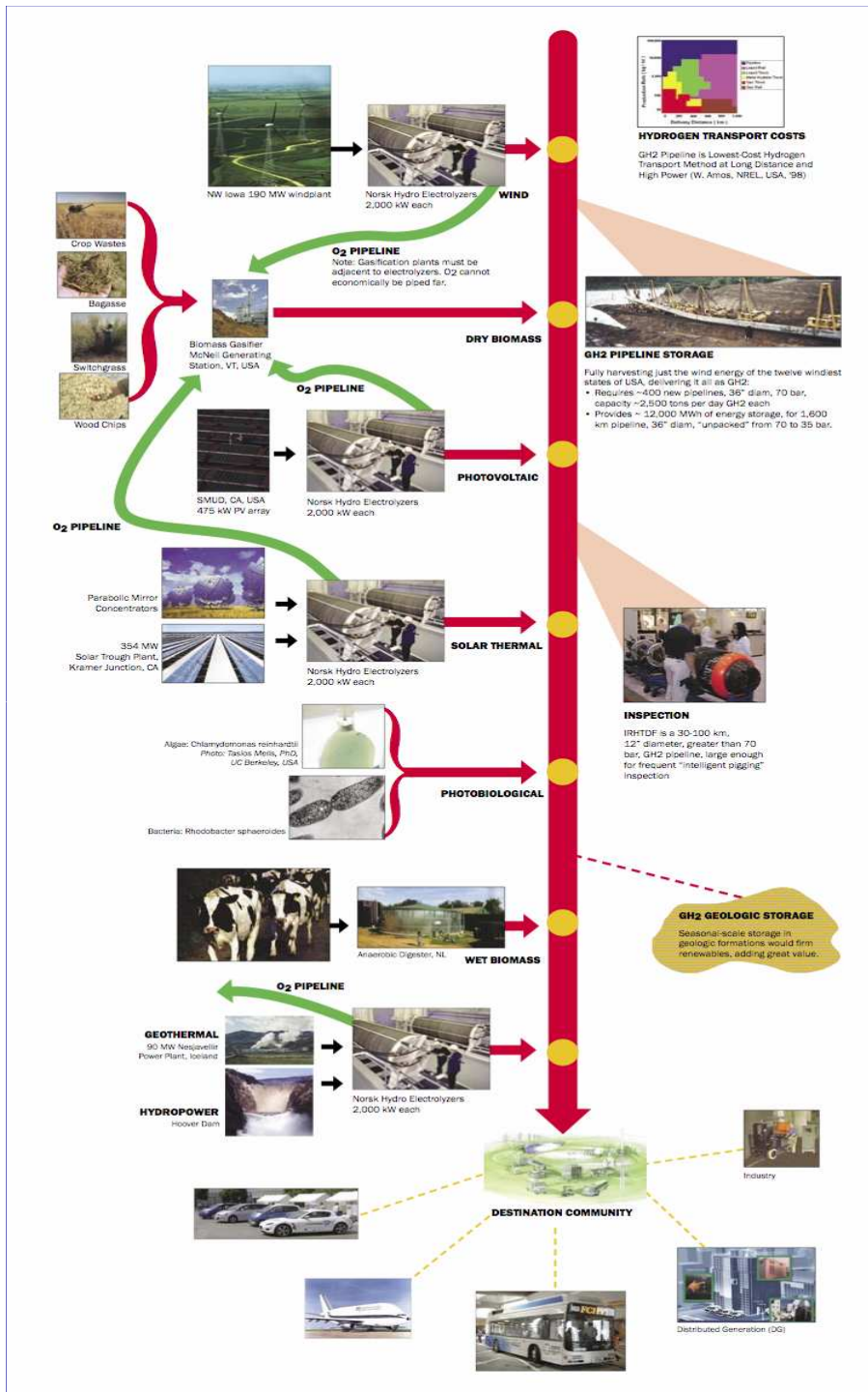


Dry Biomass



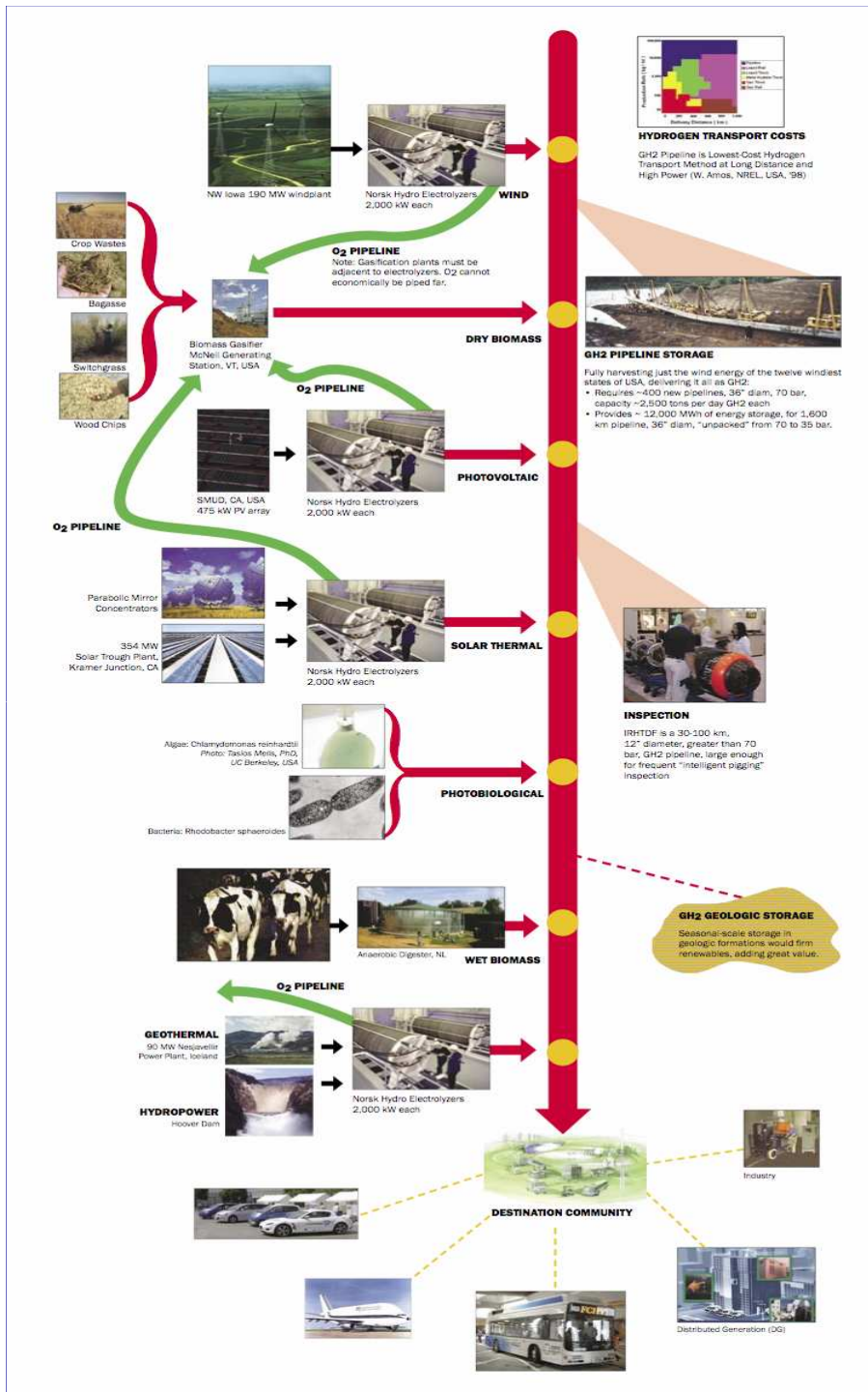
Wet Biomass: Anaerobic Digester





Pilot-scale Hydrogen Pipeline System: Renewables

- Diverse
- Dispersed, diffuse
- Large-scale
- Stranded
 - Remote
 - No transmission



International Renewable Hydrogen Transmission Demonstration Facility

