

***Running the World on Renewables:
Energy Sustainability with
God on our side ?***

**Wartburg
College**

6 October 09

**Bill Leighty
The Leighty Foundation
wleighty@earthlink.net**





1958: NE Iowa Science Fair, SCl, 9th grade



1961

12th grade
NE Iowa
Science
Fair

SCI



**Collins Radio
Field Engineer**

**Vietnam
'68**



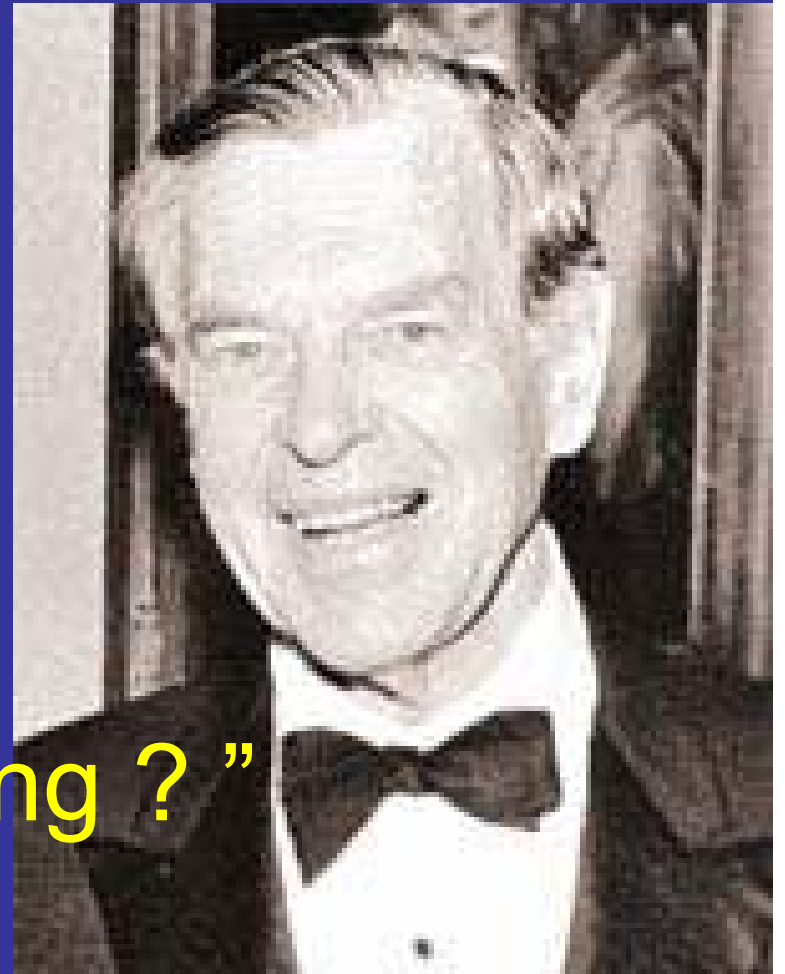
***Mendenhall Glacier
Juneau, Alaska 2005***

Humanity's Goal ?

**A sustainable,
benign-source,
equitable,
global
energy economy**

Joseph Campbell 1904 - 87

“ The Power of Myth ”, Bill Moyers



“ What Myth are we living ? ”



GOTT MIT UNS

“God with Us”



Only the Abrahamic Religions ?

MUST Run the World on Renewables – plus Nuclear ?





Earth's only source of income: Solar radiation, lunar tides

MUST Run the World on Renewables – plus Nuclear ?

- Climate Change
- Demand growth
- Depletion of Oil and Gas
- Only 200 years of Coal left
- Only Source of Income:
 - Sunshine
 - Tides
 - Meteors and dust
 - Spend our capital ?



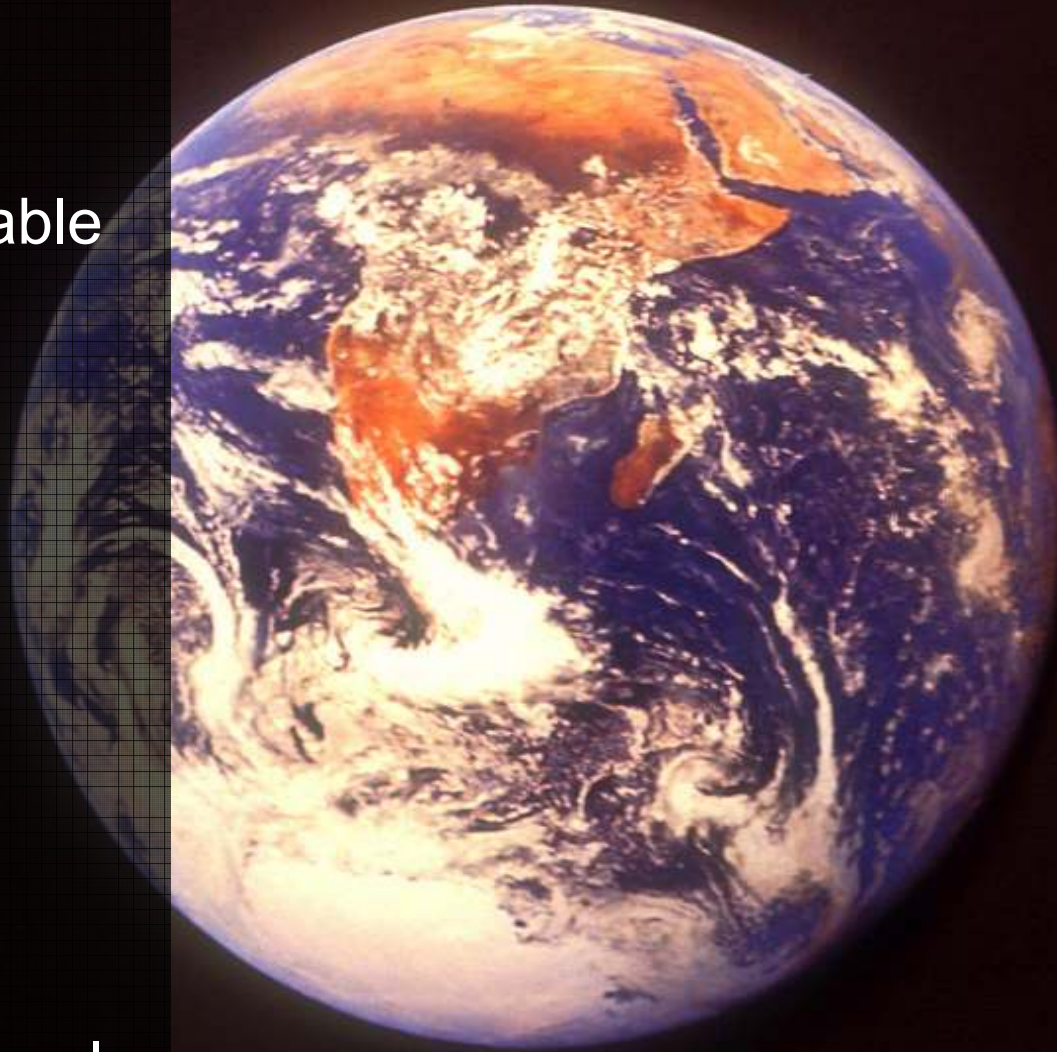
MUST Run the World on Renewables – plus Nuclear ?

- Emergencies:
 - Climate change
 - Energy prices
 - Energy security
- Conservation + efficiency
- GW scale renewables
- Beyond Electricity Grid
- Energy: beyond electricity
- Hydrogen , ammonia, ?



MUST Run the World on Renewables – plus Nuclear ?

- Global
- Indigenous
- Firm: available
- C-free
- Benign
- Abundant
- Affordable
- Equitable
- Perpetual:
 - solar
 - geothermal
 - tidal





The graph features a dark blue line on a light blue grid. The line starts at a low point on the left, rises steadily to a peak marked with an orange dot, and then descends towards the right, crossing a horizontal blue line. A second orange dot is placed on the descending line. Two orange speech bubbles point to these dots. The background is divided into a light blue upper half and a darker blue lower half by the horizontal line.

WE'RE HERE:
385.92 ppm

**WE NEED TO
GET BELOW:**
350 ppm

www.350.org

CO₂ in the Atmosphere

**Sunlight from
local star**

Electricity

O₂

Electricity

H₂

Work

Electrolyzer

Fuel Cell

PEM Electrolyzer
 $2\text{H}_2\text{O} + \text{Energy} \rightarrow 2\text{H}_2 + \text{O}_2$

Item: 2010
Solar Hydrogen System Junior Basic
www.hi-tec.com

PEM Fuel Cell
 $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{Energy}$

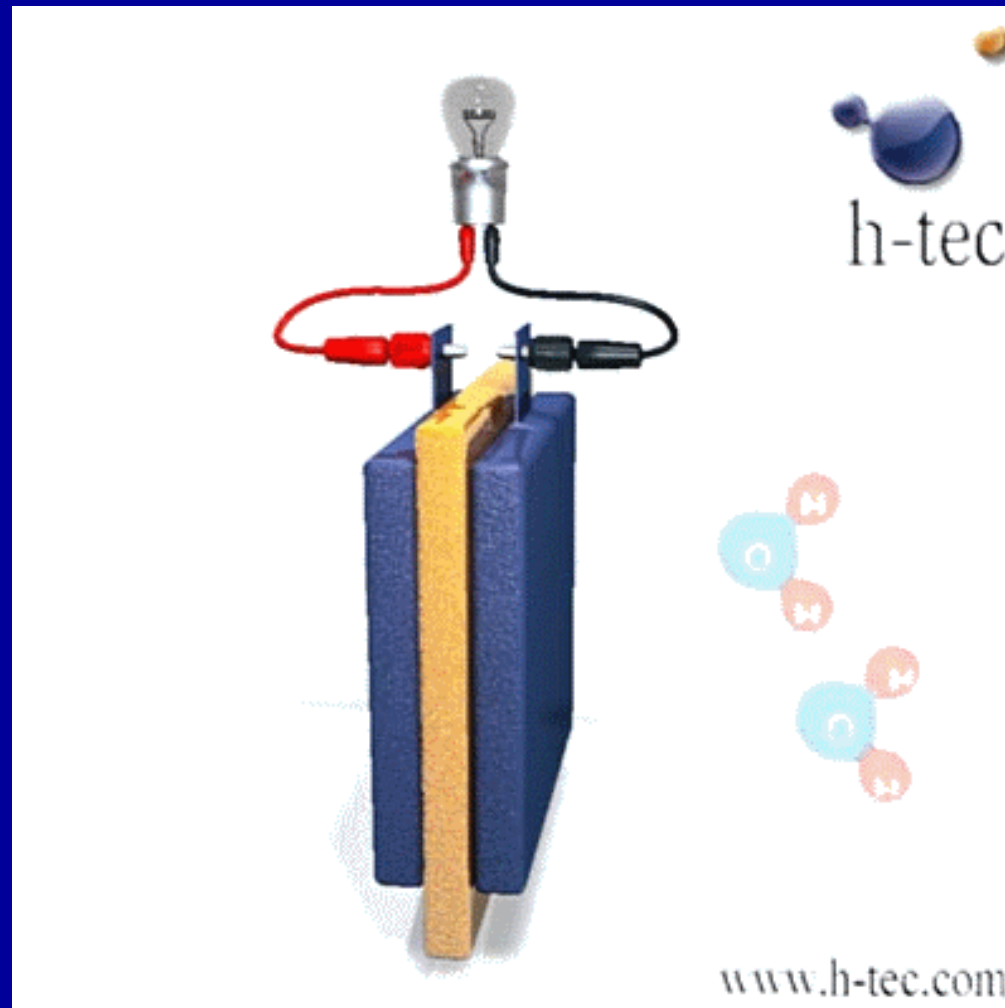
H TEC

Solar Hydrogen Energy System

Hydrogen Fuel Cell

Proton Exchange Membrane (PEM) type

Hydrogen (H_2) combines with Oxygen (O_2) to make electricity + heat + water (H_2O)



Watch our language !

“Run”

- 6. Move freely and without restraint
- 8. Take part in a race or contest
- 12. Ply between places
- 19. **Operate or function**
- 35. **Perform or accomplish**
- 46. Operate or drive
- 50. Manage or conduct
- ...
- 67.

Watch our language !

- Nuclear weapons
- Sustainable
 - Sustainability
 - Sustainable development
- Environment
 - Environmental
 - Environmentalist
 - Earth protection
- Natural
- Global warming
- Global climate change, rapid climate change
- kW, kWh
- Stewardship

Rad' i cal *adj.*

1. a) of or from the **root** or roots;
going to the **foundation** or **source**
of something **fundamental**;
basic

Sustainable

“ Meeting our needs without compromising the ability of future generations to meet their own needs ”

United Nations Commission on
Environment and Development (UNCED)
“Our Common Future”, 1987

Sustain what ?

1. Keep in existence; maintain
2. Supply with necessities or nourishment; provide for
3. Support from below; keep from falling or sinking; prop
4. Support the spirits, vitality, or resolution of; encourage
5. Bear up under; withstand
 - Economy back on track ?
 - Get my job back ?
 - More of the same ?
 - Lower price of gasoline ?
 - My grandkids ? Seventh generation ?
 - New Vision, Paradigm, Myth ?

Sustain what ?

- **New Vision, Paradigm, Myth ?**
- **“ Where there is no vision the people perish “**

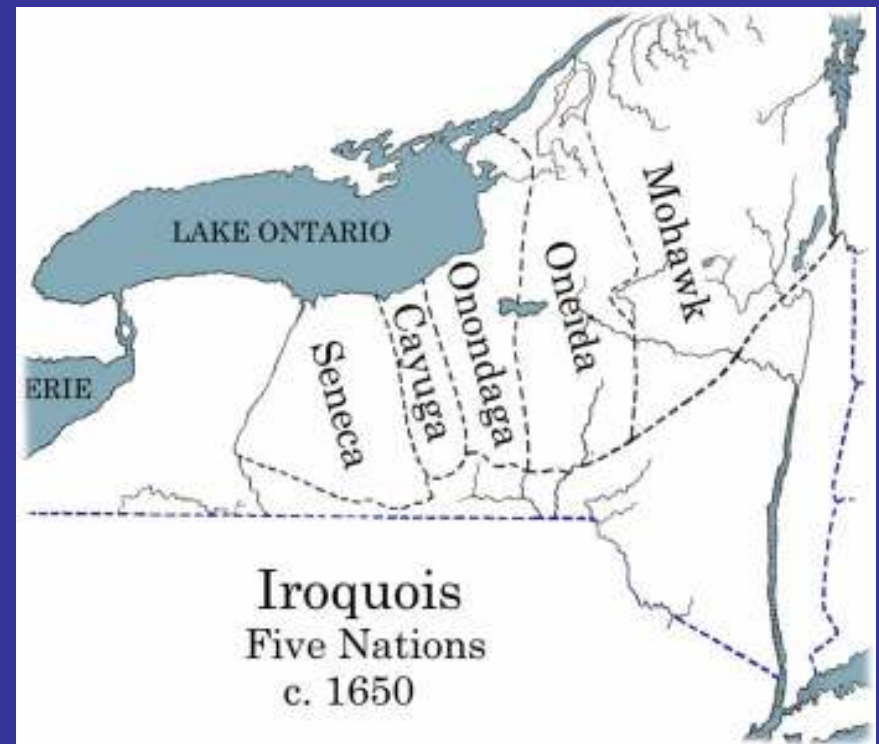
Proverbs 29

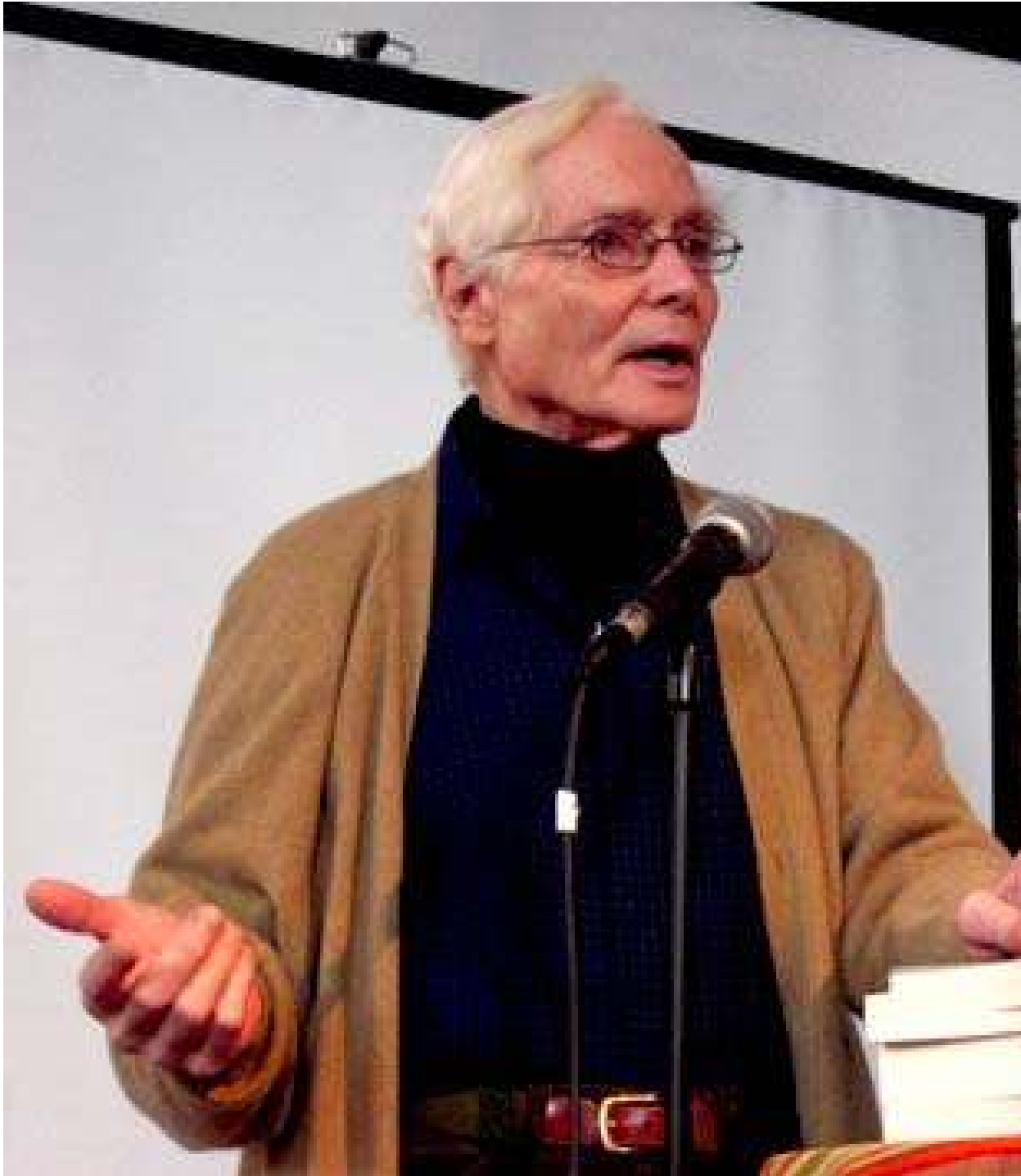


Iroquois in Buffalo, New York, 1914

**“ In every deliberation,
we must consider the impact
on the seventh generation...
even if it requires having skin
as thick as the bark of a pine.”**

— Great Law of the Iroquois

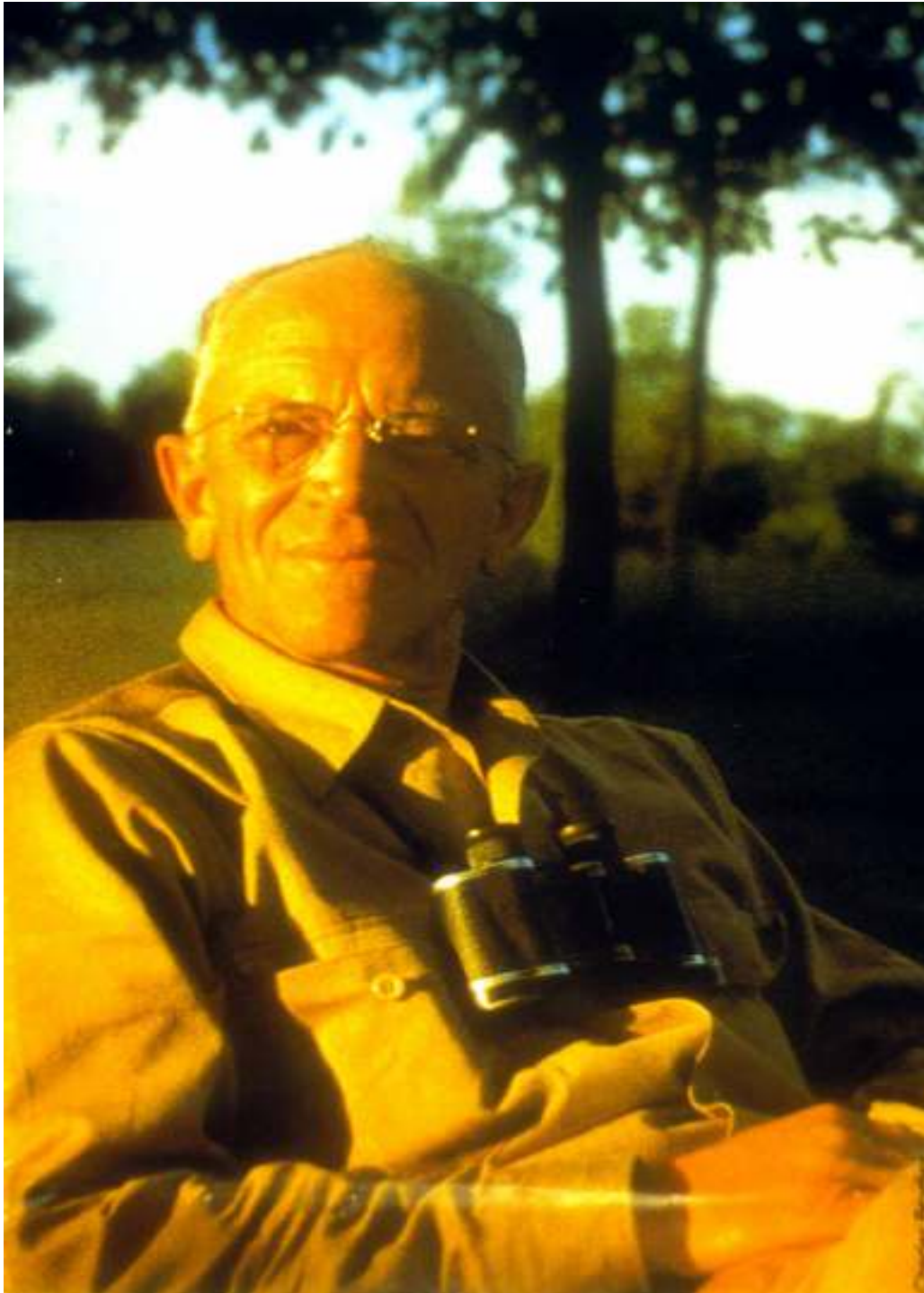




“ Poetry's
really about
what can't be
said... when
you can't find
words for
something.”

“ Nobody
finds words
for grief... for
love... for
lust. ”

W.S. Merwin
poet



**Aldo
Leopold**

1887 - 1948

**There are two spiritual dangers in not
owning a farm:**

**One is supposing that breakfast
comes from the grocery;**

**The other is supposing that heat
comes from the furnace.**

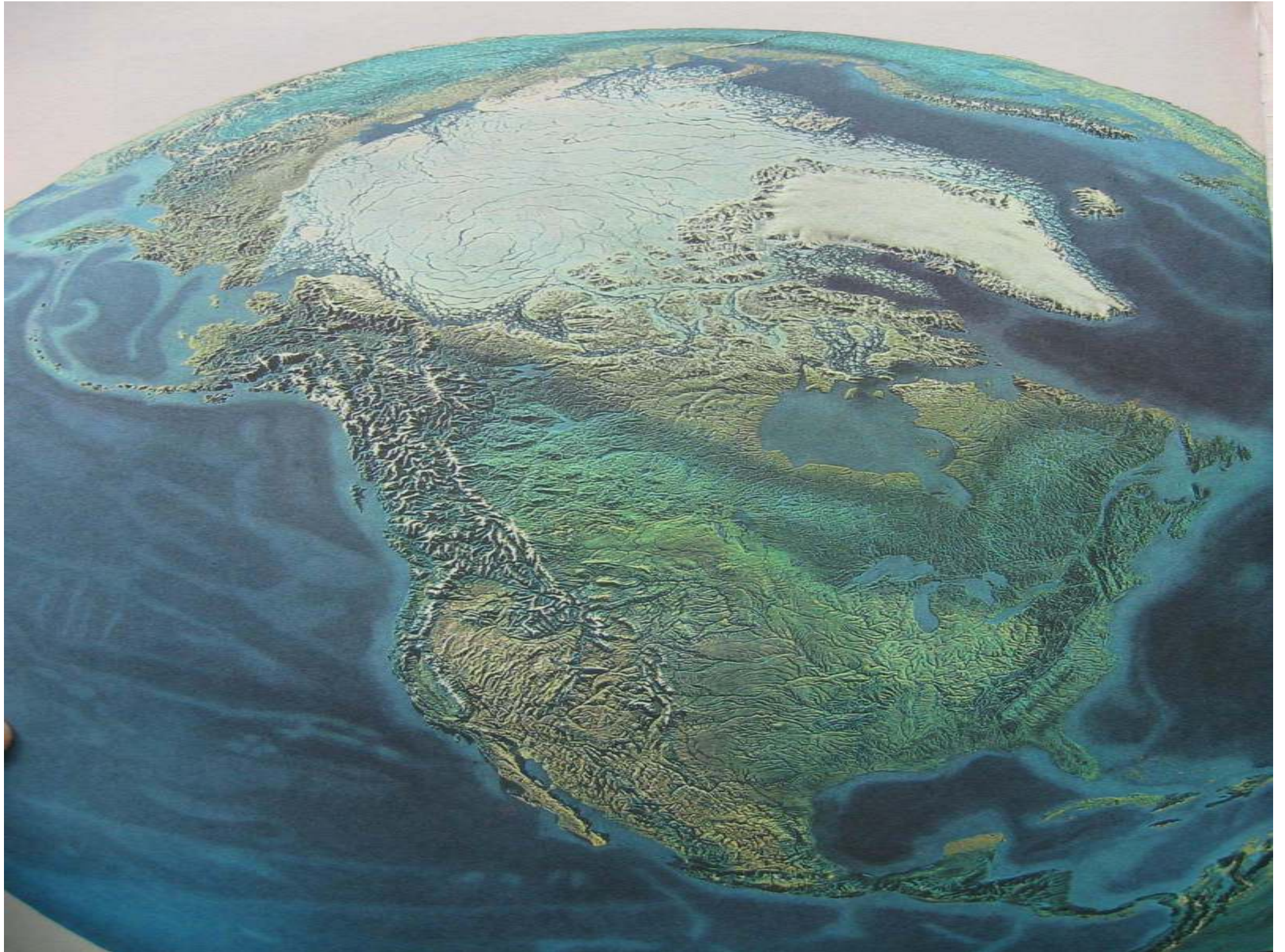
Aldo Leopold, "A Sand County Almanac"

1: Adequate Renewables

- **Run the world; humanity's needs**
- “Distributed” and “Centralized”
- Affordable, benign
- Diverse, synergistic
- Richest are “stranded”
 - Far from markets
 - No transmission


Global Opportunity









An aerial photograph of a wind farm in Iowa. Four large, three-bladed wind turbines are visible, standing on a rolling landscape of green fields. A yellow dirt road or path winds through the fields, connecting the turbines. The sky is a clear, bright blue. The text 'Wind Powering America' is overlaid in a large, stylized, yellow font on the left side of the image.

Wind Powering America

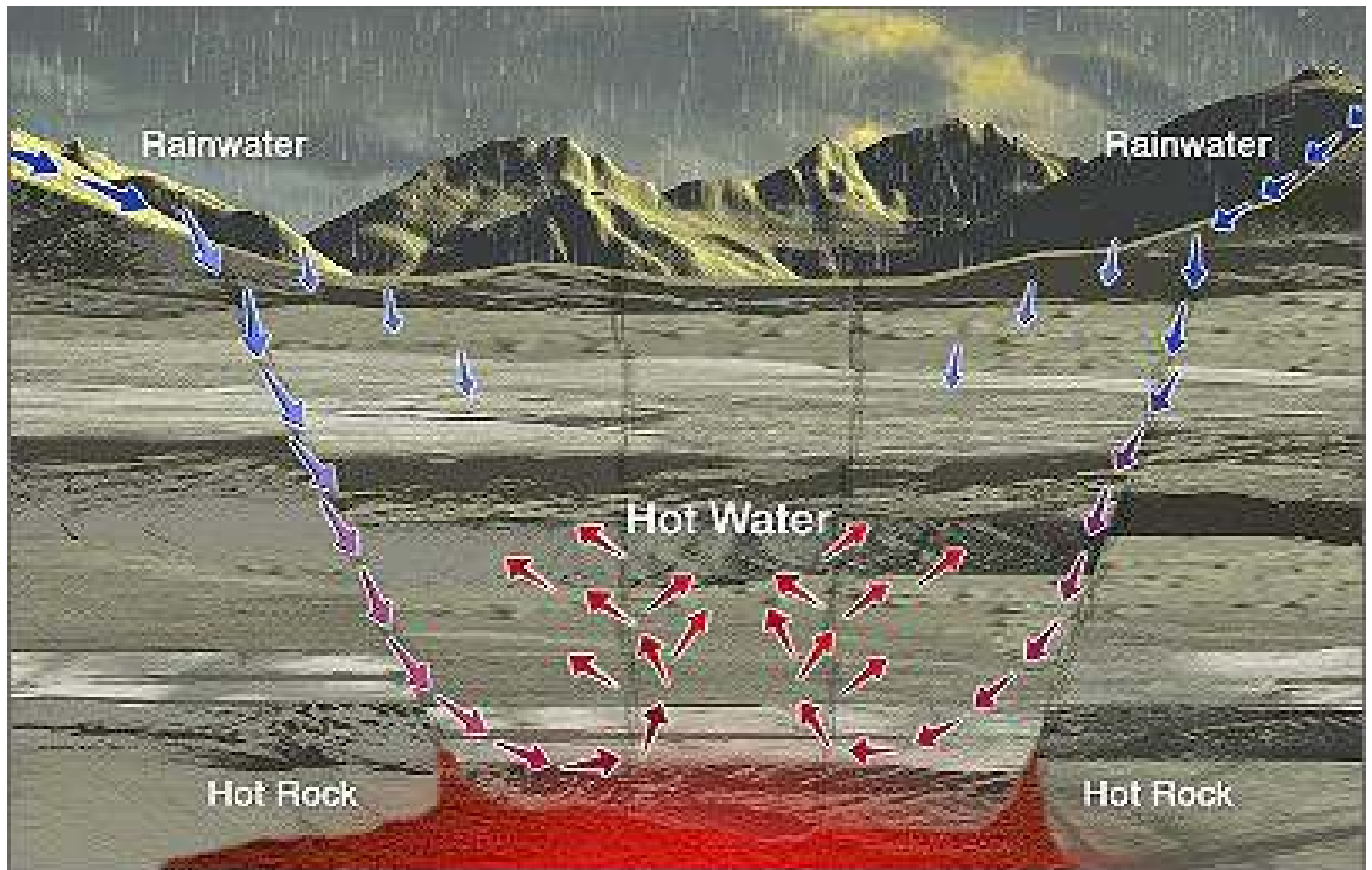
Diverse !

NW Iowa 190 MW windplant

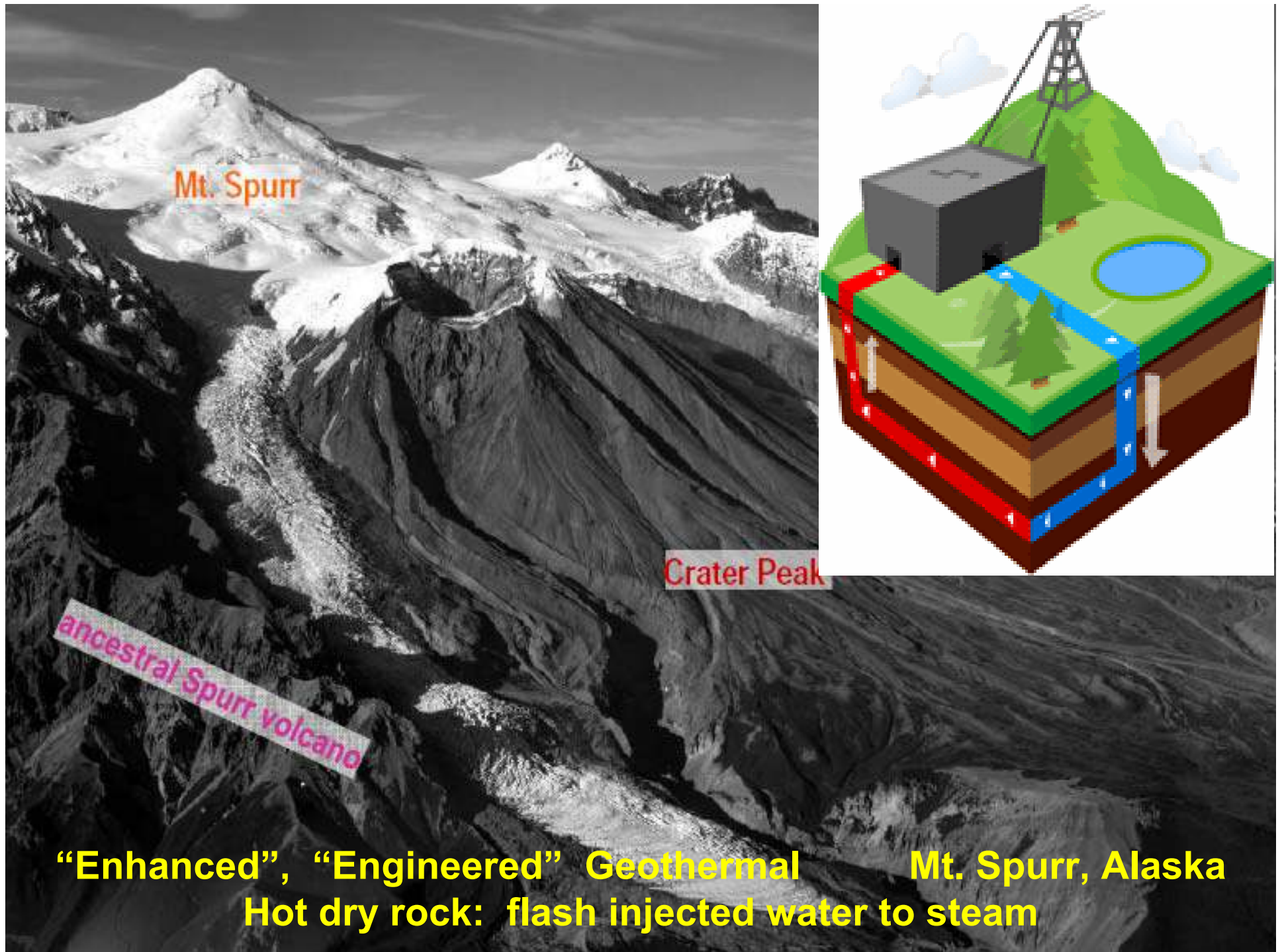


Hydro

Hoover Dam



Geothermal: hot water, surface recharge

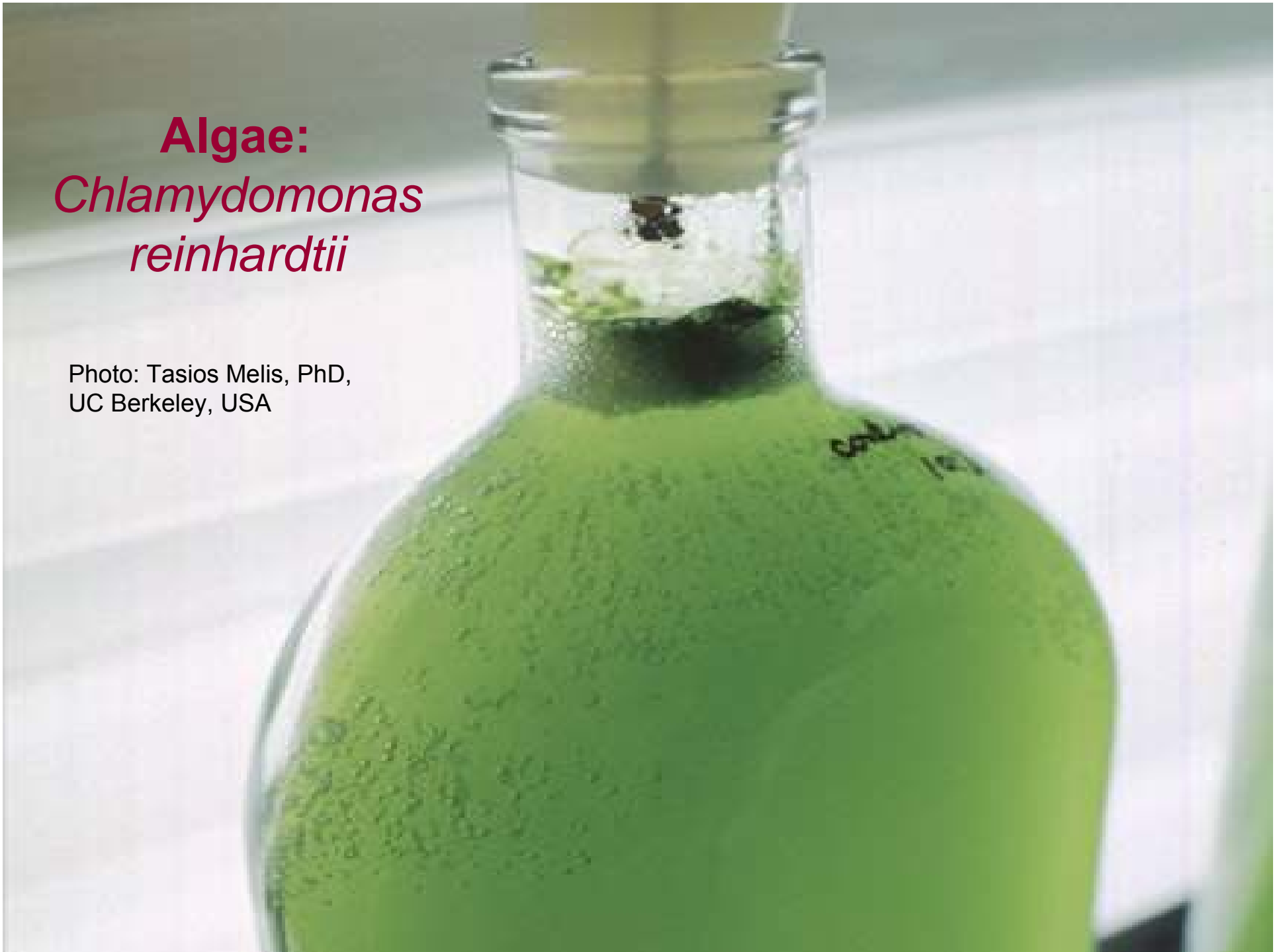


A black and white electron micrograph showing several rod-shaped bacterial cells. The cells are elongated and have a granular internal structure. One cell in the foreground is particularly prominent, showing a clear internal structure with a darker, more electron-dense region in the center. The background is light and grainy.

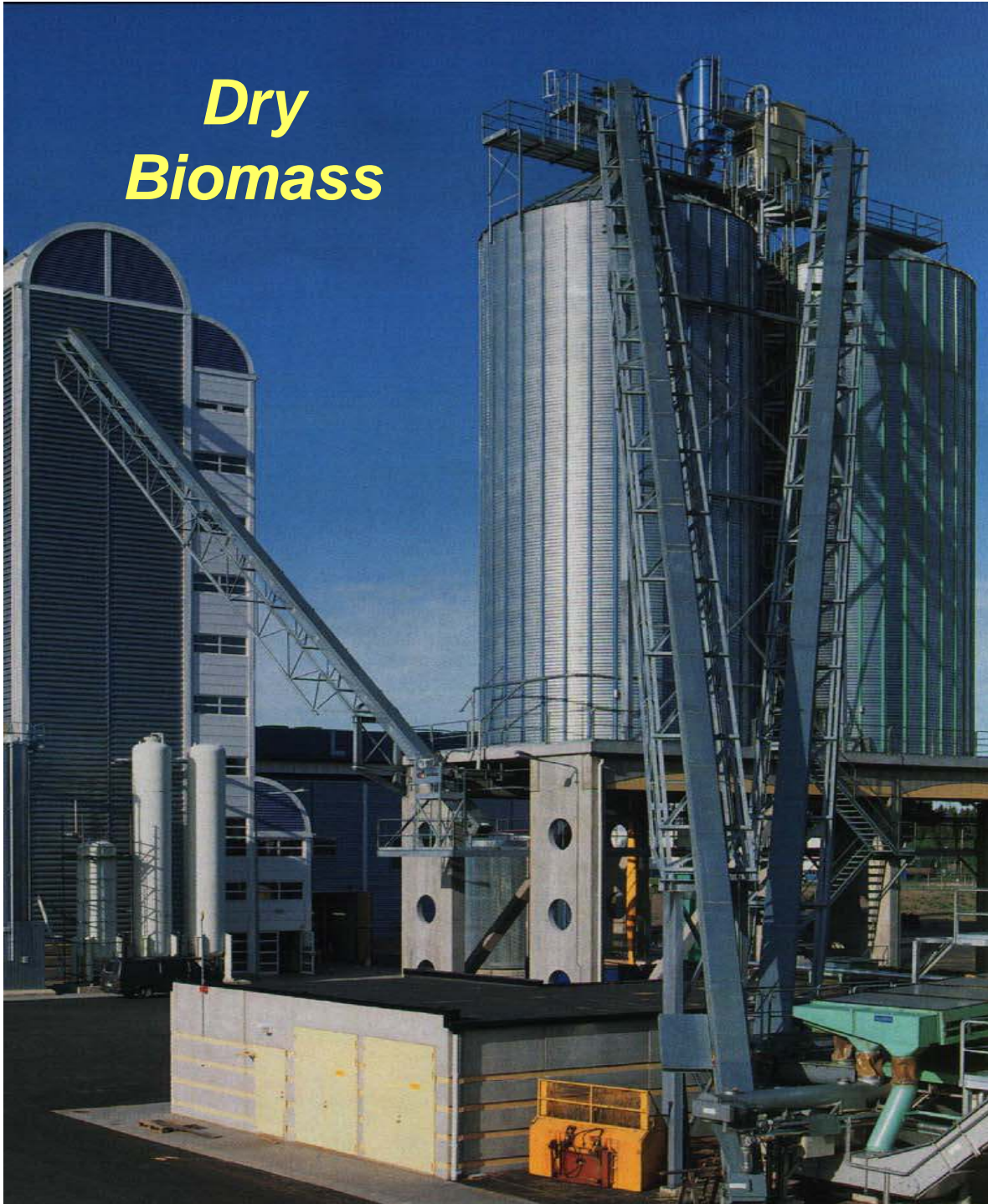
Photobiological
Rhodospirillum rubrum

Algae:
Chlamydomonas
reinhardtii

Photo: Tasios Melis, PhD,
UC Berkeley, USA



Dry Biomass



Wet Biomass: Anaerobic Digester





Concentrating Solar Power (CSP)

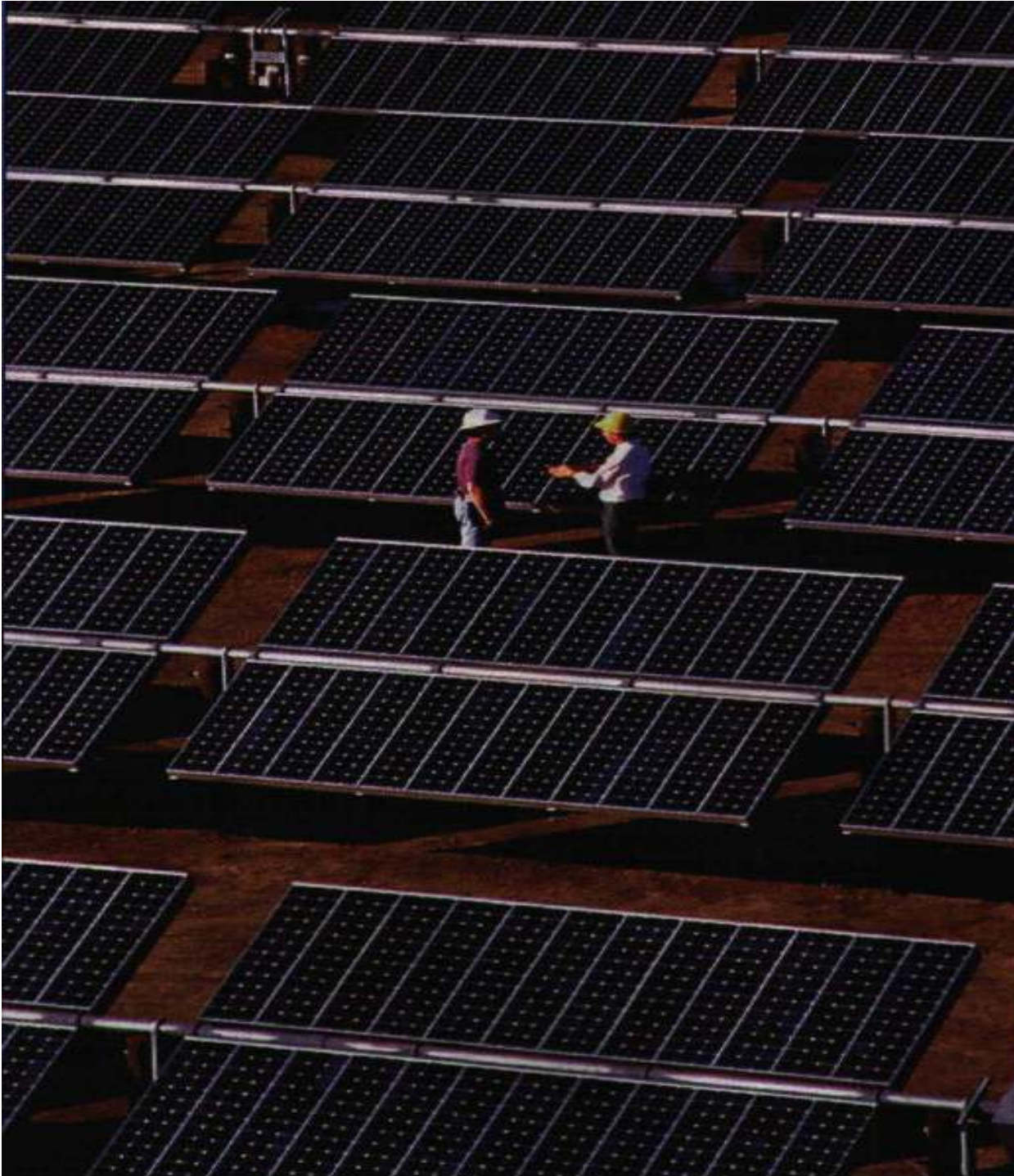


Stirling Energy Systems, Inc.
Model solar thermal power plant, NM Completed May 05

Parabolic Trough Concentrating Solar Power (CSP)

CA, Spain





Photovoltaic (PV)

***Small
Medium
Large***

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**



Currents: Tidal, River, Ocean

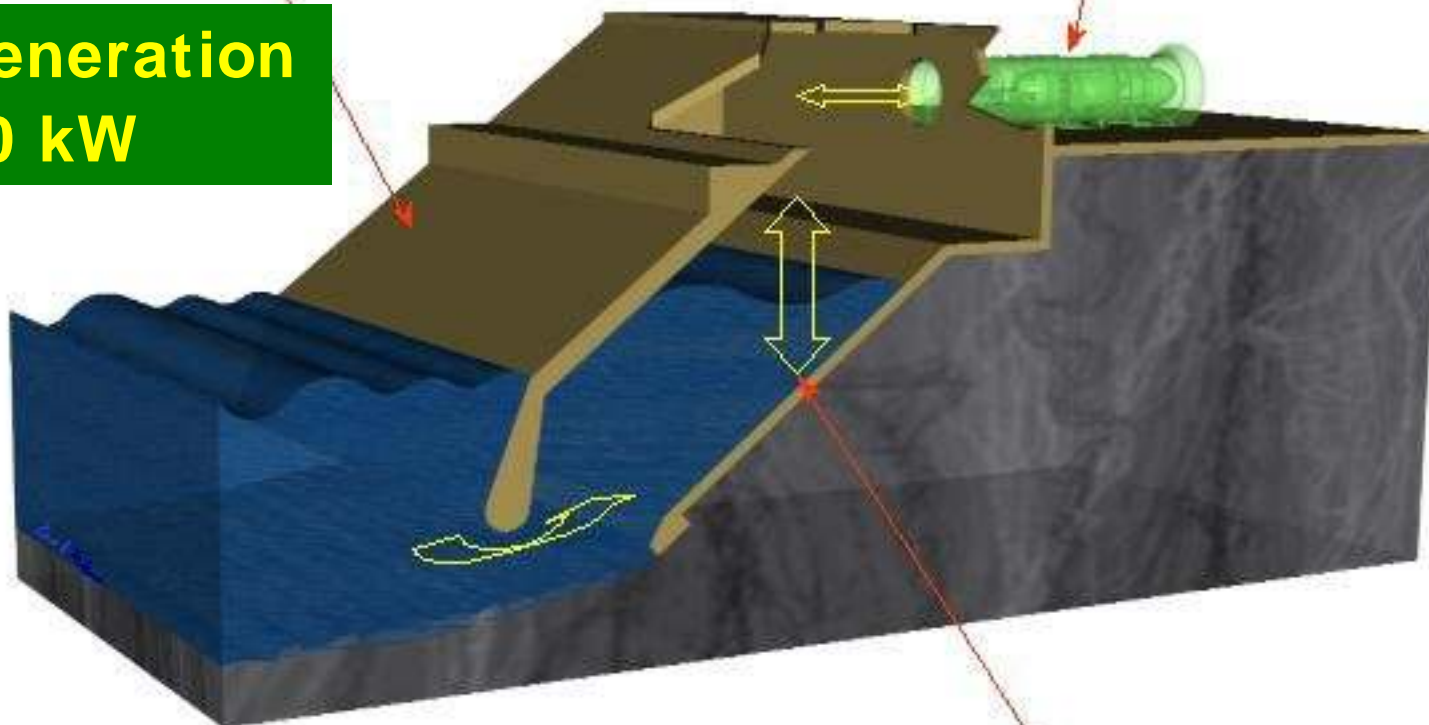


“LIMPET”, Island of Islay, off Scotland coast

Reinforced concrete Capture Chamber set into the excavated rock face.