(IRHTDF)

Pilot plant

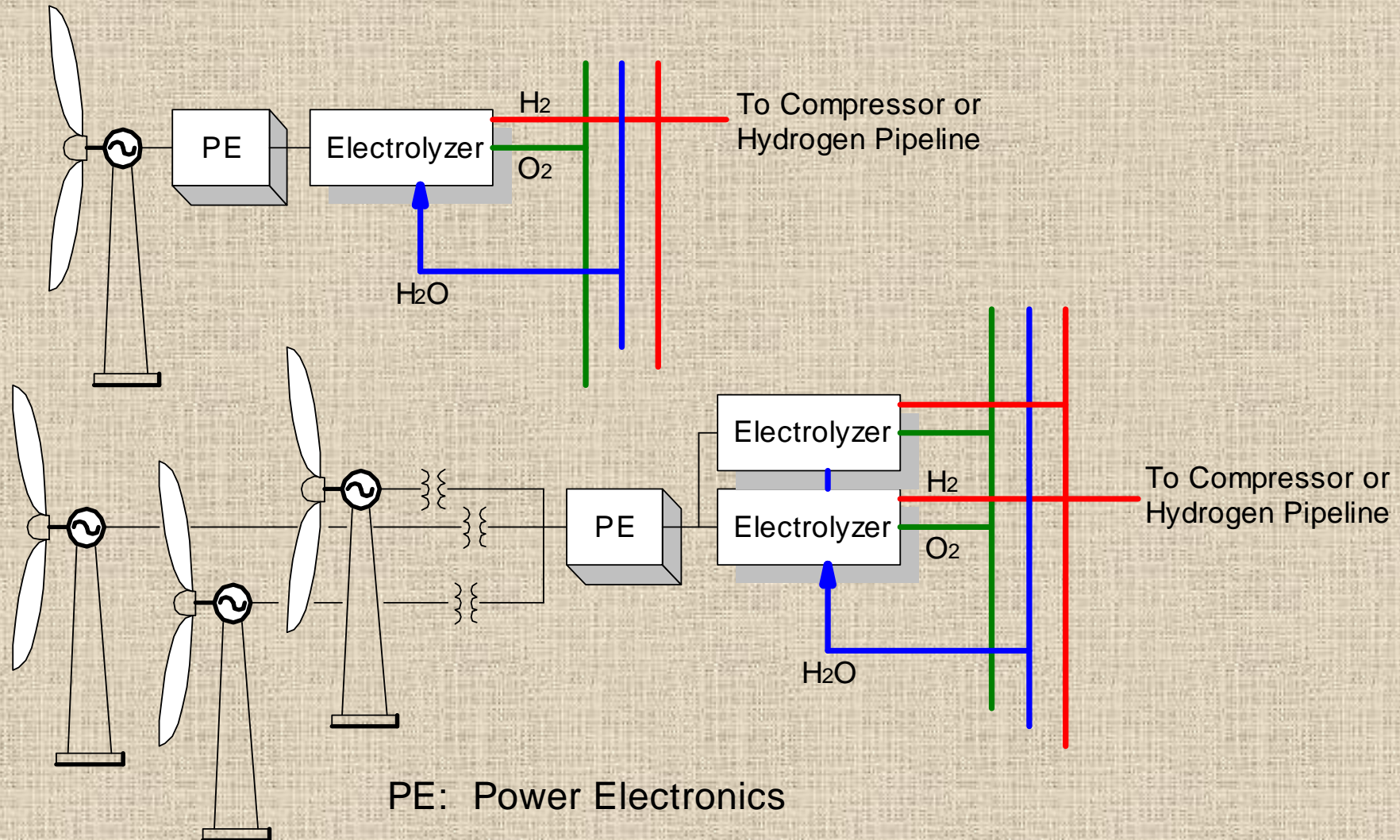
Global opportunity:
IPHE project

IRHTDF

- *Pilot plant: Every new industrial process*
- *Renewables-hydrogen **system***
 - *Generation*
 - *Conversion*
 - *Collection*
 - *Transmission*
 - *Storage*
 - *Distribution, end users*
 - *Synergy: O₂, seasonal*