The Wells Turbines rotate in the same direction regardless of the direction of the air flow. Thus generating irrespective of upward or downward movement of the water column.

**Wave Generation
500 kW**



Air is compressed and decompressed by the Oscillating Water Column (OWC). This causes air to be forced through the Wells Turbine and is then drawn back through the Wells Turbine.

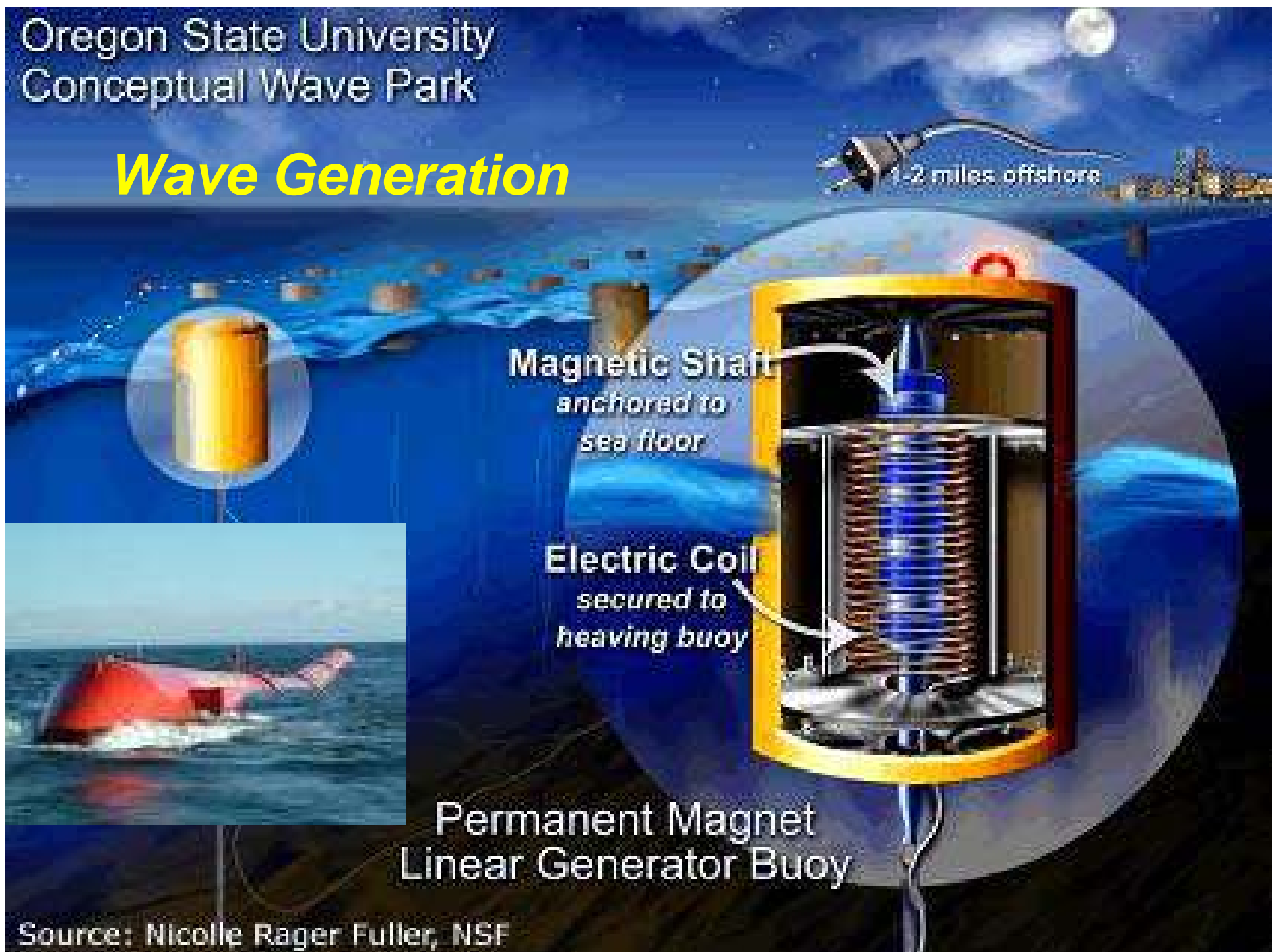
UK



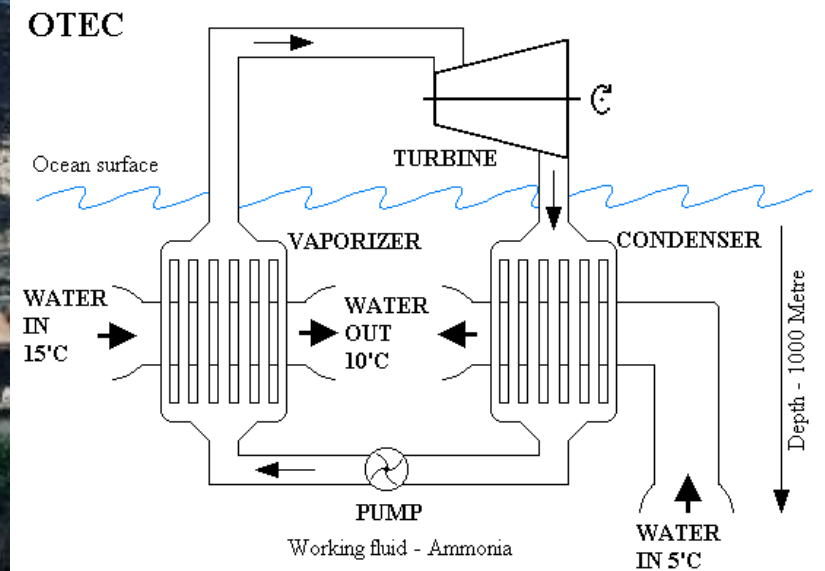
**“Limpet”: Land Installed
Marine Powered Energy
Transformer**

Oregon State University Conceptual Wave Park

Wave Generation



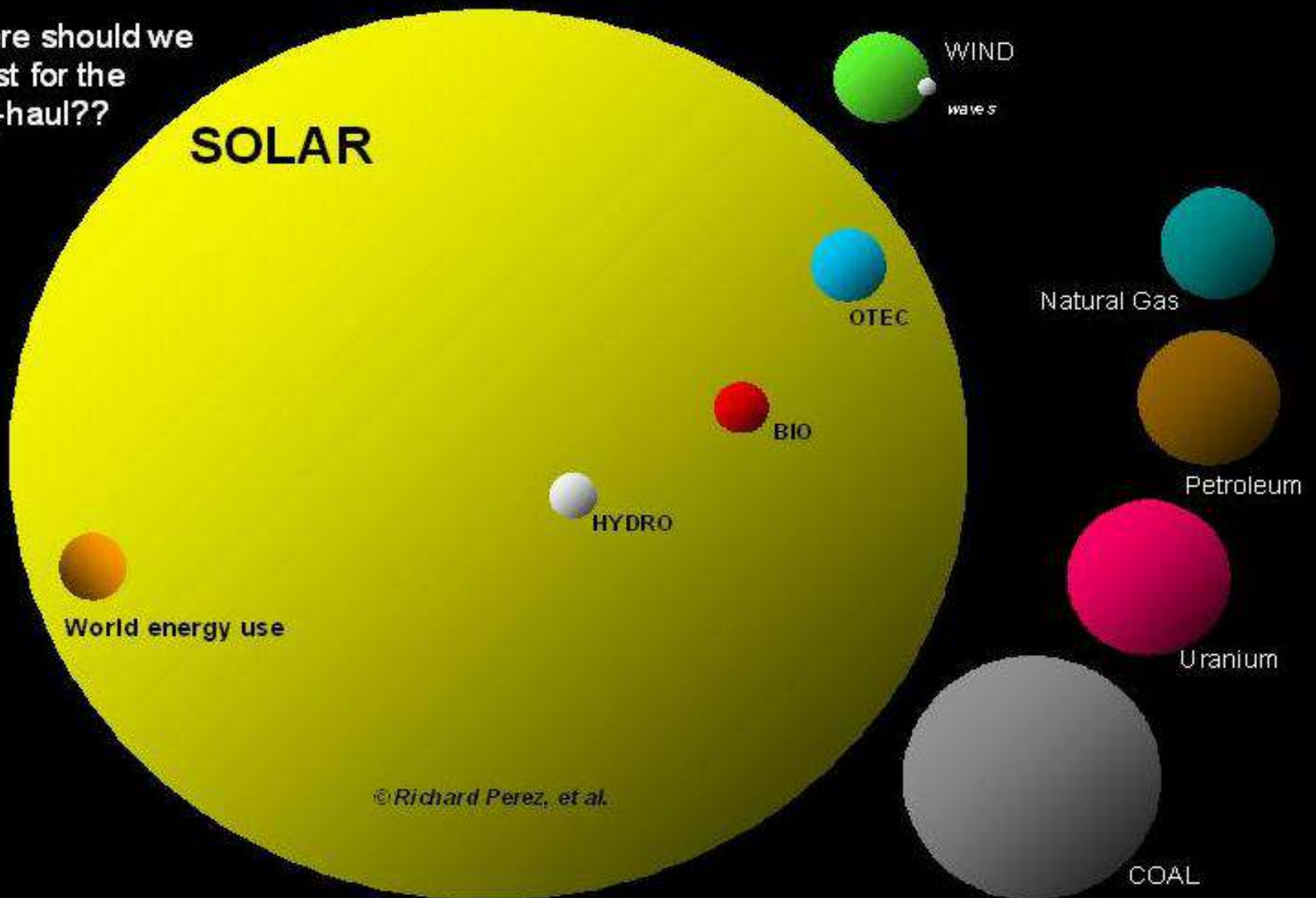
Source: Nicolle Rager Fuller, NSF



Big Island, Hawaii: OTEC: Ocean Thermal Energy Conversion

Comparing the world's energy resources*

Where should we
invest for the
long-haul??



**yearly potential is shown for the renewable energies. Total reserves are shown for the fossil and nuclear "use-them, lose-them" resources. World energy use is annual.*



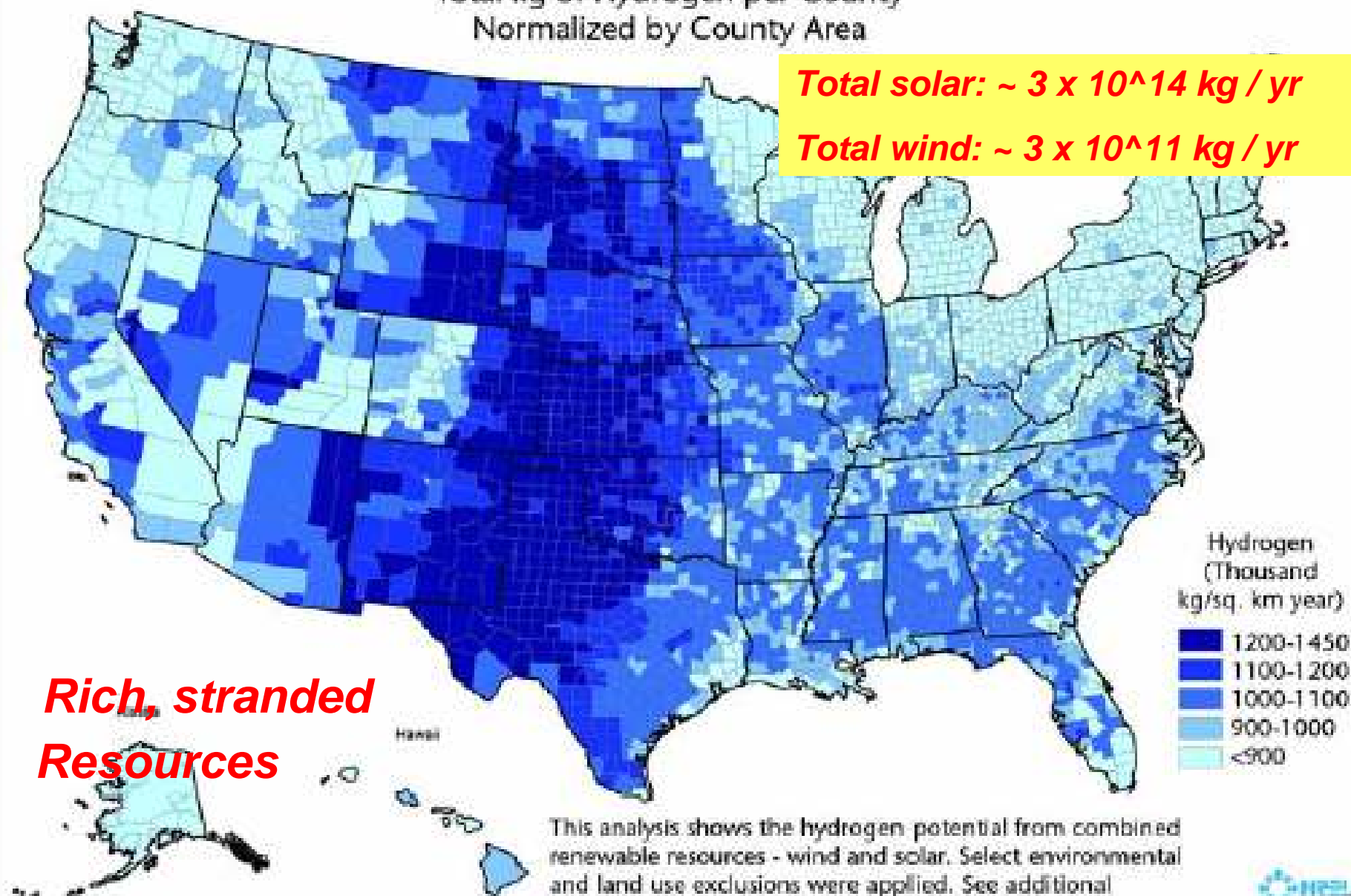
Figure 3

Hydrogen Potential from Solar and Wind Resources

Total kg of Hydrogen per County
Normalized by County Area

Total solar: $\sim 3 \times 10^{14}$ kg / yr

Total wind: $\sim 3 \times 10^{11}$ kg / yr



**Rich, stranded
Resources**

This analysis shows the hydrogen potential from combined renewable resources - wind and solar. Select environmental and land use exclusions were applied. See additional documentation for more information.

1: Adequate Renewables

- Run the world; humanity's needs
- “Distributed” and “Centralized”
- Affordable, benign
- Diverse, synergistic
- **Richest are “stranded”**
 - **Far from markets**
 - **No transmission**

2: When we realize these as emergencies:

- Global Warming, Rapid Climate Change
- Energy Security and Cost
- Peak Oil and Natural Gas

We must quickly invest in:

- Energy conservation, efficiency
- Large, new energy supplies:
 - CO₂ – emissions – free; benign
 - Indigenous
 - Both distributed, centralized

3: Shortest path to benign, secure, abundant energy

- Renewables
 - Diverse
 - Diffuse
 - Dispersed
- Centralized:
 - Large, rich; lower cost than distributed ?
 - But **stranded (no transmission)**
- Gaseous hydrogen (GH₂) pipelines
 - Conversion, gathering,
 - Transmission,
 - Distribution
 - “Firming” storage: salt caverns, tanks
- Pilot plants needed:
 - every major new industrial process
 - IRHTDF

3: Shortest path to benign, secure, abundant energy

- Anhydrous Ammonia (NH_3) fuel pipelines
 - Conversion, gathering
 - Transmission
 - Storage: tanks
 - Distribution
- Pilot plants needed:
 - Every major new industrial process
 - '08 Farm Bill Title IX:
“Renewable Fertilizer Research”



Jon Wellinghof

FERC* Chairman

About new coal + nuclear
plants:

**“ We may not
need any, ever ”**

NY Times, 22 Apr 09

*** FERC = Federal Energy
Regulatory Commission**

“America is addicted to oil.”

Jan 31, 2006, State of the Union,
President G. W. Bush

Humanity is addicted to energy







INSPECTION AND SALE OF A NEGRO.



TO BE SOLD, on board the
Ship Bance Island, on Tuesday the 6th
of *May* next, at *Abley-Ferry*, a choice
cargo of about 150 fine healthy

NEGROES,
just arrived from the
Windward & Rice Coast.
—The utmost care has
already been taken, and
shall be continued, to keep them free from
the least danger of being infected with the
SMALL-POX, no boat having been on
board, and all other communication with
people from *Charles-Town* prevented.

Aubin, Laurens, & Appleby.

*N. B. Tell one Half of the above Negroes have had the
SMALL-POX in their own Country.*

Slavery in America

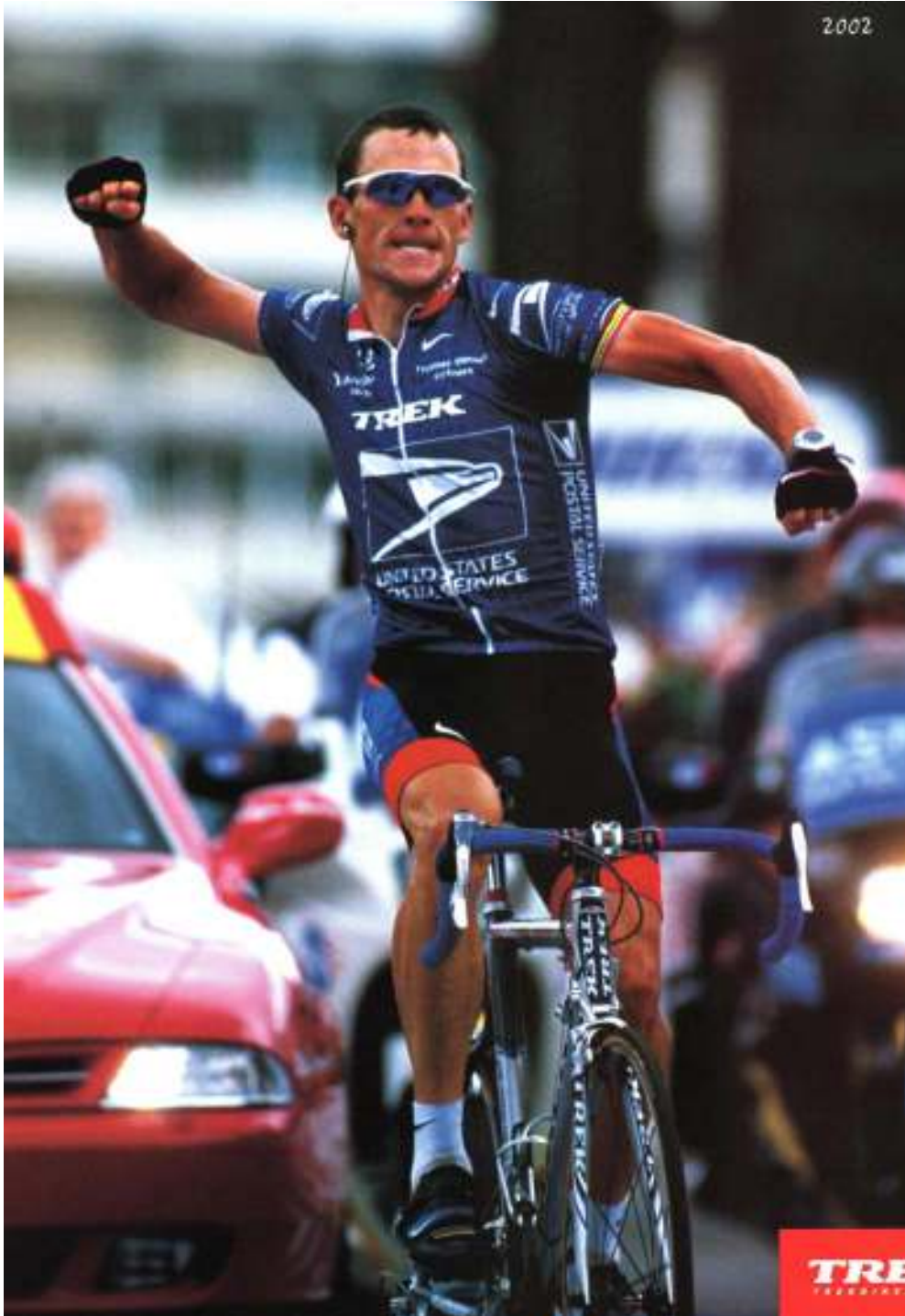






Energy Slaves

2002



Lance Armstrong

2002

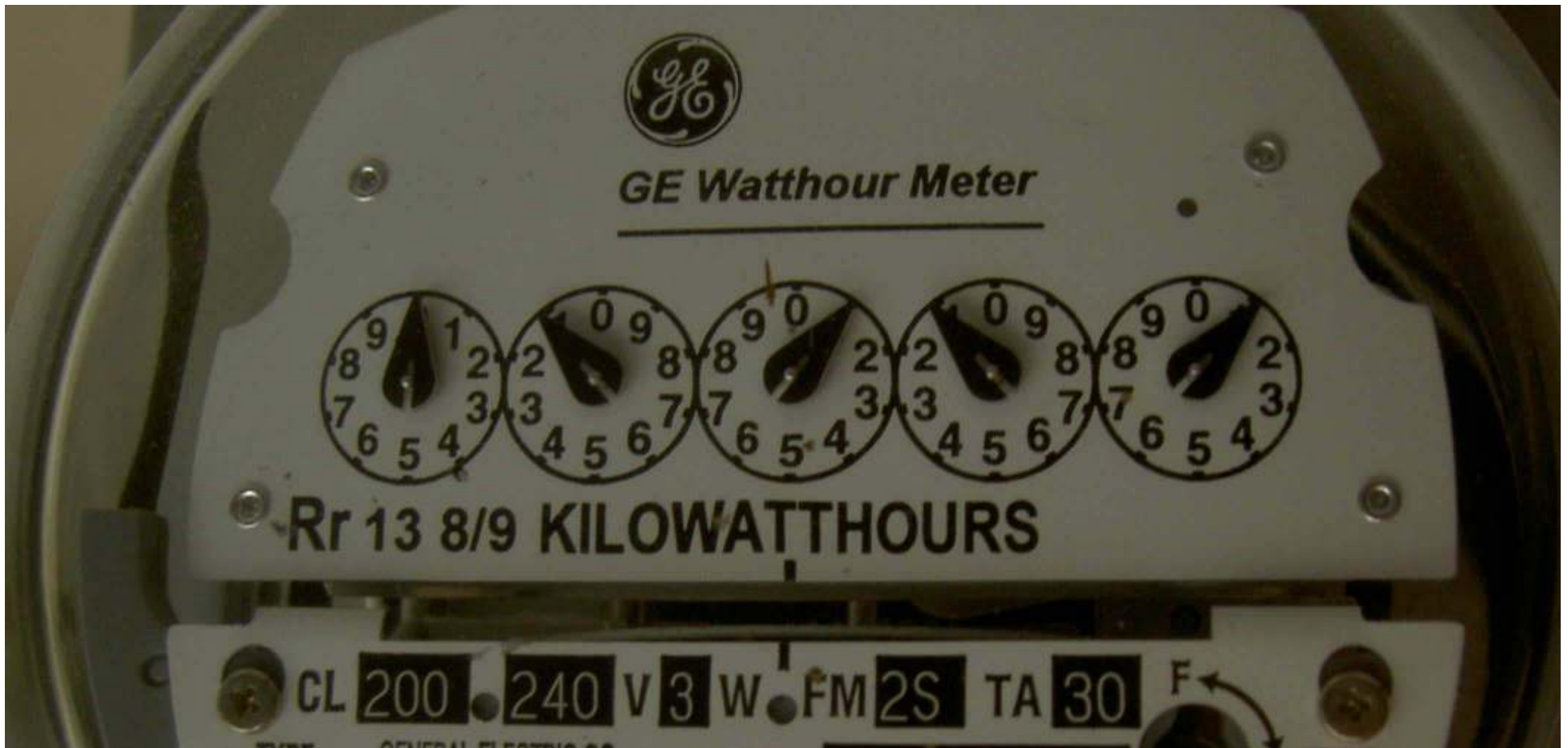
Peak 500 Watts

Average 250 Watts

3 kWh per day

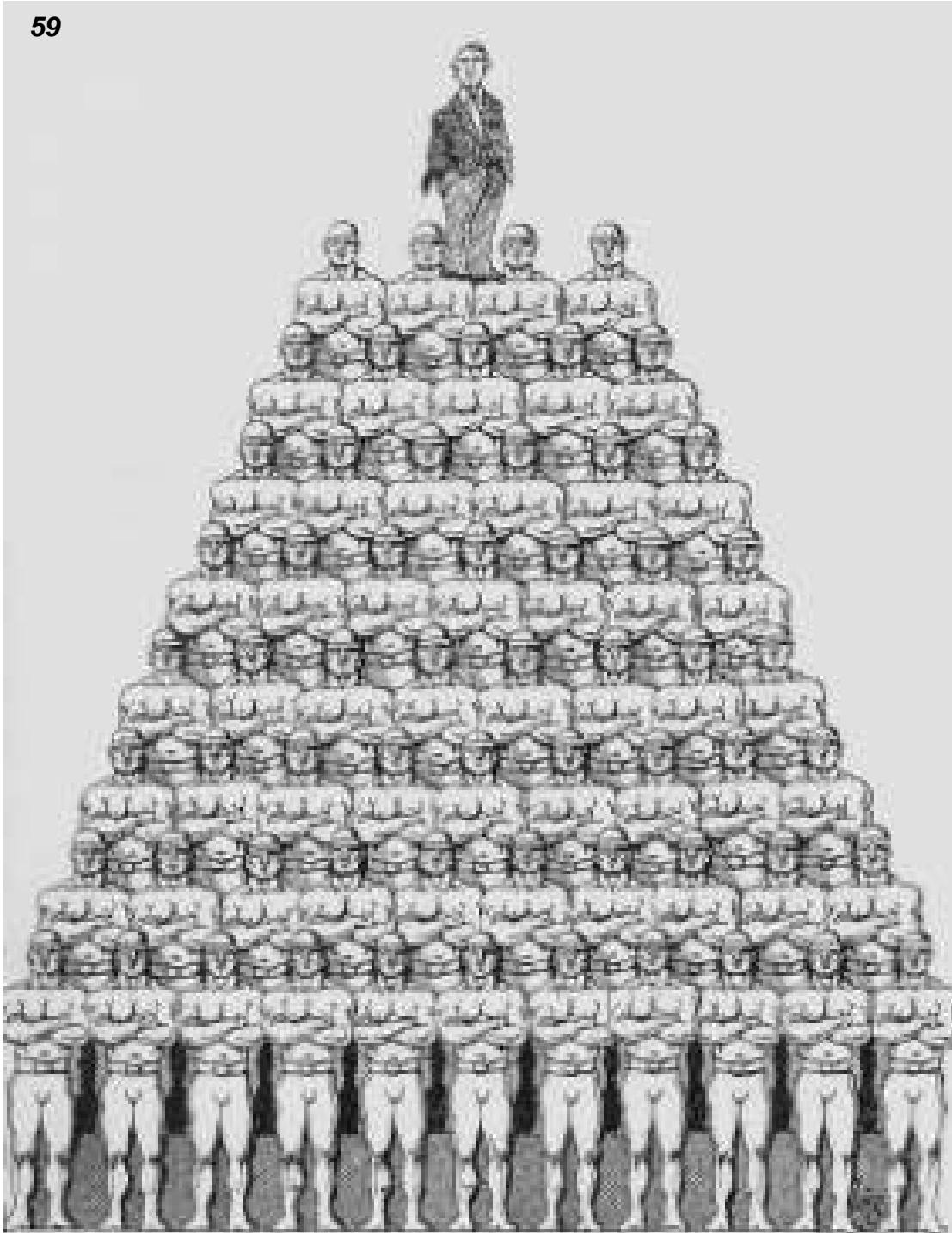
(12 hour day)

746 Watts = 1 hp



Kilowatt-hour (kWh):

- ***Energy = power (Watts) x time (hours)***
- ***1,000 Watt-hours***
- ***2.6 million foot-pounds***
- ***1 Sherpa-week (100 pounds from 3,000 ft to 29,000 ft)***
- ***3,410 Btu = 640 lbs water heated 5 ° F***



Energy Slaves

USA:

***35 Lance
Armstrongs
per person***

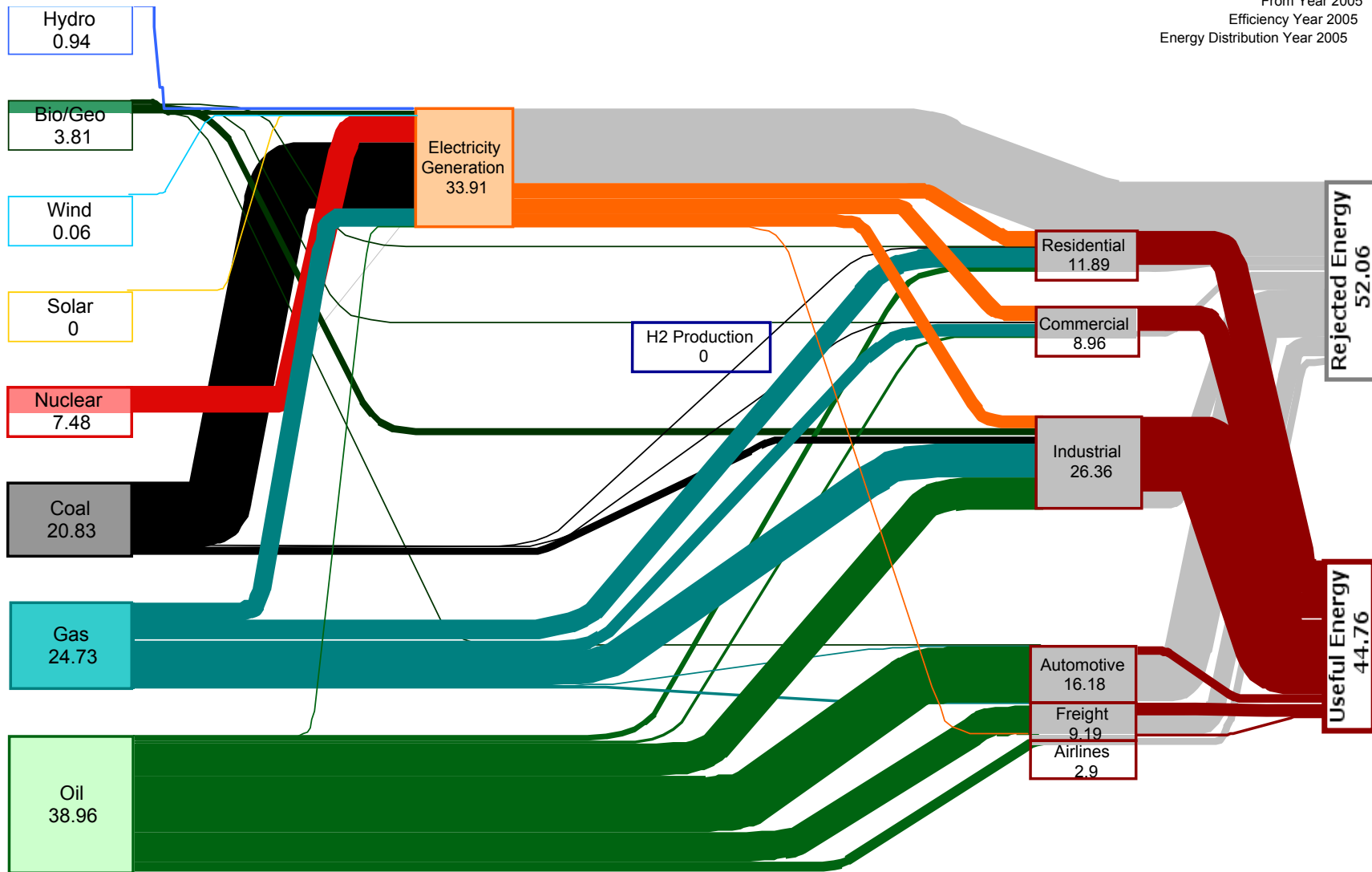
***working
24 / 7***



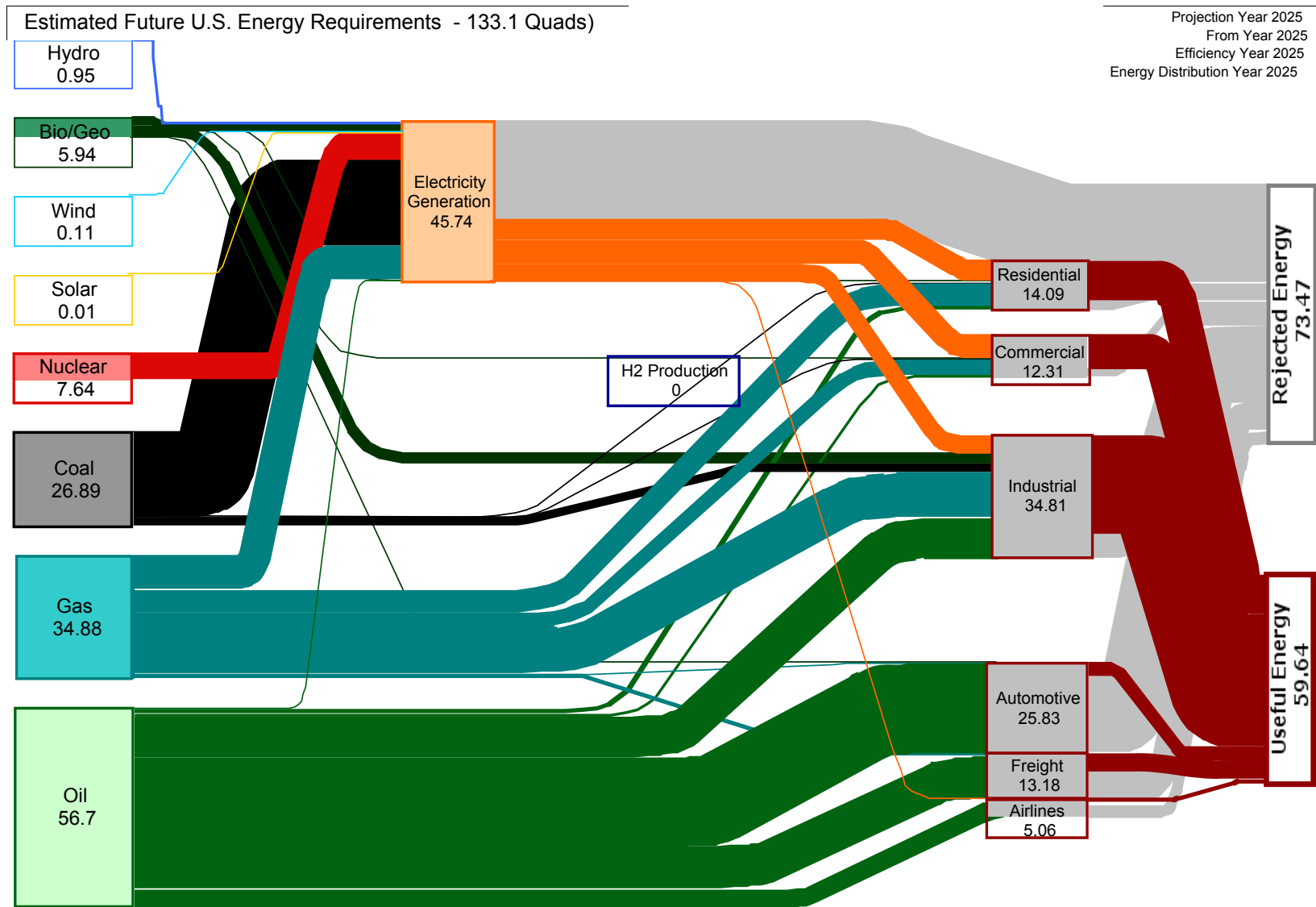
DOE-EIA: Estimated **2005** US energy use

Estimated Future U.S. Energy Requirements - 96.8 Quads)

Projection Year 2005
From Year 2005
Efficiency Year 2005
Energy Distribution Year 2005



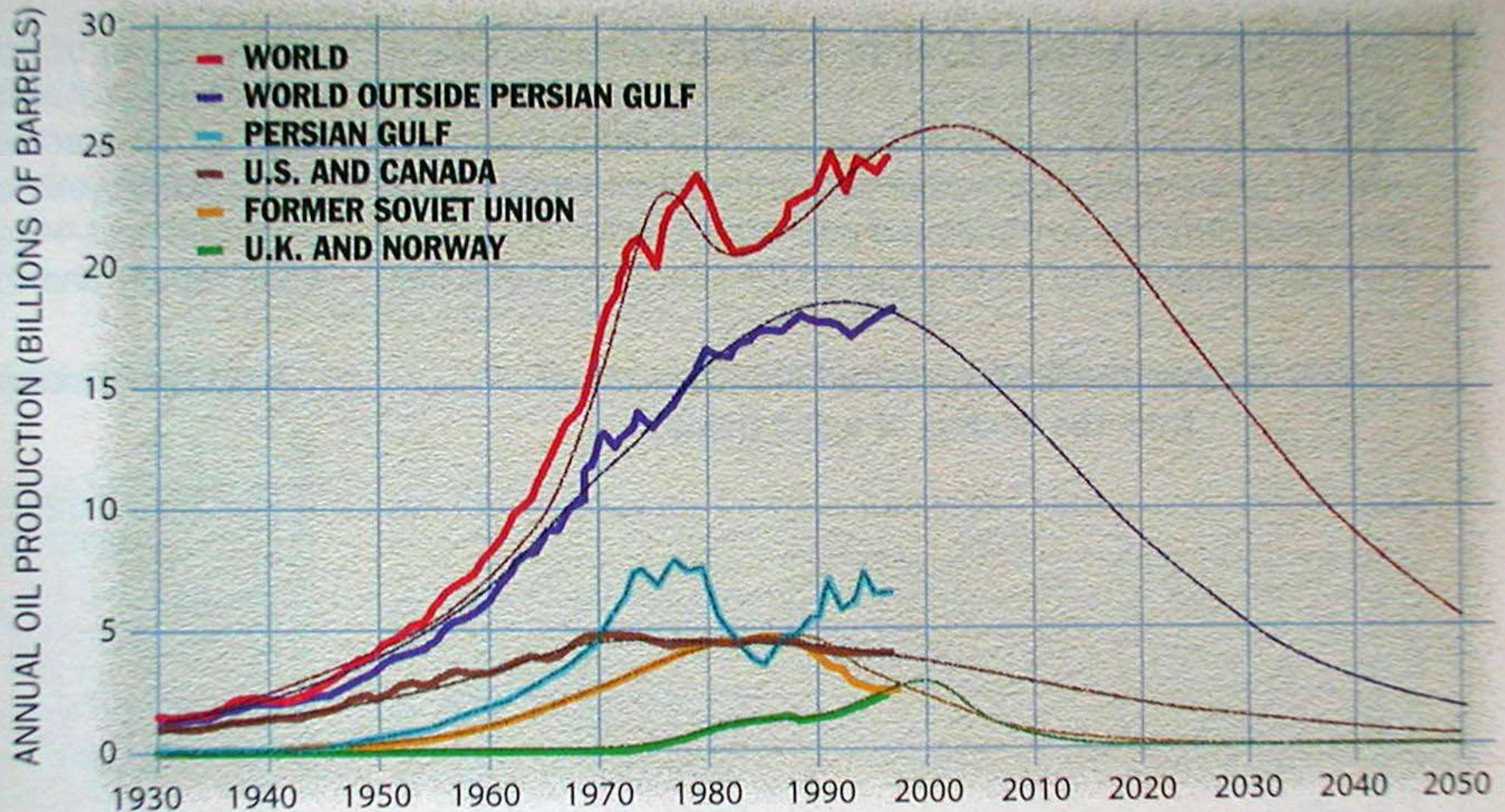
EIA estimated 2025 energy use



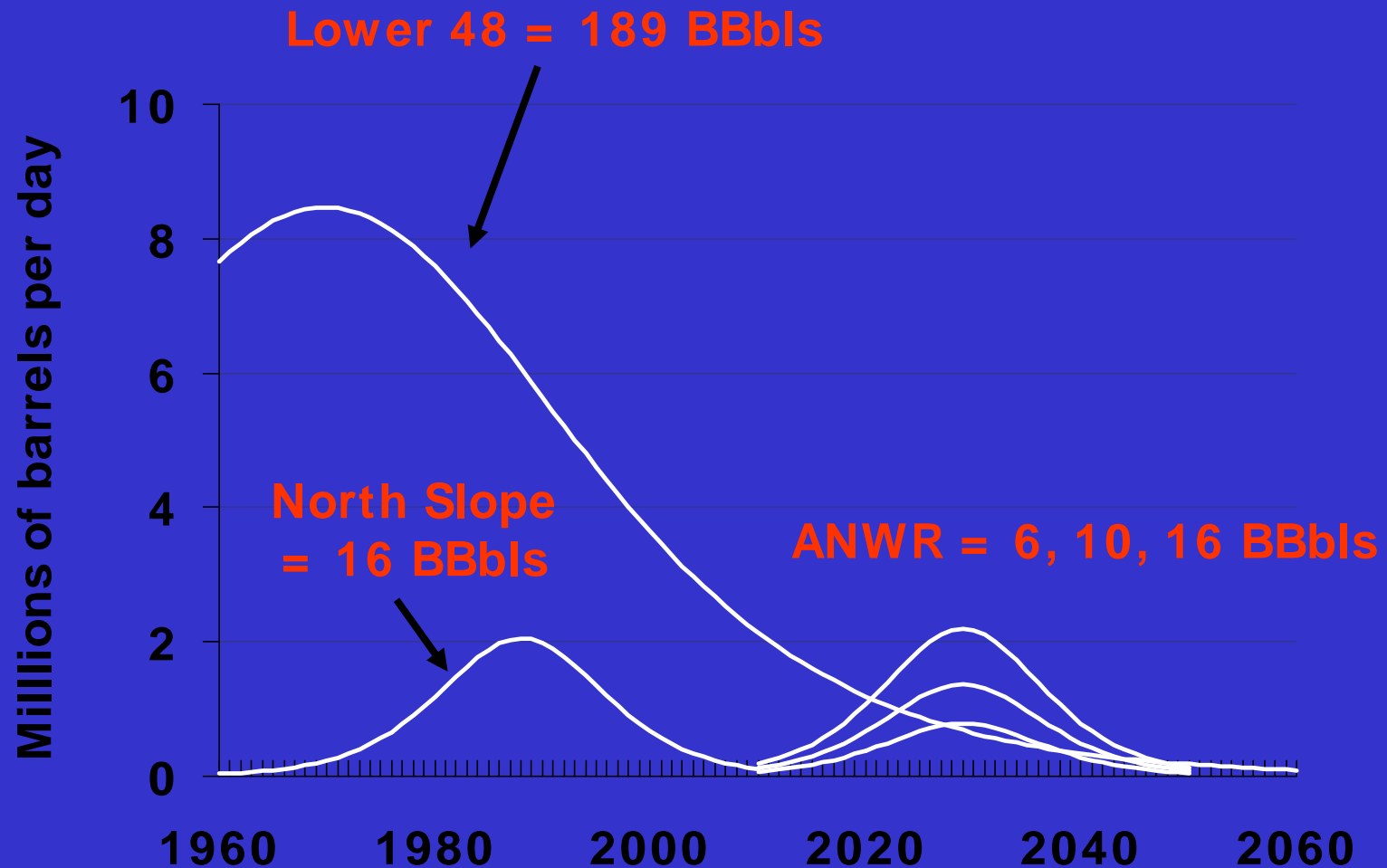
SCIENTIFIC AMERICAN

MARCH 1998 \$4.95

SPECIAL REPORT:
THE END OF CHEAP OIL
It's Coming Fast.
But New Technologies Might
Prevent an Energy Crisis



USA total crude oil production





Proposed ANS* Gas Pipeline

“ALCAN” Alaska
Highway Route

TransCanada
Pipelines

* Alaska North Slope



Arctic National Wildlife Refuge (ANWR)

* 1002 Area

Methane Hydrate (clathrate)

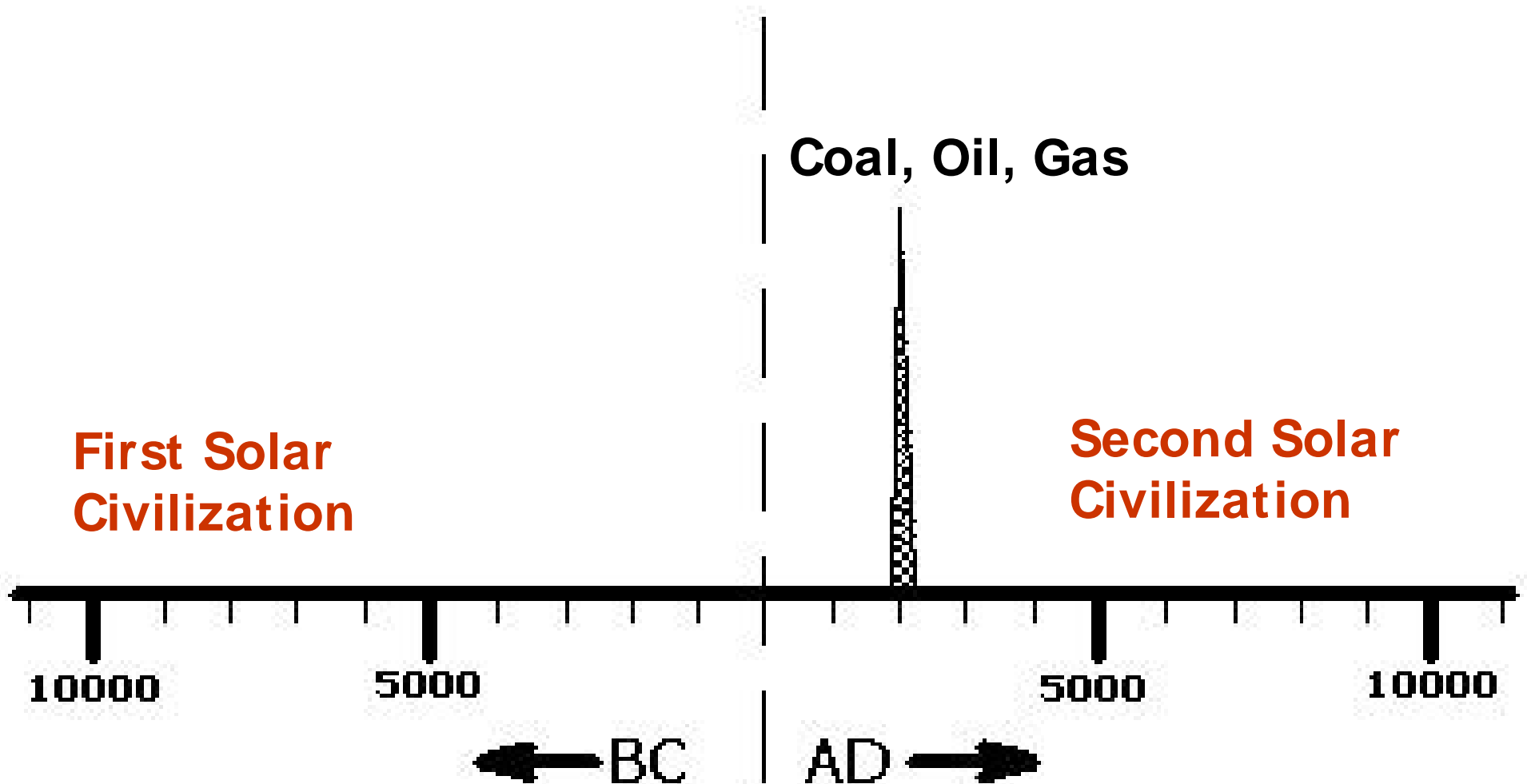
Methane: CH_4

Water ice: H_2O

- More hydrocarbon than all oil + gas
- Deep seabed
- Inaccessible ?
- Methane release ?



***The Fossil Fuel Age:
a “Blink of an Eye” between the
First and Second Solar Civilizations***





Titusville, PA

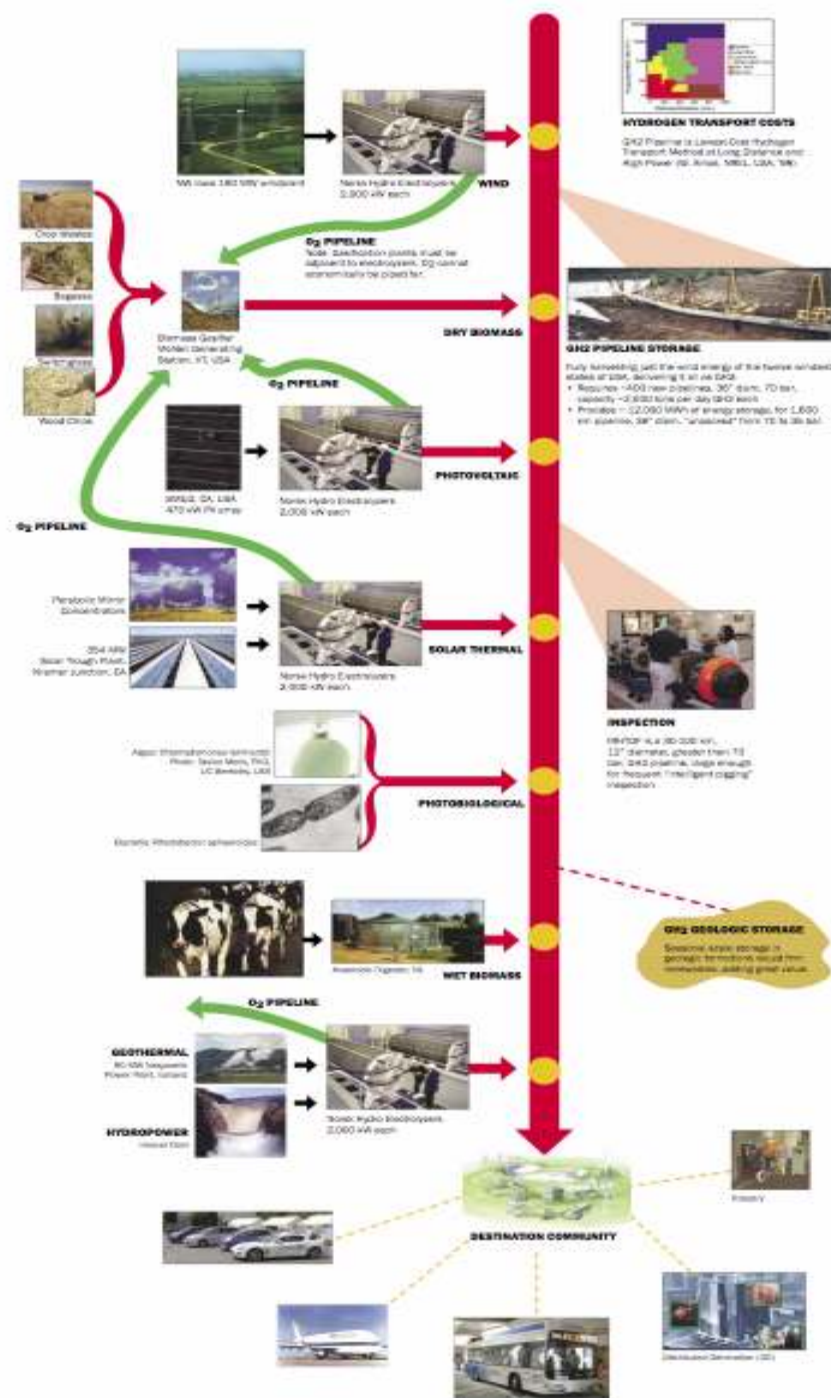
1859

*First oil well
in USA*

The First Solar Civilization



One-fourth of farm's solar energy harvest to draft animals



The Second Solar Civilization

- Diverse
- Benign
- Renewable
- Remote
 - Electricity
 - Hydrogen
 - Ammonia



MUST Run the World on Renewables – plus Nuclear ?

- Emergencies:
 - Climate change
 - Energy prices
 - Energy security
- Conservation + efficiency
- GW scale renewables
- Beyond Electricity Grid
- Energy: beyond electricity
- “Hydricity” , ammonia, ?





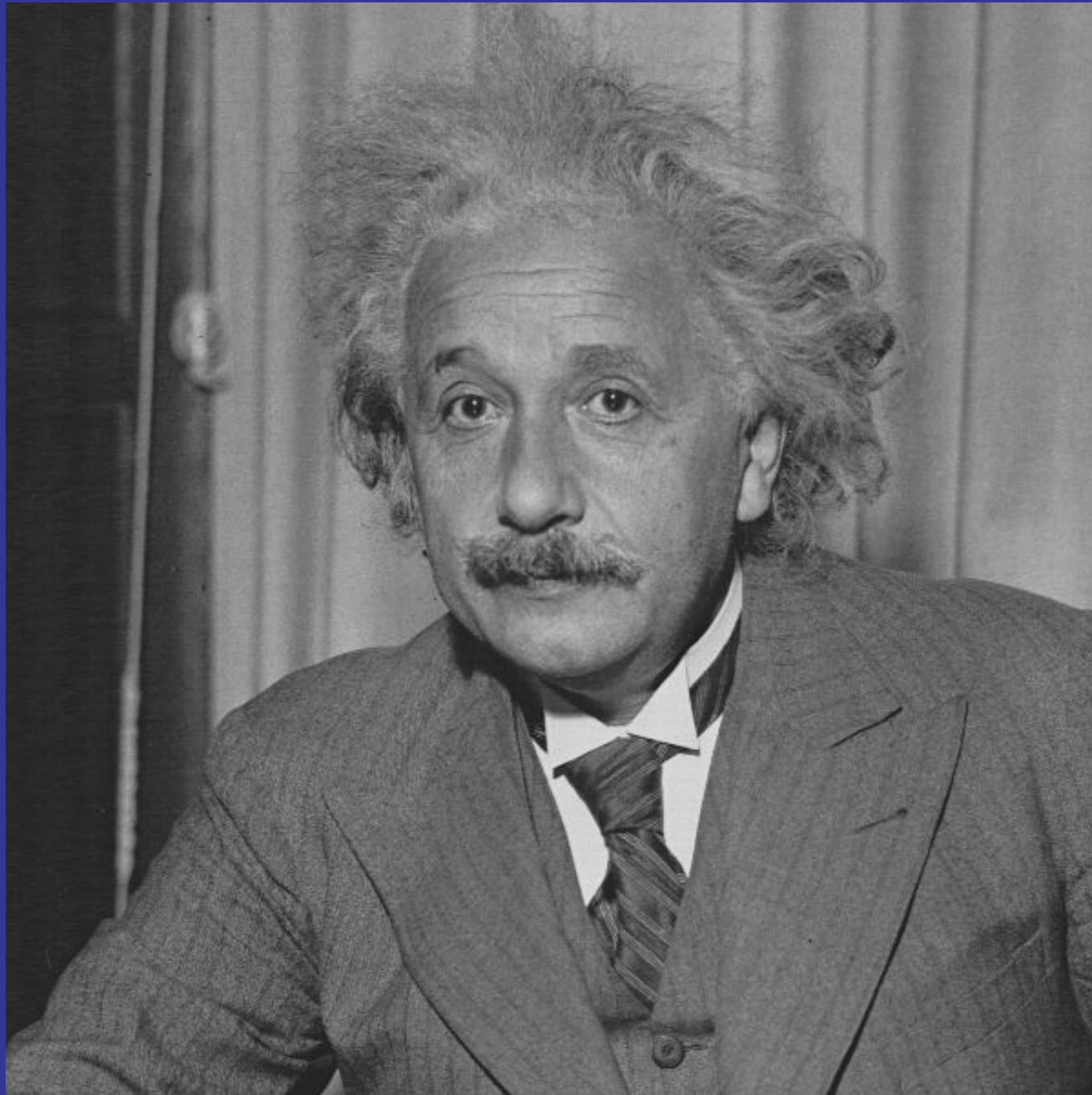
The graph features a dark blue line on a light blue grid. The line starts at a low point on the left, rises steadily to a peak marked with an orange dot, and then descends towards the right, crossing a horizontal blue line. A second orange dot is placed on the descending line. Two orange speech bubbles point to these dots. The background is divided into a light blue upper half and a darker blue lower half by the horizontal line.

WE'RE HERE:
385.92 ppm

**WE NEED TO
GET BELOW:**
350 ppm

www.350.org

CO₂ in the Atmosphere



“The unleashed
power of the
atom has
changed
everything

save our modes
of thinking

and we thus drift
toward
unparalleled
catastrophe.”

New York
Times 25
May 1946



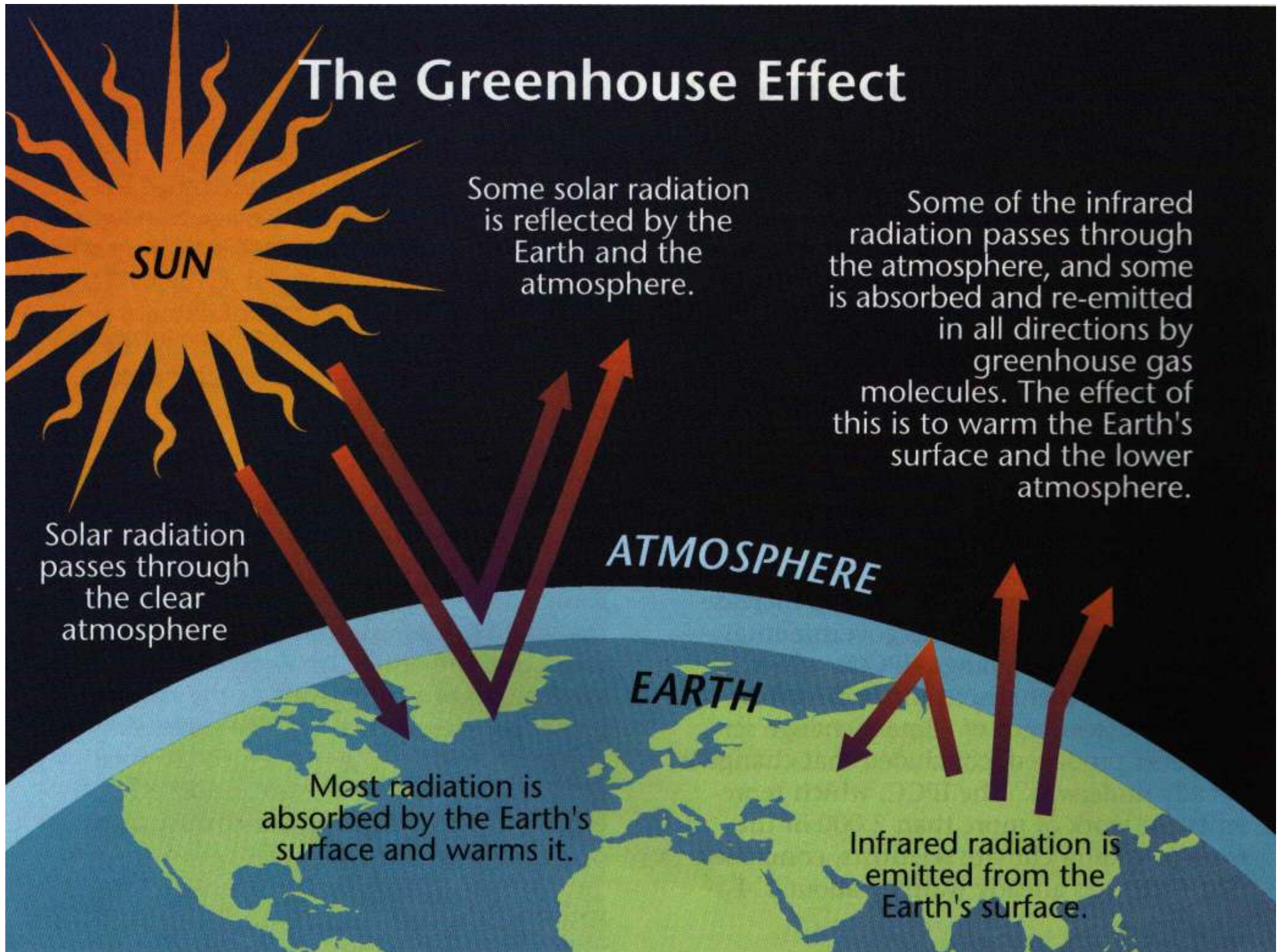
***Svante
Arrhenius***

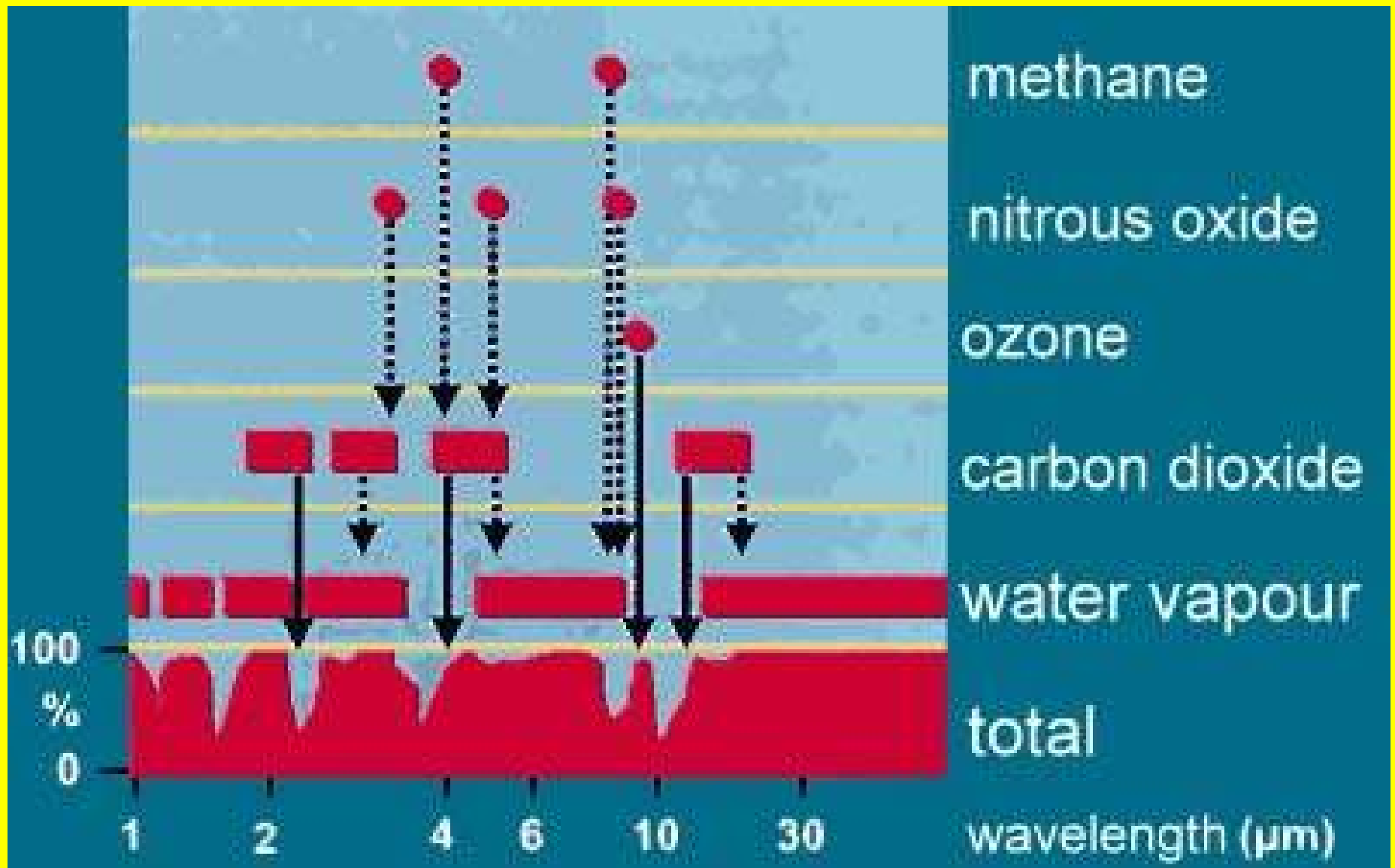
Sweden

***1905
Nobel Prize
Chemistry***

***Proved CO₂ is
heat-trapping
gas in 1896***

The Greenhouse Effect





Five Principal Greenhouse Gases (GHG's)



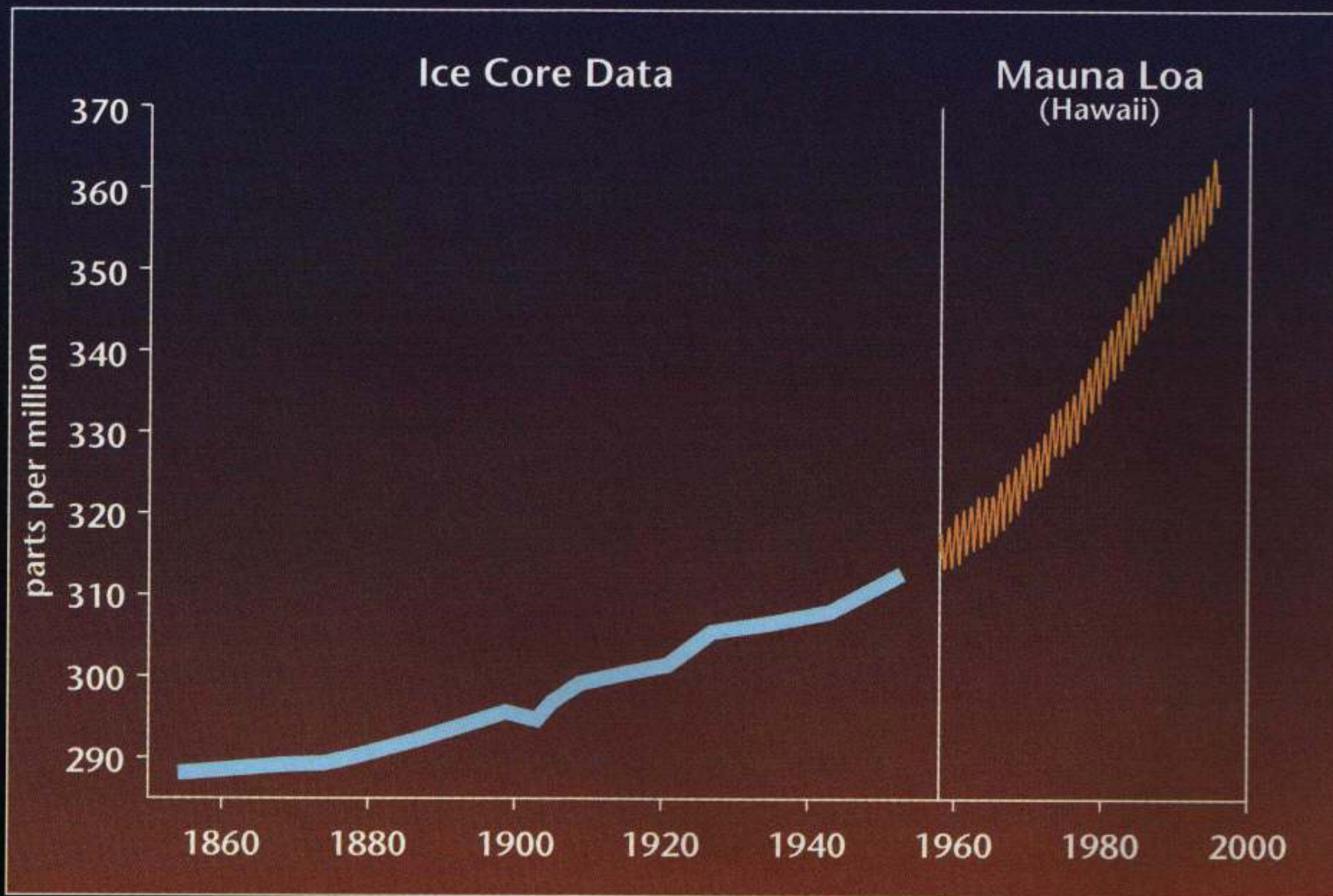
1 gallon = 7 lbs

- Gasoline
- Diesel
- Jet

Burned = 20 lbs CO₂

(carbon dioxide)

Carbon Dioxide Concentrations

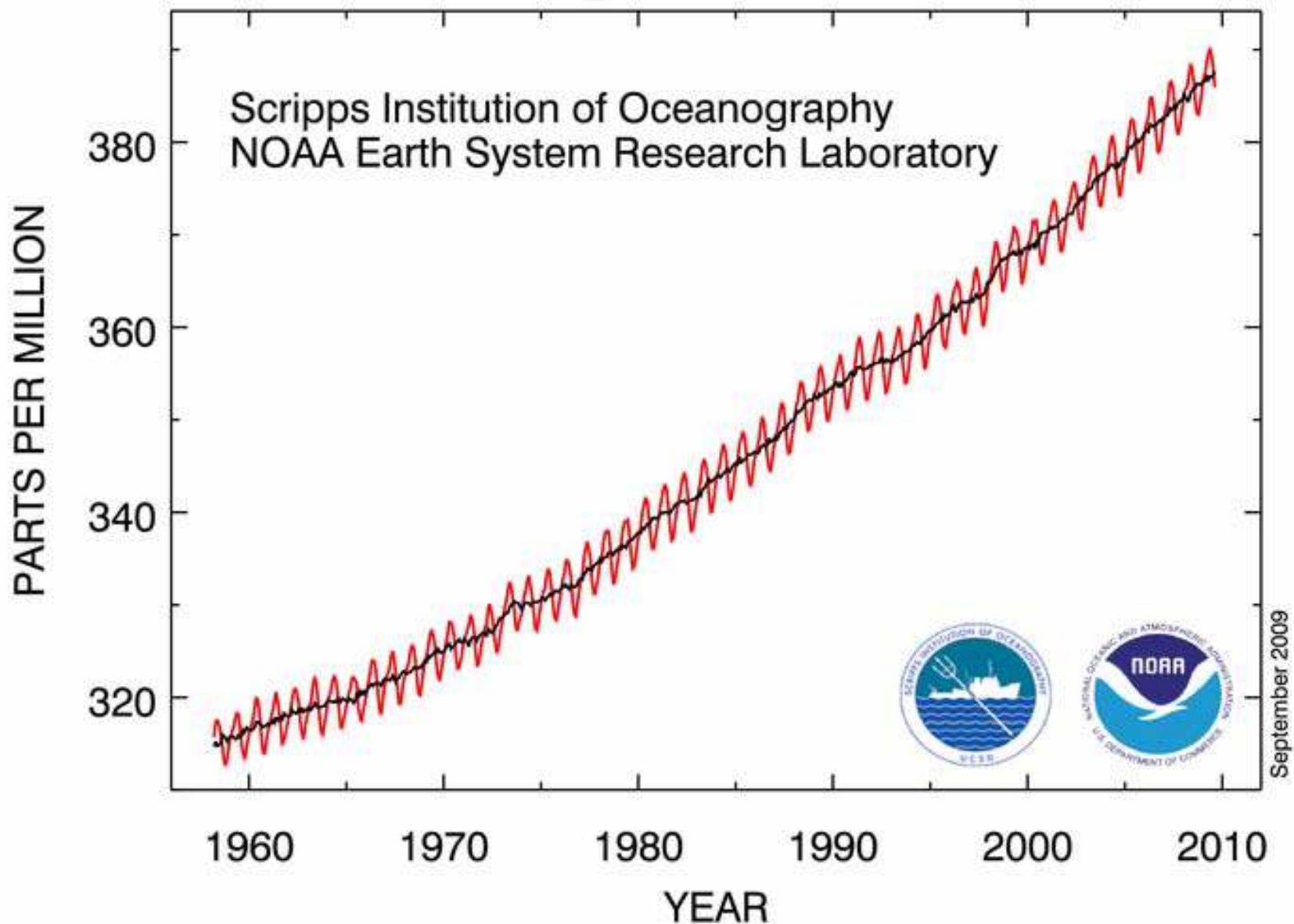




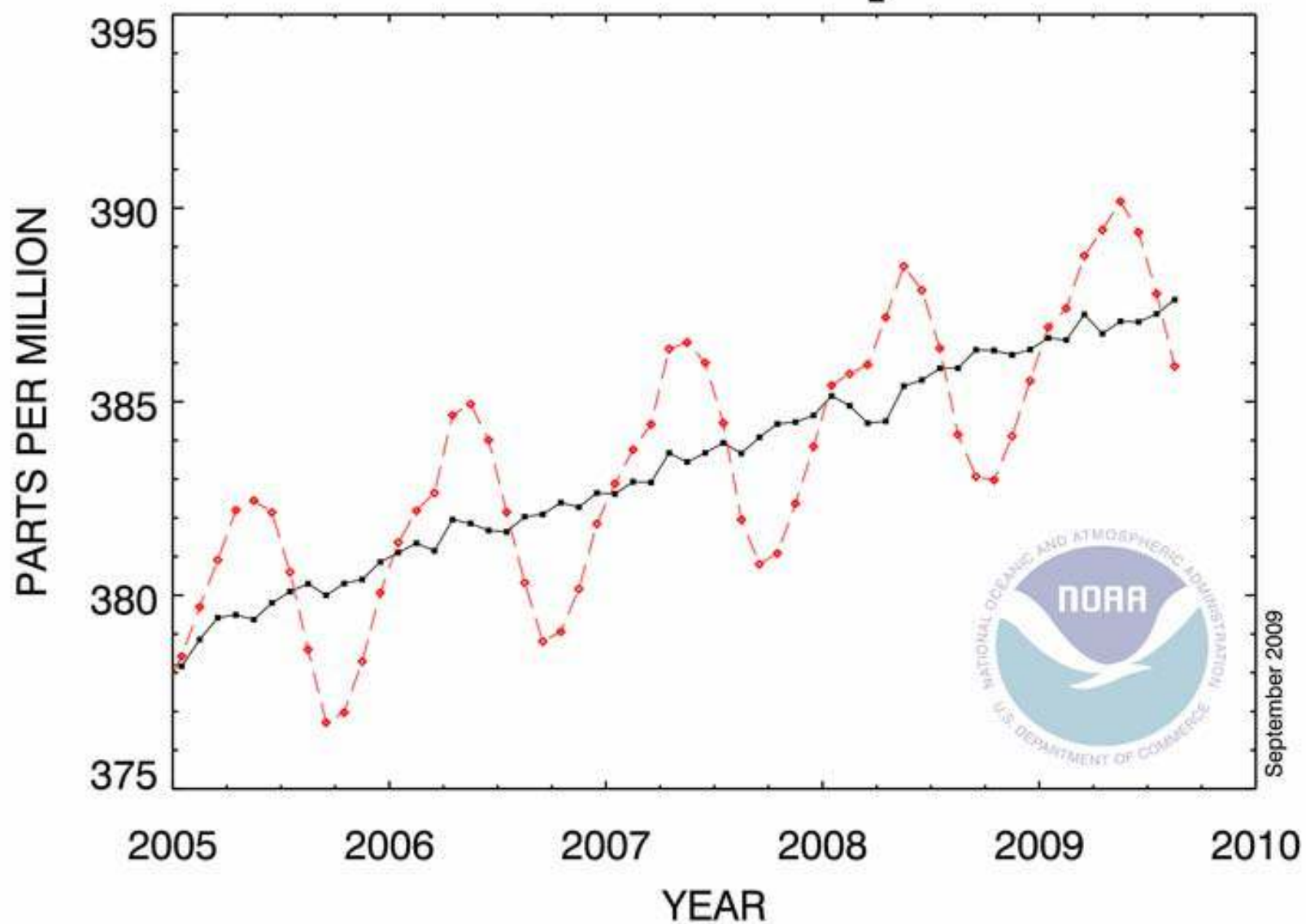
CO₂ concentration (parts per million)

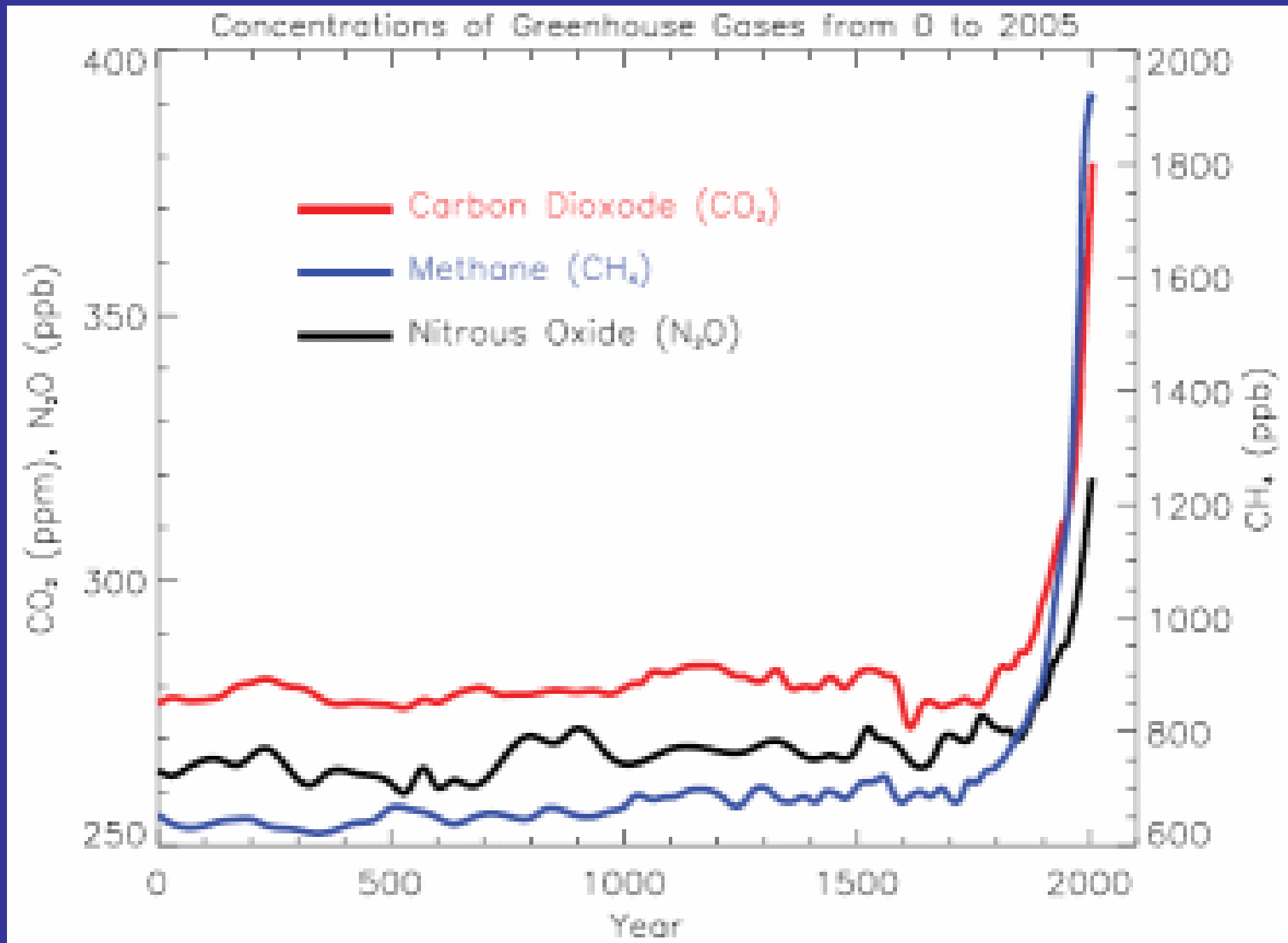
Thousands of years before 2006

Atmospheric CO₂ at Mauna Loa Observatory



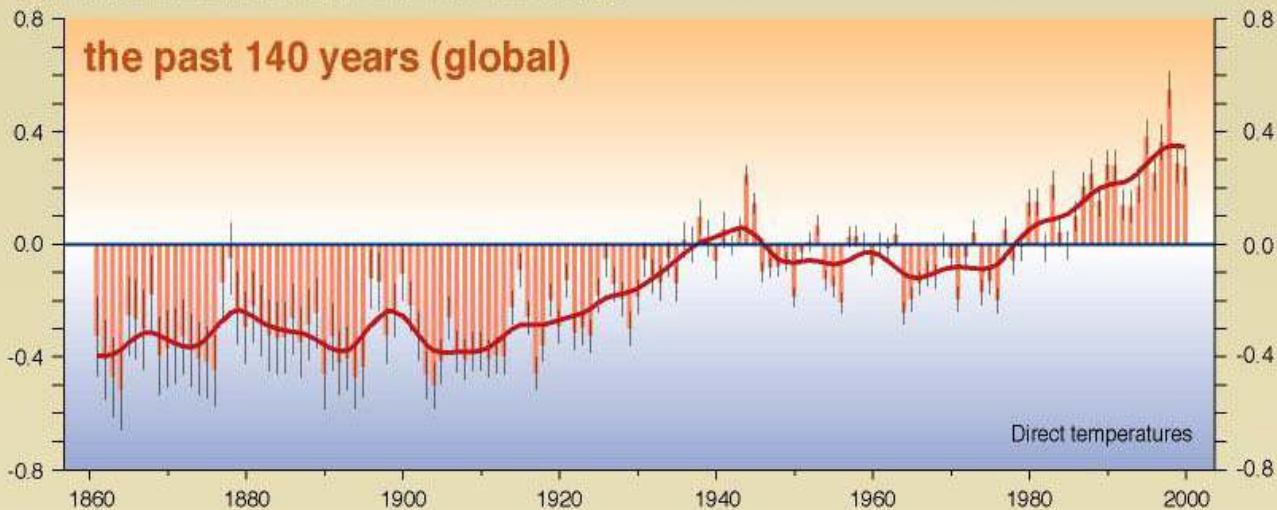
RECENT MONTHLY MEAN CO₂ AT MAUNA LOA



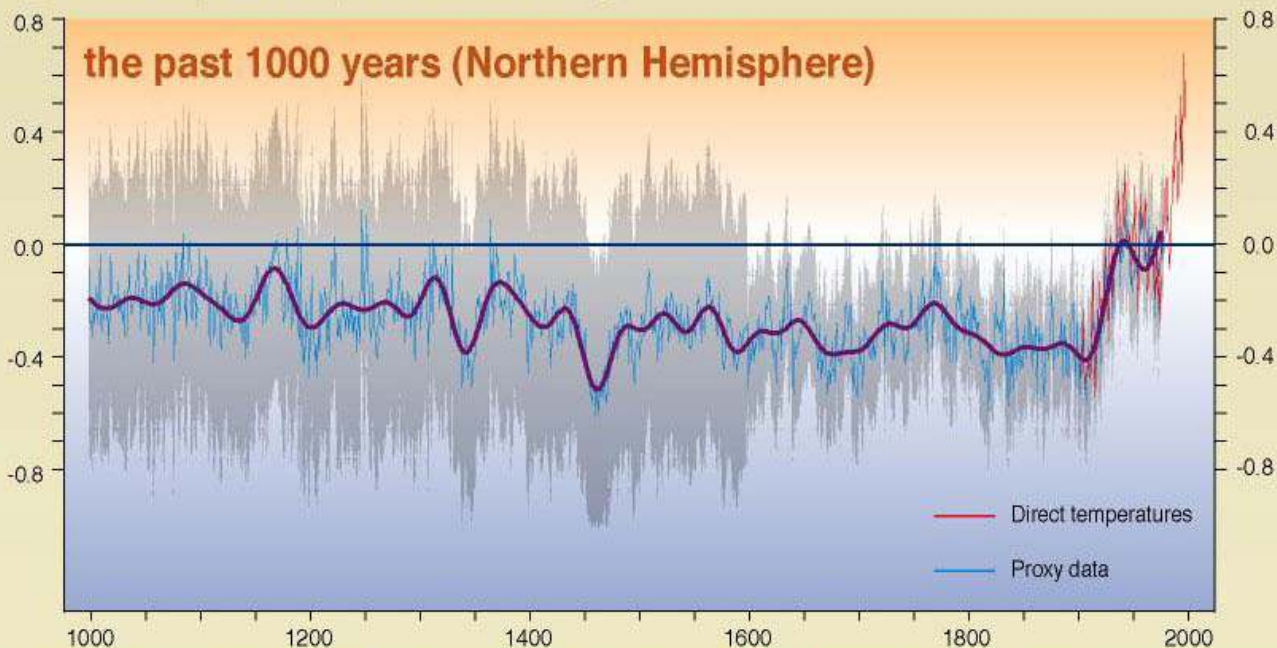


Variations of the Earth's surface temperature for...

Departures in temperature in °C (from the 1961-1990 average)



Departures in temperature in °C (from the 1961-1990 average)



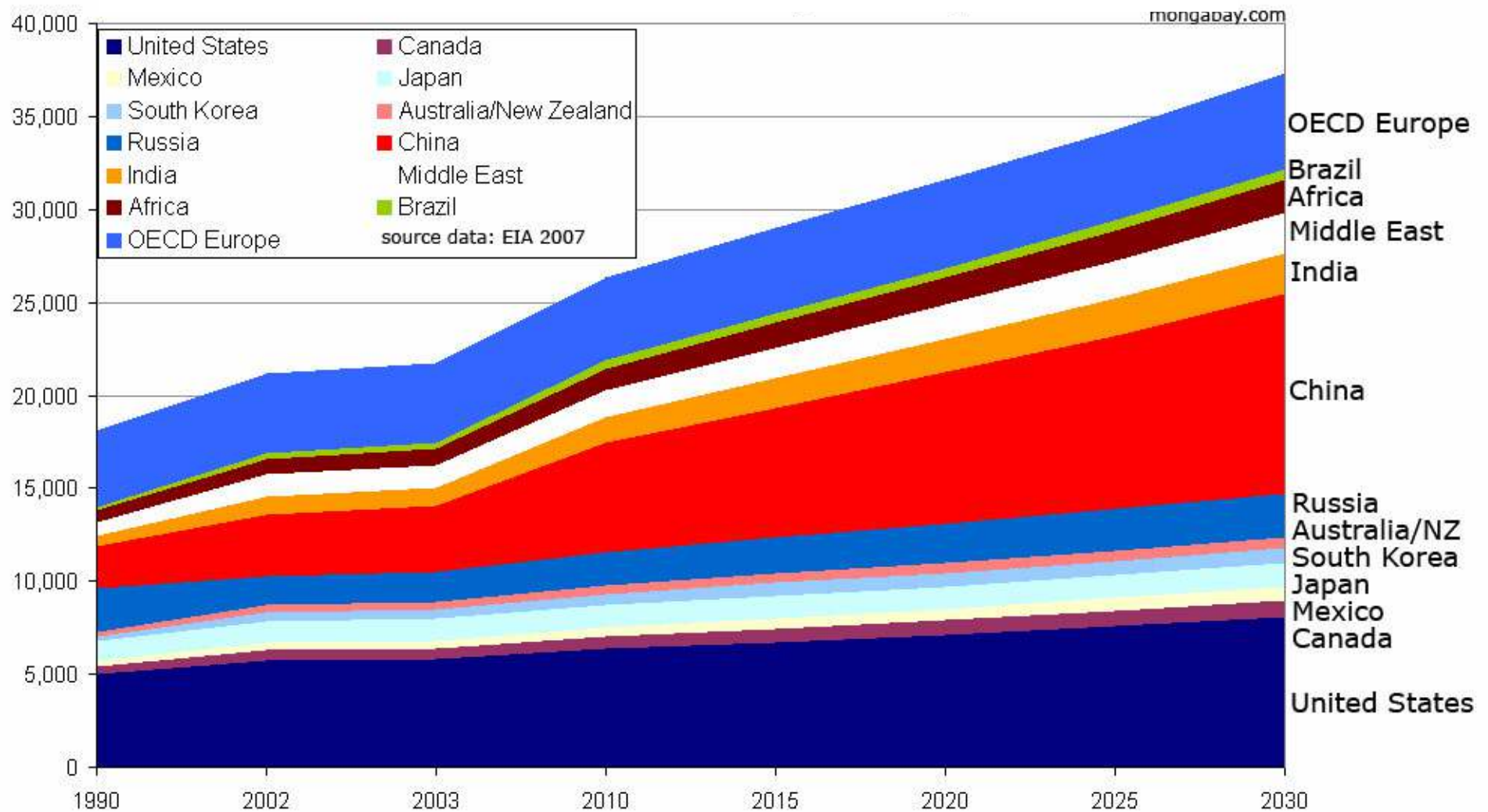
Earth's Surface Temperature

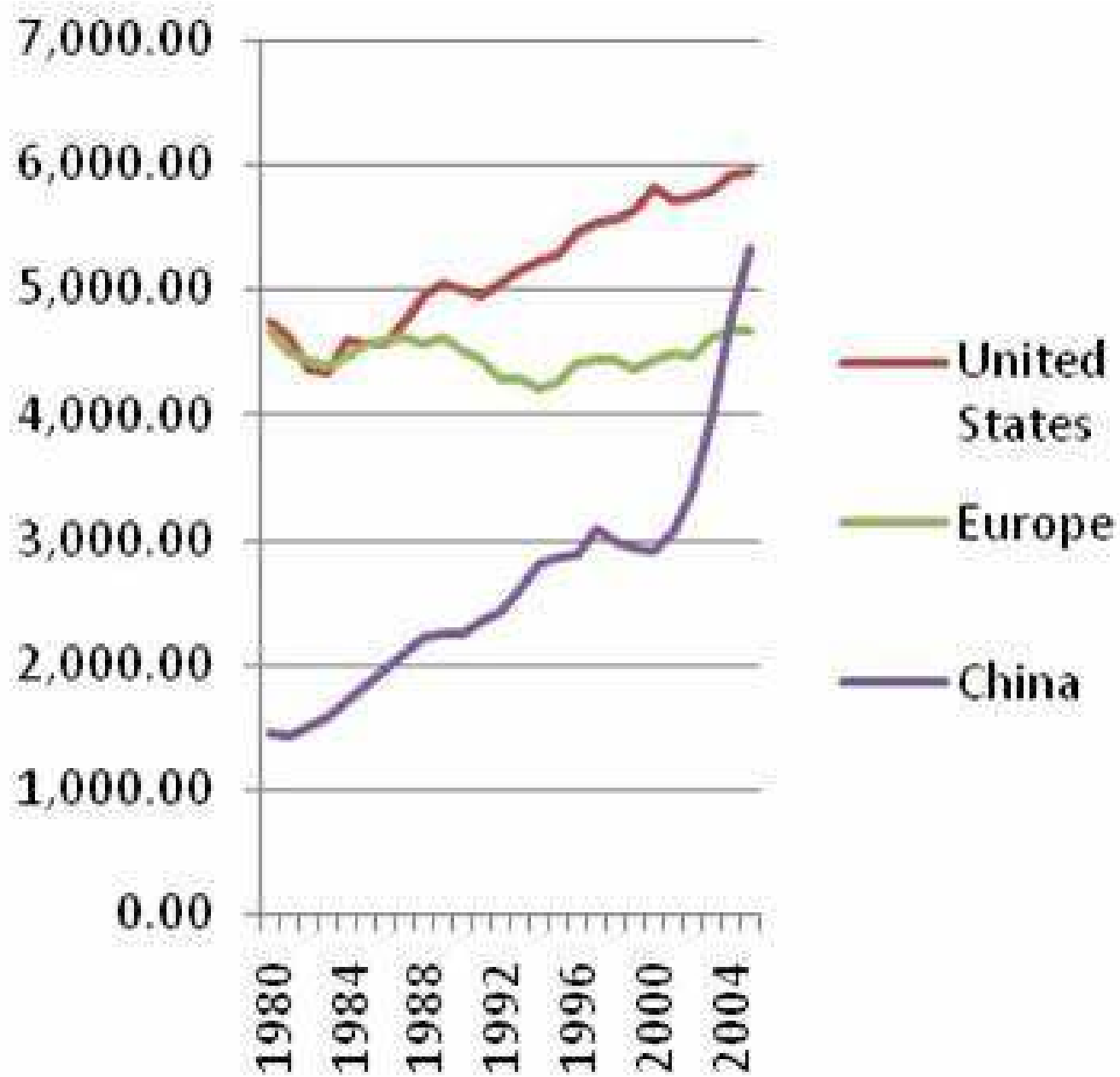
140 years: global

1,000 years:
northern
hemisphere

World Carbon Dioxide Emissions by Country

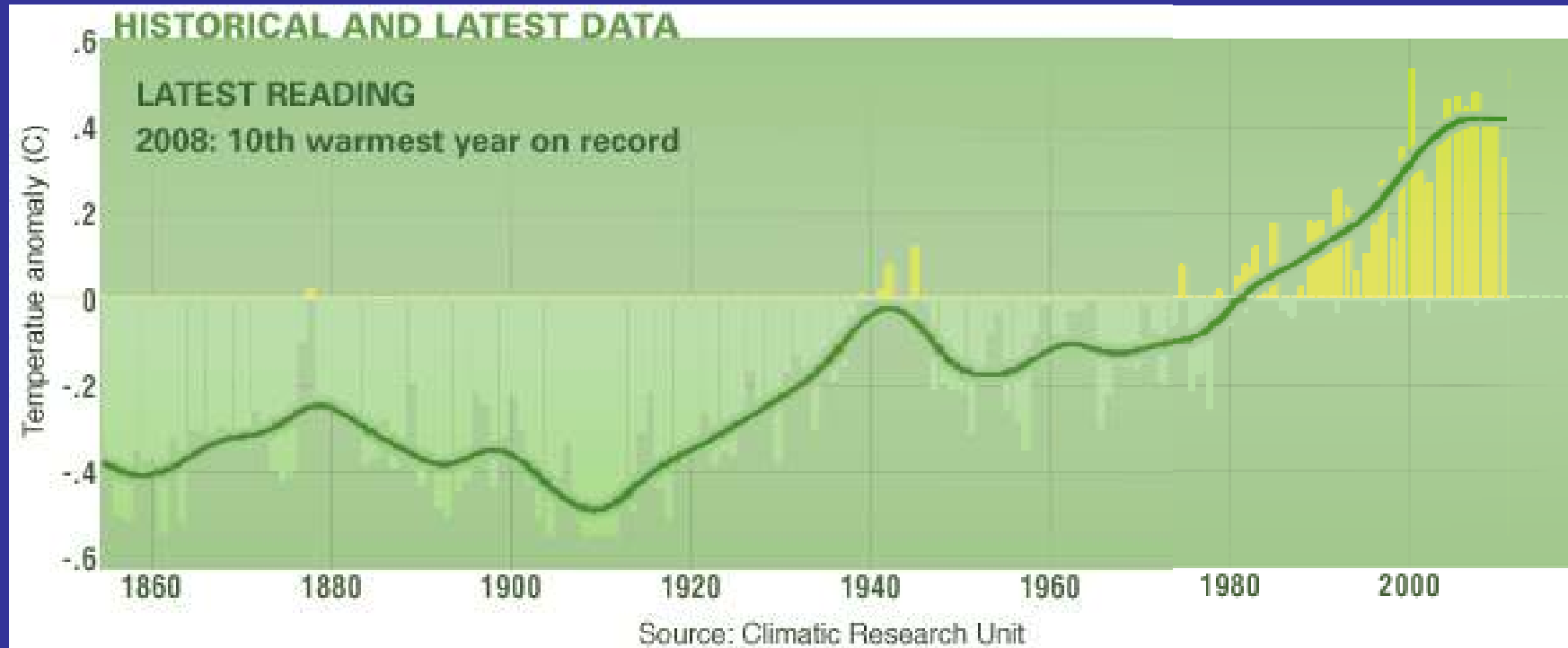
1990 - 2030



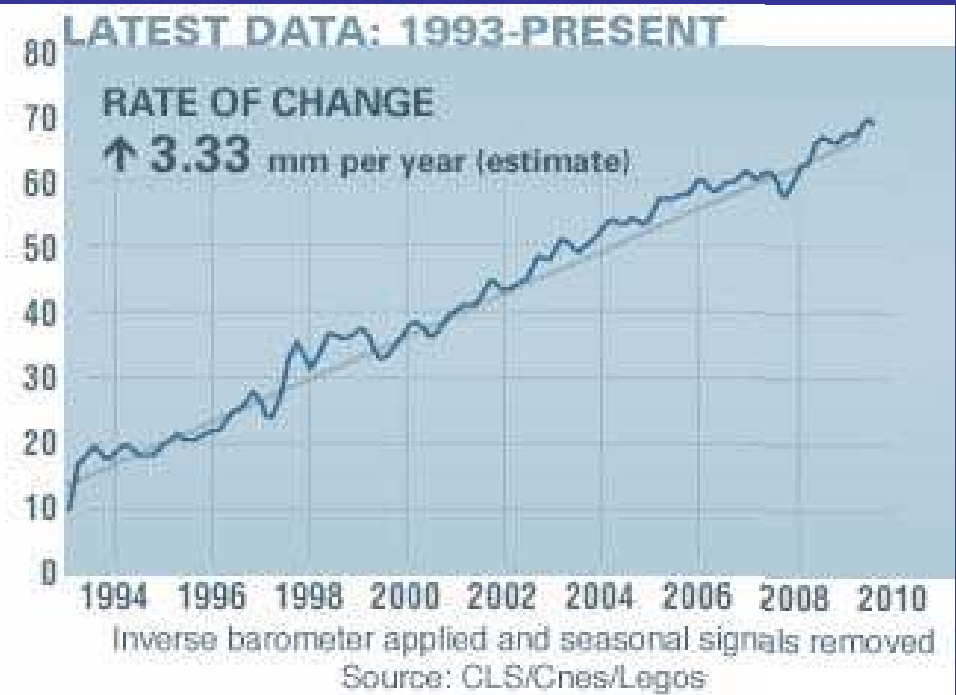
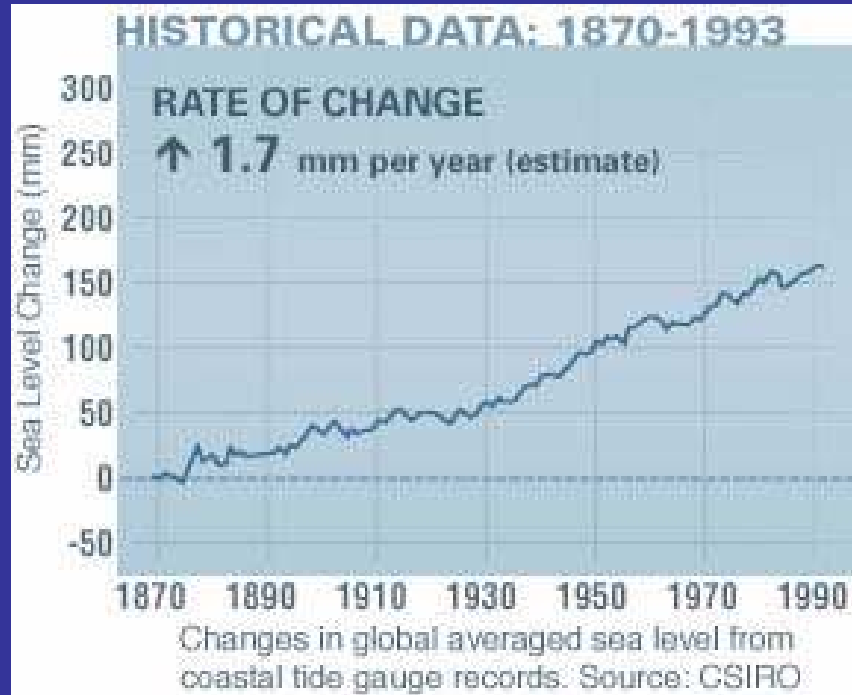