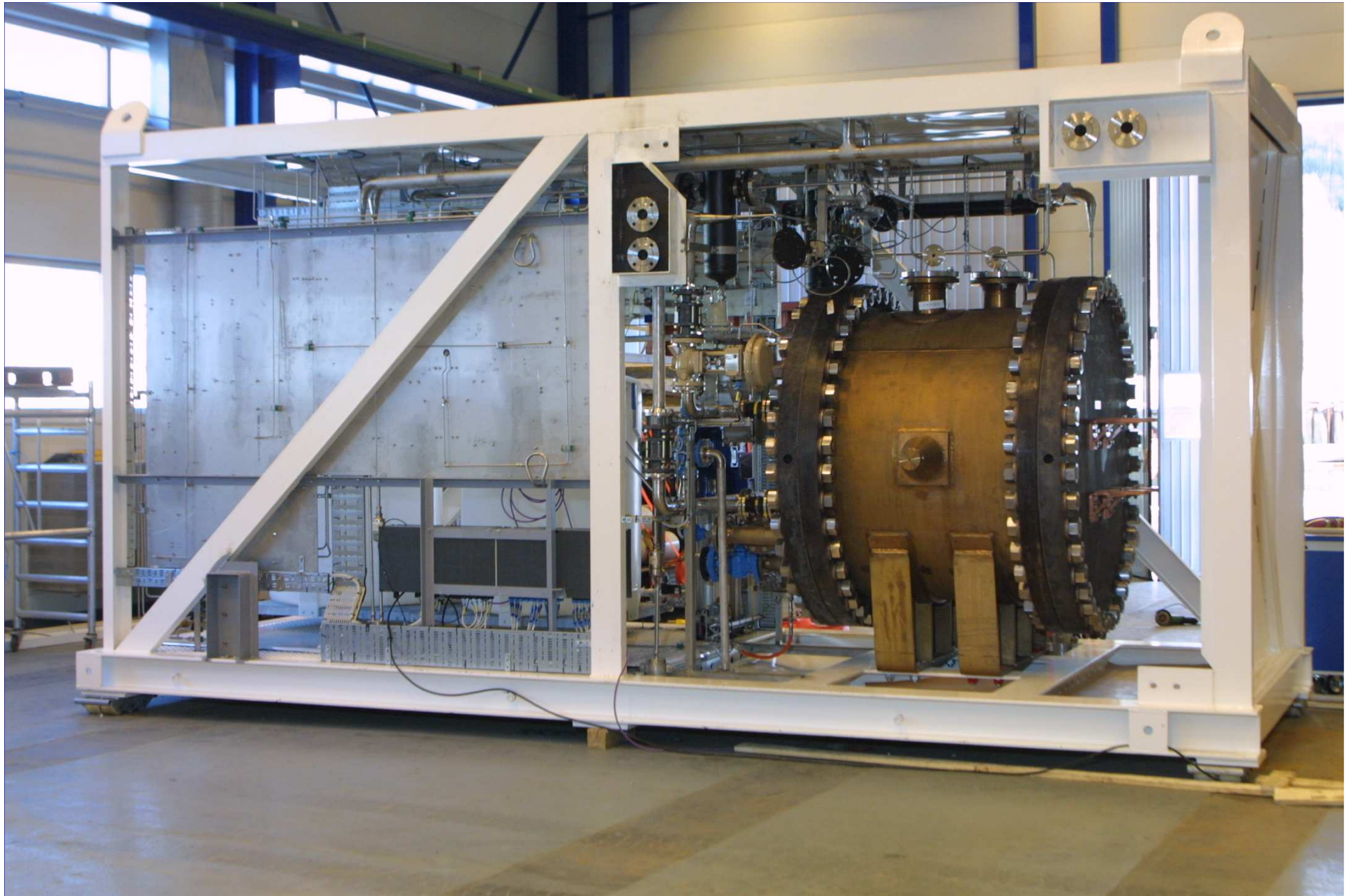
“Hydrogen Transmission Scenario”

Collection Topology Options: Electrolyzer and Rectifier Location



***Norsk Hydro
Electrolyzers
2 MW each***

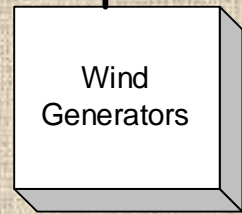
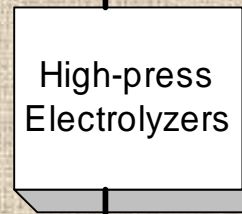
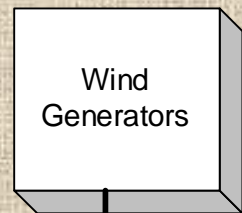




***Norsk Hydro electrolyzer, KOH type
560 kW input, 130 Nm³ / hour at 450 psi (30 bar)***

Transmission

Distribution



1,500 psi

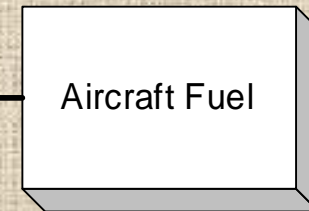
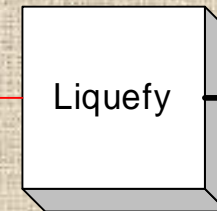
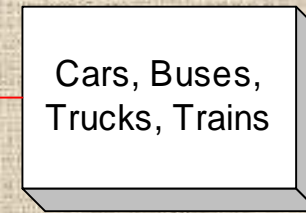
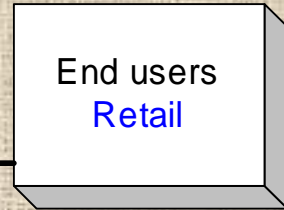
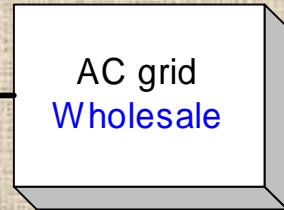
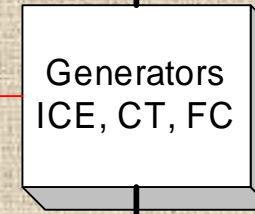
*Pipeline Energy
Storage*