CO₂ emission

**Million tons
Per year**



Earth Surface Temperature °C
Relative to 1980

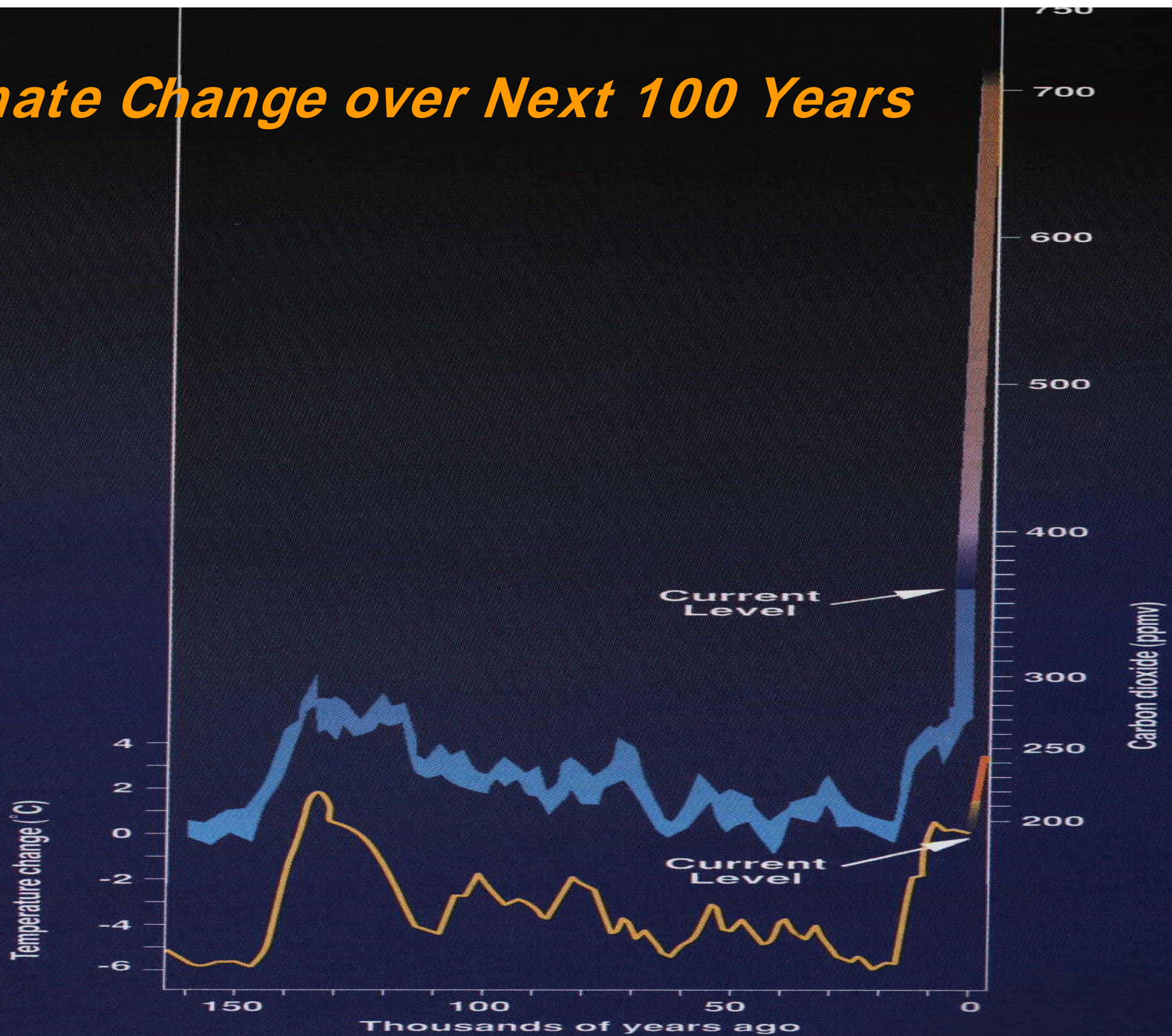


1870 – 1993
~ 1.7 mm / year

1993 – 2009
~ 3.3 mm / year
~ 1 ft / century

Sea Level Rise: mm per year (estimate)

Climate Change over Next 100 Years

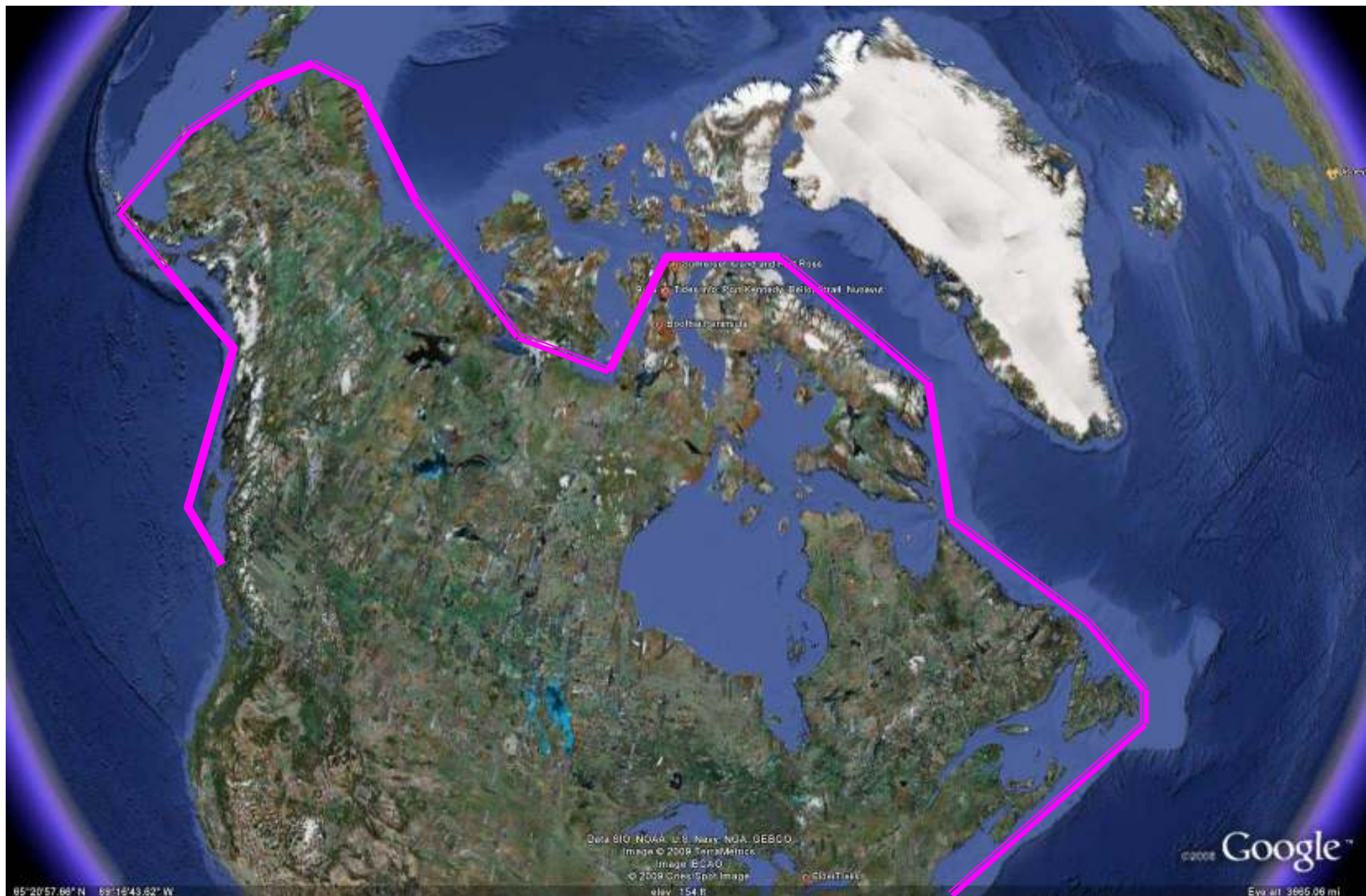


CO₂ concentration in the atmosphere (Antarctic Ice Core)

Temperature changes through time compared to the present temperature



Around the Americas “Ocean Watch”
Dave Thoreson, Arnolds Park, IA

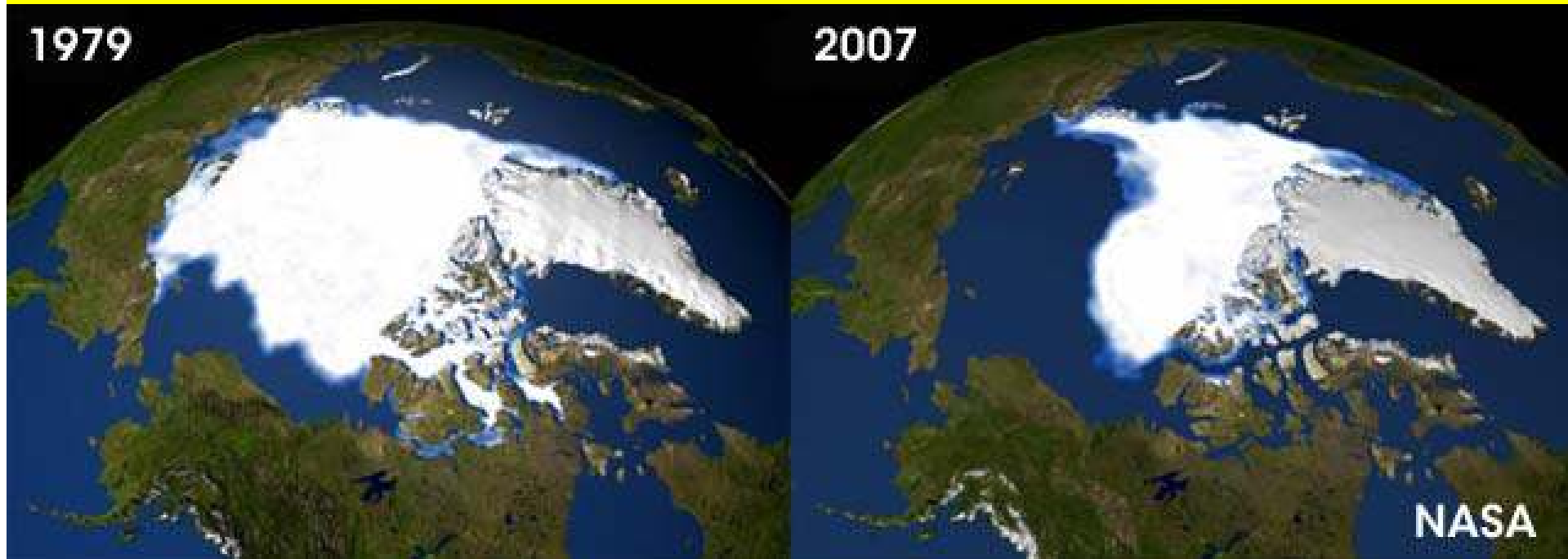


Around the Americas June '09 → Aug '10
Bellot Strait 27 Aug 09

1979

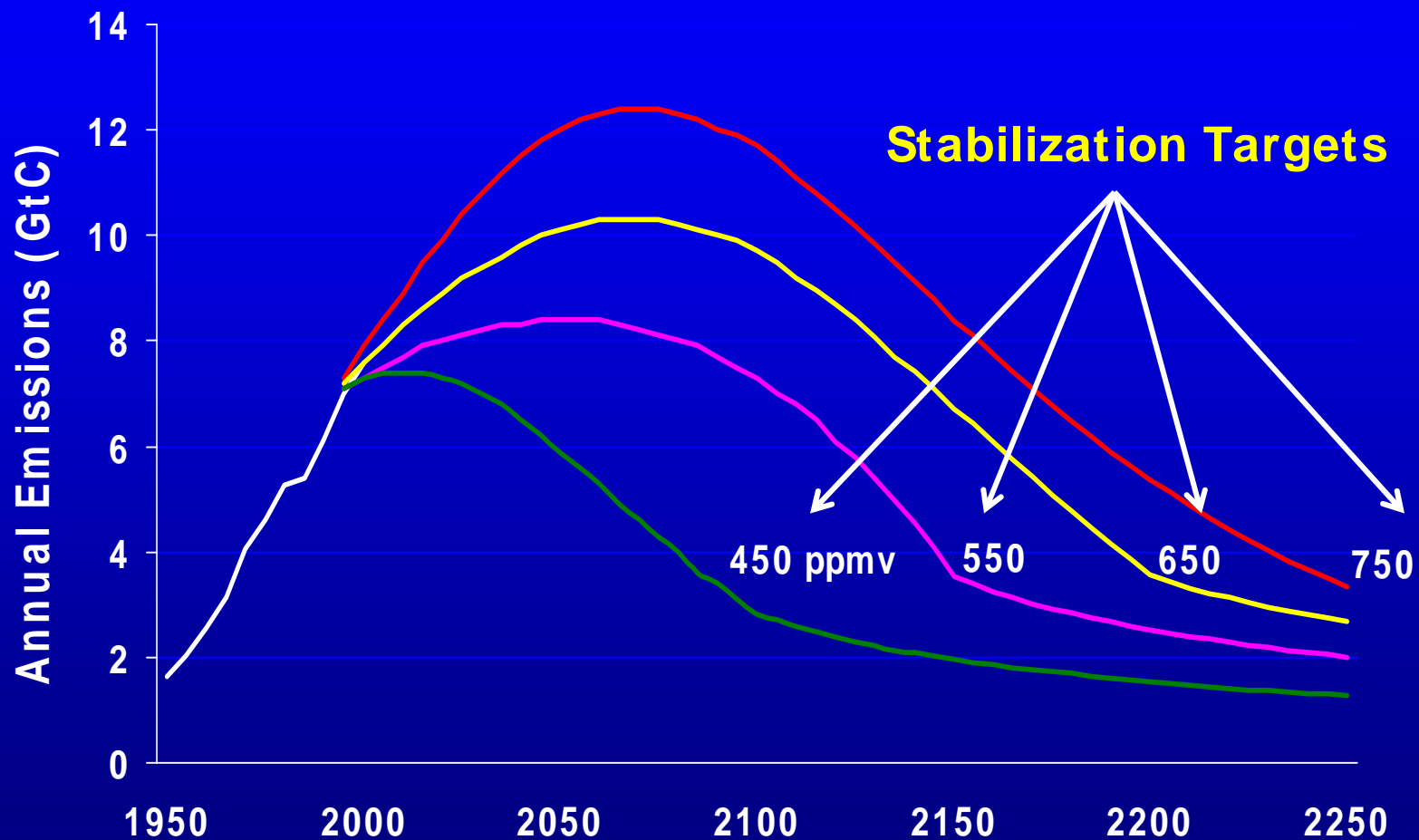
2007

NASA



Greenhouse gas emission scenarios

Pre-industrial age: 280 ppm Today: 385 ppm



www.350.org 24 Oct 09



The graph features a dark blue line on a grid. The line starts at a low point on the left, rises steadily to a peak marked with an orange dot, and then falls sharply to a point below the baseline, also marked with an orange dot. A horizontal blue line serves as a reference level. Two orange callout boxes point to the peak and the subsequent drop. The entire chart is enclosed in a thick orange border, which is itself within a blue frame.

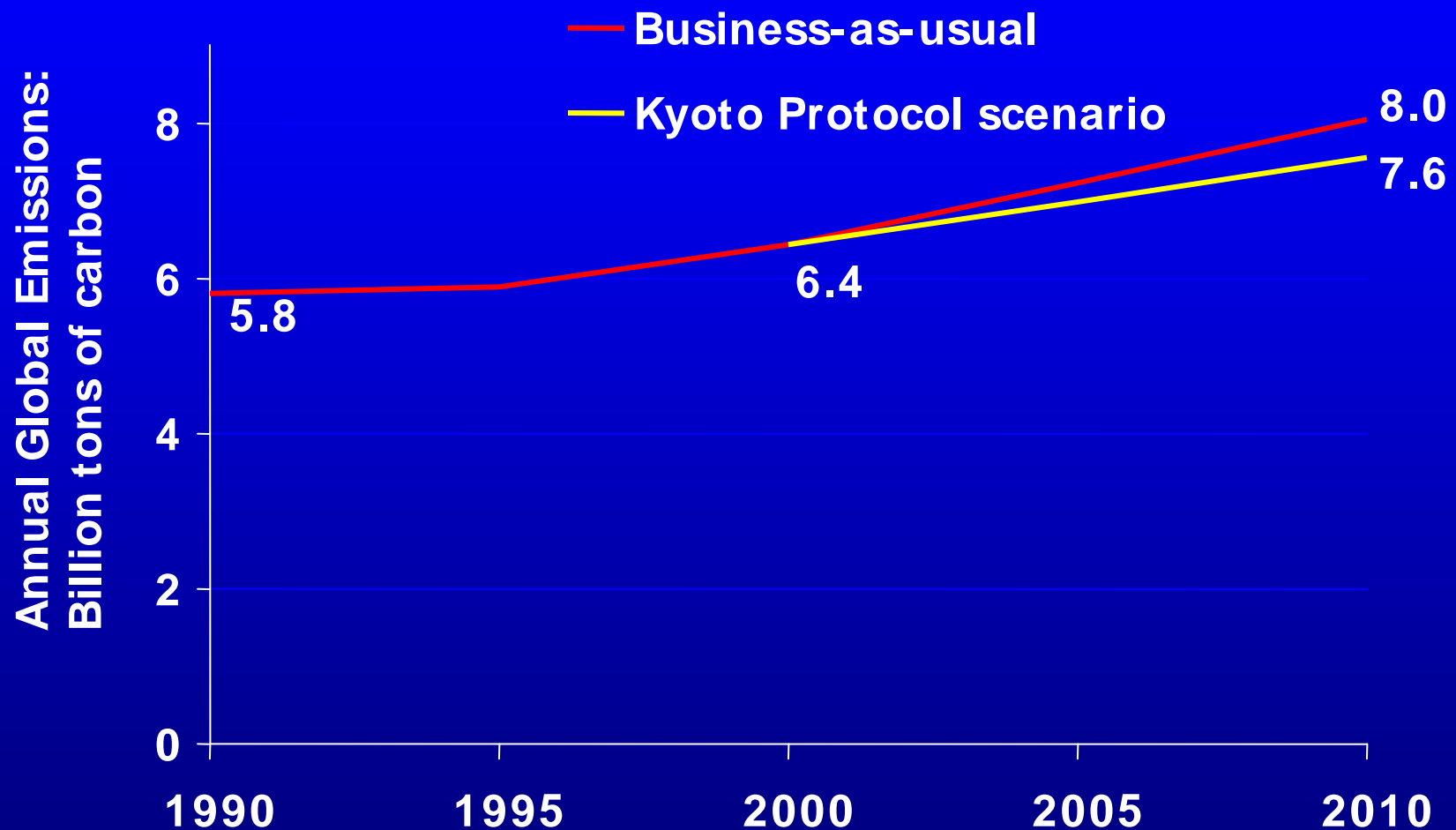
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CO2 in the Atmosphere

How much will the Kyoto Protocol reduce emissions?



Data Sources: United States Department of Energy, Energy Information Administration, *International Energy Outlook*, 1998 and 1999.

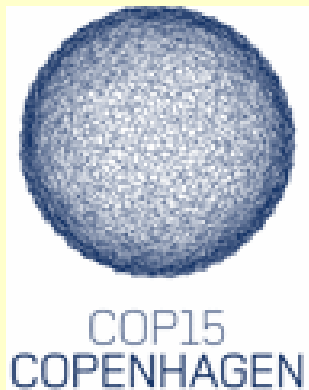


Kyoto Protocol

Greenhouse Gas Limit

The
Wrong Trousers

Wallace & Gromit
Techno Trousers

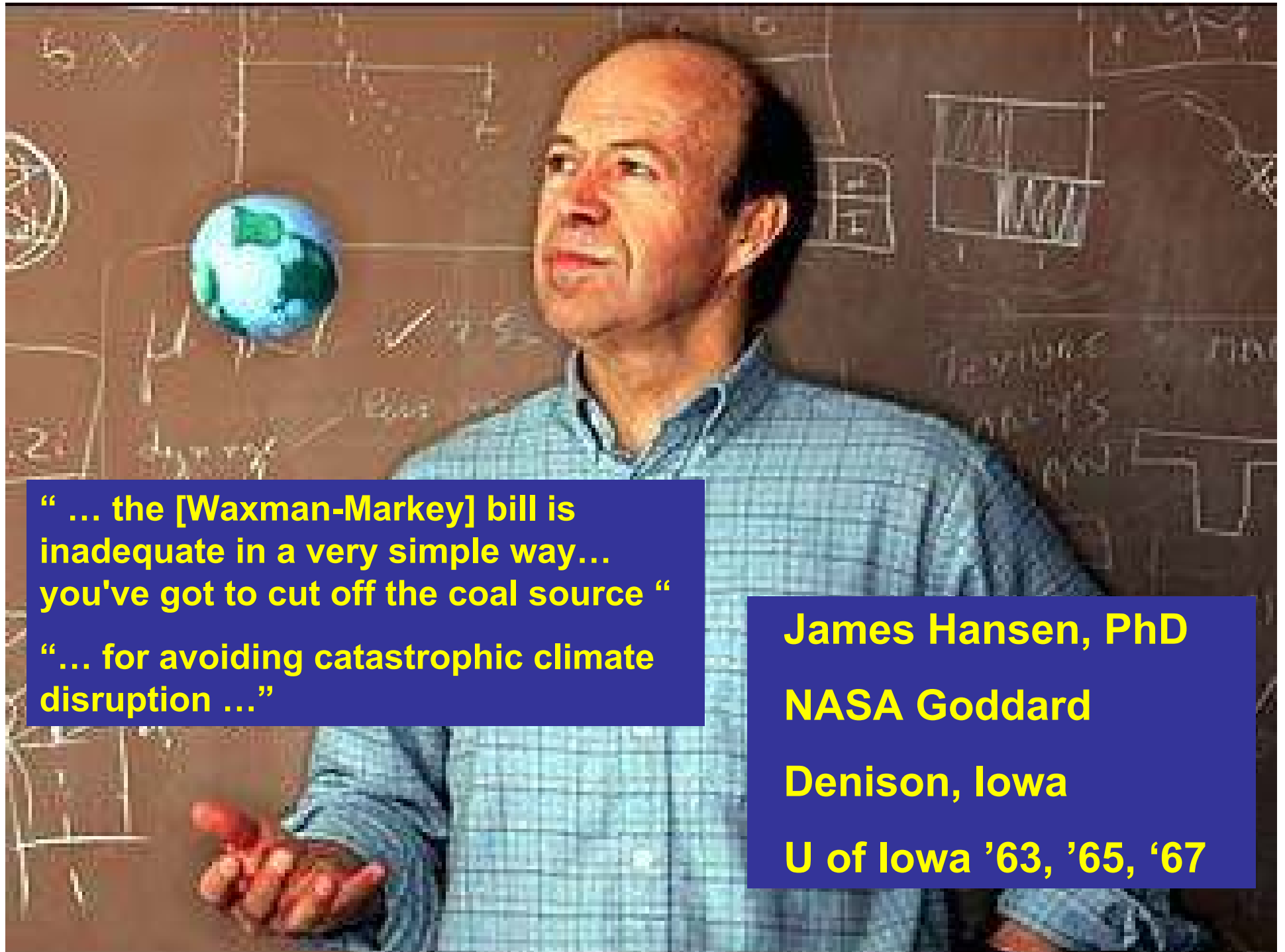


UNITED NATIONS
CLIMATE CHANGE
CONFERENCE
DEC 7-DEC 18
2009

- **15th Conference of the Parties (COP15)**
- **United Nations Framework Convention on Climate Change (UNFCCC)**

Opened for signature on May 9, 1992, at Rio Earth Summit

In force March 21, 1994 “... to achieve stabilization of greenhouse gas concentrations in the atmosphere at a low enough level to prevent dangerous anthropogenic interference with the climate system “
- **Intergovernmental Panel on Climate Change (IPCC)**
- **Successor to Kyoto Protocol**
- **Ban Ki-moon: “We sink or swim together”**



“ ... the [Waxman-Markey] bill is inadequate in a very simple way... you've got to cut off the coal source “

“... for avoiding catastrophic climate disruption ...”

James Hansen, PhD

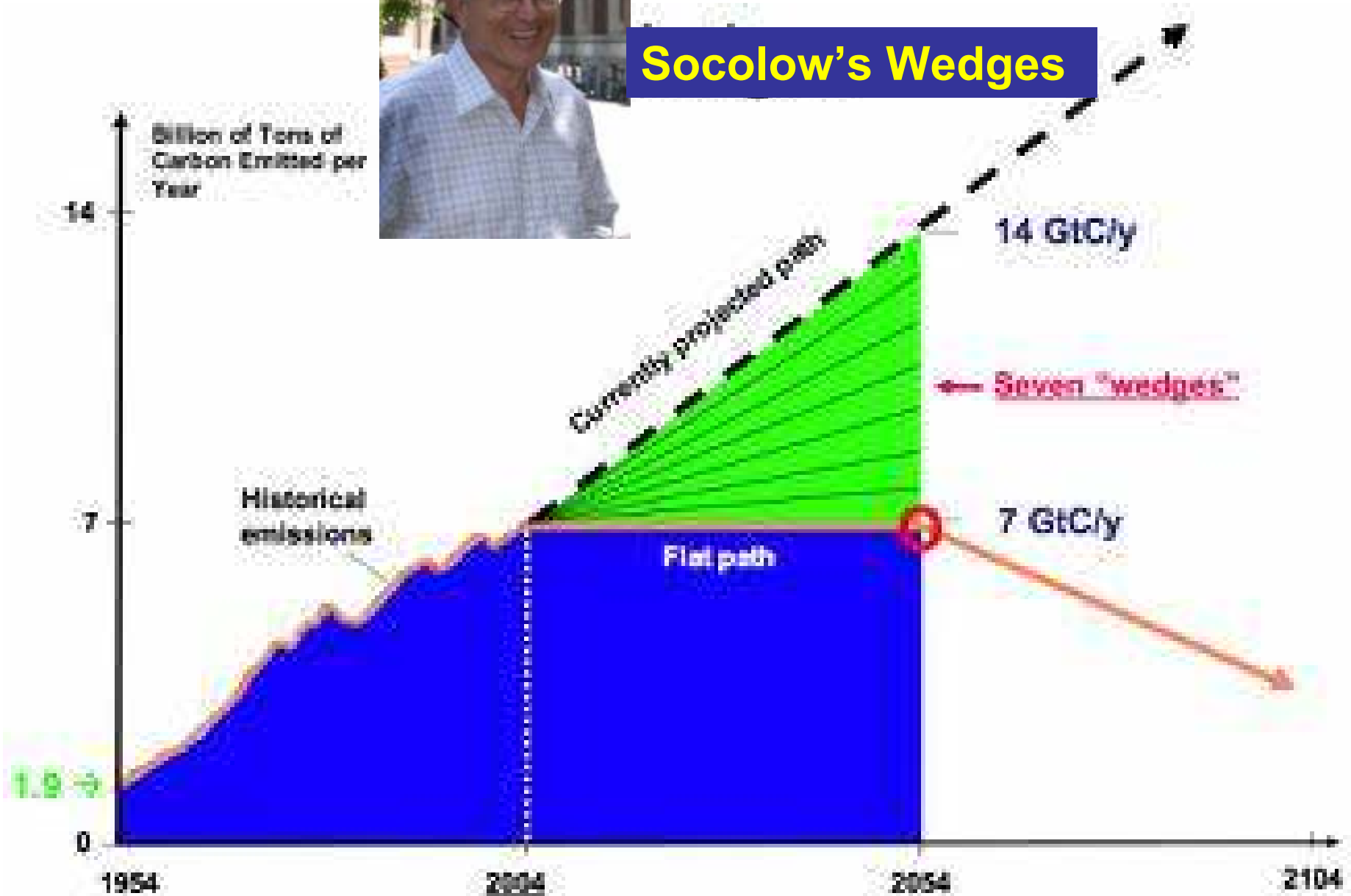
NASA Goddard

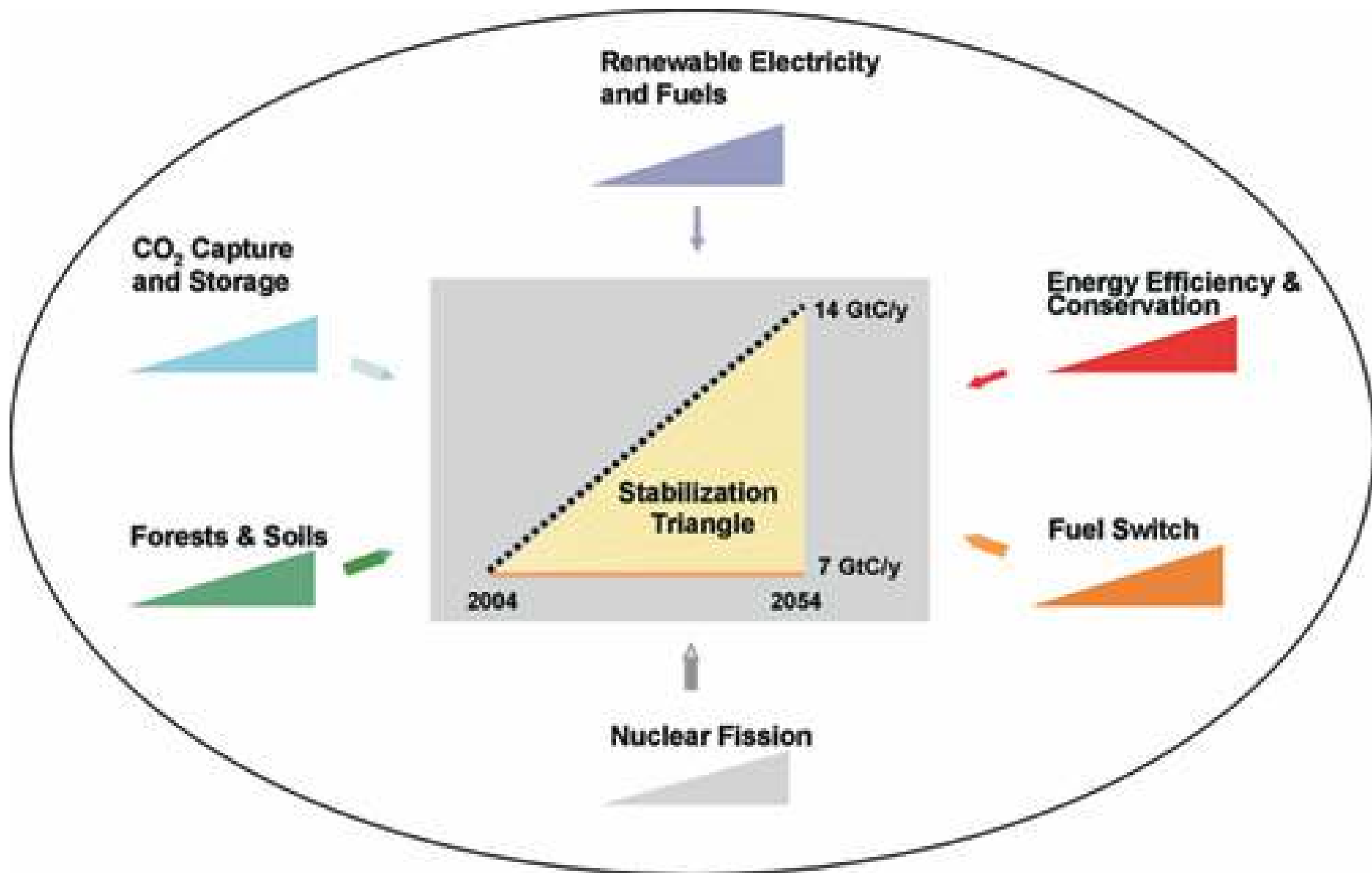
Denison, Iowa

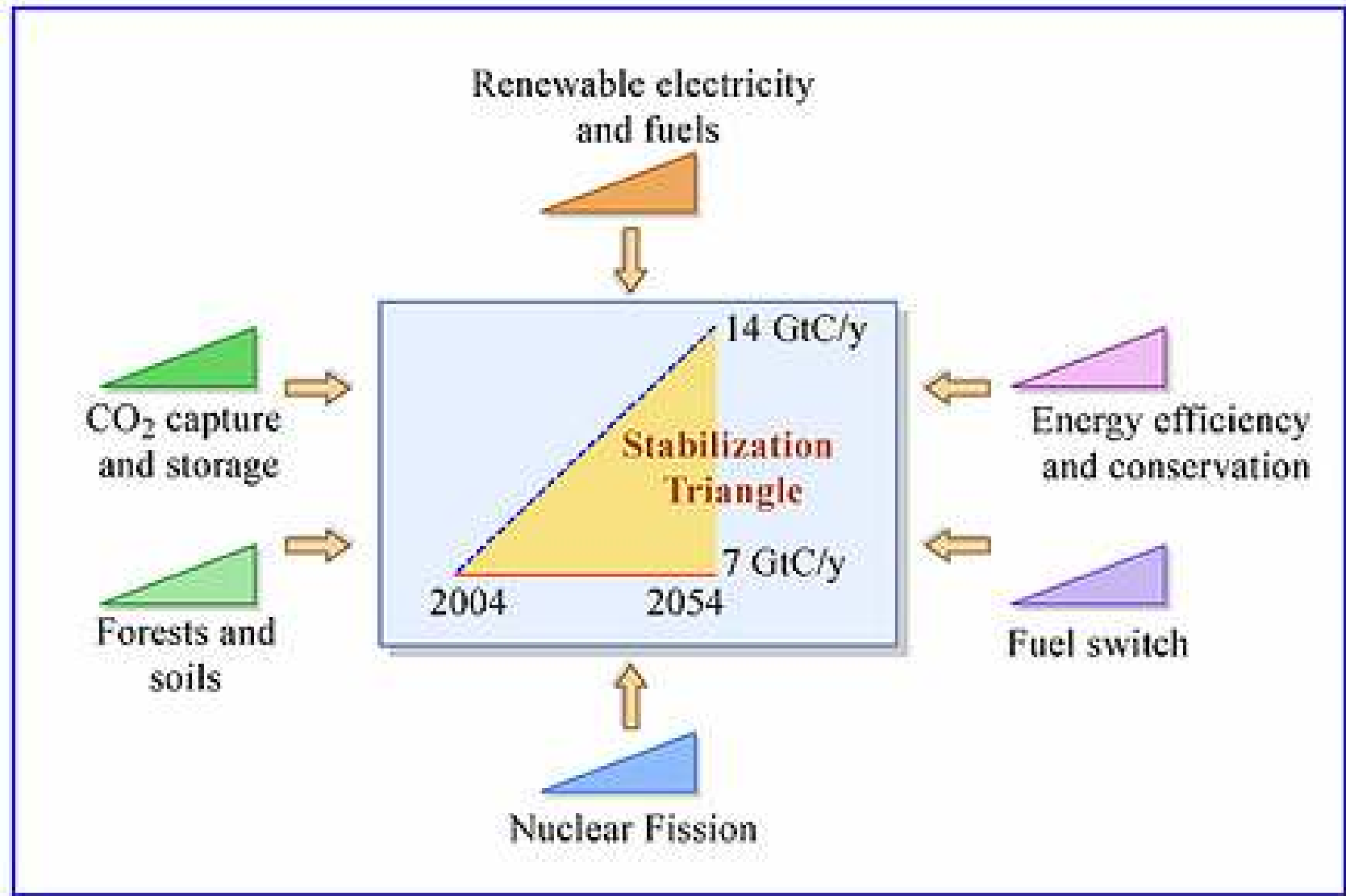
U of Iowa '63, '65, '67



Socolow's Wedges







Wedges

Efficiency & Conservation

- Increased transport efficiency
- Reducing miles traveled
- Increased heating efficiency
- Increased efficiency of electricity production

Fossil-Fuel-Based Strategies

- Fuel switching (coal to gas)
- Fossil-based electricity with carbon capture & storage (CCS)
- Coal synfuels with CCS
- Fossil-based hydrogen fuel with CCS

Nuclear Energy

- Nuclear electricity

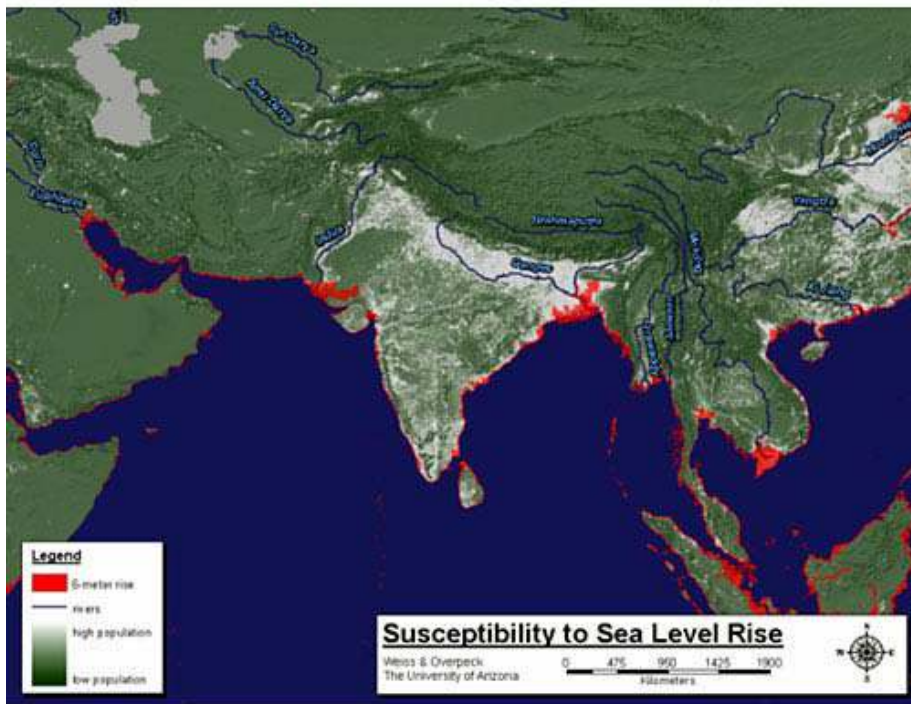
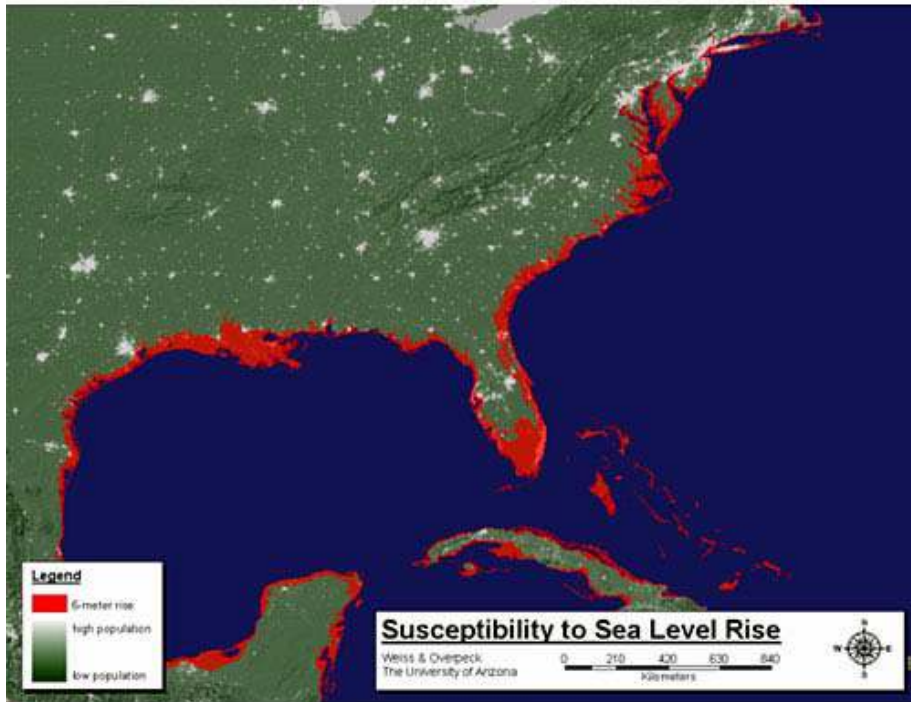
Renewables and Biostorage

- Wind-generated electricity
- Solar electricity
- Wind-generated hydrogen fuel
- Biofuels
- Forest storage
- Soil storage



5 meter sea level rise by 2100: high CO2 emissions

18 ft sea level rise





***Mendenhall Glacier
Juneau, Alaska 2005***



The graph features a dark blue line on a grid. The line starts at a low point on the left, rises steadily to a peak marked with an orange dot, and then falls to a point marked with another orange dot. A horizontal blue line is drawn across the graph, representing the 350 ppm target. The area below this line is shaded light blue. Two orange callout boxes point to the peak and the target line. The entire graph is enclosed in a thick orange border, which is itself within a blue frame.