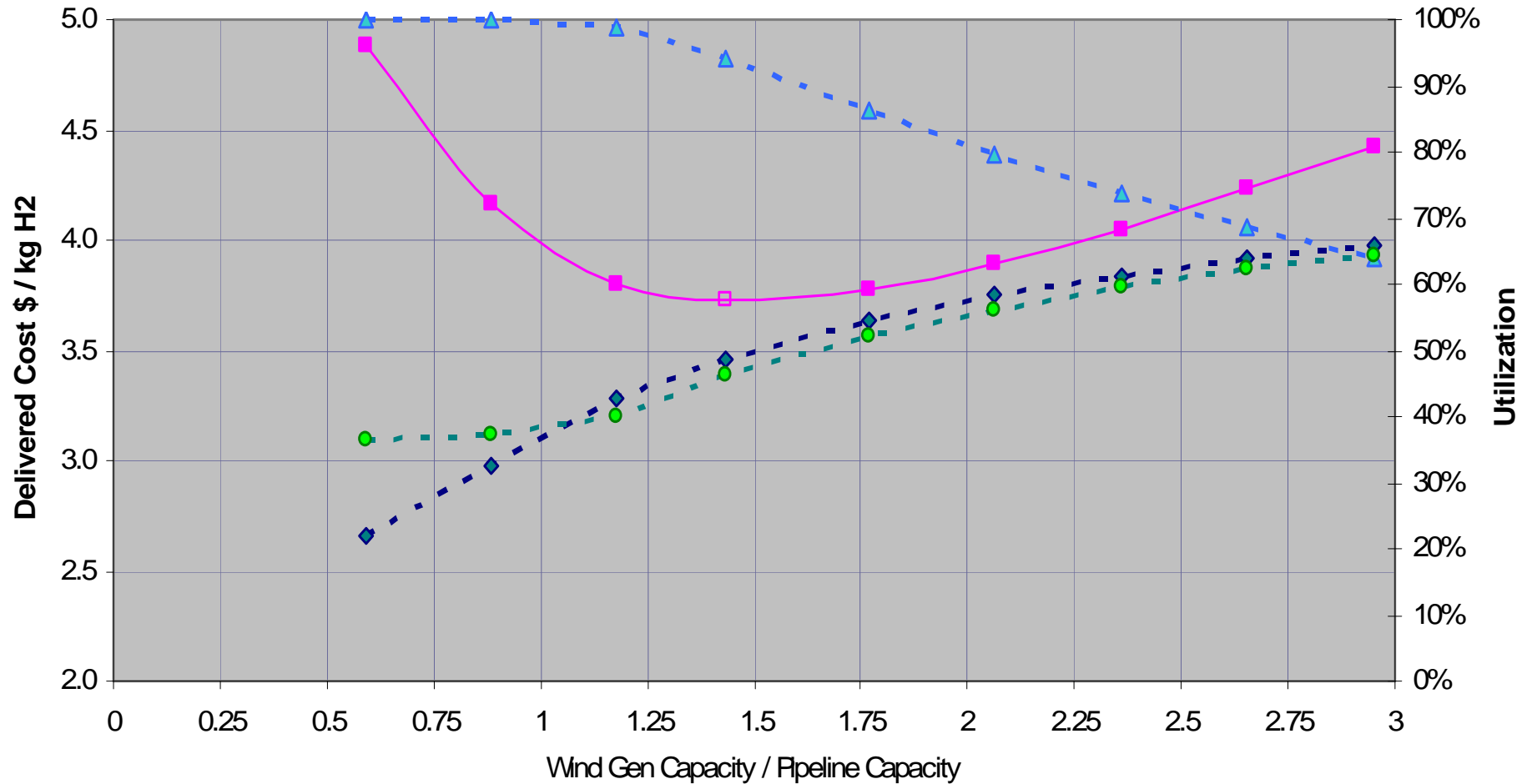
500 psi

**500 miles
Hydrogen Gas
Pipeline
20" diameter
1,500 -- 500 psi**

City gate →

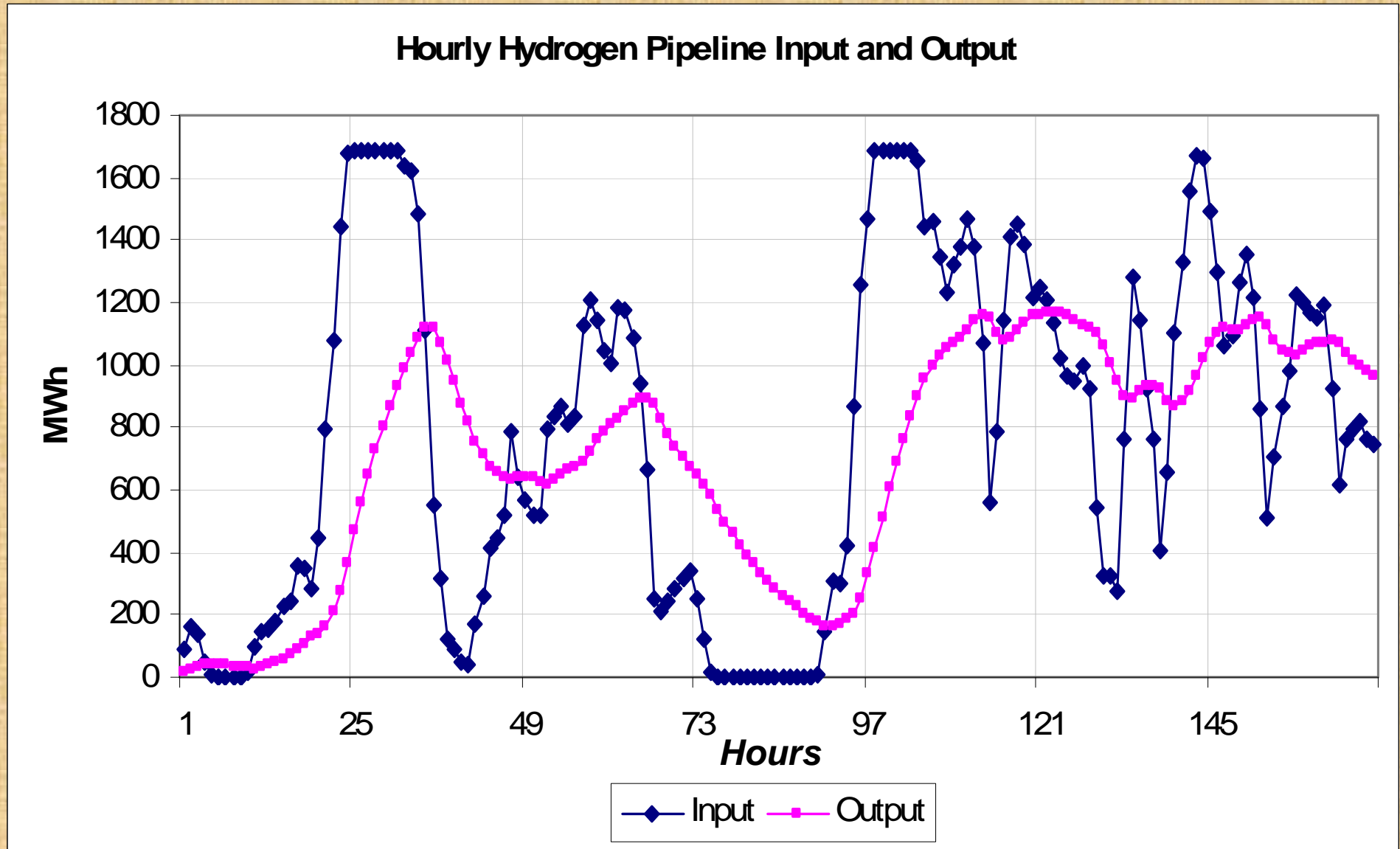


Wind-Hydrogen 1,000 Mile Pipeline Optimization Simulation

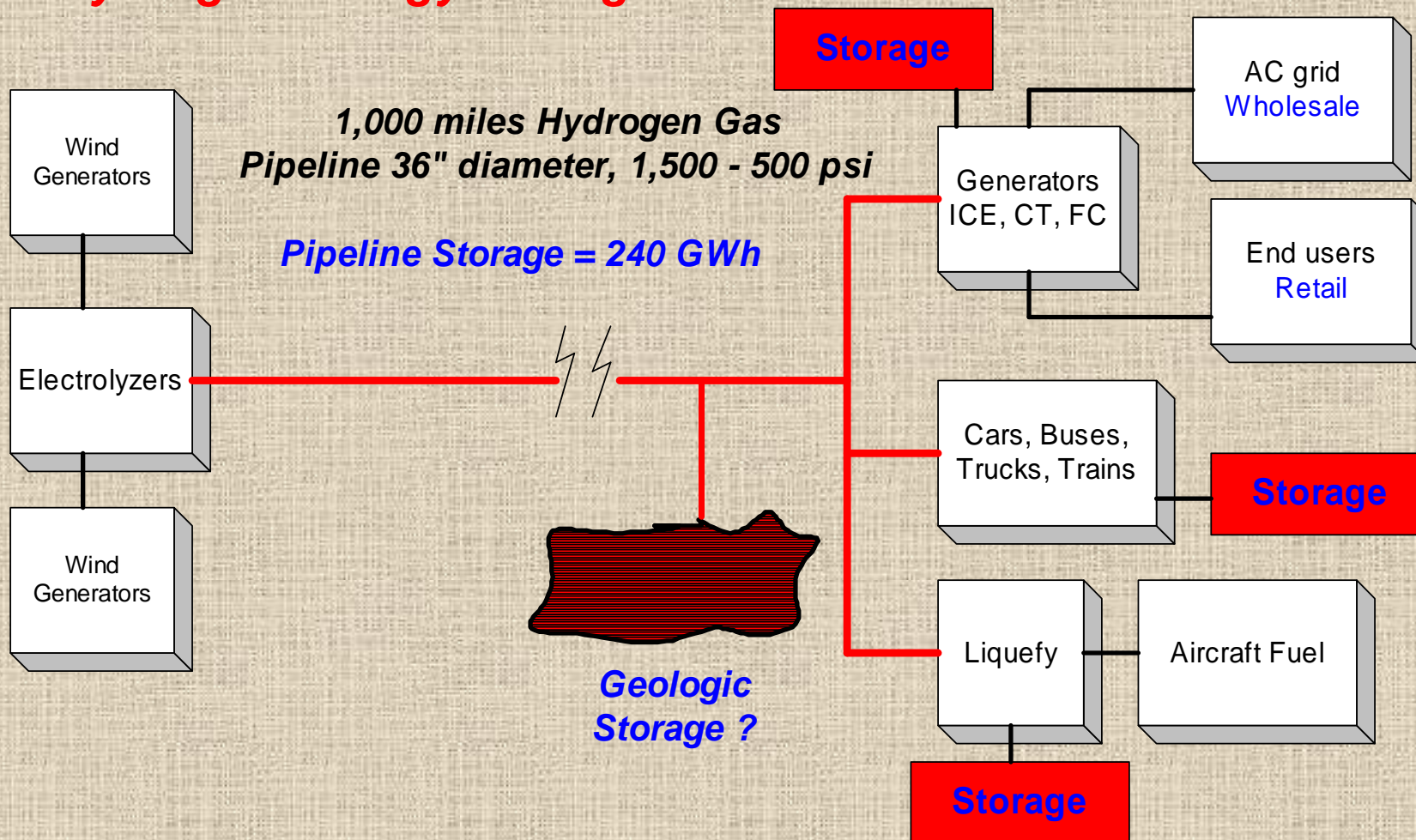


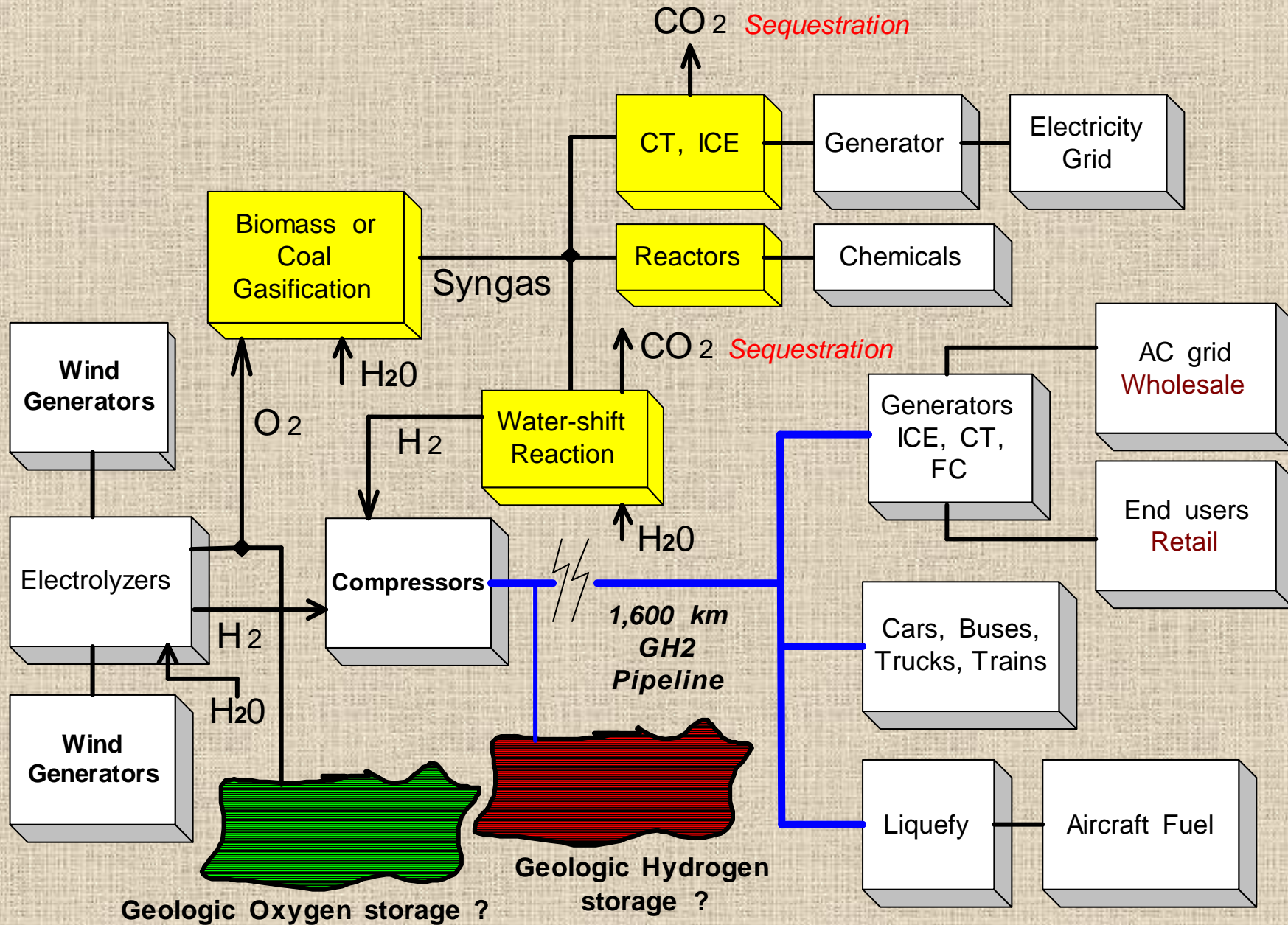
—■— Delivered Cost - -▲- - WindGen Utilization - -◆- - Pipeline Utilization - -●- - Electrolyzer Utilization