WE'RE HERE:
385.92 ppm

**WE NEED TO
GET BELOW:**
350 ppm

www.350.org

CO₂ in the Atmosphere



Doomsday Scenario

- “Hot, Flat, and Crowded” -- T. Friedman
- “Catastrophic climate disruption”
- Ocean acidification
- Rising sea level
- Storms, flood, drought
- Tropical pests and diseases move north
- Peak oil, gas, coal
- Environmental refugees: humans, other
- Species extinction

Doomsday Scenario

- Cannot accept, indulge, yield
- Unfair: species, future generations
- Profane, insult creation-evolution
- Rapture: “Gott mit Uns”
- WWII: amazing
 - Mobilization
 - Sacrifice

Pogo

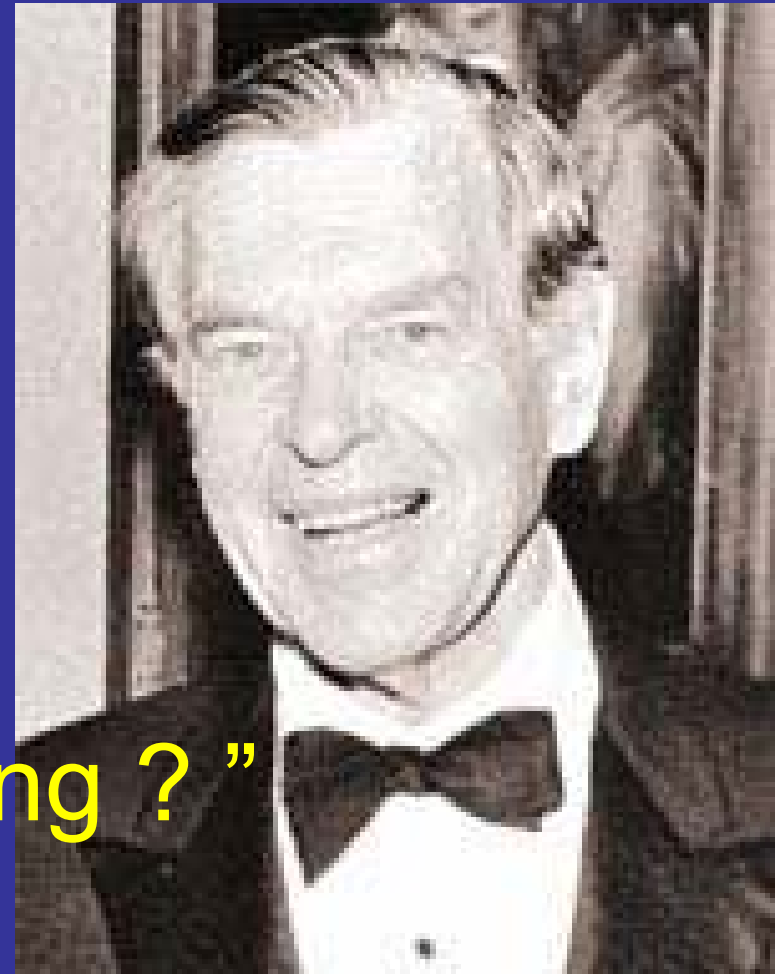
“We have met the enemy...”



Joseph Campbell 1904 - 87

“The Power of Myth”, Bill Moyers

“ Follow your bliss ”



“ What Myth are we living ? ”

New Myth

- **Beyond “Gott mit Uns”**
- **Bigger loyalty, allegiance, patriotism**
- **Run world on renewables**
- **Responsibility: united by threat**
-
-
-
-



planetary defense

.blogspot.com

In Defense of the Future

Administered by:
SpaceWorks Commercial
 A Division of SpaceWorks Engineering, Inc. (SEI)
www.sei.aero

 SpaceWorks
COMMERCIAL



Humanity's Goal ?

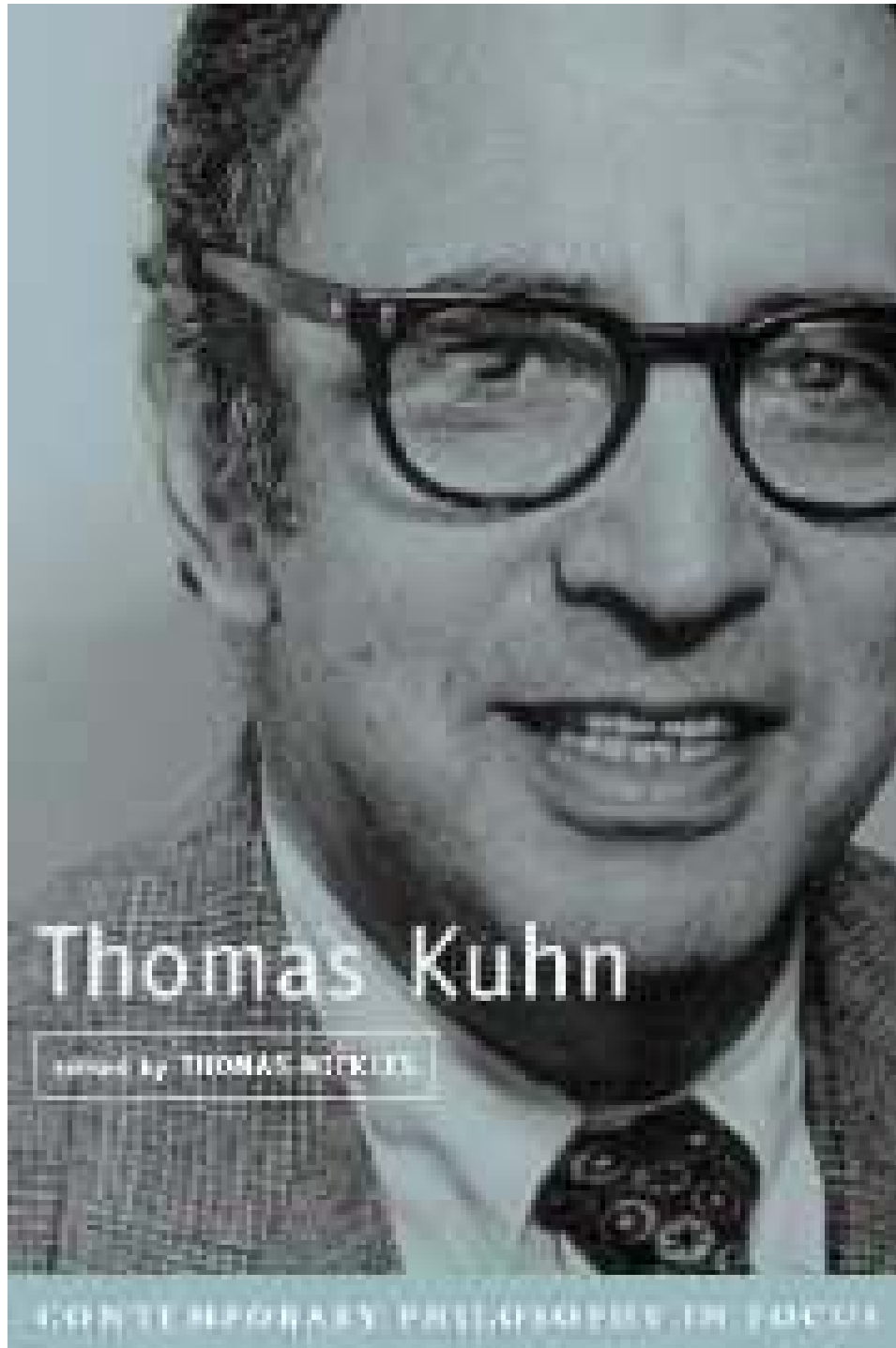
**A sustainable,
benign-source, equitable,
global energy economy**

- **Rapid Climate Change (GCC)**
- **Peak oil, gas, coal**
- **Energy security**



Joel Barker:

- **The Business of Paradigms**
- **Paradigm Paralysis**



“The Structure of Scientific Revolutions” -- 1973

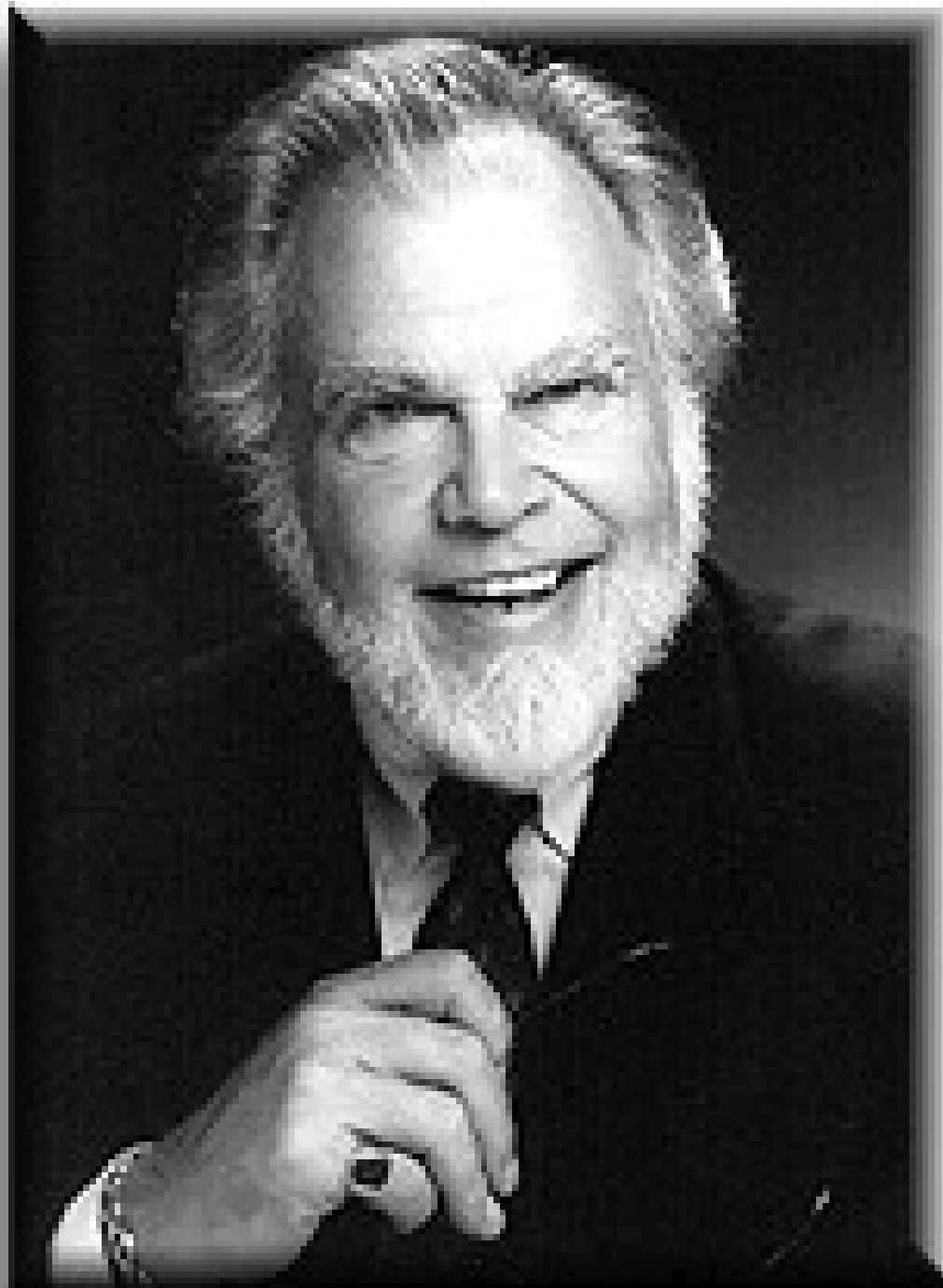
- Paradigm
- Paradigm paralysis
- Paradigm shift



Ilya Prigogine

1977 Nobel Prize, Chemistry

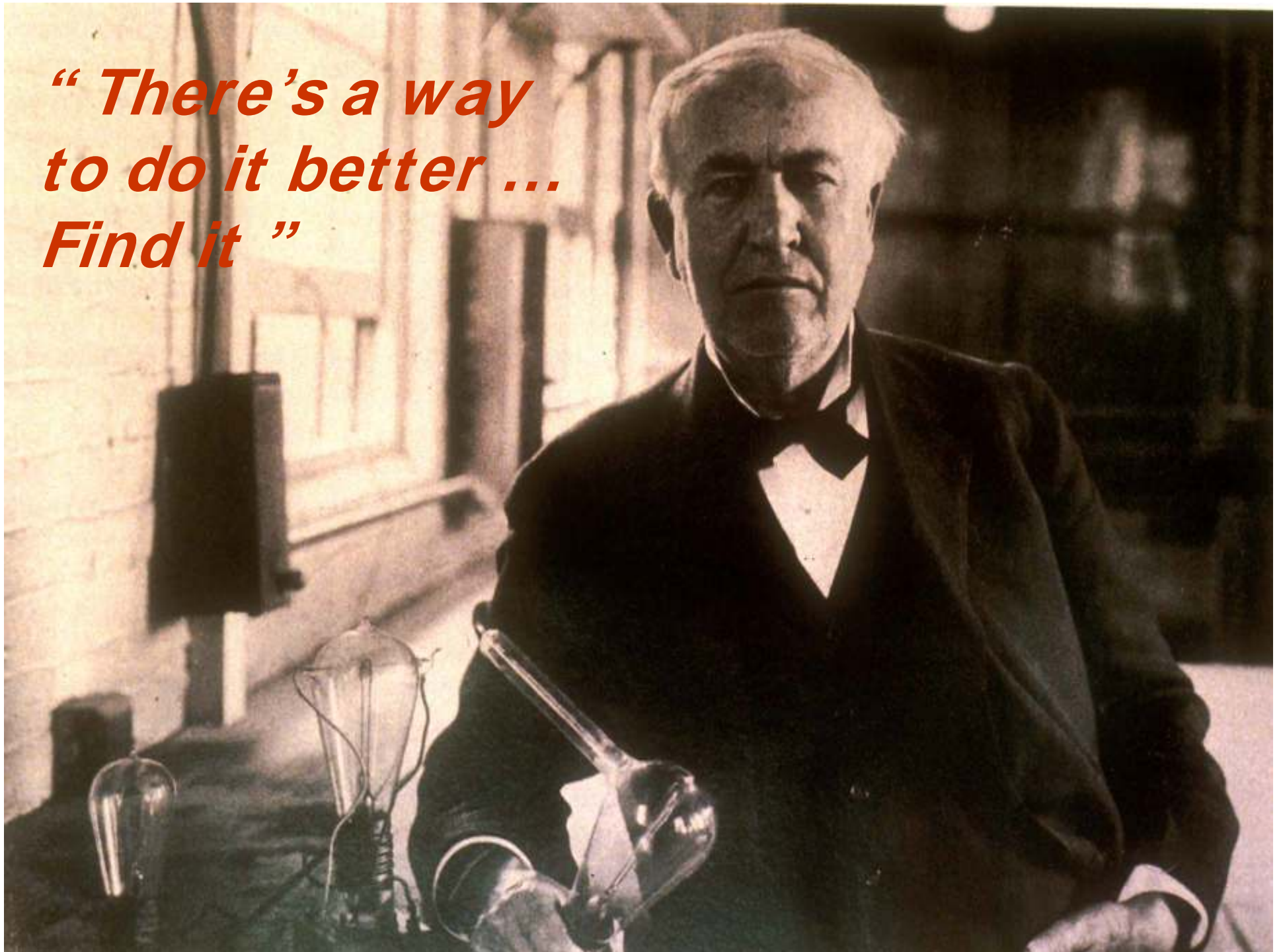
- Surprisingly alive
- Twitchy, searching, self aware
- Self-destruct ?
- Self-shaking to higher ground



George Land

- Purpose of all life
- Growth
- Higher, more complex
 - organization
 - individual

***“ There’s a way
to do it better ...
Find it ”***





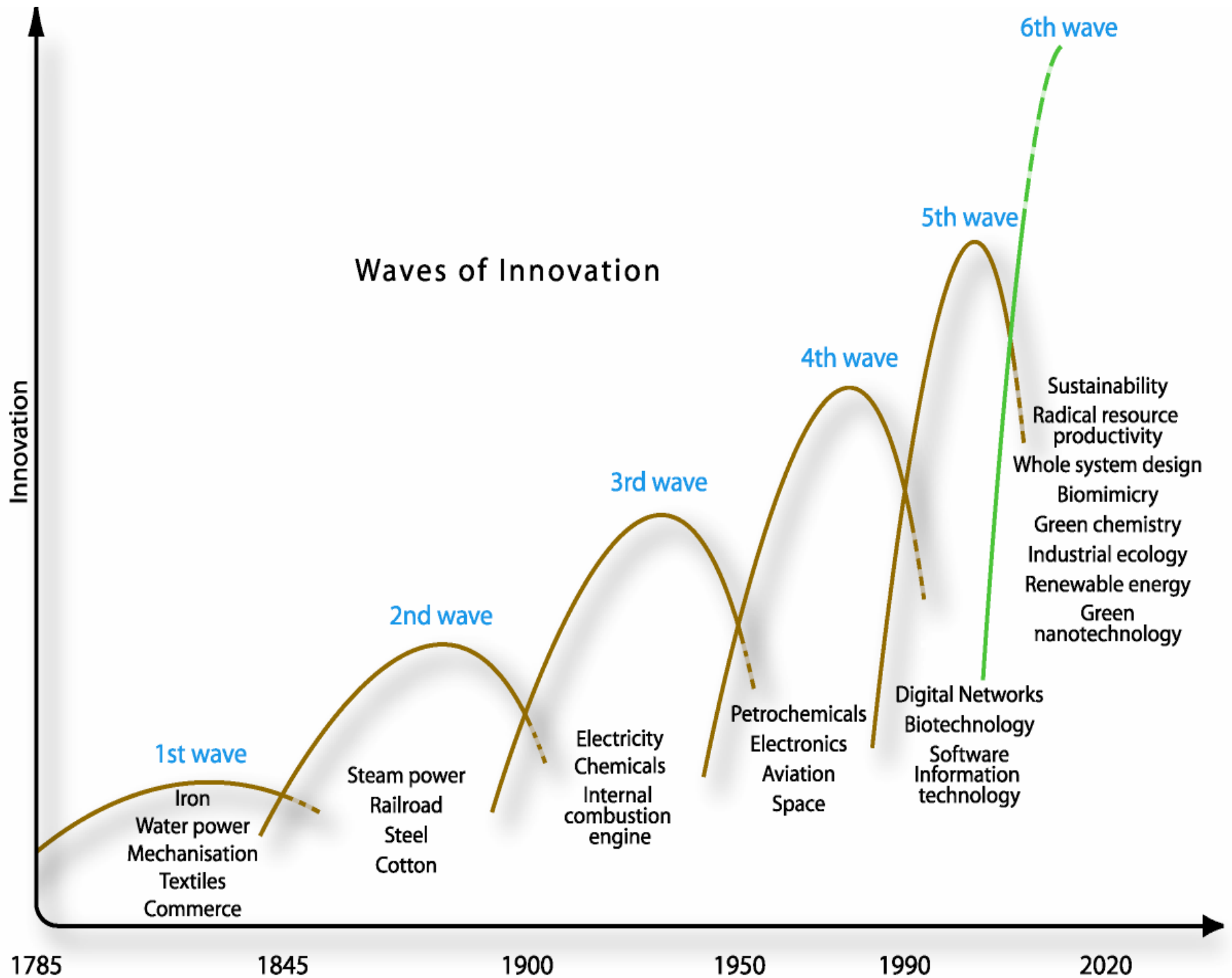
**“ Americans can be
counted on to
always do the right
thing –**

**but only after they
have tried
everything else ”**

Winston Churchill

The dog caught the car.

Dan Reicher



Business Case for Sustainability

- Dow Jones Sustainability Index outperforms DJIA
- Goldman Sachs July '09: ESG companies lead by average 25%
- 72% outperformed industry peers
- Regional environmental protection outperforms
- Triple bottom line: people, planet, profit
- Attract, retain talent
- Reduce risk, distrust cost
- Labor productivity

DuPont Goals



- Cut GHG 65% 1990–2010: - 80 %
- Rev up 6%/y 2000–10, no increased energy
Energy - 9 % since '90
Production + 30 %
- 2010: from renewables
10% of energy
25% of feed stock
- Saved \$3 B, 2000 - 05



| | Annual Savings |
|-------------------|----------------|
| • Waste reduction | \$1.8 B |
| • Energy use flat | \$0.4 B |

Eco-Efficiency savings = \$2.2 B

Average Net Income (2003-2007) = \$2.2 B

Carbon Disclosure Project (CDP)

Wal-Mart

Wal-Mart hired CDP to assess suppliers in China:

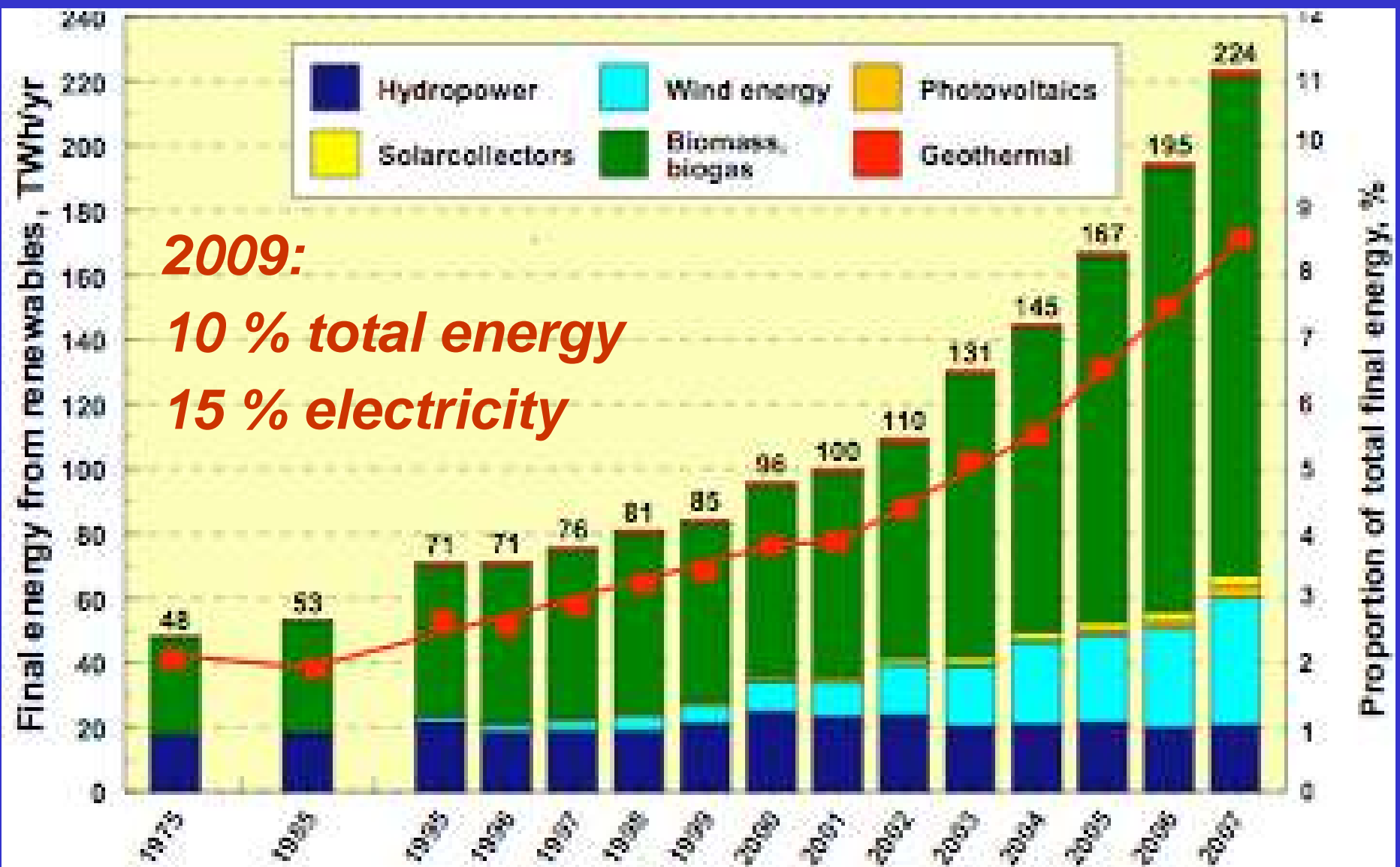
- **Carbon footprint**
 - **Supplier standards**
-
- ☐ 100% renewable energy
 - ☐ Zero waste
 - ☐ Carbon neutral
 - ☐ Saved \$11B / yr packaging



Clorox & Sierra Club

- Clorox Greenworks #2 USA Green Brand '09
- First year sales \$40M
- \$470,000 to Sierra Club '08 sales.





Renewable Energy Sources in Germany, 1975 – 2007



The Land Institute

Salina, KS

- **Perennial, herbaceous, seedbearing polyculture**
- **Nature as measure**
- **Mimic pre-Columbus prairie**
- **Save topsoil**
- **Reduce inputs:
energy, fertilizer, chemicals**

Wes Jackson, co-founder

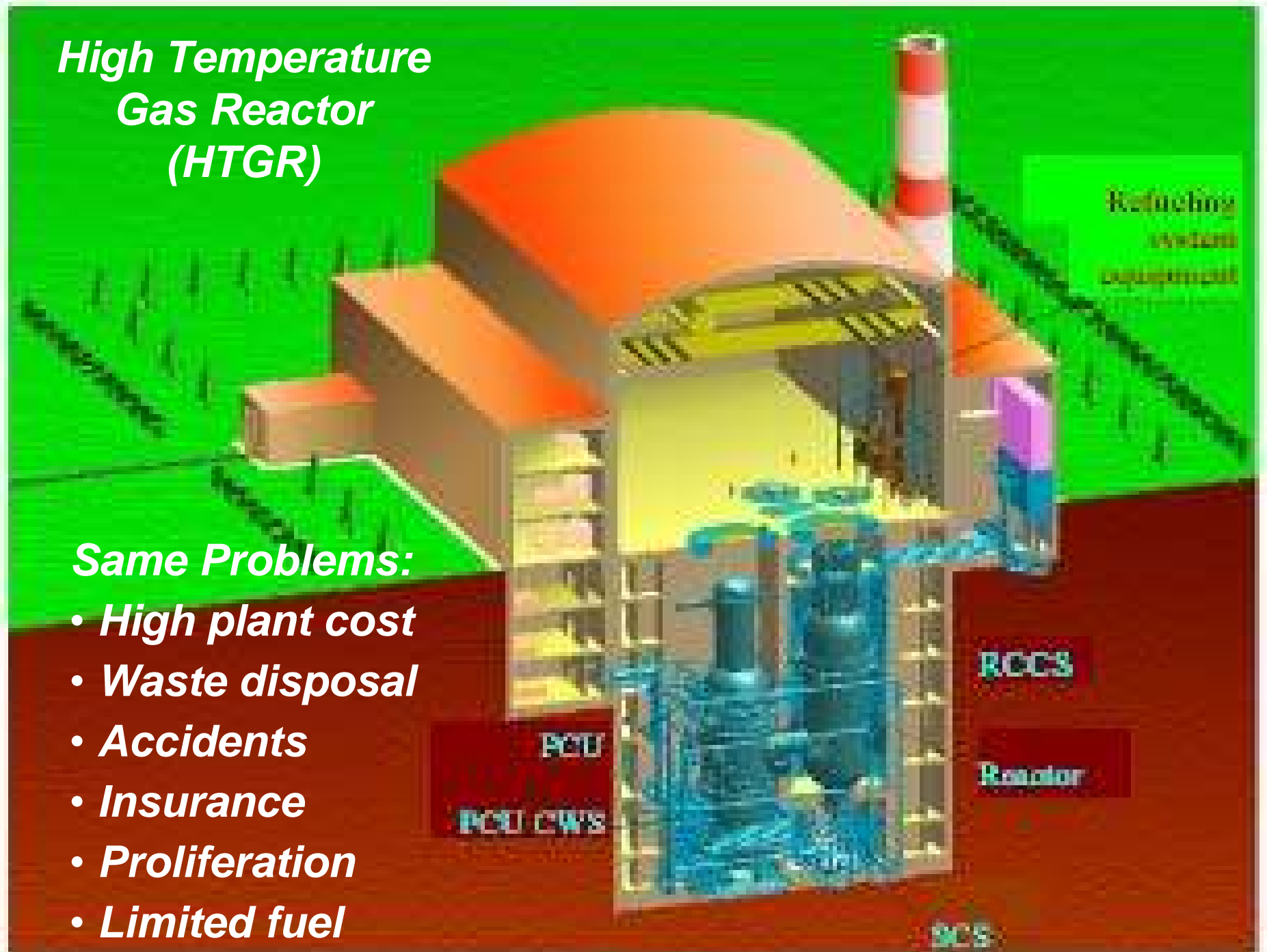
Green Jobs in Renewable Energy

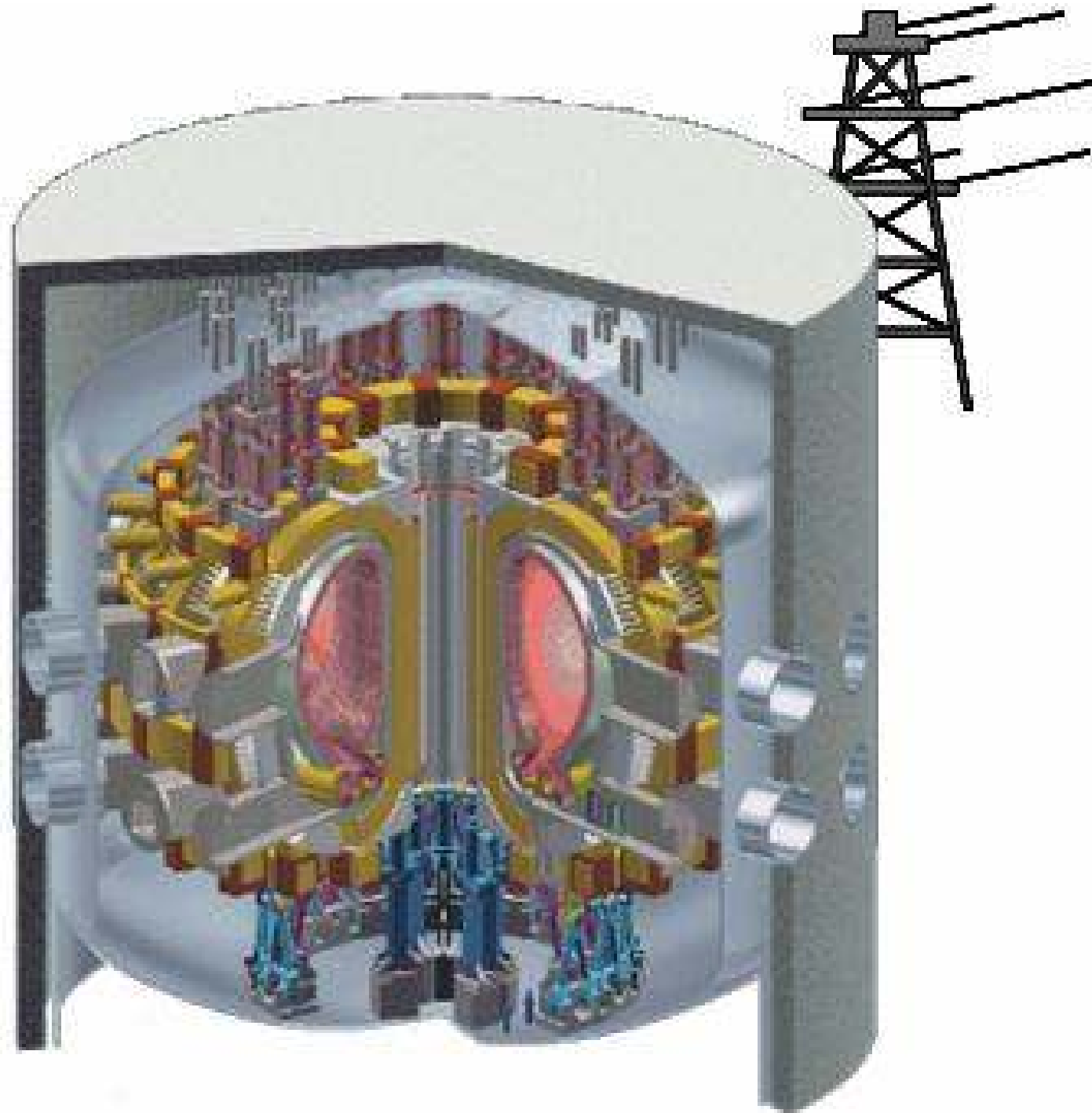
- Invent, design, engineer, test
- Component mfg: blade, tower, gearbox, panel, geothermal block, tank, pipe
- Project planning, finance
- Project installation: transport, road, underground wire + pipe, substation, erection crane, electricians, mechs
- Project maintenance: elec, mech tech, supervisor

High Temperature Gas Reactor (HTGR)

Same Problems:

- *High plant cost*
- *Waste disposal*
- *Accidents*
- *Insurance*
- *Proliferation*
- *Limited fuel*





**Nuclear
Fusion**

ITER

**International
Thermonuclear
Energy Reactor**

France

**2018
first plasma**

***Running the World on Renewables:
Energy Sustainability with
God on our side ?***





The graph features a dark blue line on a grid. The line starts at a low point on the left, rises steadily to a peak marked with an orange dot, and then falls to a point marked with another orange dot. A horizontal blue line is drawn across the graph, representing the 350 ppm target. The area below this line is shaded light blue. Two orange callout boxes point to the peak and the target line. The entire graph is enclosed in a thick orange border, which is itself within a blue frame.

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**WE NEED TO
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www.350.org

CO₂ in the Atmosphere

The Great Plains Wind Resource



Exporting From 12 Windiest Great Plains States

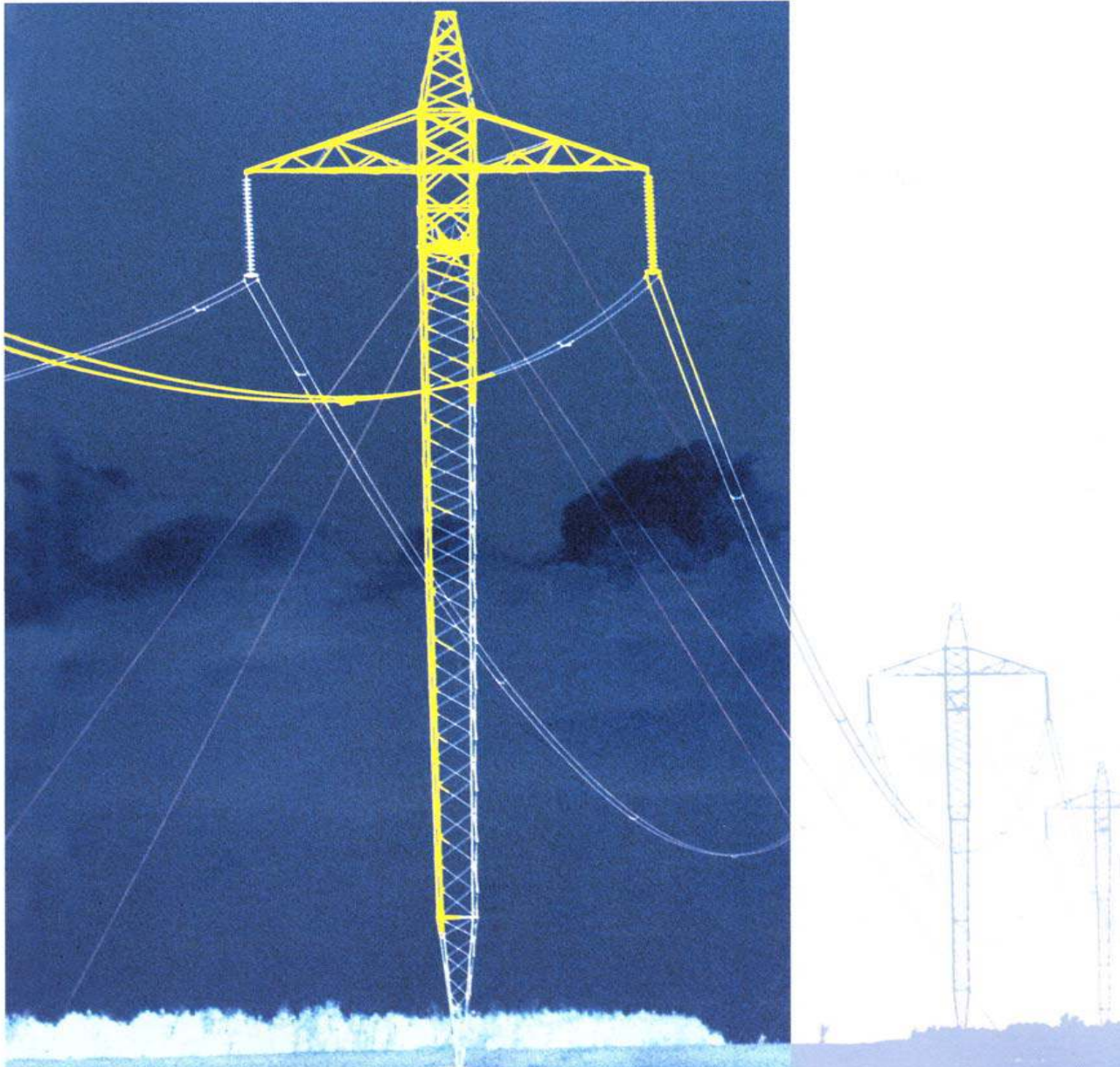
Number of GH2 pipelines or HVDC electric lines necessary to export total wind resource

Wind energy source: PNL-7789, 1991

* at 500 miles average length

| State | AEP, TWh | Wind Gen MW (nameplate) (40% CF) | 6 GW 36" GH2 export pipelines | \$ Billion Total Capital Cost * | 3 GW export HVDC lines | \$ Billion Total Capital Cost * |
|---------------|--------------|----------------------------------------------|----------------------------------------|------------------------------------------|---------------------------------|------------------------------------------|
| North Dakota | 1,210 | 345,320 | 50 | 50 | 100 | 60 |
| Texas | 1,190 | 339,612 | 48 | 48 | 100 | 60 |
| Kansas | 1,070 | 305,365 | 43 | 43 | 100 | 60 |
| South Dakota | 1,030 | 293,950 | 41 | 41 | 100 | 60 |
| Montana | 1,020 | 291,096 | 41 | 41 | 90 | 54 |
| Nebraska | 868 | 247,717 | 35 | 35 | 80 | 48 |
| Wyoming | 747 | 213,185 | 30 | 30 | 70 | 42 |
| Oklahoma | 725 | 206,906 | 29 | 29 | 60 | 36 |
| Minnesota | 657 | 187,500 | 26 | 26 | 60 | 36 |
| Iowa | 551 | 157,249 | 22 | 22 | 50 | 30 |
| Colorado | 481 | 137,272 | 19 | 19 | 40 | 24 |
| New Mexico | 435 | 124,144 | 17 | 17 | 40 | 24 |
| TOTALS | 9,984 | 2,849,316 | 401 | \$ 401 | 890 | \$ 534 |

High Voltage Direct Current Transmission



***North Dakota
wind needs
115 lines
at 3,000 MW
each***

***Six Plains
states
wind needs
560 lines
at 3,000 MW
each***

***SIEMENS
HVDC line
+/- 500 kv***

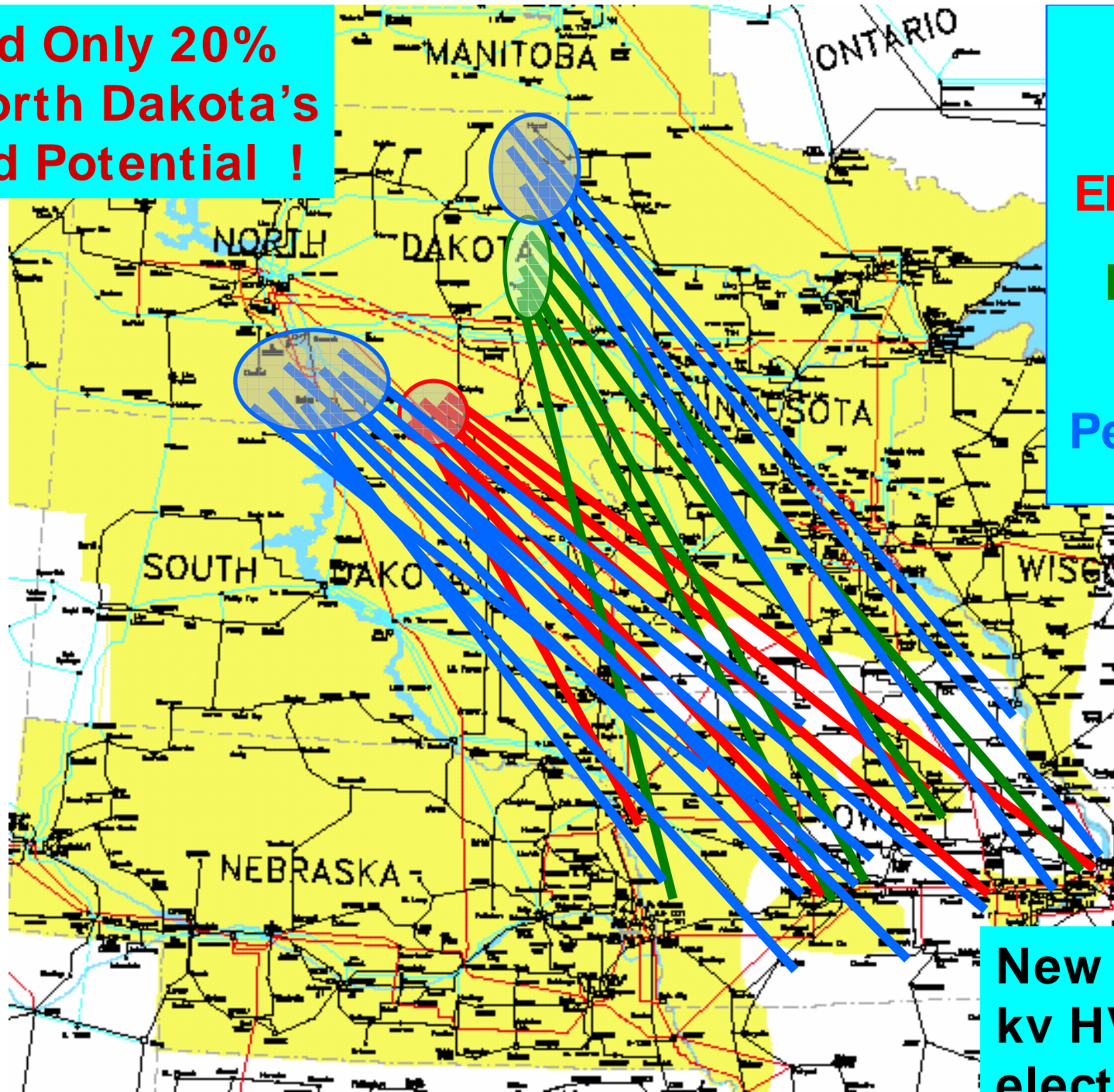
Iowa Wind Potential

| | |
|--------------------------------------|----------------|
| Annual energy production, TWh | 550 |
| Installed wind generation, MW | 157,249 |

| | |
|-----------------------------------|----------------------|
| Export electric lines | 50 |
| Export electric lines cost | \$ 30 billion |

| | |
|---------------------------------------|----------------------|
| Export hydrogen pipelines | 20 |
| Export hydrogen pipelines cost | \$ 20 billion |

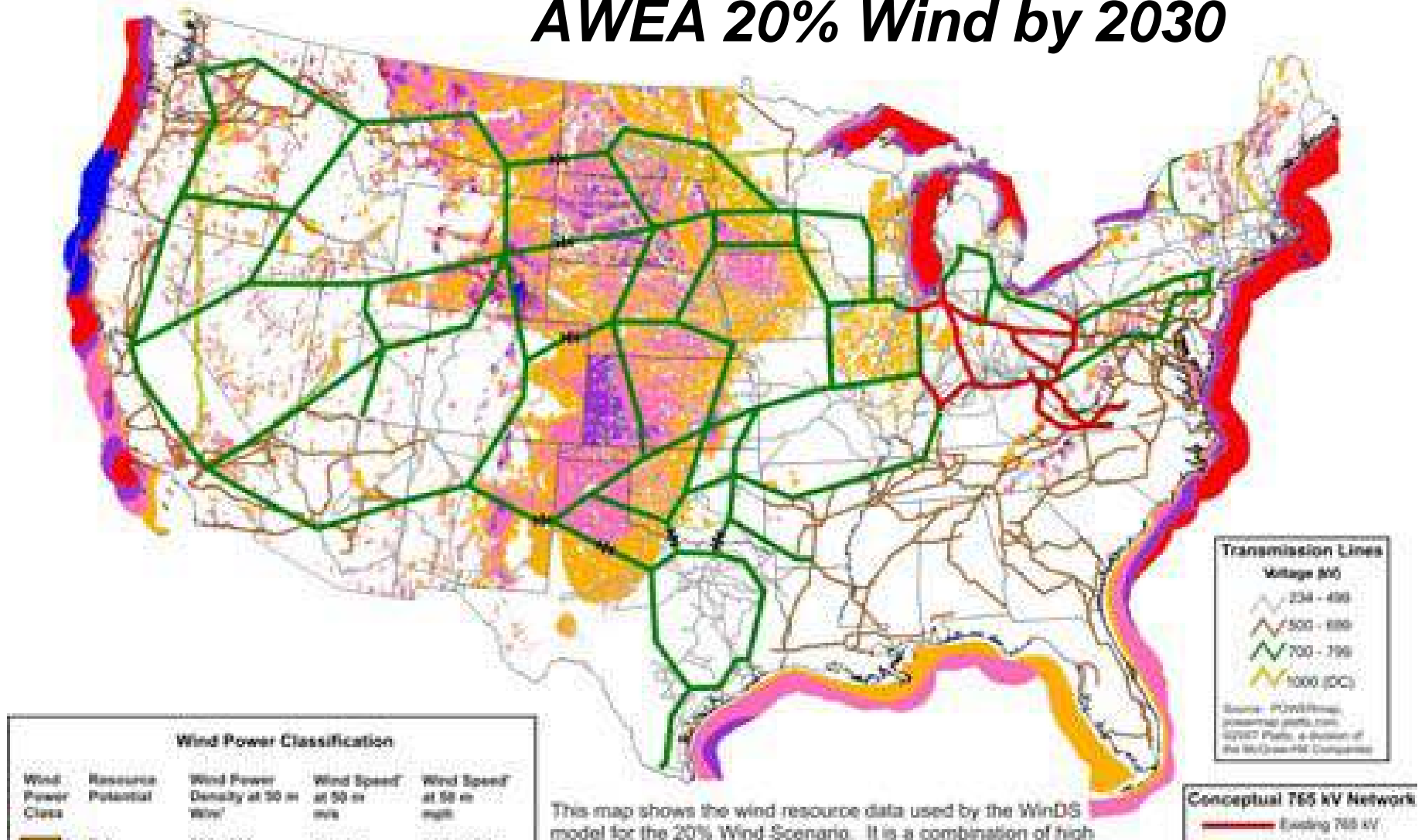
**Used Only 20%
of North Dakota's
Wind Potential !**



**All of
Iowa's
Electricity
Natural
Gas
Petroleum**

**New +/- 500
kv HVDC ----
electric lines**

AWEA 20% Wind by 2030



Frontier Line + Transwest Express ≈ 115 GW
Wind Potential ≈ 3,000 GW

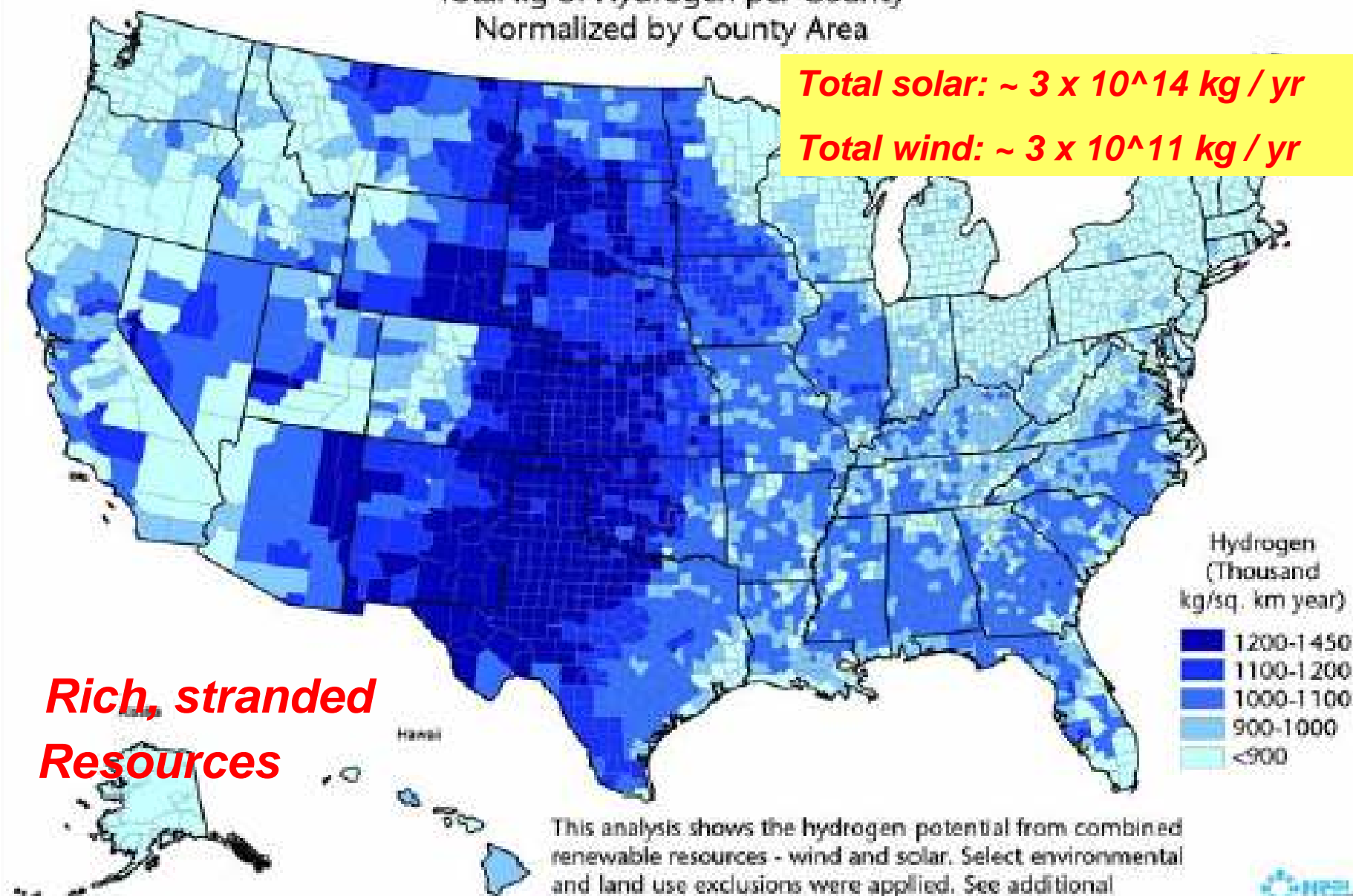
Figure 3

Hydrogen Potential from Solar and Wind Resources

Total kg of Hydrogen per County
Normalized by County Area

Total solar: $\sim 3 \times 10^{14}$ kg / yr

Total wind: $\sim 3 \times 10^{11}$ kg / yr



**Rich, stranded
Resources**

This analysis shows the hydrogen potential from combined renewable resources - wind and solar. Select environmental and land use exclusions were applied. See additional documentation for more information.