Great Plains Windplant, Pipeline Hourly Output for Typical Week



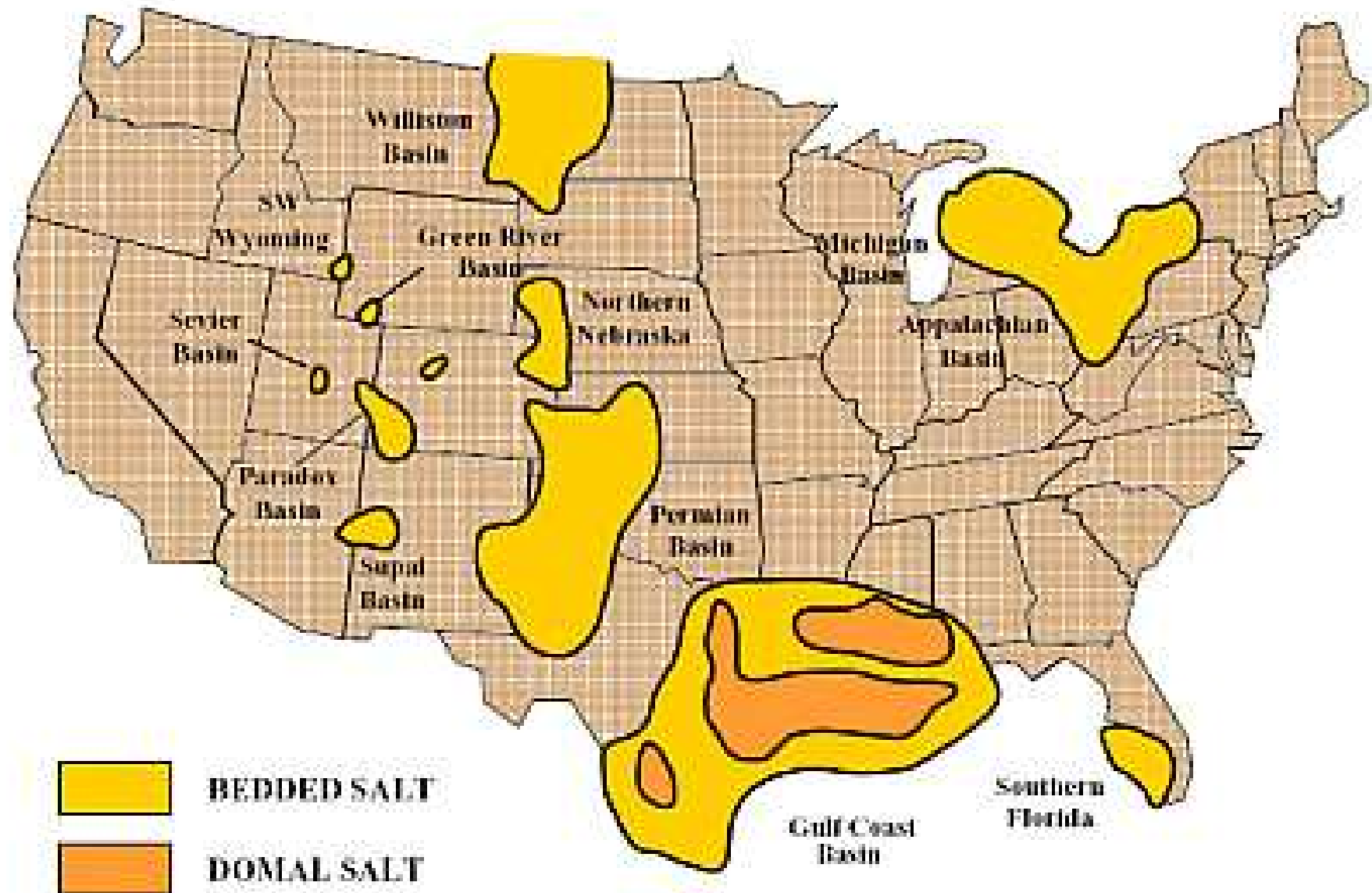
Hydrogen Energy Storage



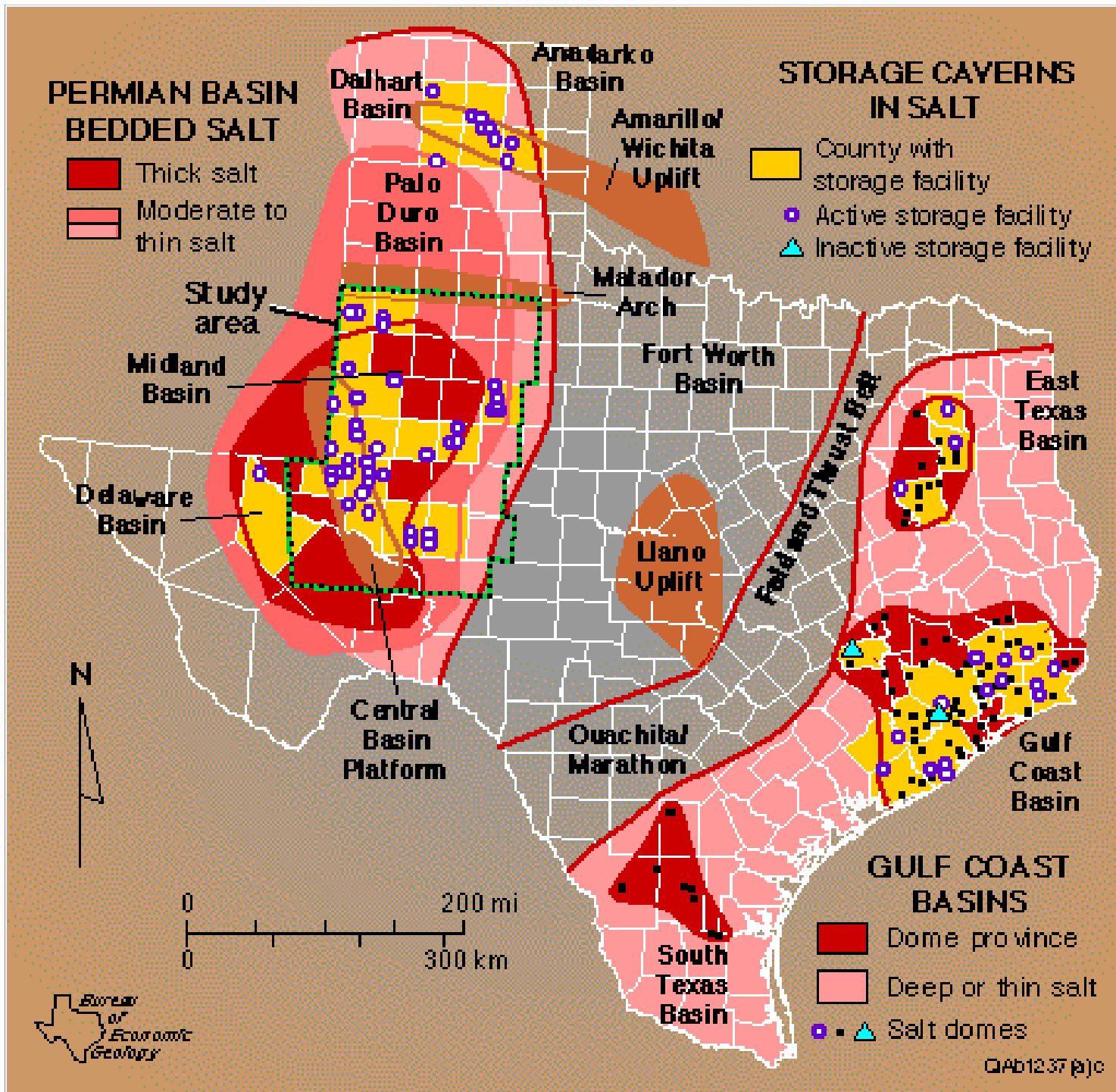




Renewable-source GH2 geologic storage potential.
 Candidate formations for manmade, solution-mined,
 salt caverns

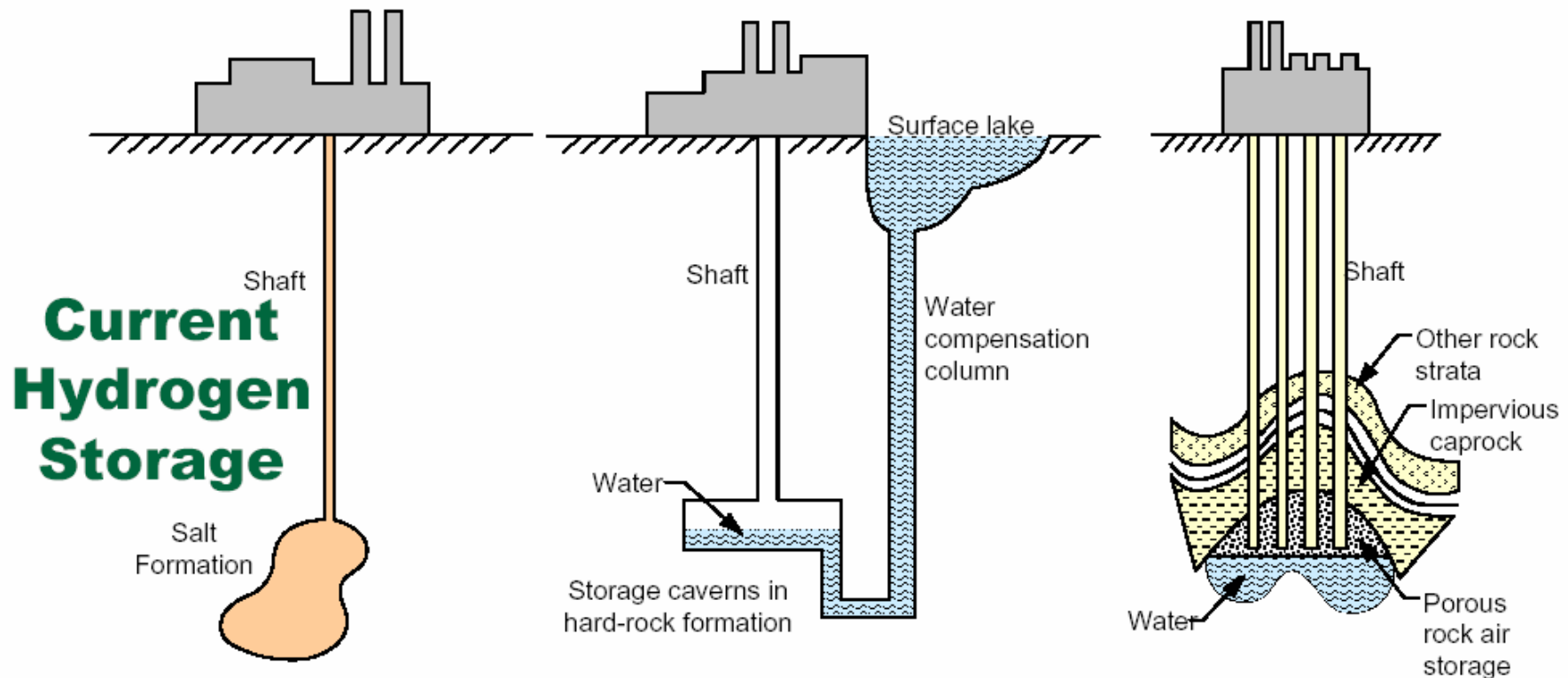


Geologic Salt: “Domal”, “Bedded”