Trouble with Renewables

- Diffuse, dispersed: gathering cost
- Richest are remote: “stranded”
- Time-varying output:
 - “intermittent”
 - “firming” storage required
- Transmission:
 - low capacity factor (CF) or curtailment
 - NIMBY
- Distributed or centralized ?

Trouble with Renewables - Electricity Transmission

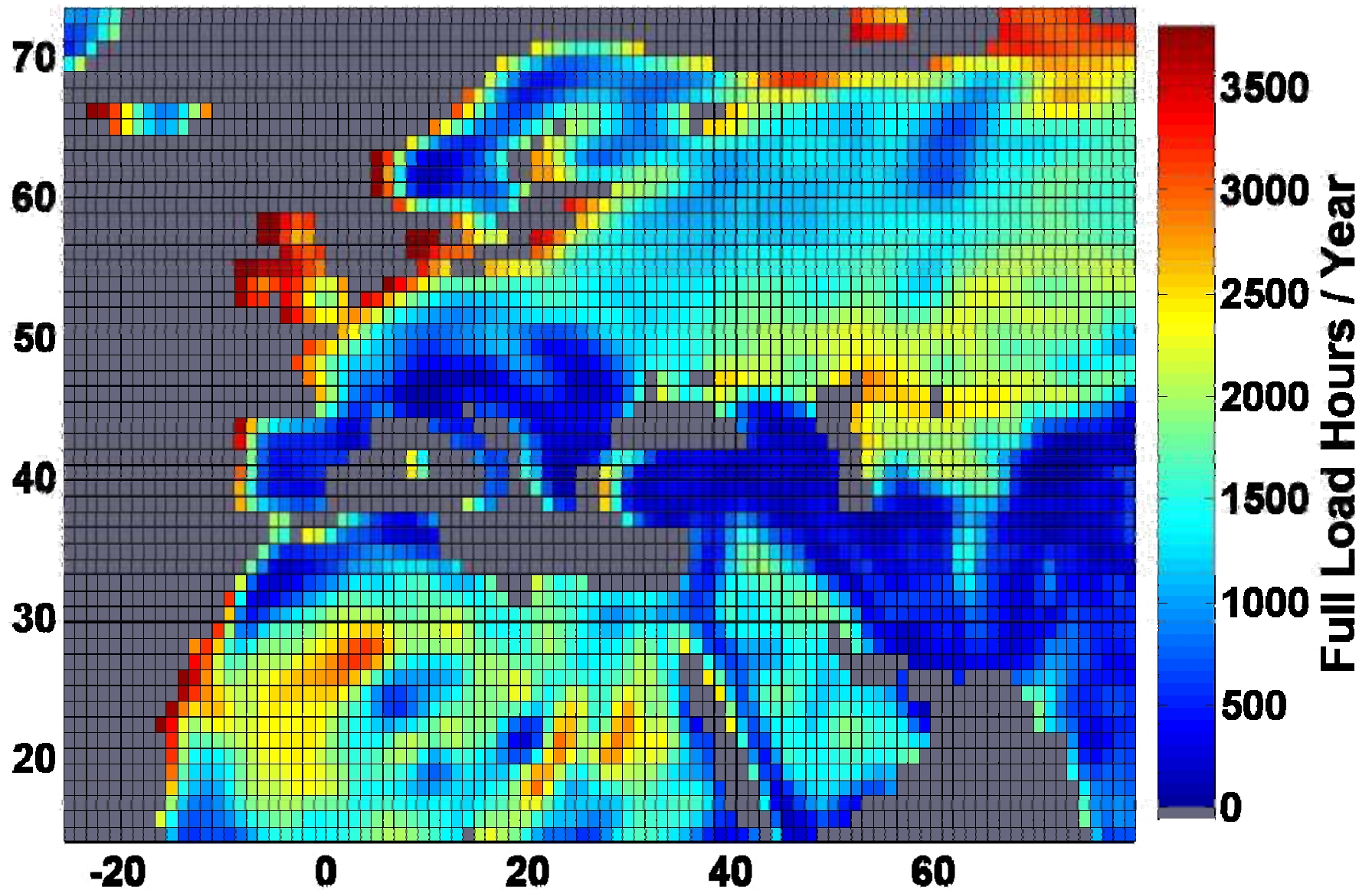
- **Grid nearly full**
 - **New wind must pay for transmission**
 - **Costly: AC or DC**
- **NIMBY**
- **Low capacity factor or curtailment**
- **No storage: smoothing or firming**
- **Overhead towers vulnerable: God or man**
- **Underground: Only HVDC**

Pickens Plan

- **Bold, large-scale, motivates thinking**
- **Rally public: “Army”**
- **Disappoint ? Disillusion ?**
- **GW scale: economies**
- **Underestimates**
 - **Transmission**
 - **Grid integration, thermal plant abuse**
 - **Firming storage needed**
- **Disregards Hydrogen demand**
 - **Gulf Coast refineries**
 - **Transport fuel**
- **New turbine manufacturers, designs ?**

ABB, ISET Kassel “Huge Catchment Area”

Windpower 01



Trouble with GW-scale wind today

- **Lowest-cost renewable ?**
- **Electricity only**
- **Grid nearly full**
 - New wind must pay for transmission
 - Costly: AC or DC
- **No storage: smoothing or firming**
- **“Cherry-picked” windplants, to date**
 - Best wind sites
 - Low-cost transmission access
- **Depend on fed PTC: \$ 0.019 / kWh**

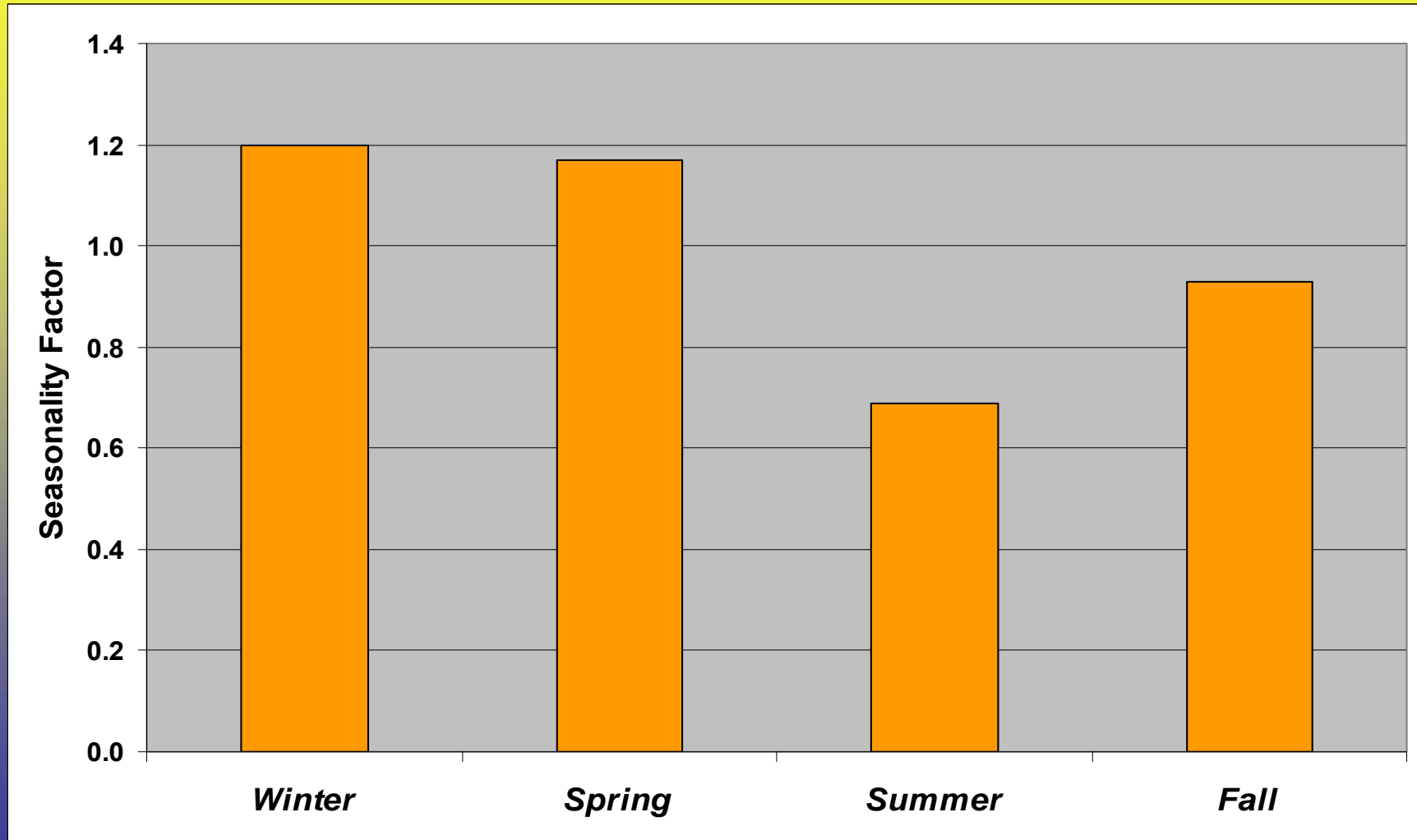
Wind seasonality, Great Plains

- Winter = 1.20
- Spring = 1.17
- Summer = 0.69
- Autumn = 0.93

Source: D. Elliott, et al, NREL

Wind Seasonality, Northern Great Plains

Normalized to 1.0 per season



Wind Seasonality, Northern Great Plains

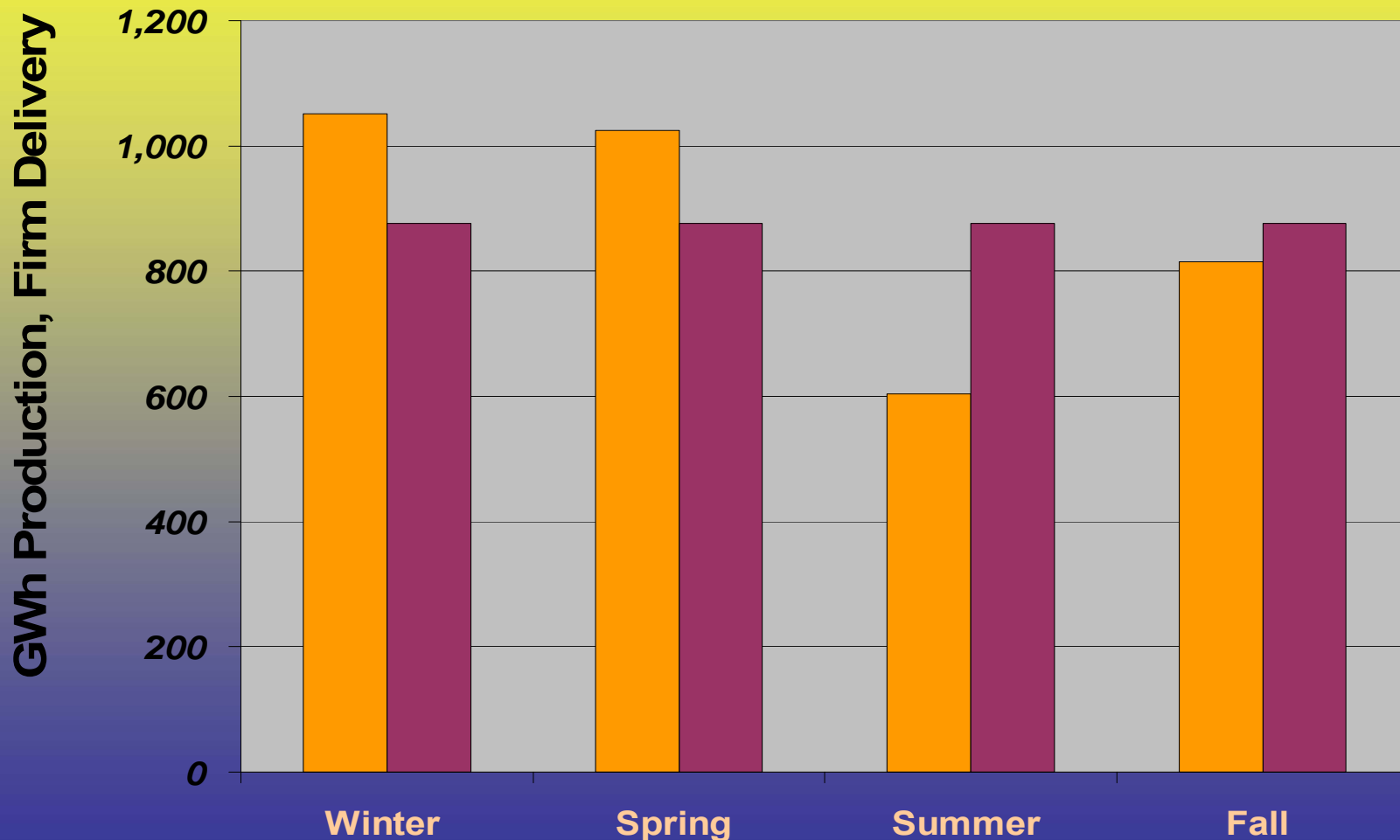
1,000 MW windplant:

AEP = 3,500 GWh / yr

“Firm” goal = 875 GWh / season

Storage: 320 GWh per 1,000 MW wind

Source: NREL, D. Elliott



Annual – scale “Firming” Great Plains Wind

- **Potential, 12 states, ~50% land area:**
 - 10,000 TWh = 100 quads = entire USA
 - 2,800,000 MW nameplate
- **Seasonality:**
 - “Firming” energy storage,
per 1,000 MW wind = **320 GWh**

“Firm” energy worth more

- **Every hour, every year**
- **Strategically: indigenous, secure**
- **Market price**
- **Dispatchable**
- **Bankable large projects**
- **Risk avoidance: rapid climate change**

**Sunlight from
local star**

Electricity

O₂

Electricity

H₂

Work

Electrolyzer

Fuel Cell

PEM Electrolyzer
 $2\text{H}_2\text{O} + \text{Energy} \rightarrow 2\text{H}_2 + \text{O}_2$

Item: 2010
Solar Hydrogen System Junior Basic
www.hi-tec.com

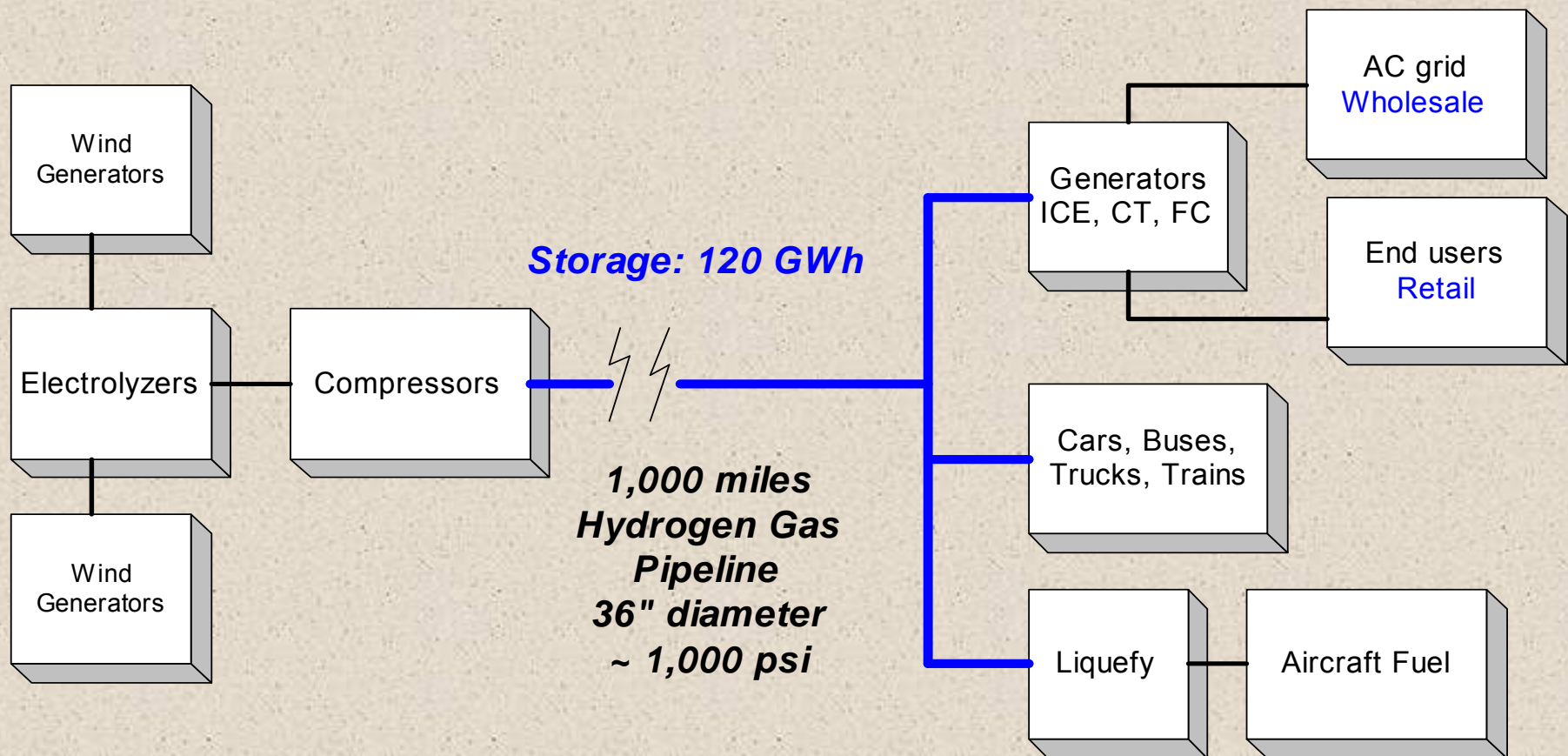
PEM Fuel Cell
 $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{Energy}$

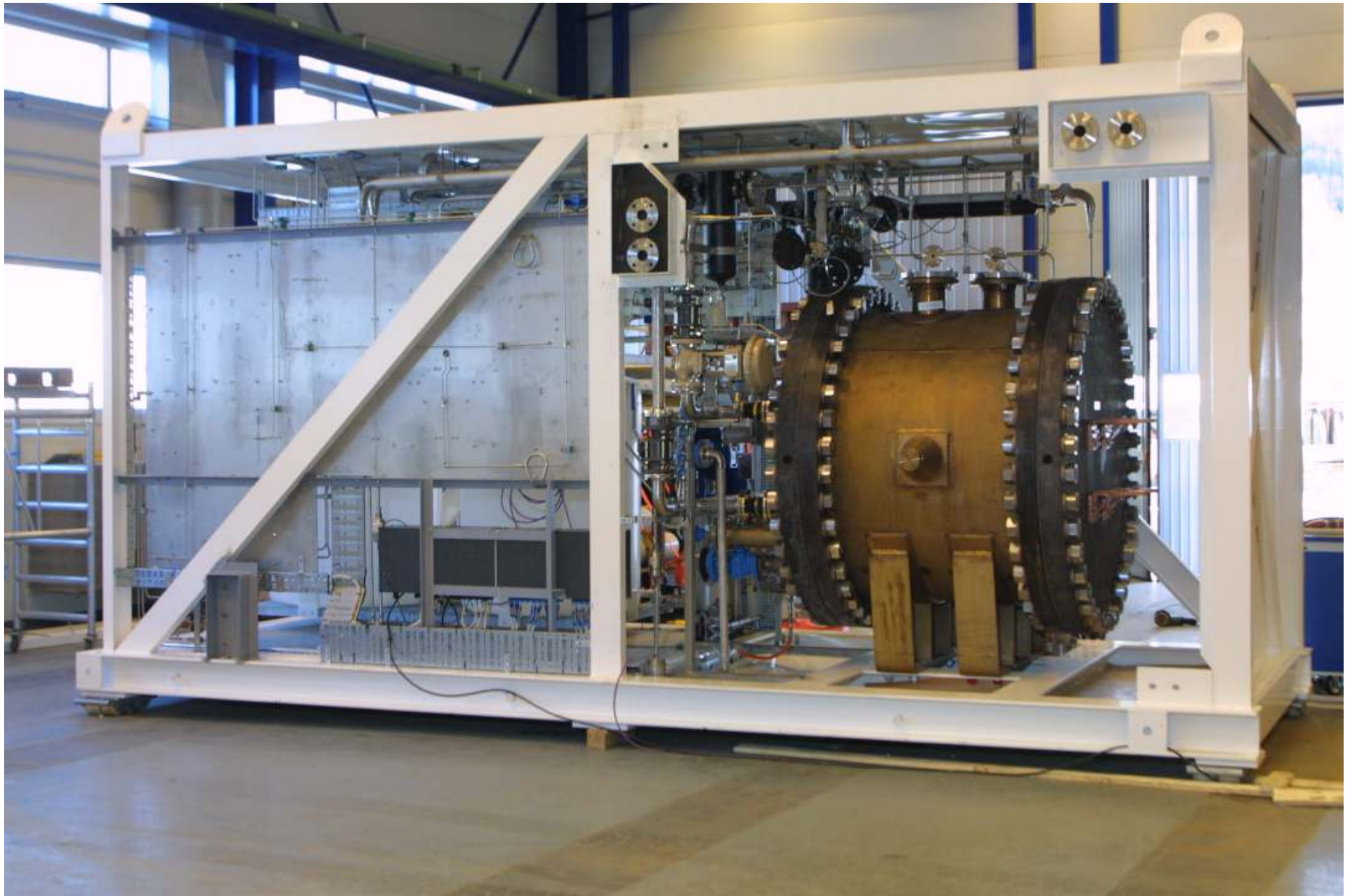
H TEC

Solar *Hydrogen* Energy System

Hydrogen Transmission Scenario

- *Low-pressure electrolyzers*
- *“Pack” pipeline: ~ 1-2 days’ storage = 120 GWh*



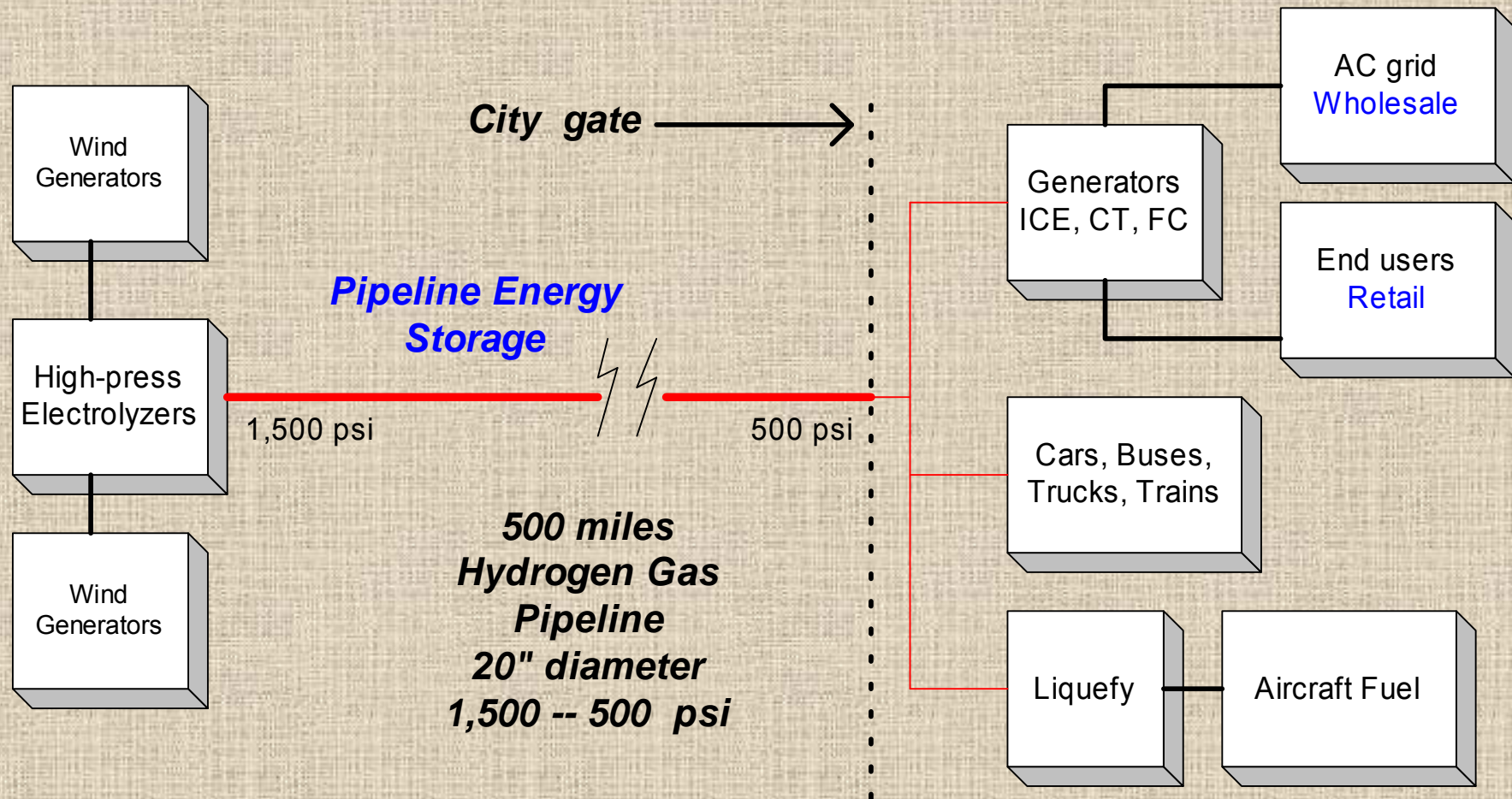


***Norsk Hydro electrolyzer, KOH type
560 kW input, 130 Nm³ / hour at 450 psi (30 bar)***

Compressorless system: No firming storage

Transmission

Distribution

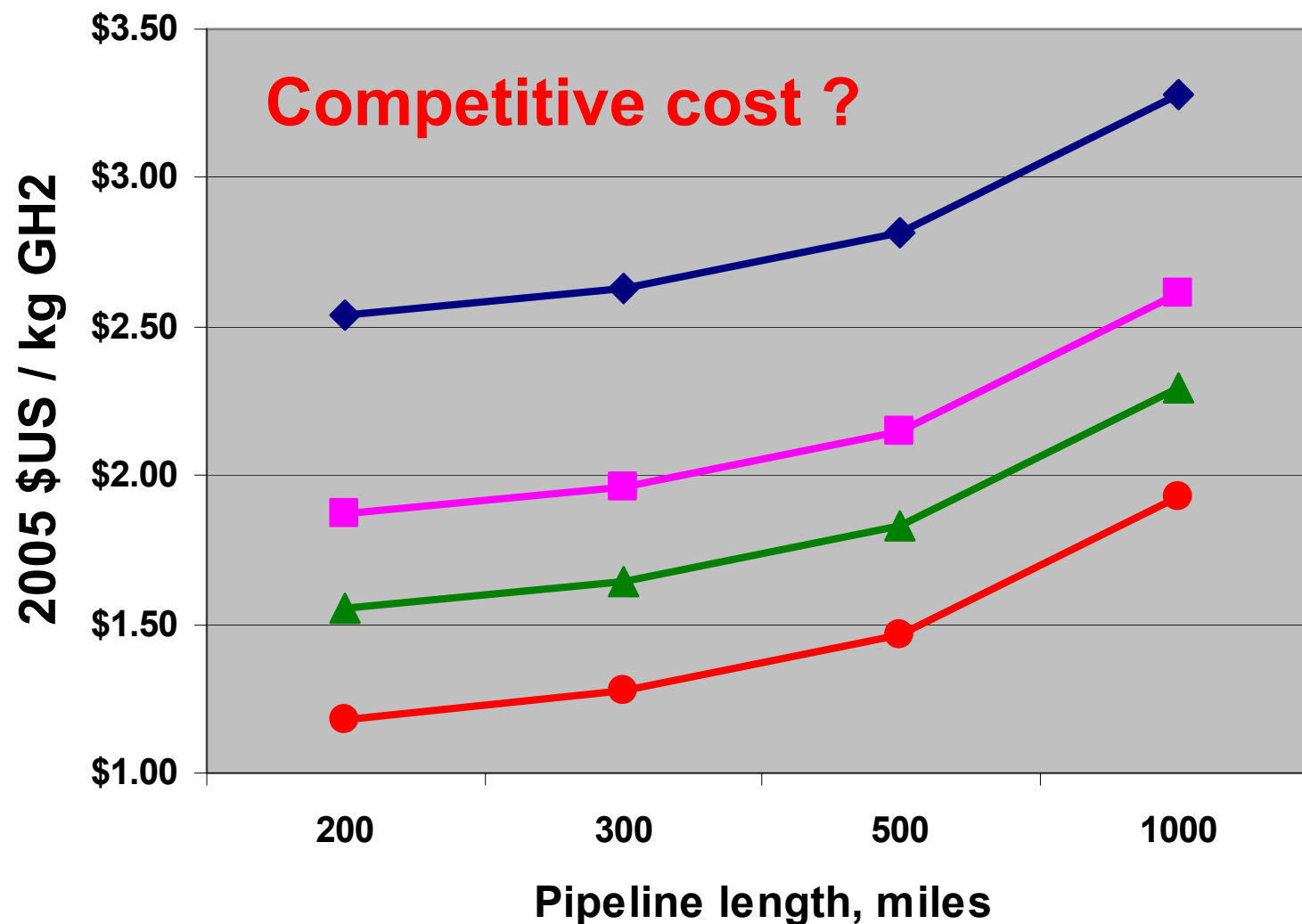




CRLP™ is a trademark of
NCF Industries, Inc.

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

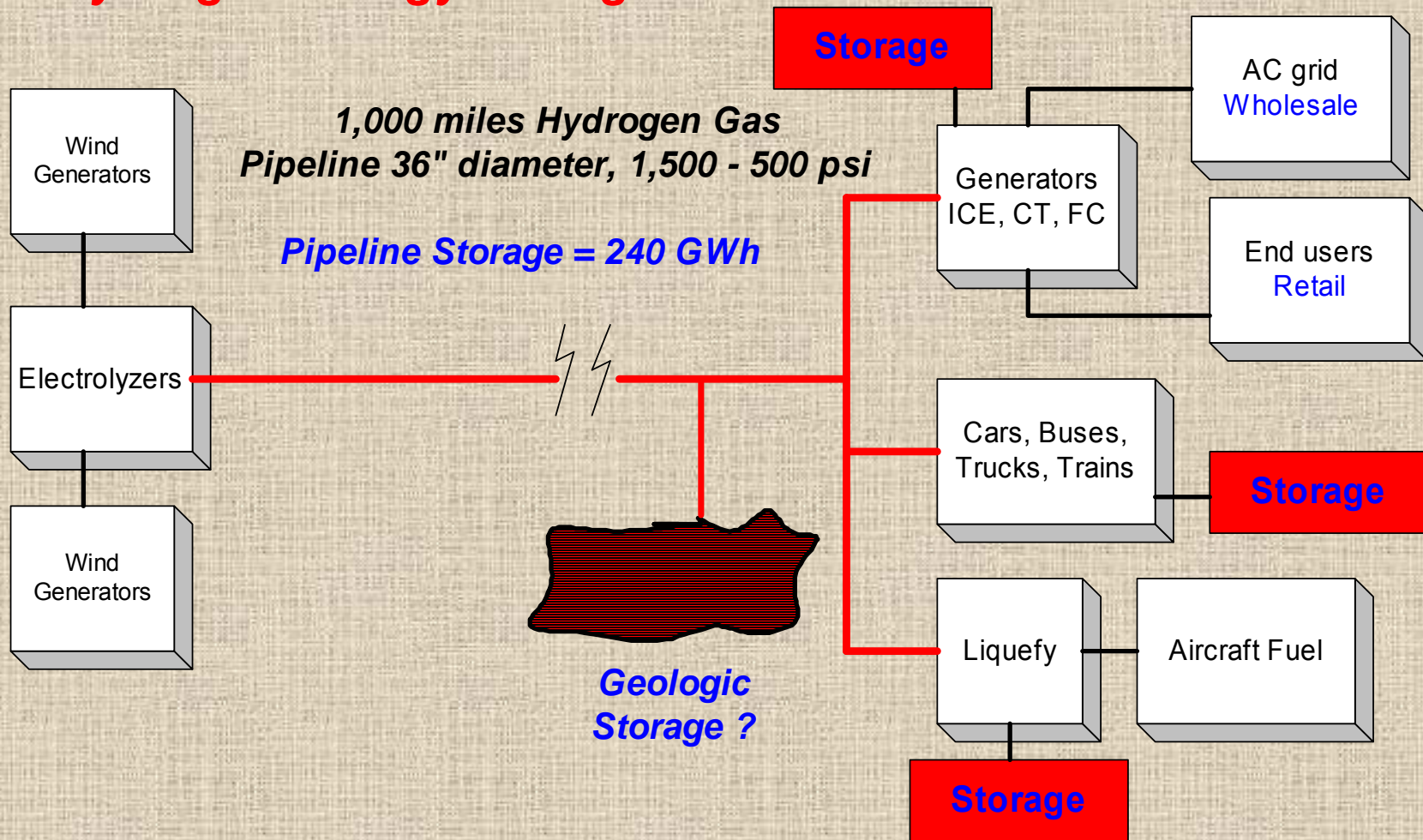
City-gate GH2 cost @ 15% CRF, 20" pipeline, from 2,000 MW Great Plains windplant



—◆— B1: Unsubsidized —■— B2: US fed PTC only —▲— B3: PTC + Oxygen sales —●— B4: PTC + O2 sale + C-credit

“Firming” Cavern Storage

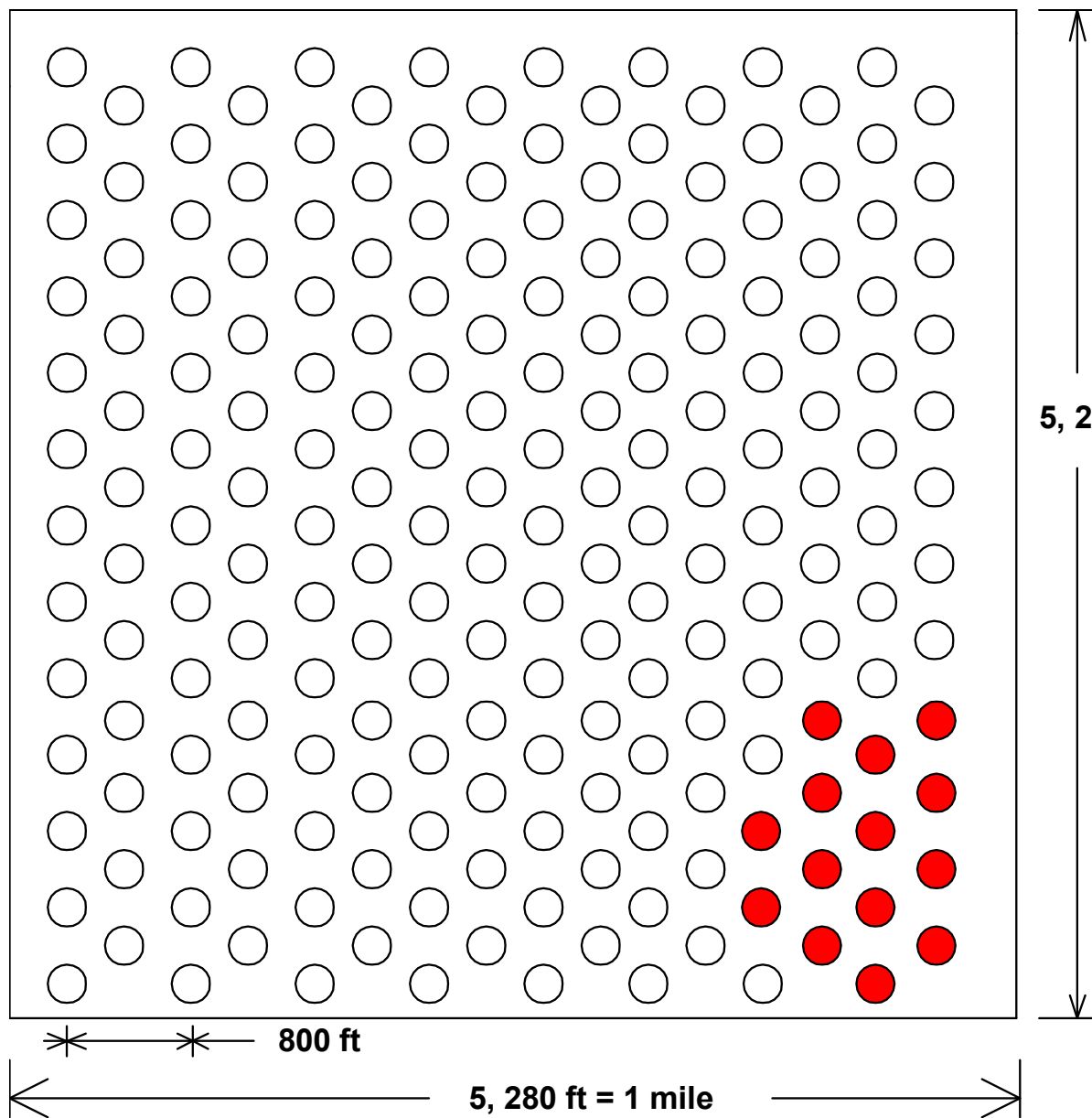
Hydrogen Energy Storage





Domal Salt Storage Caverns

PB ESS



5,280 ft = 1 mile

**“Firm” 4,000
MW Great
Plains wind
14 caverns**

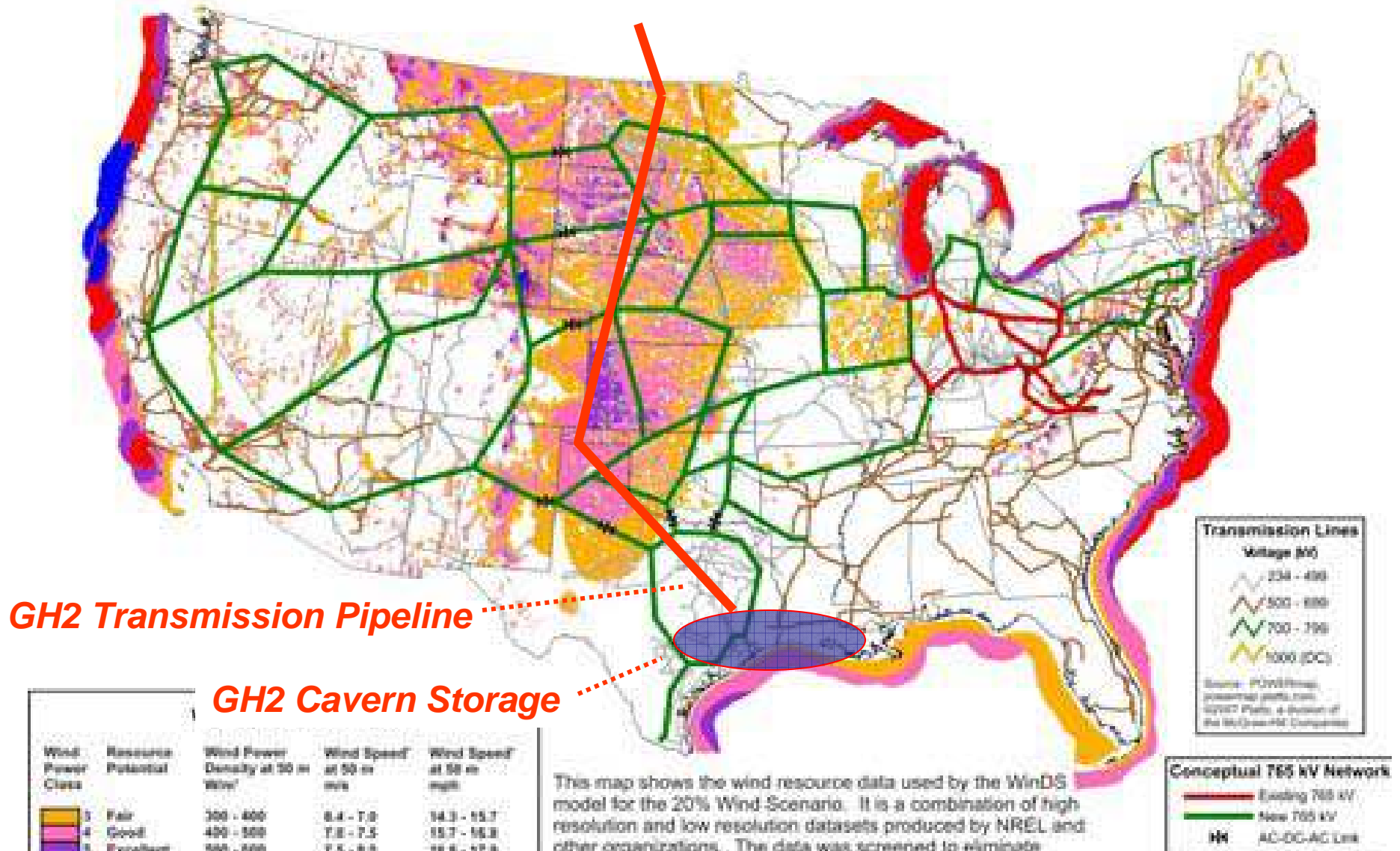
**Maximum Cavern
Packing Density**

$(8 \times 13) = 104 + (8 \times 12) = 96$ Total = 200 caverns per square mile
Each cavern is 200 ft diam, with minimum 200 ft web separation.