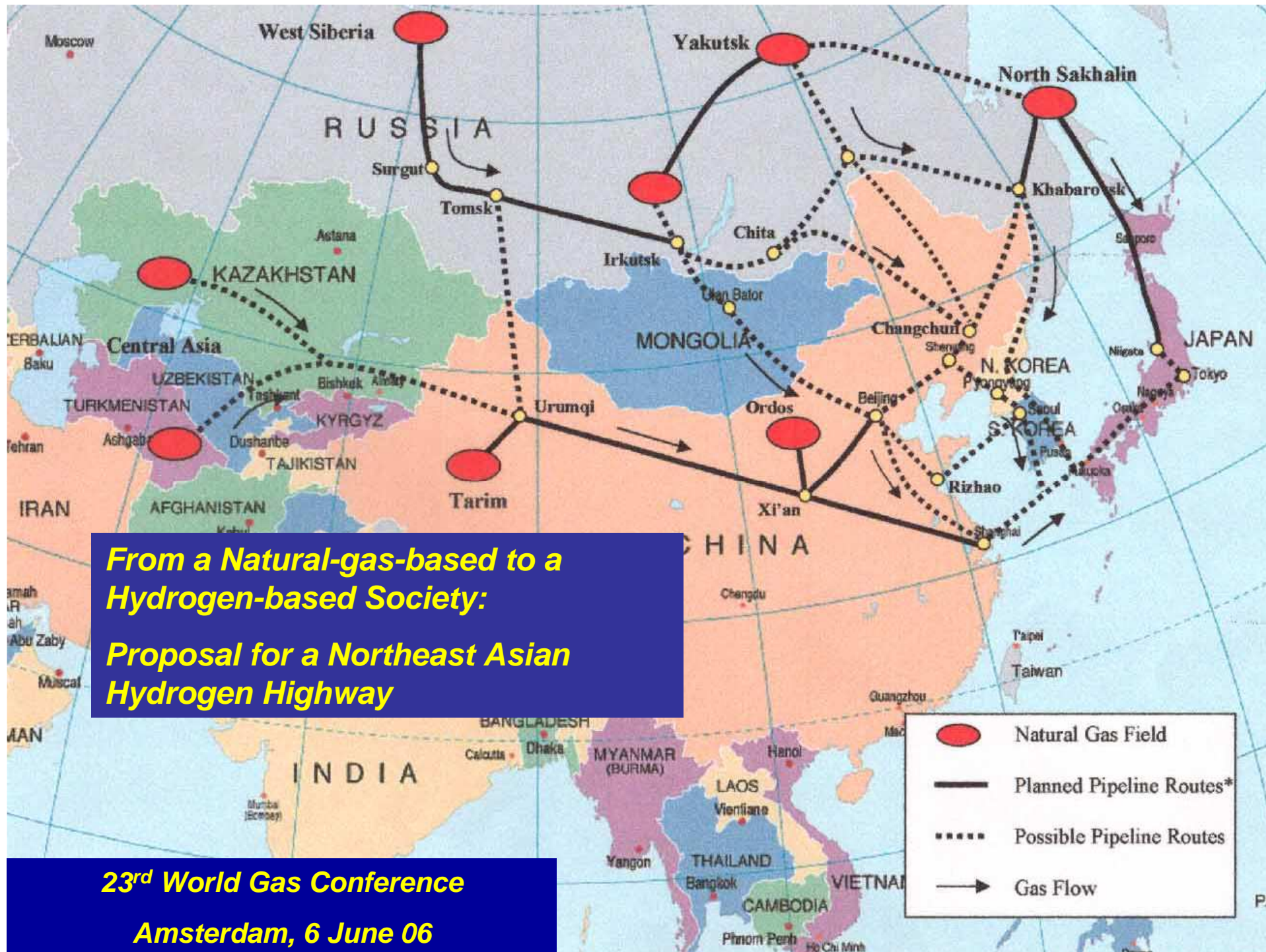


“Dome” salt deposits are thicker and more homogeneous than “bedded”

Hydrogen Can Be Stored Underground At Low Costs



Natural Gas Stored Underground



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	Possible Pipeline Routes
	Gas Flow



Hydrogen, Fuel Cell

25 Feb 05, Torrance, CA



Sadi Carnot
1796 - 1832

Thermodynamics:

Heat engines;
Efficiency limits



***Sir William
Grove
1839***

***Electrochemical
Engine***

***demonstrates
fuel cell:***

***H₂ to electricity, with
catalyst***

PEMFC Hybrid 2x miles / kg H₂ fuel as ICE Hybrid ?



Hydrogen, Fuel Cell

25 Feb 05, Torrance, CA

“PM” fuel cell (Poor Man’s)



*Model “U”
Hydrogen-fueled, ICE hybrid*



Hydrogen-fueled ICE by Electric Transportation Engineering Corp.

17th National Hydrogen Association Conference, March 06, Long Beach





**Hydrogen - fueled
2005 Prius
ICE Hybrid**

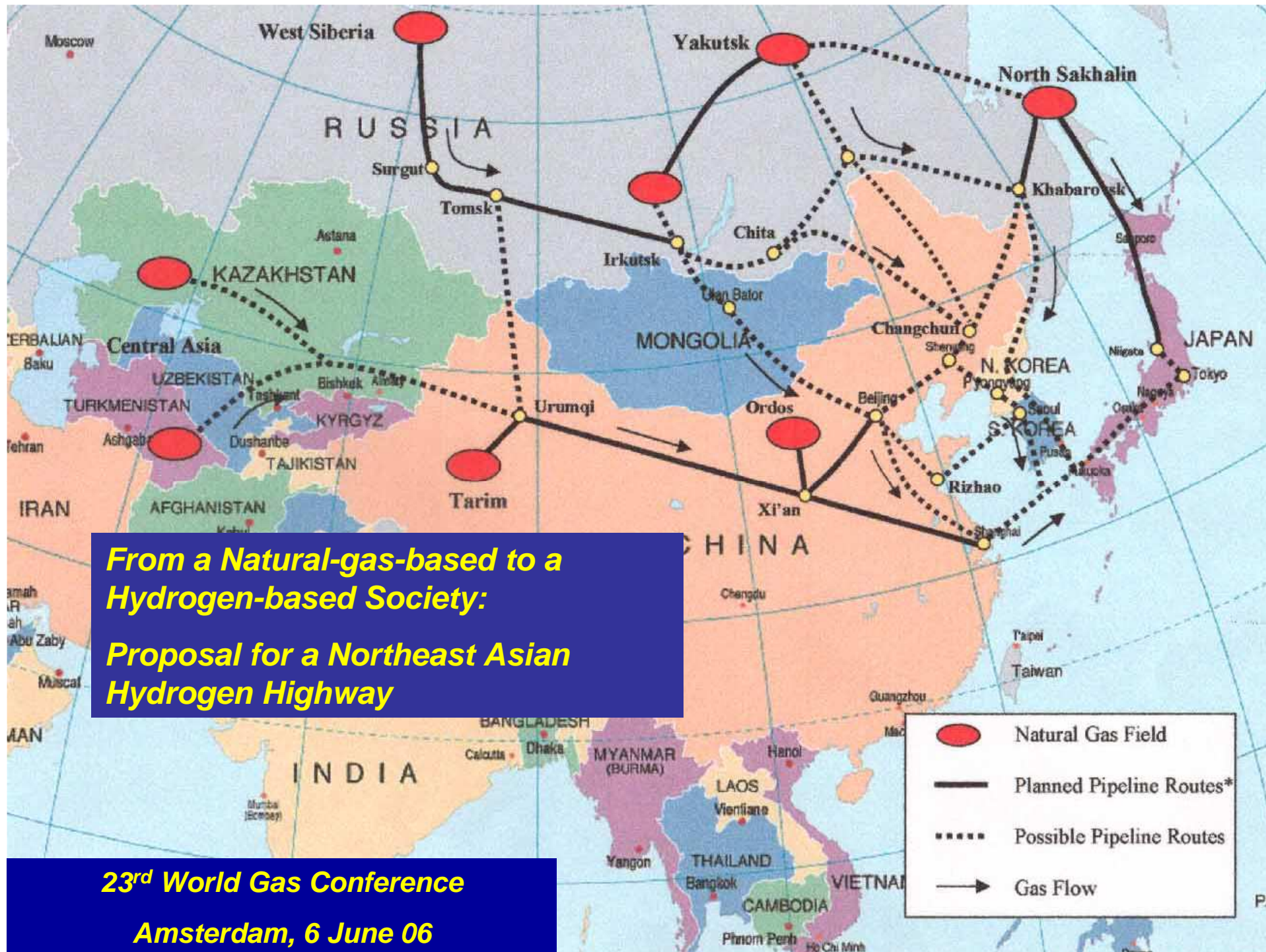


www.qtwww.com

**Hydrogen - fueled
2005 Prius
ICE Hybrid**



***ISE H2-fueled ICE Hybrid, V10
April 05, NHA, Washington DC***



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