Annual – scale “Firming” Great Plains Wind

- **Potential, 12 states, ~50% land area:**
 - 10,000 TWh = 100 quads = entire USA energy
 - 2,800,000 MW nameplate
- **Seasonality:**
 - “Firming” energy storage, per 1,000 MW wind:
 - as electricity = **450 GWh**
 - as GH2 = 15,712 tons, metric @ 2,500 tons / cavern = **6 caverns**
 - “Firming” energy storage, all great Plains wind:
 - as GH2 = **17,000 caverns @ \$15M each = \$264 billion**

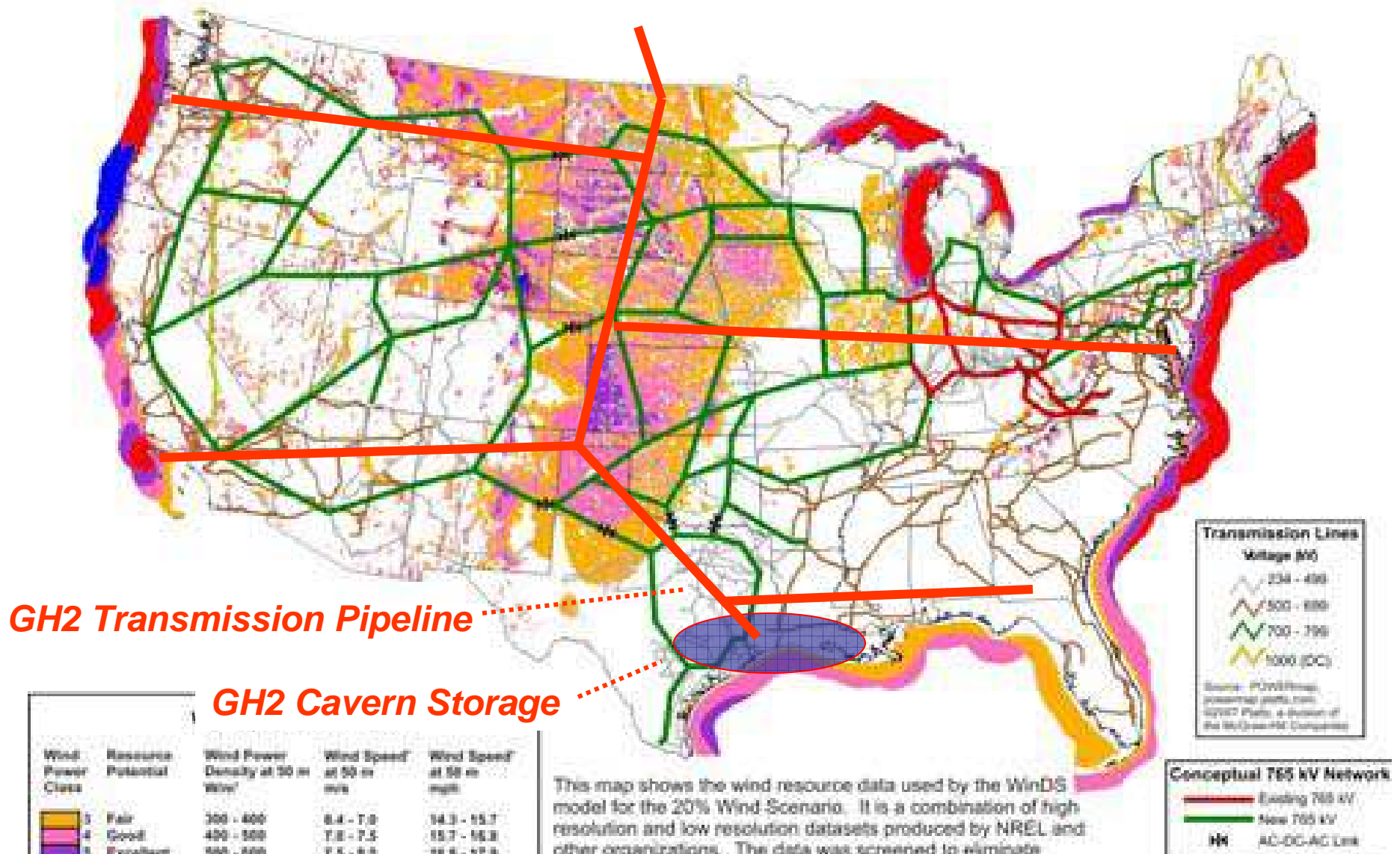
AWEA 20% Wind by 2030



Wind Potential \approx 3,000 GW

Frontier Line + Transwest Express \approx 115 GW

AWEA 20% Wind by 2030



Wind Potential \approx 3,000 GW

Frontier Line + Transwest Express \approx 115 GW

AWEA 20% Wind by 2030

This map shows the wind resource data used by the WindS model for the 20% Wind Scenario. It is a combination of high

Wind Power Classification

| Resource Potential | Wind Power Density at 50 m 'ave' | Wind Speed at 50 m m/s | Wind Speed at 50 m mph |
|--------------------|----------------------------------|------------------------|------------------------|
| | | | |

Transmission Voltage (kV)

- 230 - 400
- 500 - 800
- 700 - 1100
- 1000 (DC)

Conceptual 765 kV

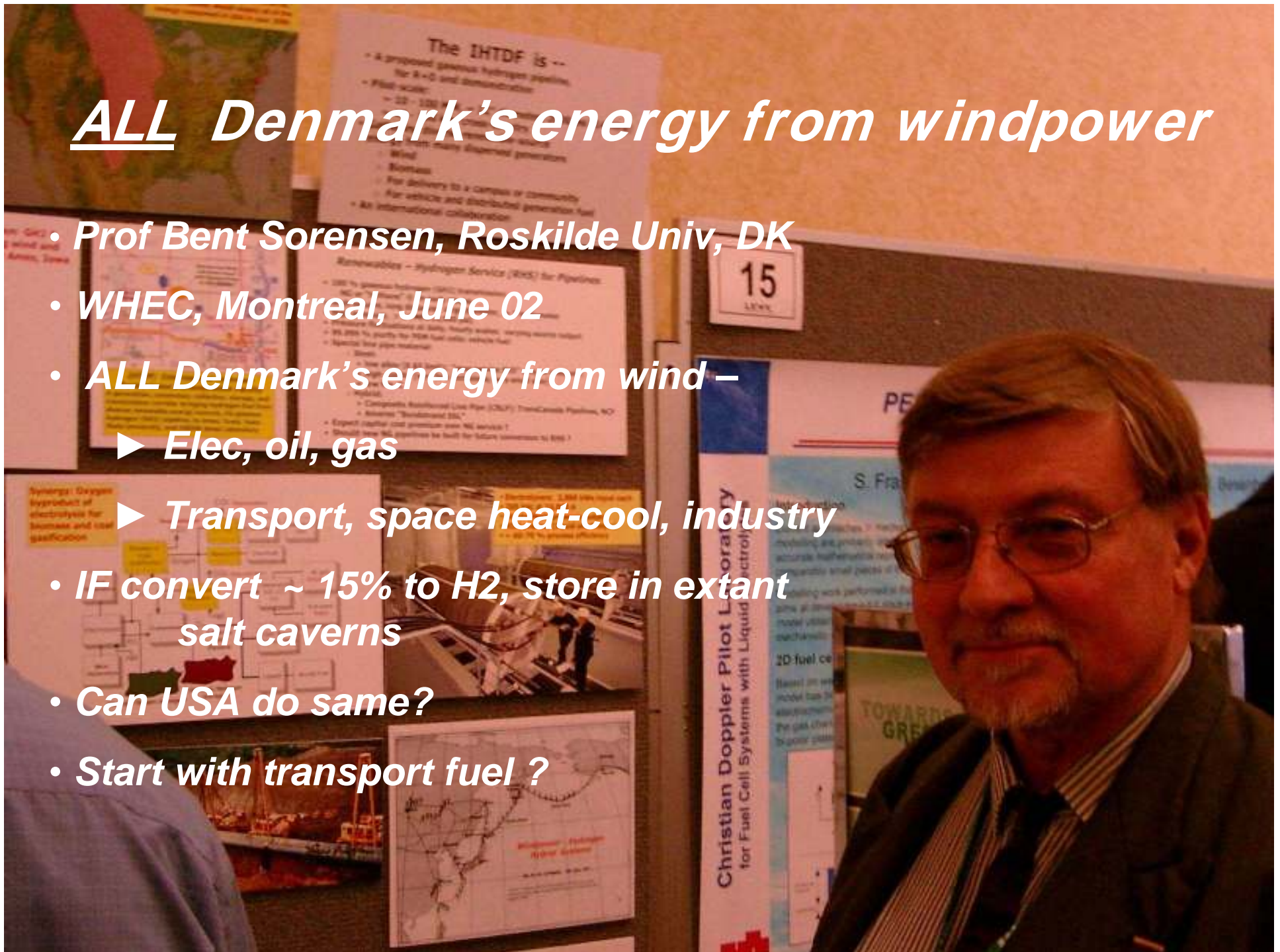
- Existing

Source: POWERmap, powermap.earth.com, 10/2012 Photo: © from the WindPower4Me Campaign

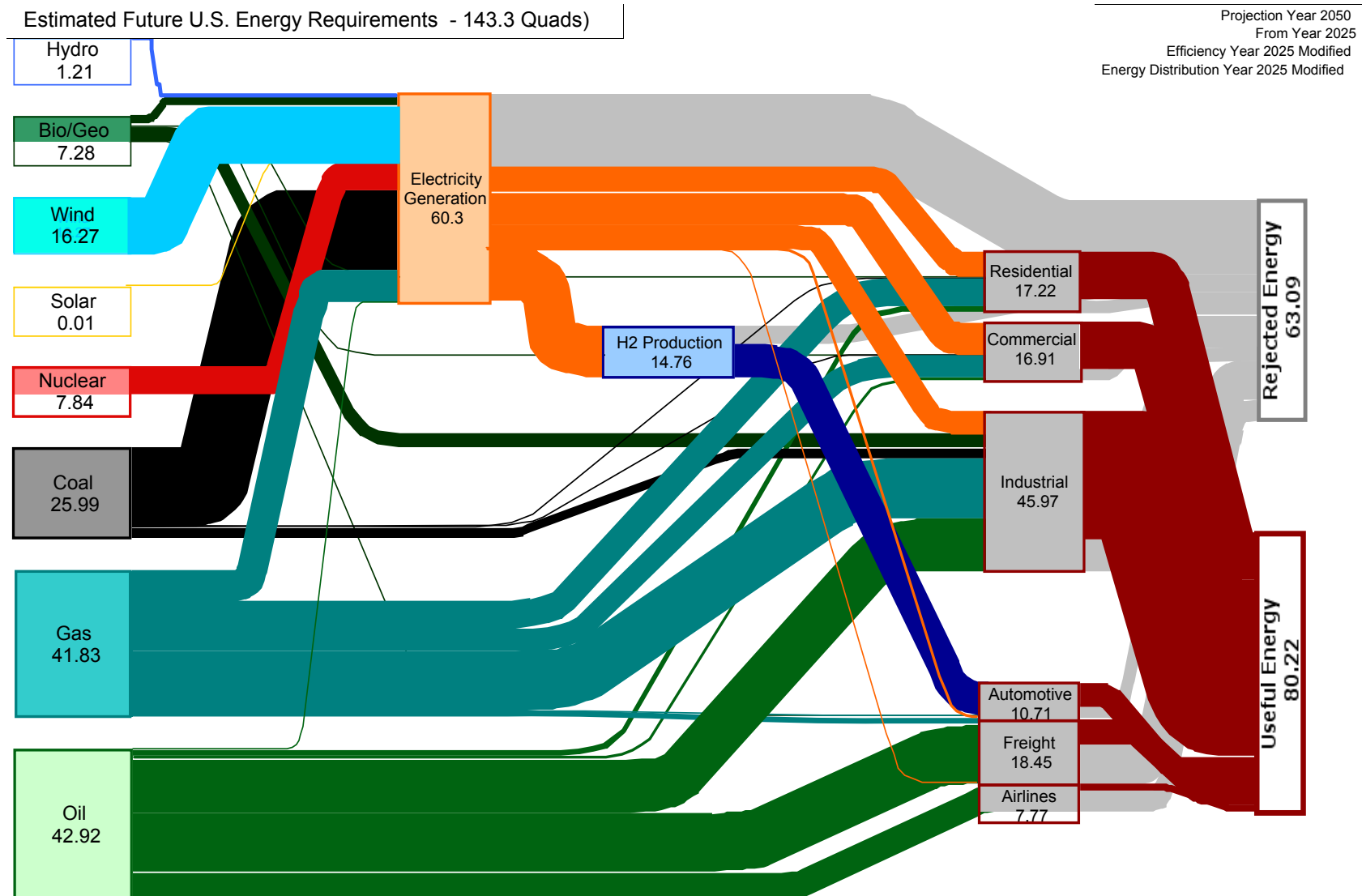
Frontier Line + Transwest Express ≈ 115 GW
Wind Potential ≈ 3,000 GW

ALL *Denmark's energy from windpower*

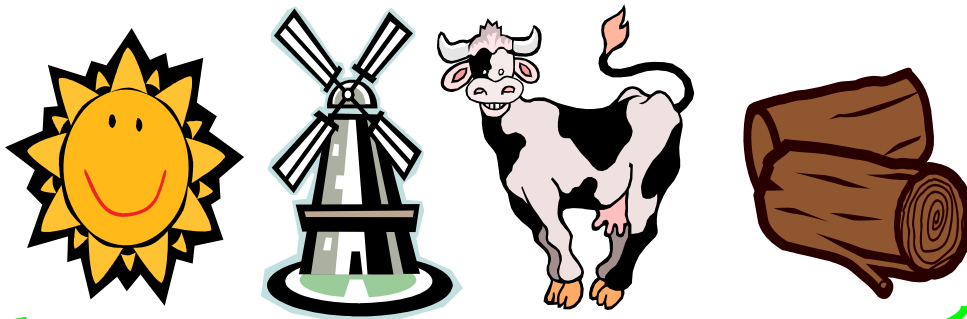
- *Prof Bent Sorensen, Roskilde Univ, DK*
- *WHEC, Montreal, June 02*
- *ALL Denmark's energy from wind –*
 - ▶ *Elec, oil, gas*
 - ▶ *Transport, space heat-cool, industry*
- *IF convert ~ 15% to H₂, store in extant salt caverns*
- *Can USA do same?*
- *Start with transport fuel ?*



Estimated 2050 energy use (H₂ fleet using wind electrolysis)



EC: The NATURALHY concept



H₂

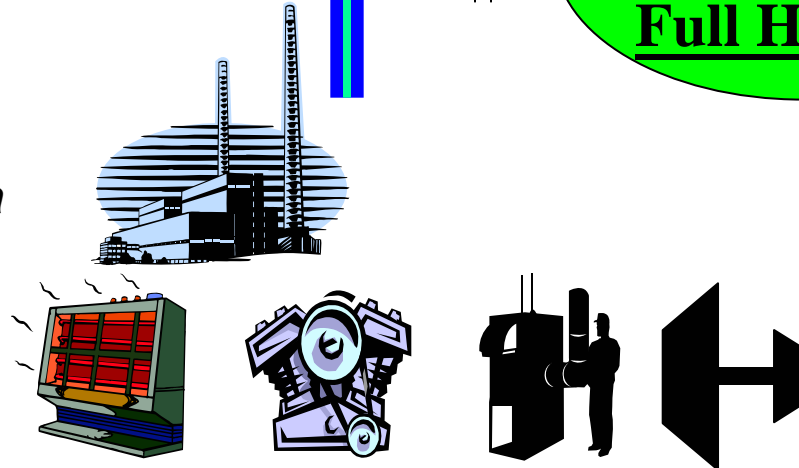


N.G.



NATURALHY:

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





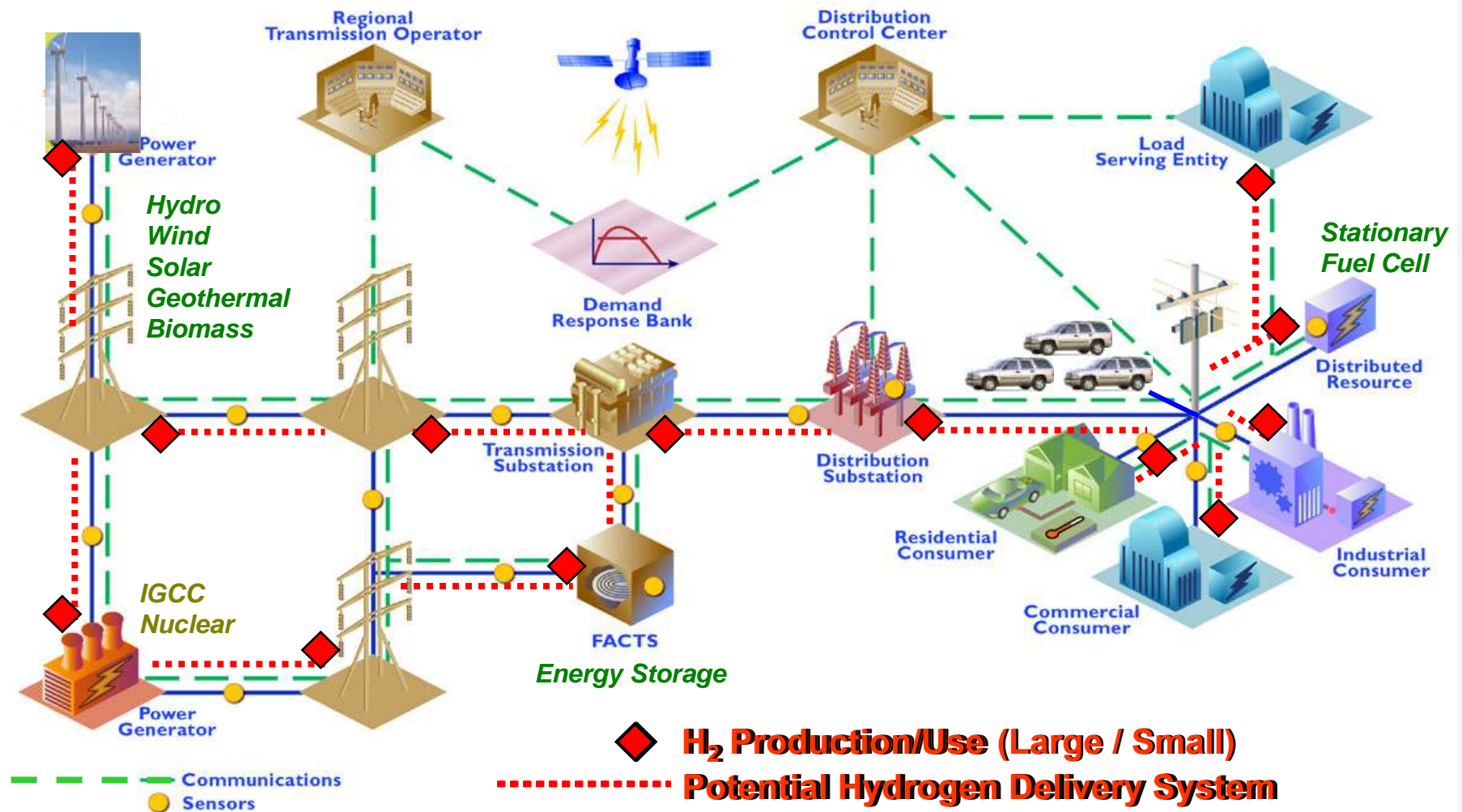
Hydrogen, Fuel Cell Running on water ?



www.qtw.com

***Hydrogen - fueled
2005 Prius
ICE Hybrid***

Energy System of the Future

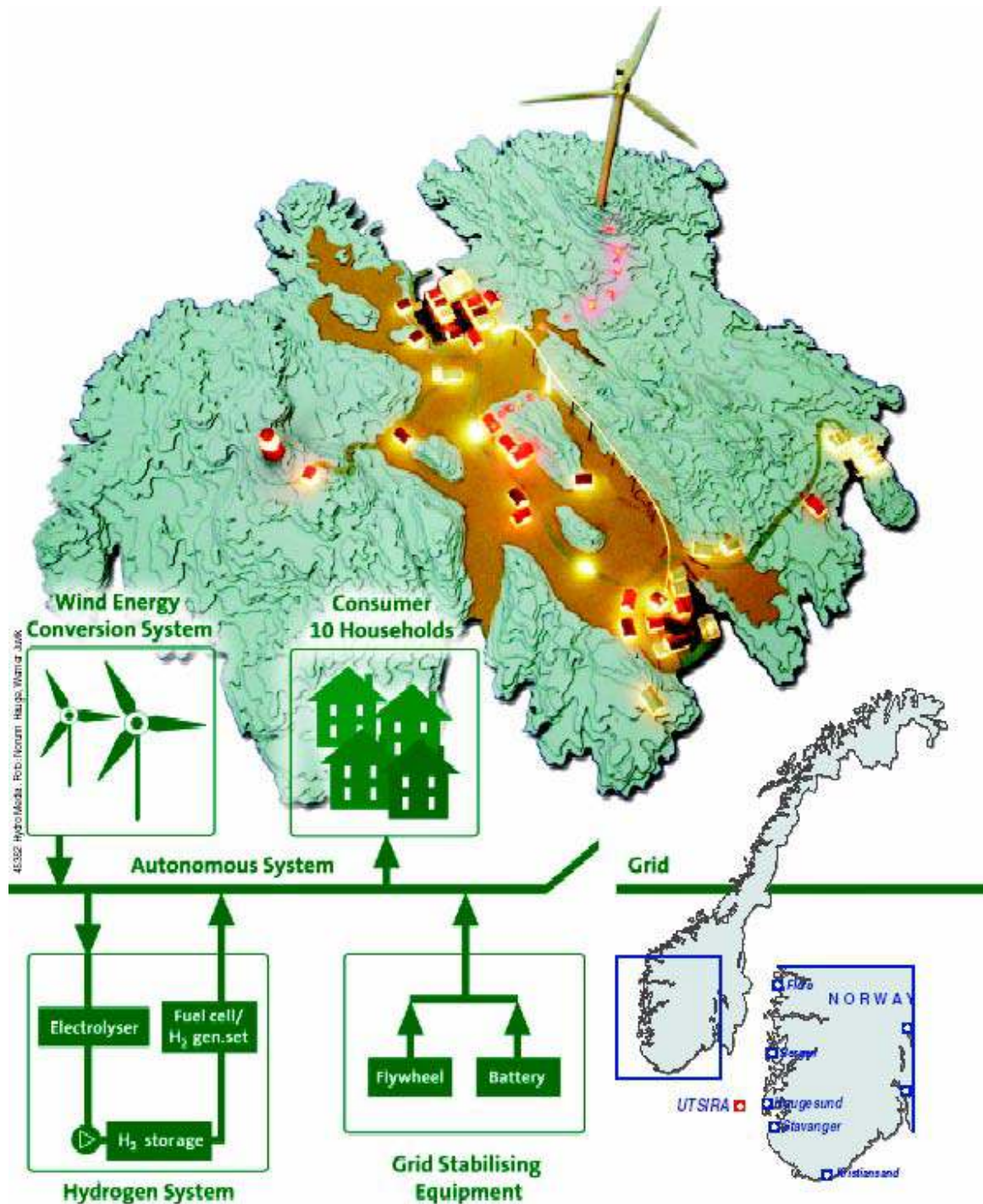


Frank Novachek, Director Corporate Planning



Utsira Island, Norway





Utsira Island

Norway

Wind – Hydrogen Autonomous System

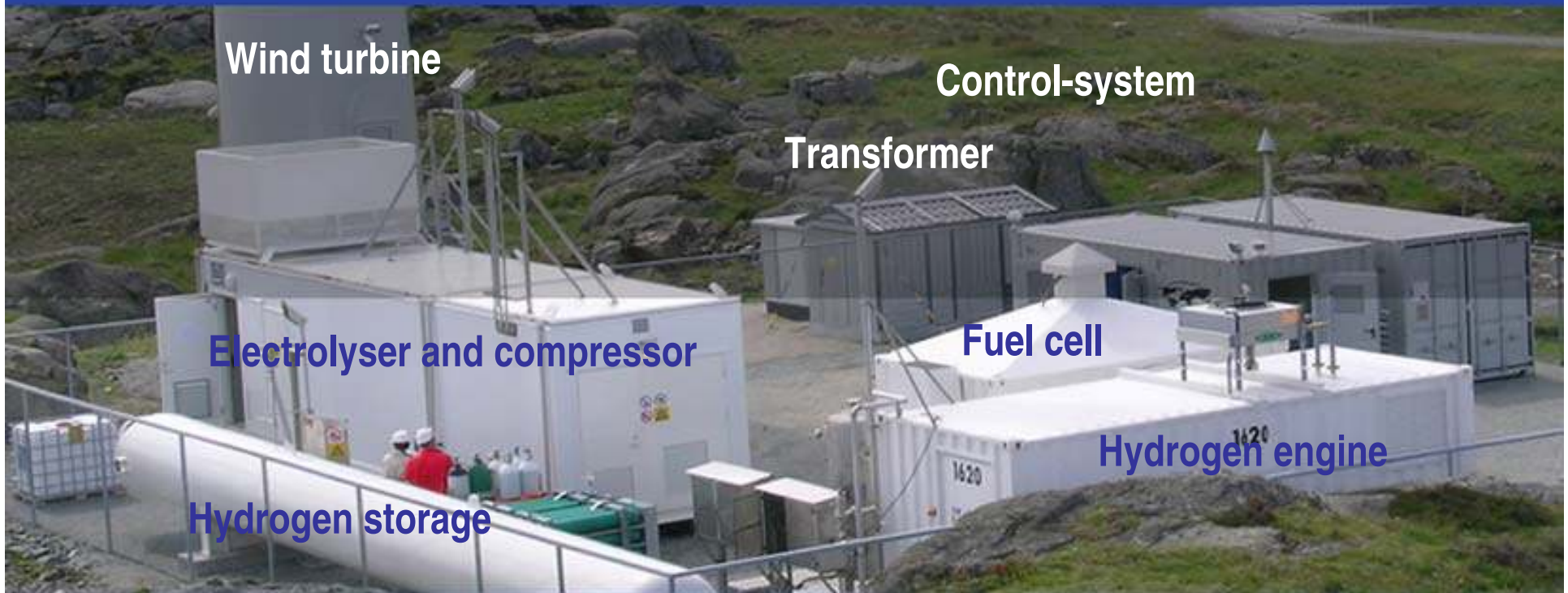
Replaces aging
electricity cable
from mainland

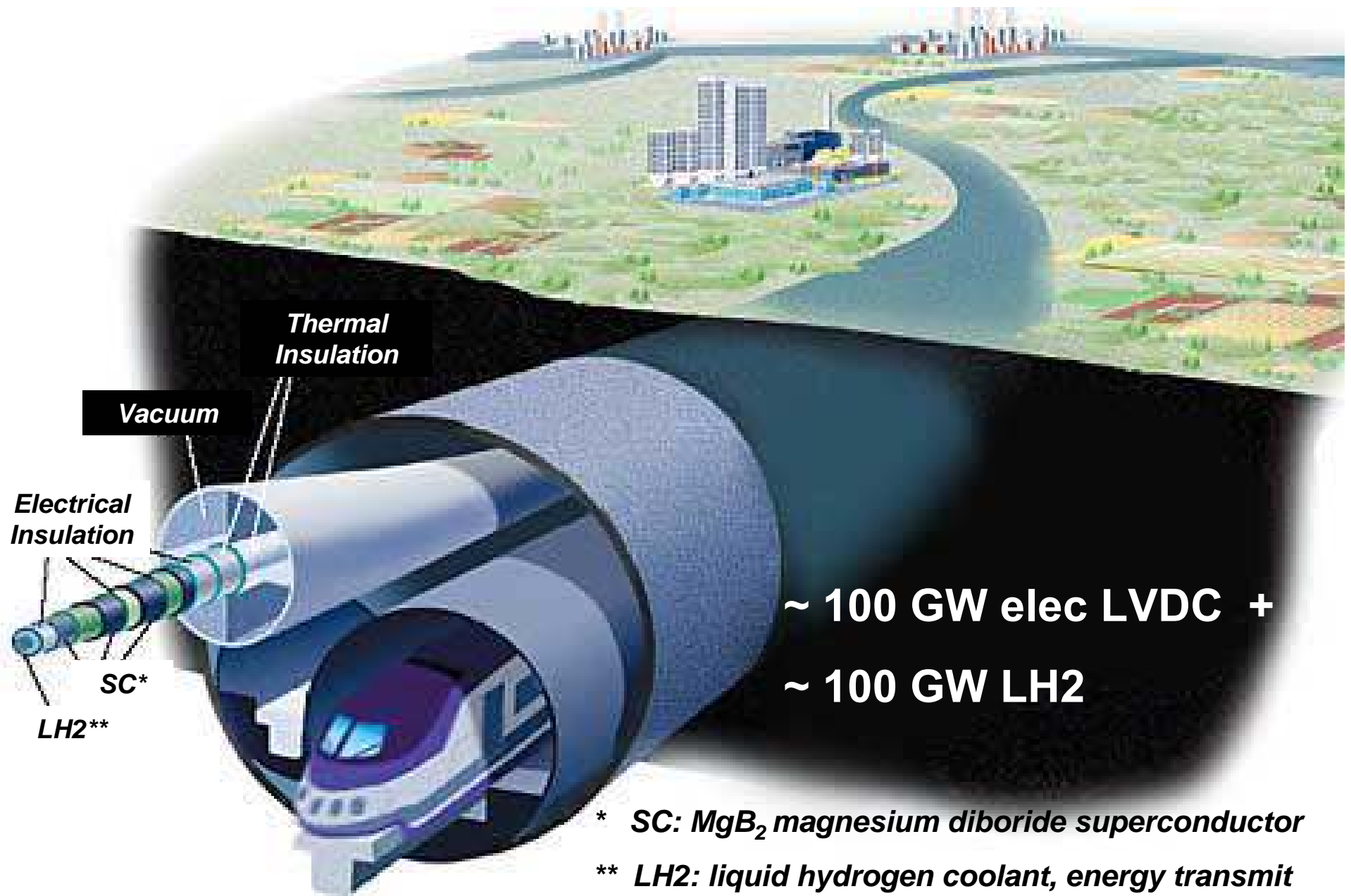


Utsira Island, Norway. 200 people. Isolated wind – hydrogen.

The wind – hydrogen plant at Utsira

A vision becoming reality

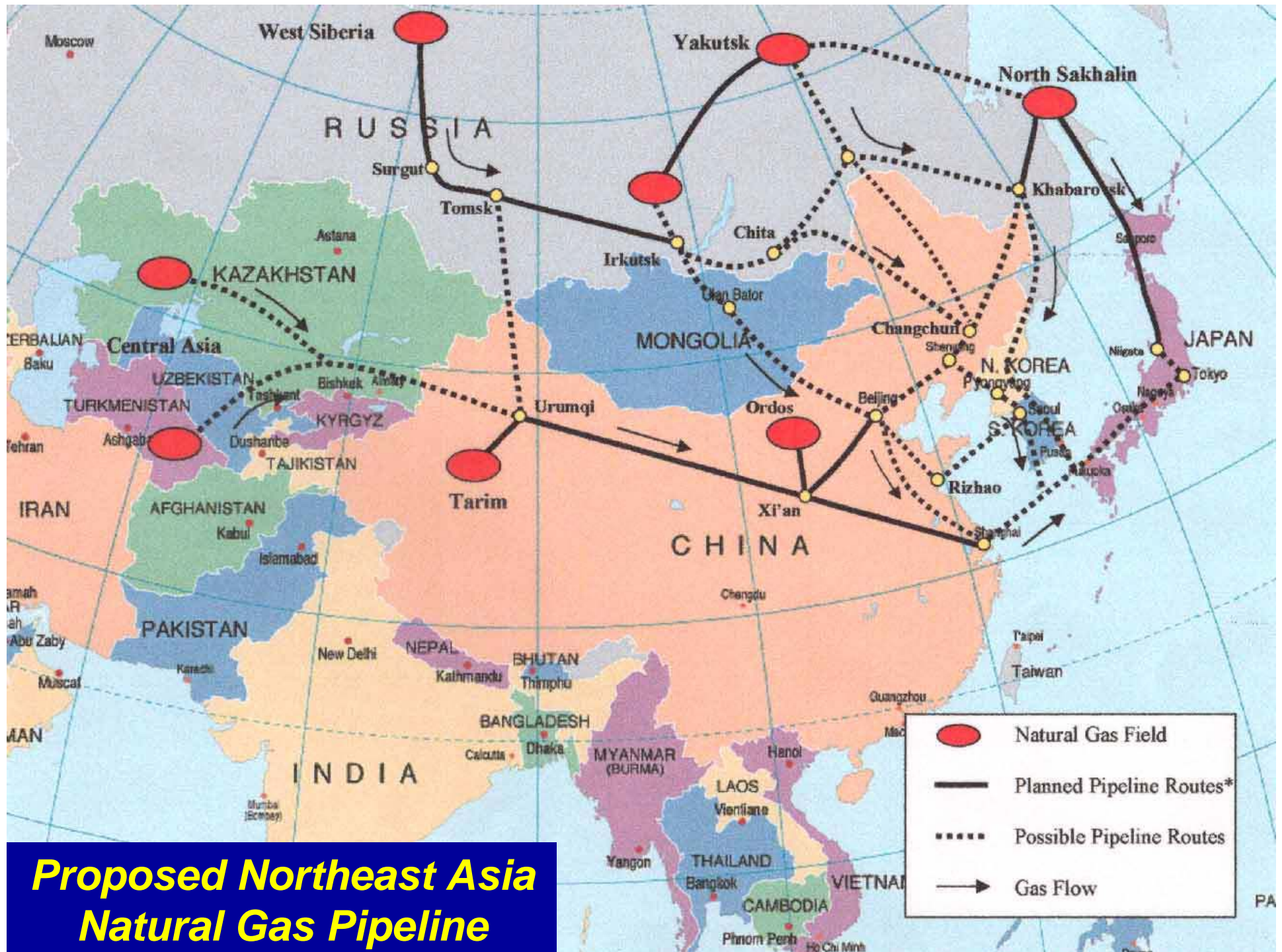




Continental Supergrid – EPRI concept “Energy Pipeline”

Airbus Industrie concept: liquid hydrogen fueled





4: Hydrogen's principal value

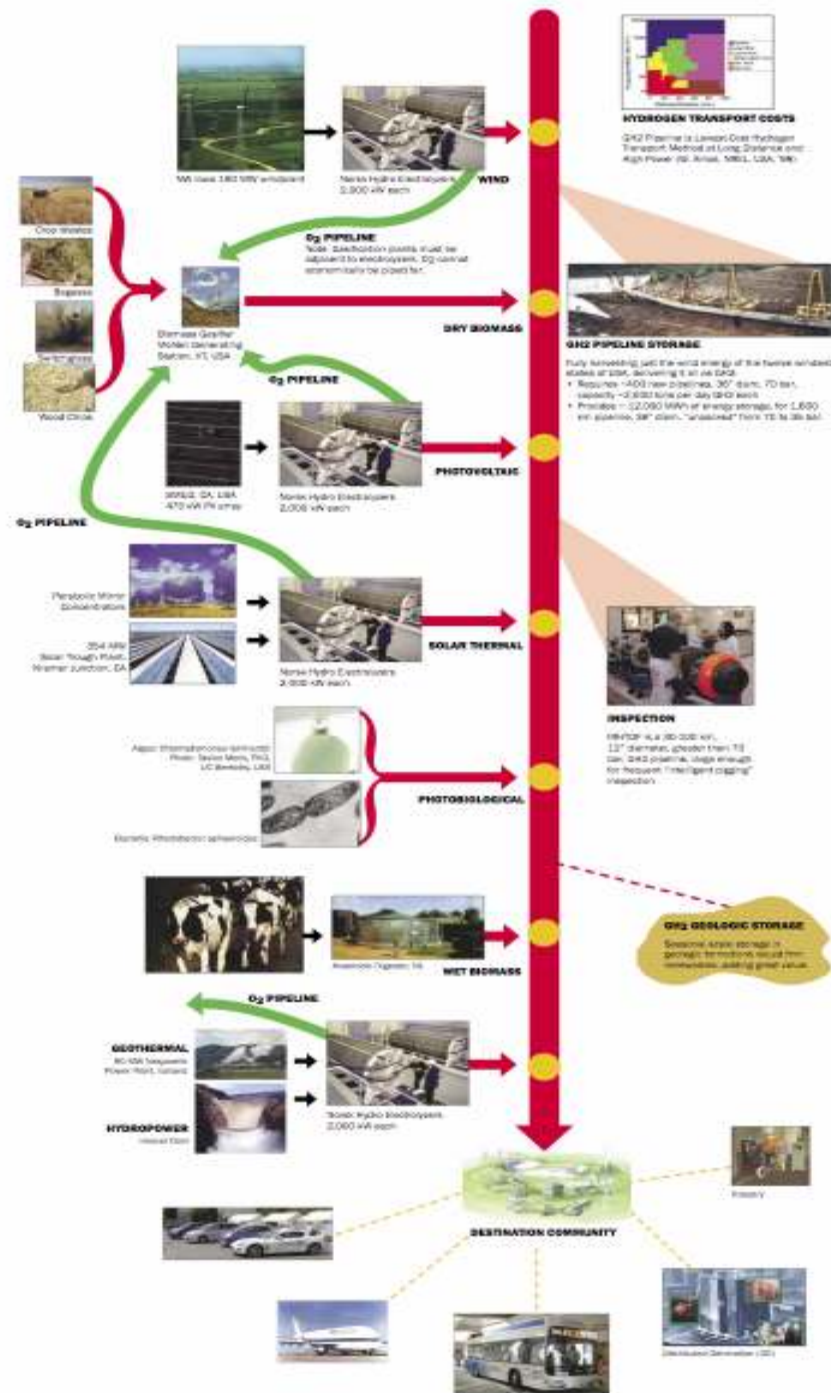
- NOT fuel cell cars
- Gather, transmit, store:
 - Large-scale, diverse, stranded renewables
 - FIRM time-varying-output renewables
 - Pipeline transmission, storage
 - Geologic storage
 - “Renewables – nuclear Synergy ...”, C. Forsberg
- Benign, if from renewables
- Global opportunity
- Hydrogen “sector”,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

5: Pilot plant needed

- **Every major new industrial process**
- **Diverse, large-scale, stranded**
- **Renewables-source systems**
- **IRHTDF**
- **Posters: Japan, Canada, IPHE**

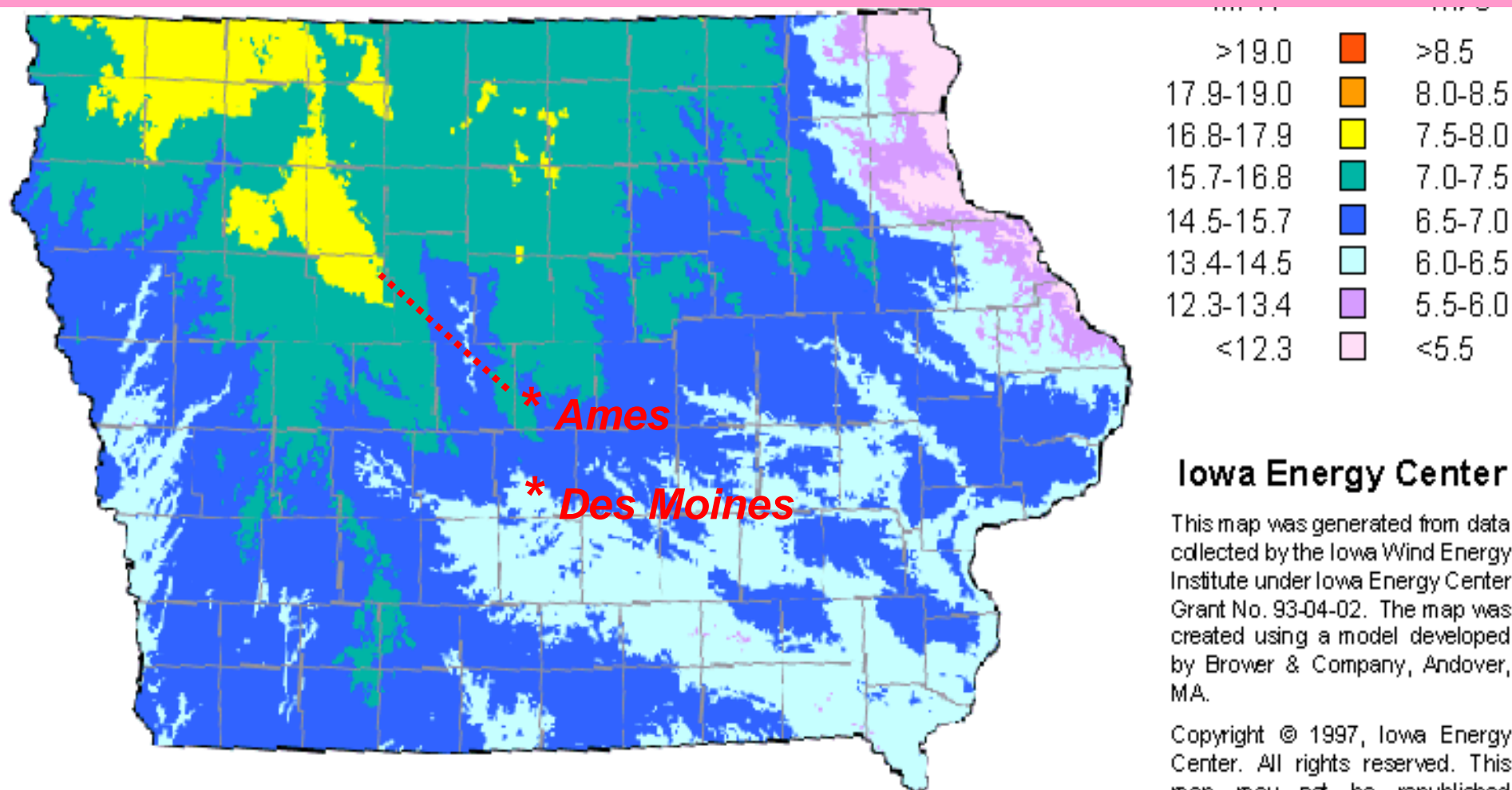
***The Second
Solar Civilization***

***Alaska
should begin to
build it***

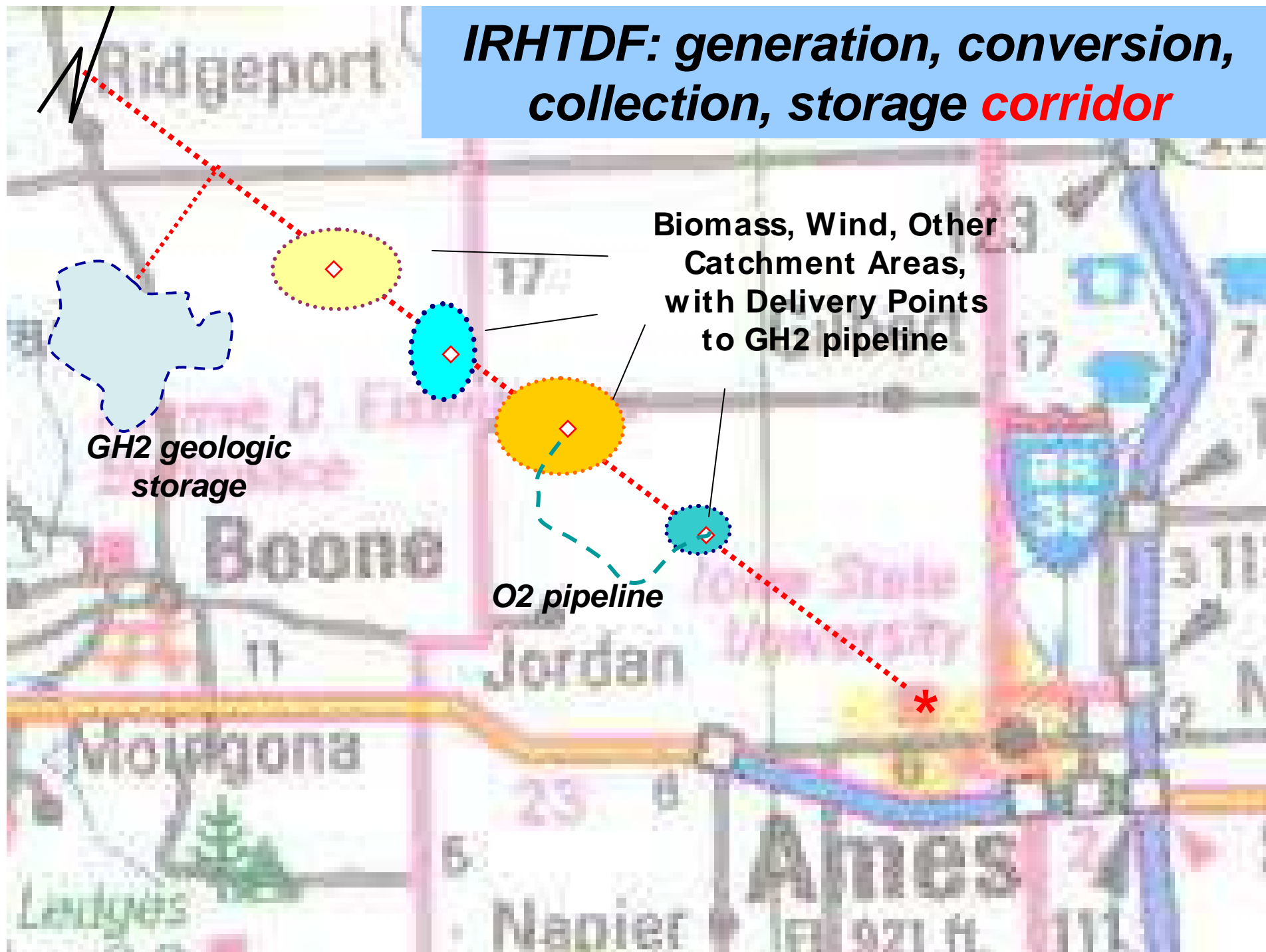


IRHTDF

International Renewable Hydrogen Transmission Demonstration Facility



IRHTDF: generation, conversion, collection, storage *corridor*





1: Adequate Renewables, IF

- 1. “Efficient” capture + conversion equipment**
 - Technical**
 - Economic**
 - Low “plant gate” COE**
- 2. Transmission**
- 3. “Firming” storage**
- 4. Optimum CF via good system design**
- 5. Competitive delivered COE**

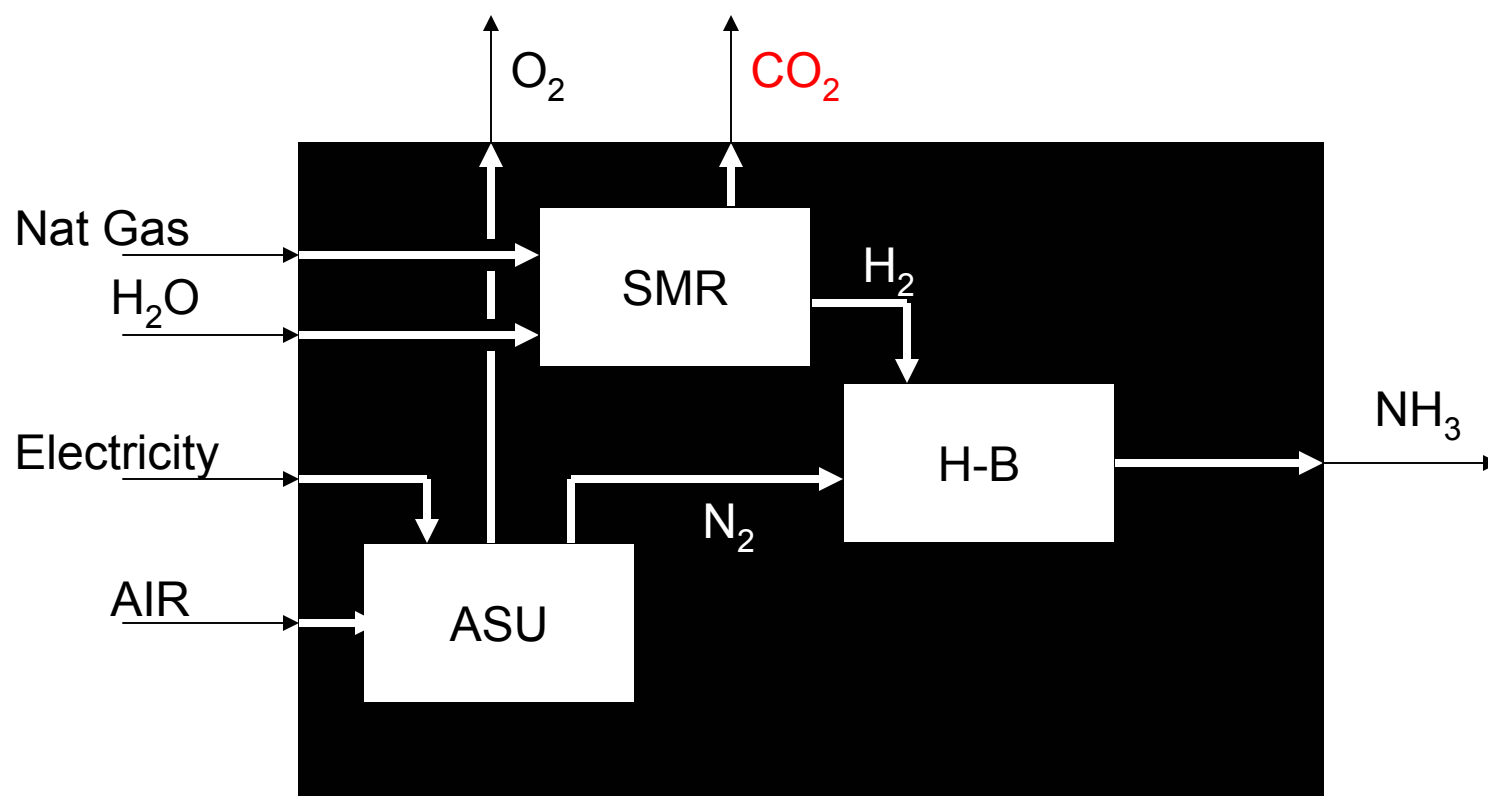


***Ammonia
(NH_3)
Synthesis
Plant
Natural Gas
Feed***

1 – 3,000 tpd

***Haber-Bosch
“Synloop”***

Inside the Black Box: Steam Reforming + Haber-Bosch

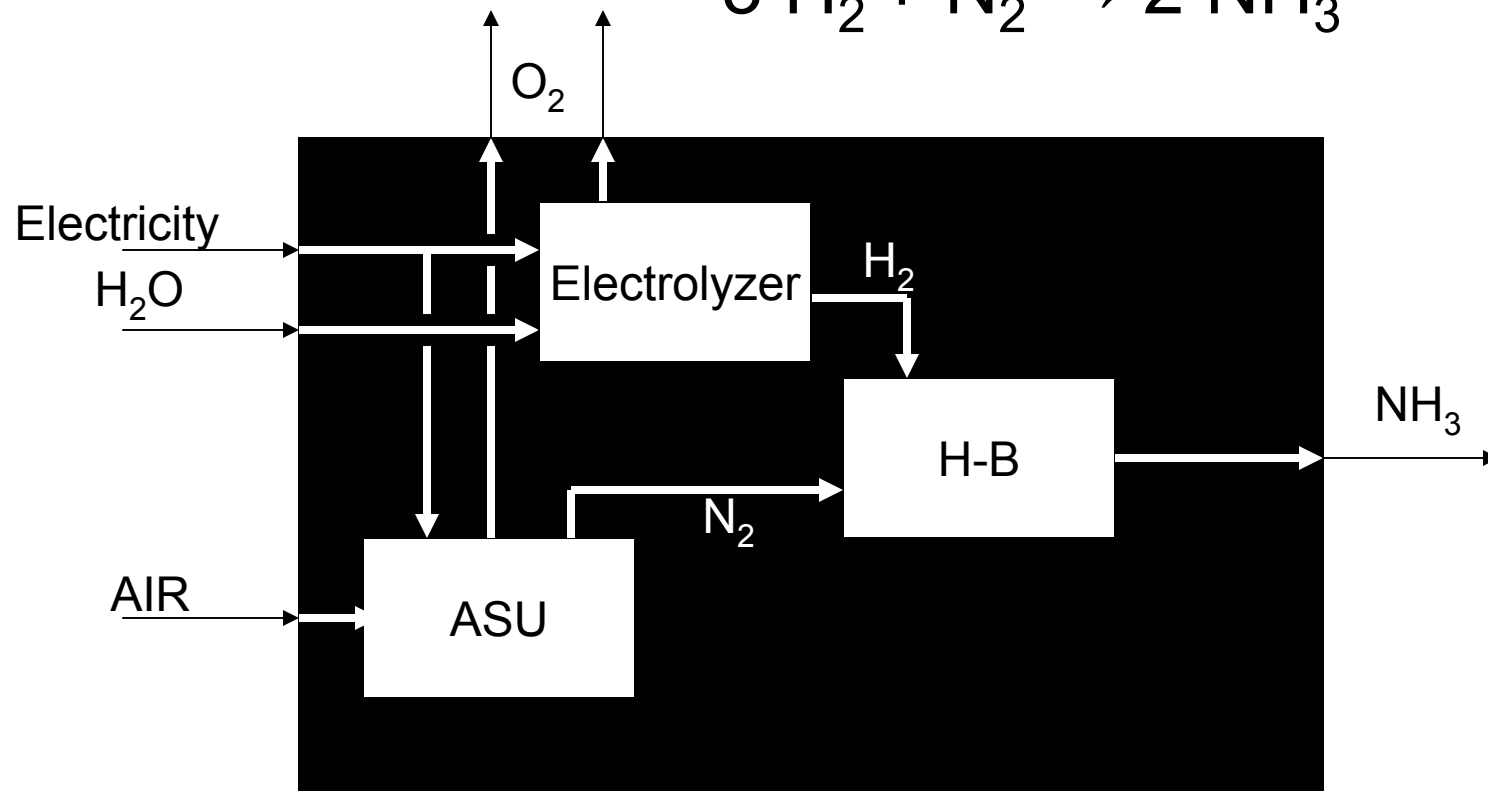
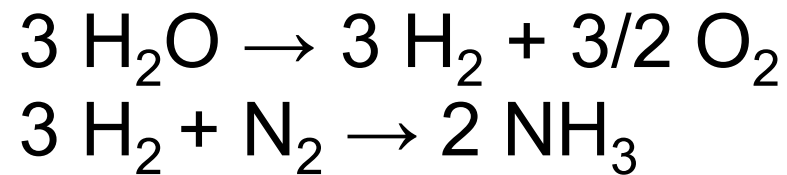


Energy consumption ~33 MBtu (9500 kWh) per ton NH₃

NH₃ Ag Fertilizer Tanks, Wind Generators, NW Iowa

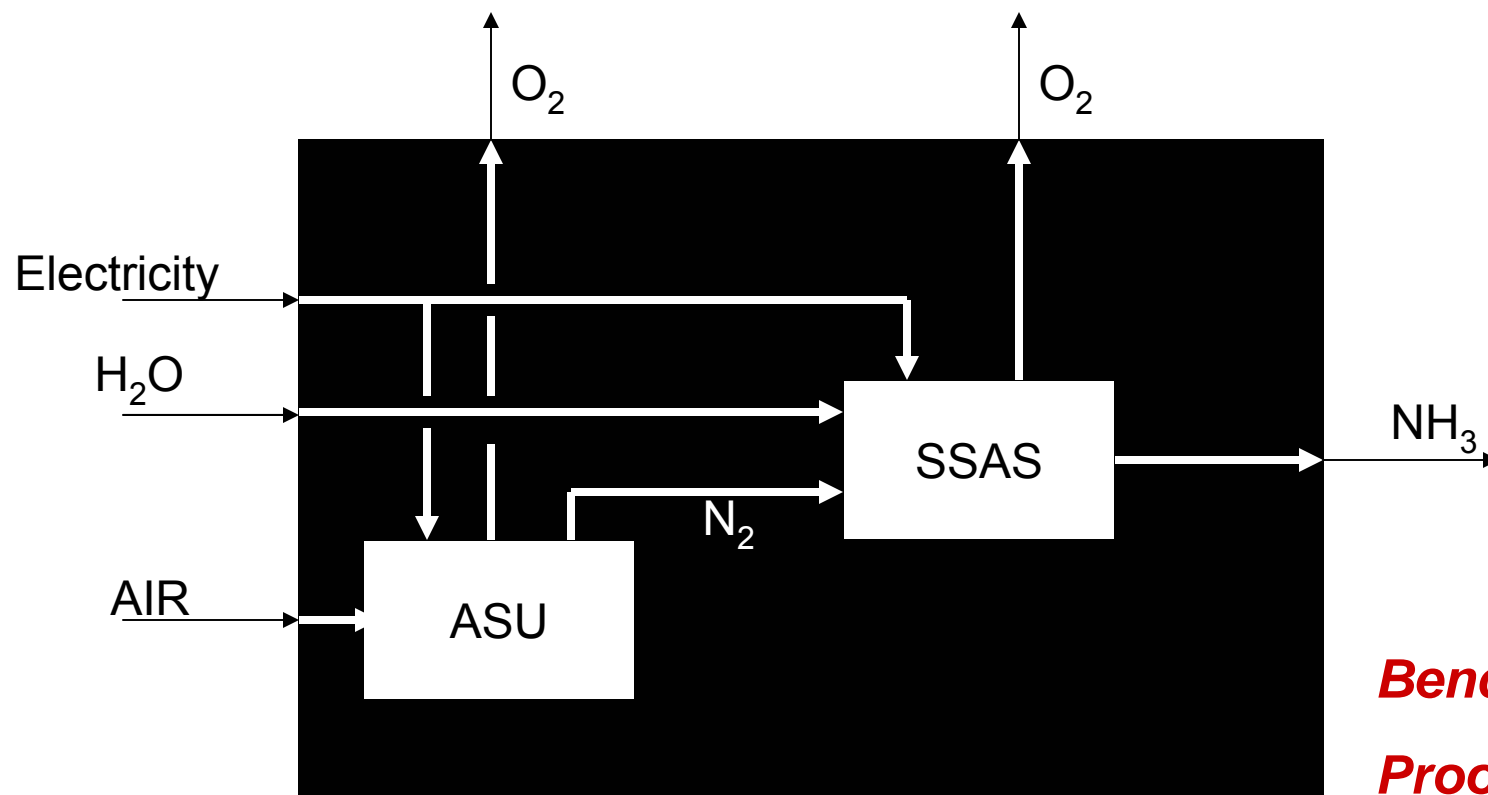
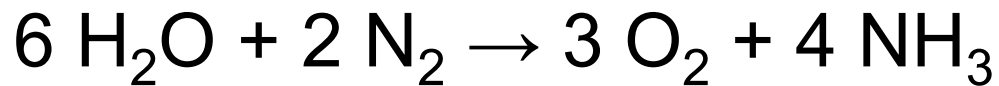


Inside the Black Box: HB Plus Electrolysis



Energy consumption ~12,000 kWh per ton NH₃

Inside the Black Box: Solid State Ammonia Synthesis



***Benchtop
Proof-of-concept***

Energy consumption 7000 - 8000 kWh per ton NH₃

***Ammonia-fueled ICE, irrigation pump, Visalia, CA
Installed Nov 06***



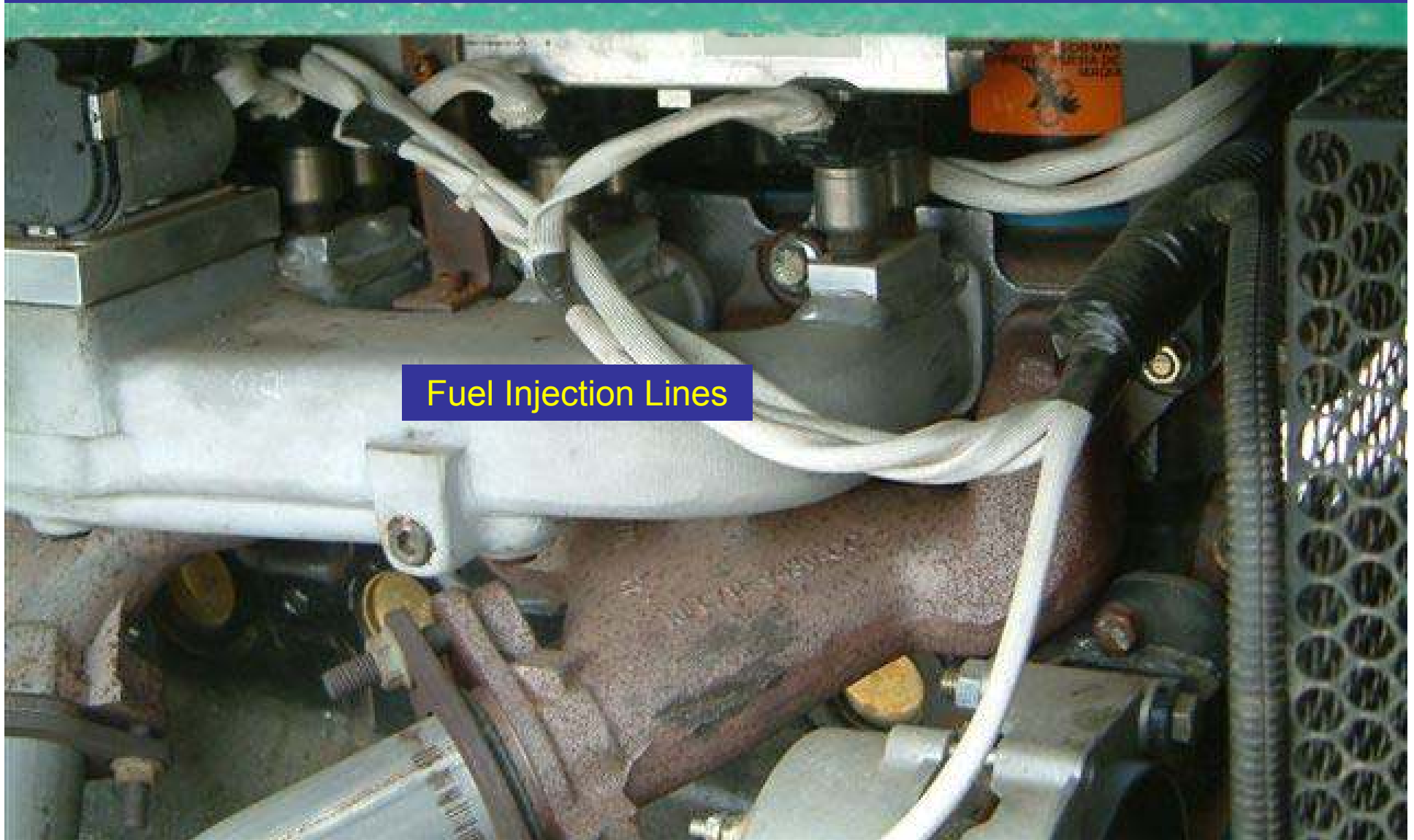
***1,000 hours, ICE, 6 cyl, 100 hp
75% ammonia, 25% propane***



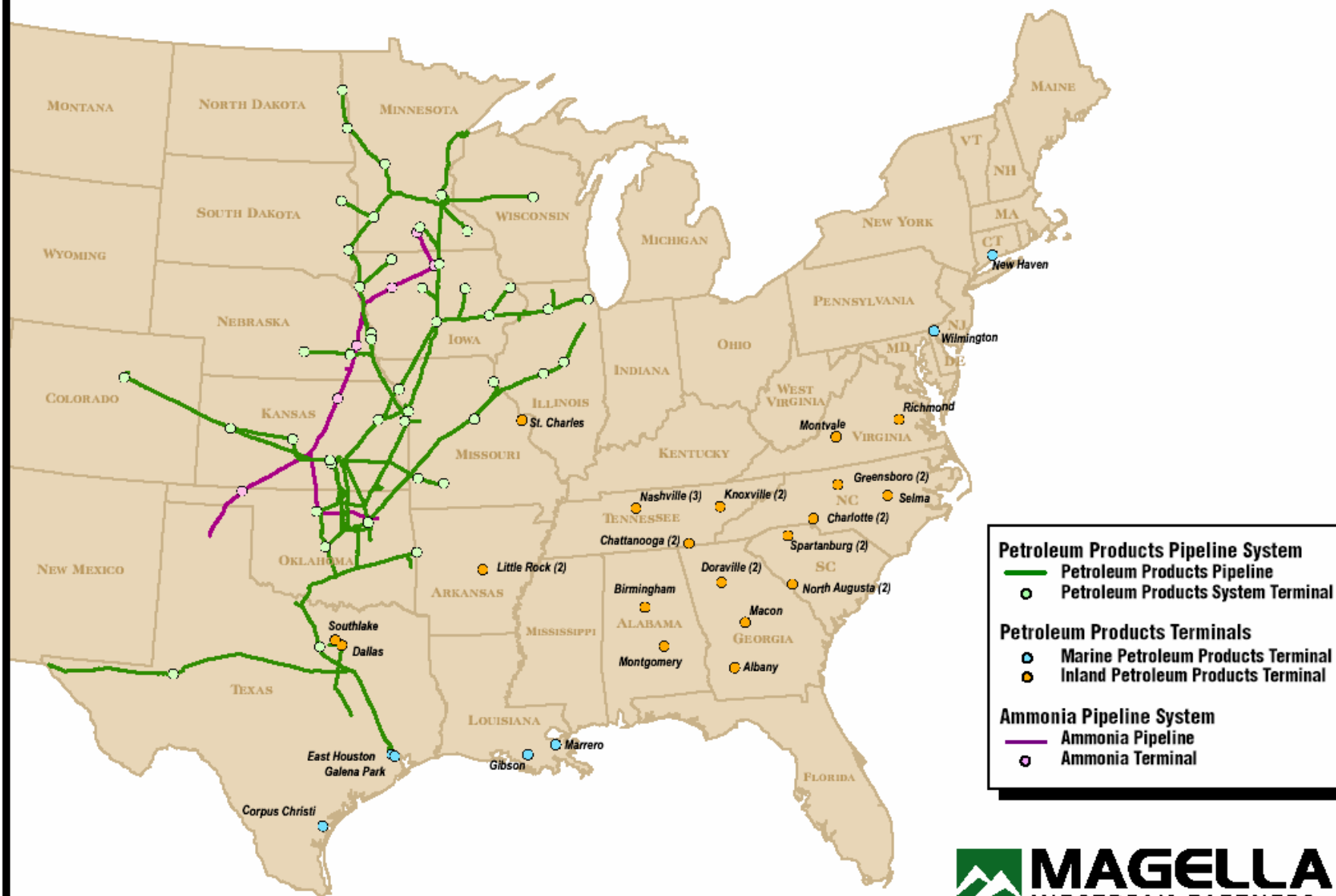
Hydrogen Engine Center, Algona, IA
1,000 hours, ICE, 6 cyl, 100 hp
75% ammonia, 25% propane

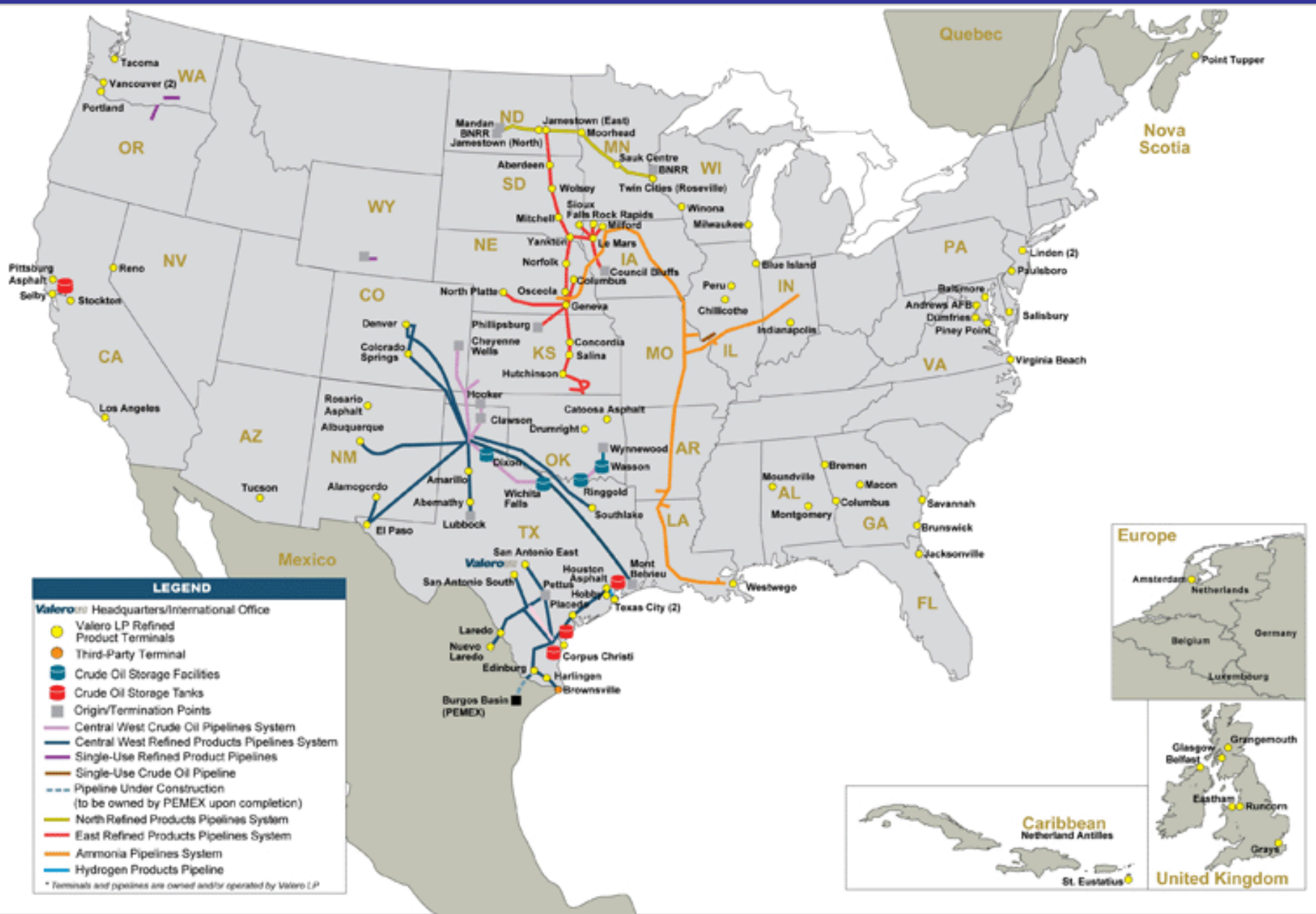


Hydrogen Engine Center, Algona, IA
Fuel Injected ICE, 6 cyl, 100 hp
75% ammonia, 25% propane

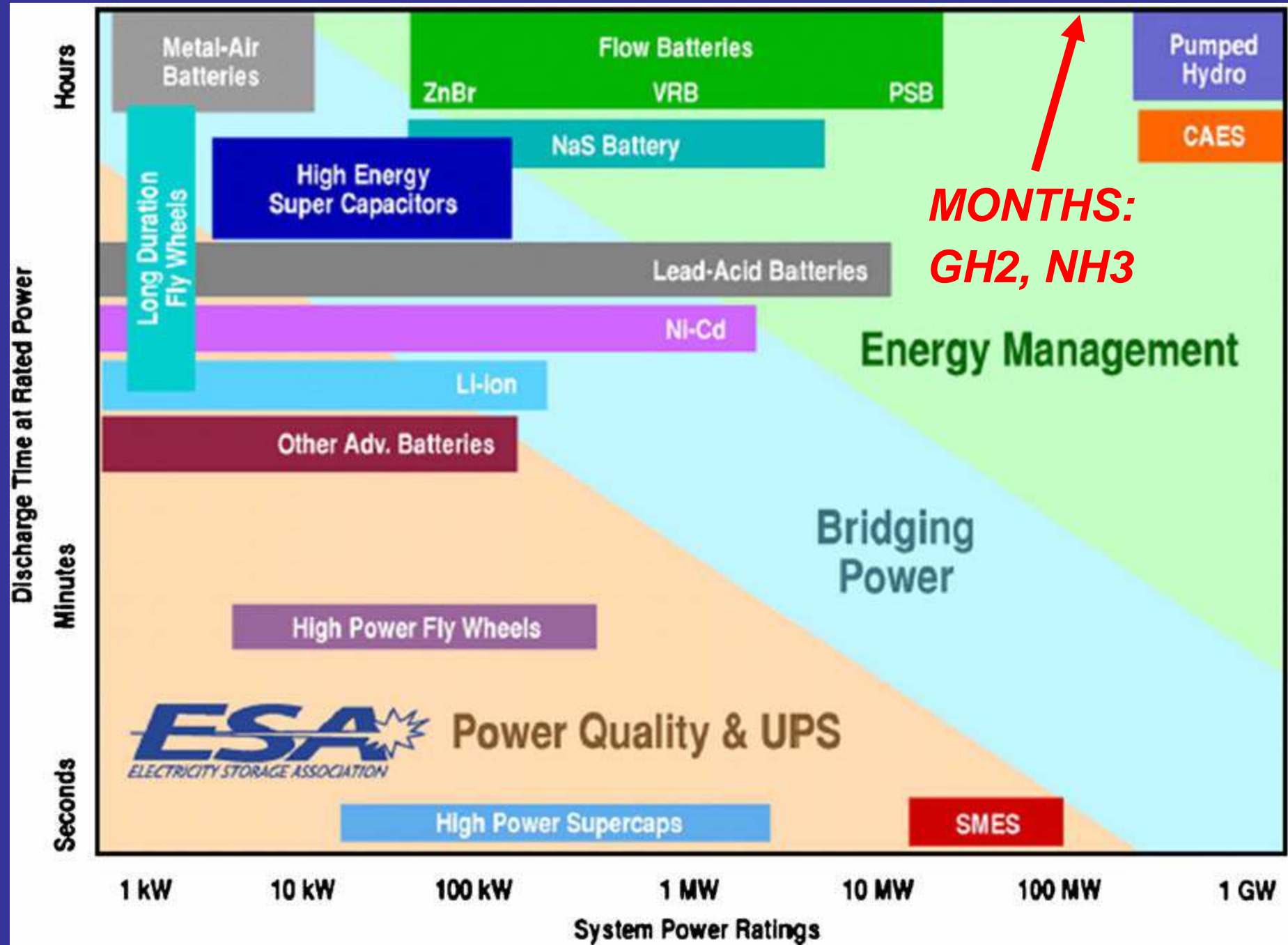


Asset Portfolio





Valero LP Operations





“Atmospheric”

***Liquid
Ammonia
Storage Tank***

30,000 Tons

190 GWh

\$15M turnkey

\$77 / MWh

-33 C

1 Atm



Ammonia
534 kg H₂
\$ 10,000

Hydrogen gas
350 kg H₂
\$ 400,000



“Ammonia Nation ?”

Anhydrous ammonia (NH₃)

- Low-cost transmission, storage: liquid
- Transportation fuel
- Stationary generation, CHP
- Total USA annual energy '02 - 06
 - 100 quads
 - 10,000 TWh
- More renewables than coal
- Coal limits:
 - Only 200 year supply ?
 - CCS limits: where to put the CO₂ ?

320,000 MWh storage
Annual firming, 1,000 MW wind

- **VRB**
 - O&M: 80% efficiency round-trip
 - Capital: \$500 / kWh = **\$160 Billion**
- **CAES**
 - O&M: \$46 / MWh typical
 - Iowa: Power = 268 MW
Energy capacity = 5,360 MWh
Capital: 268 MW @\$800 / kW = \$214 M
@\$40 / kWh = **\$13 Billion**
- **GH2** Capital **\$70 Million**
- **NH3** Capital **\$30 Million**

Annual – scale “Firming” Great Plains Wind

- **Potential, 12 states, ~50% land area:**
 - 10,000 TWh = 100 quads = entire USA energy
 - 2,800,000 MW nameplate
- **Seasonality:**
 - Summer minimum
 - Spring – Summer maximum storage
 - “Firming” energy storage, per 1,000 MW wind:
 - as electricity = 450 GWh
 - as GH2 = 15,712 tons, metric @ 2,500 tons / cavern = 6 caverns
 - as NH3 = 87,291 tons, metric @ 60,000 tons / tank = 1.4 tanks
 - “Firming” energy storage, all great Plains wind:
 - as GH2 = 17,000 caverns @ \$15M each = \$264 billion
 - as NH3 = 5,000 tanks @ \$25M each = \$127 billion

Annual – scale “Firming” Great Plains Wind

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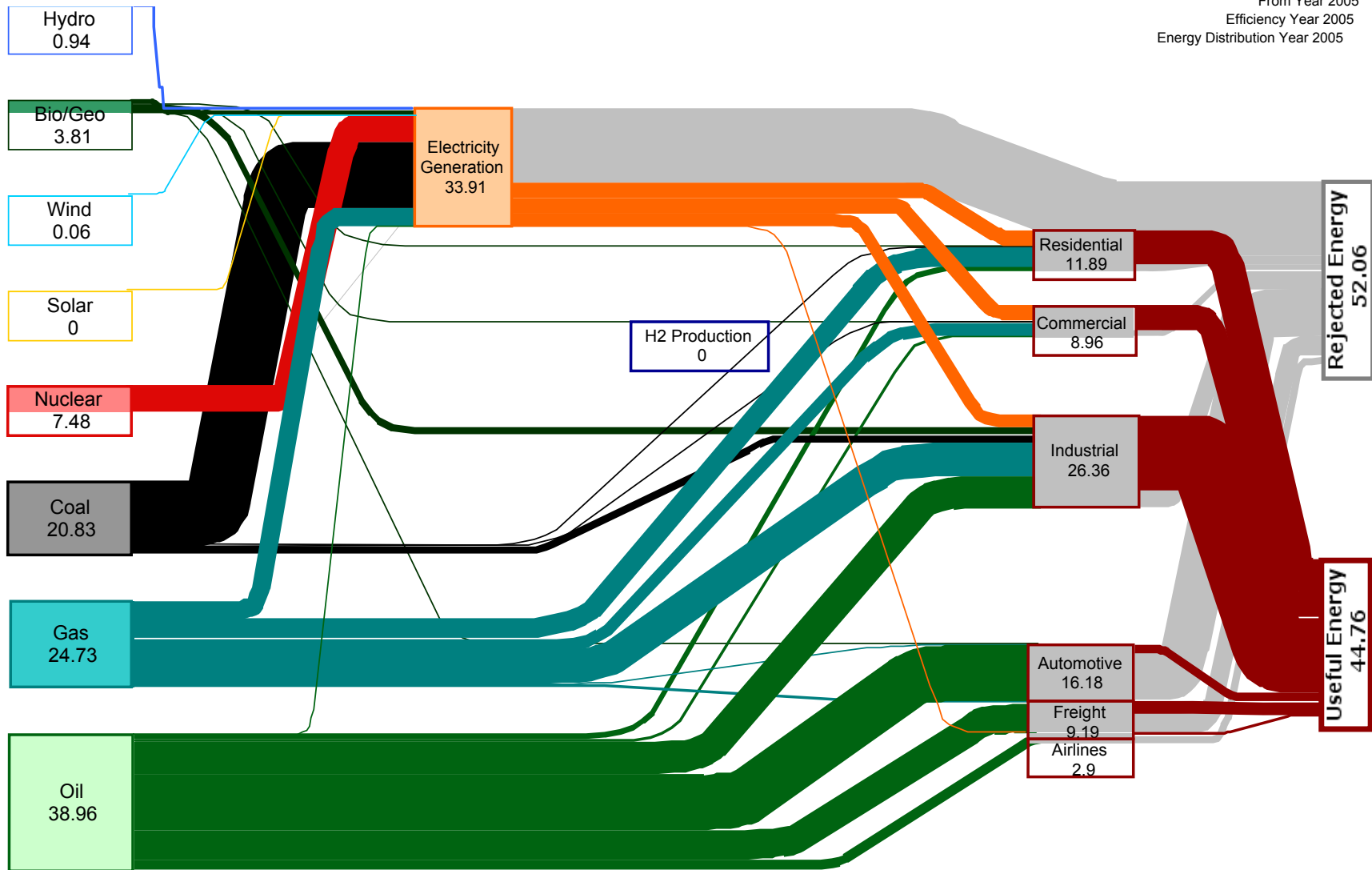
***Running the World on Renewables:
Energy Sustainability with
God on our side ?***



DOE-EIA: Estimated **2005** US energy use

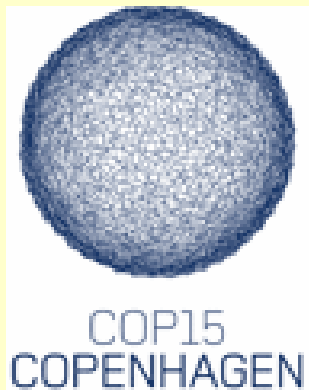
Estimated Future U.S. Energy Requirements - 96.8 Quads)

Projection Year 2005
From Year 2005
Efficiency Year 2005
Energy Distribution Year 2005



What can I do ?

- 350.org 24 Oct 09
- Learn, understand: invest in confidence
 - Energy: world, USA, local, self
 - GW / GCC: emergency?
 - DECIDE
- Invest in efficiency, conservation, lifestyle
- Drive a small car; buy a hybrid
- Drive NO car; public transit
- Join: IRENEW, UCS, NRDC, ED,
- Many others – connect
- No new coal plants; retire old ones
- Congress: strong climate protection law by Copenhagen
- Ag: Land Institute



UNITED NATIONS
CLIMATE CHANGE
CONFERENCE
DEC 7-DEC 18
2009

- **15th Conference of the Parties (COP15)**
- **United Nations Framework Convention on Climate Change (UNFCCC)**
Opened for signature on May 9, 1992, at Rio Earth Summit
In force March 21, 1994 “... to achieve stabilization of greenhouse gas concentrations in the atmosphere at a low enough level to prevent dangerous anthropogenic interference with the climate system “
- **Intergovernmental Panel on Climate Change (IPCC)**
- **Successor to Kyoto Protocol**
- **Ban Ki-moon: “We sink or swim together”**



WE'RE HERE:
385.92 ppm

**WE NEED TO
GET BELOW:**
350 ppm

www.350.org

CO₂ in the Atmosphere



John
Madden



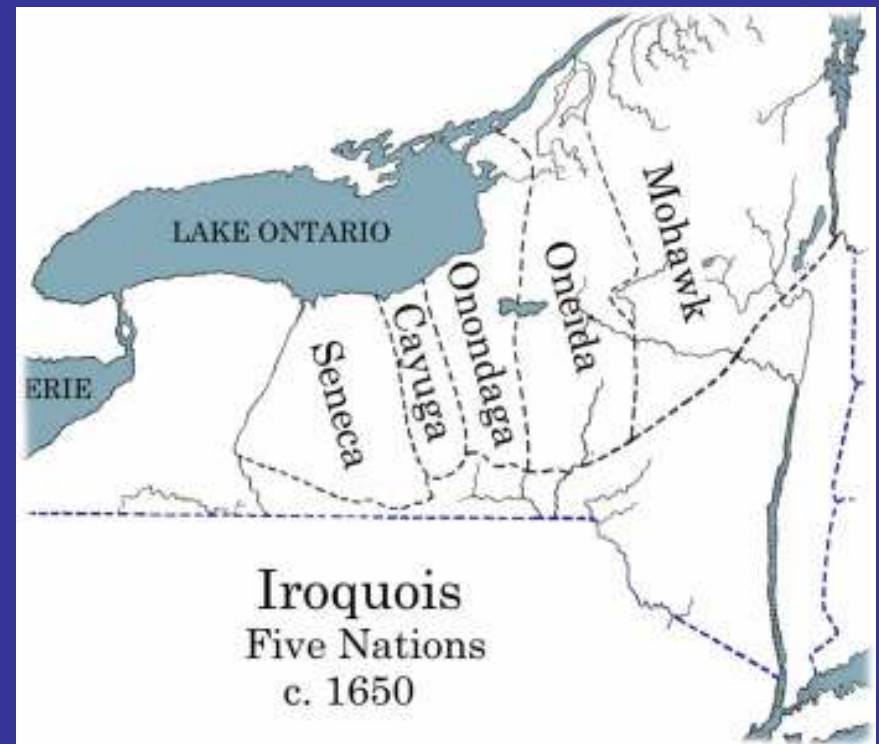
“Toughness is seeing what you don’t want to see,
hearing what you don’t want to hear,
and doing what you don’t want to do...
with enthusiasm.”



Iroquois in Buffalo, New York, 1914

**“ In every deliberation,
we must consider the impact
on the seventh generation...
even if it requires having skin
as thick as the bark of a pine.”**

— Great Law of the Iroquois



GAIA theory: Earth is a single living organism



James Lovelock



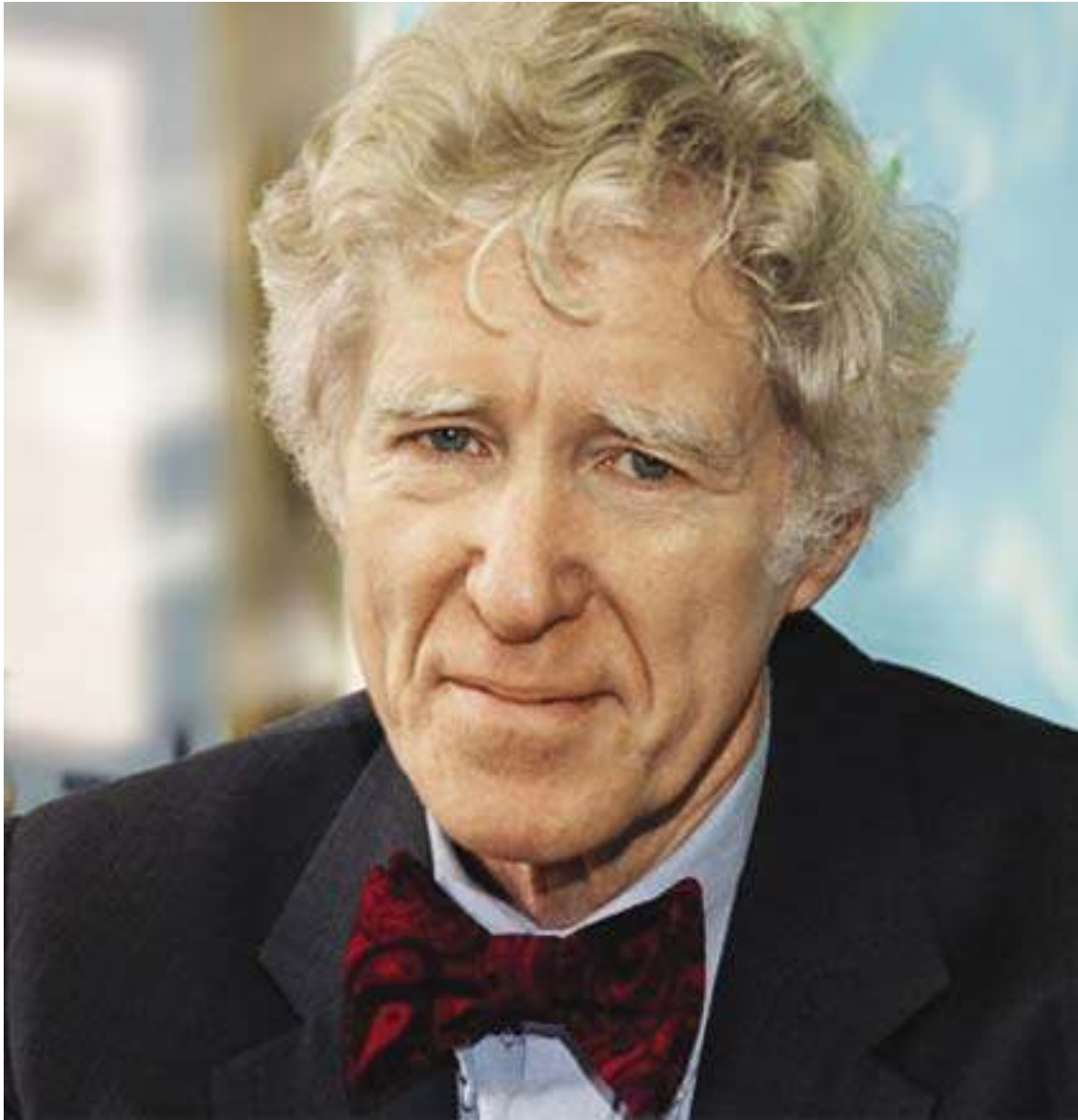


Garrett Hardin

1915 – 2003

1968, Science

***“The Tragedy
of the
Commons”***

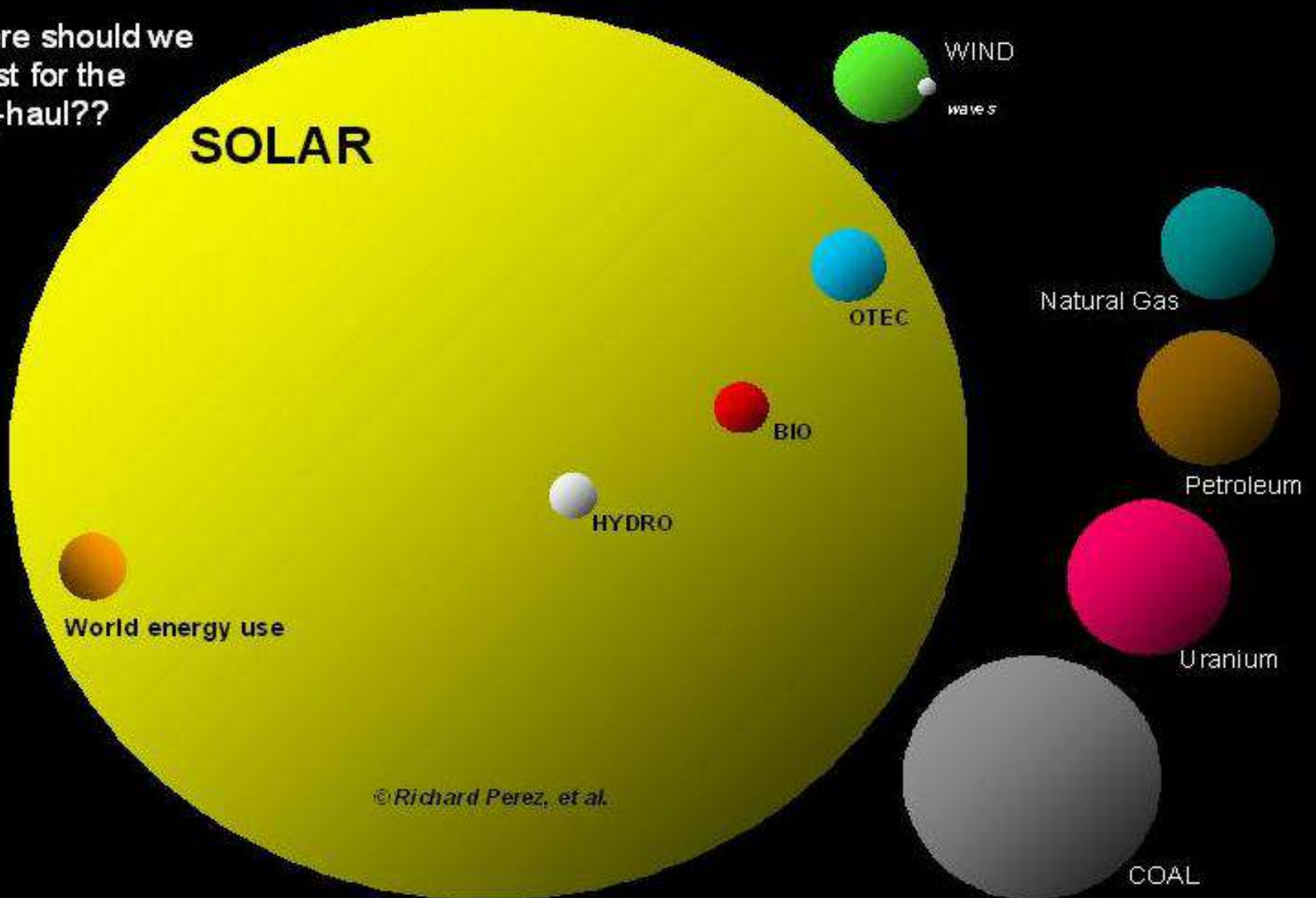


Plan B 4.0: Mobilizing To Save Civilization

**Lester Brown
Earth Policy Institute**

Comparing the world's energy resources*

Where should we
invest for the
long-haul??



**yearly potential is shown for the renewable energies. Total reserves are shown for the fossil and nuclear "use-them, lose-them" resources. World energy use is annual.*

What can I do ?

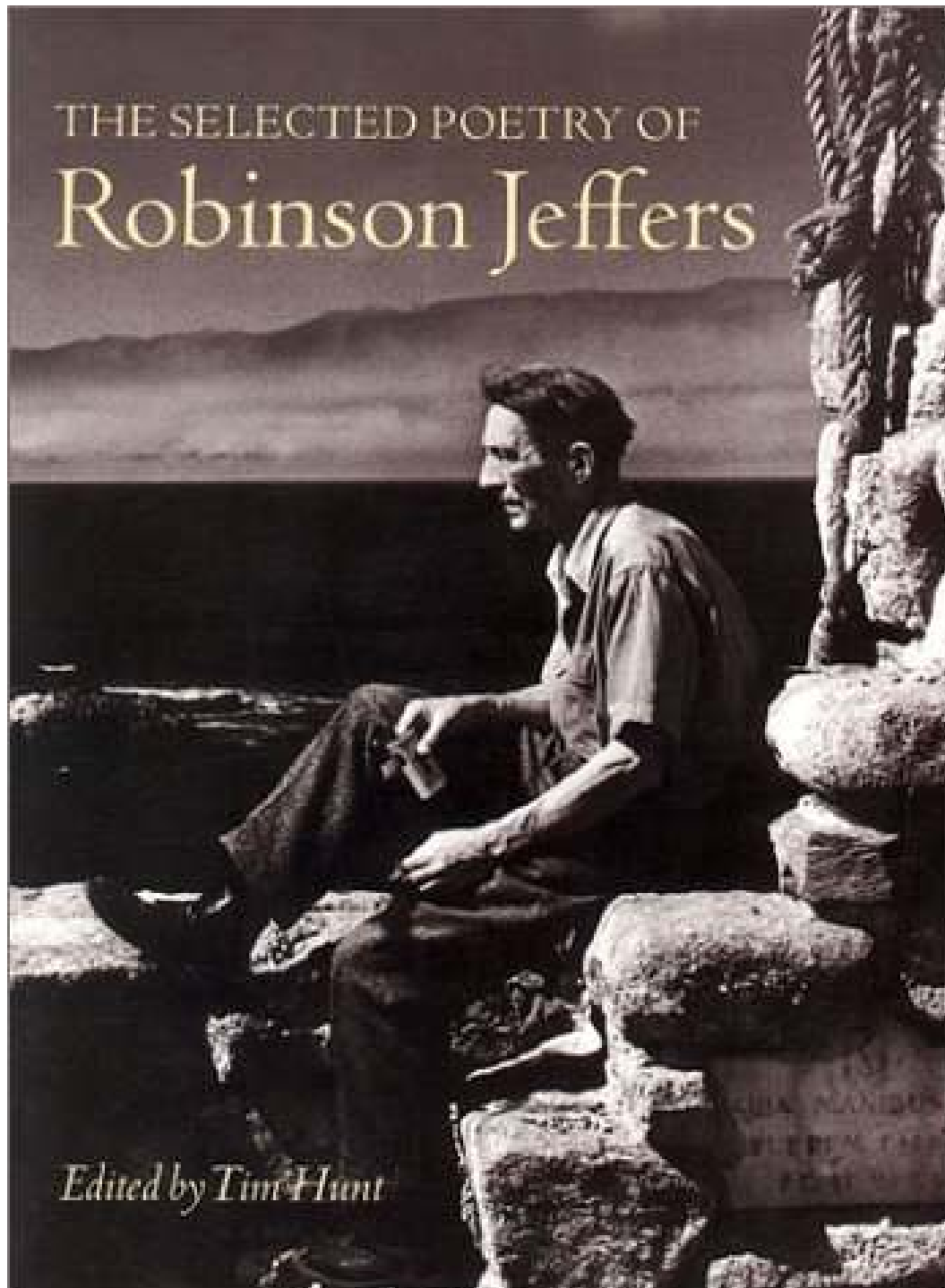
- “Toughness” Planet Manager, Earth Protector
- Tough, not enviro wimp
- Oct 24 action: 350.org
- Decide about climate change danger
- Help each other; get help: Your church, club, “circle”, college
- Imagine + build a New Myth
- Attitude and action
- Take responsibility
- Become Earth Protector and Planet Manager
- “Be the change you want to see in the world.” -- Gandhi
- Beyond blame, fear, hate
- NO bottled water
- NO new coal plants
- Green your investment portfolio
- Stop Iowa sprawl: KFOI
- Join renewables + conservation: IRENEW, other non-profit
- Imagine a world Beyond War
- Imagine a bigger patriotism – wear an Earth pin
- Market for green jobs

New Vision, Strategy, Action

- YOU, WE must decide: *L. de – cisio To cut away*
- Mobilizing to save civilization
- 60 days to Copenhagen COP15:
 - Need strong Senate “climate defense” bill
 - Empower Congress - be “tough”
- Run the world, and USA, on renewables
- Green jobs
- Agronomy: The Land Institute – perennial, herbaceous, seedbearing polyculture
- Conservation & efficiency best investments
- WWII response, sacrifice, investment

New Myth

- Beyond “Gott mit Uns”
- What “sustain” ?
- Responsibility: seventh generation
- Toughness: “ ... bark of a pine”
- GAIA
- Our Common Future. We are One. Global Commons
- Earth Protector and Planet Manager
- Unite to face common threat
- “Be the change you want to see in the world.” -- Gandhi
- Bigger loyalty, allegiance, patriotism – Earth pin, poster
- **Astronauts speak**
- **“... Not man apart ...”**



Integrity is wholeness,
the greatest beauty is
Organic wholeness,
the wholeness of life and
things,
the divine beauty
of the universe.

Love that, not man
Apart from that,
or else you will share
man's pitiful confusions,
or drown in despair
when his days darken.

Running the World on Renewables: Energy Sustainability with God on our side ?

DVD's, handouts

**Wartburg
College**

6 October 09

**Bill Leighty
The Leighty Foundation
wleighty@earthlink.net**

