Engineered Sequestration and Advanced Power Technologies. Klaus Lackner, Columbia University.

Predictions of innovative energy technologies for the next century usually include everything from fusion to photovoltaics with the one notable exception of fossil fuels. Because of fears of diminishing supplies, pollution and climate change, the public is reluctant to consider these hydrocarbon fuels for the energy needs of the twenty-first century. An energy strategy for the new century, however, cannot ignore fossil fuels. Contrary to popular belief, they are plentiful and inexpensive. While it is true that fossil fuels are limited by their environmental impact, new technologies to eliminate environmental concerns are currently being developed. Managing the emission of fossil carbon into the environment requires the capture of carbon dioxide and its permanent and safe disposal. Carbon dioxide could be captured at central plants that convert raw fossil hydrocarbons into carbon free energy carriers like electricity and hydrogen. Alternatively, carbon dioxide could be captured directly from the air, which would compensate for emissions from myriad distributed and often mobile sources. Power conversion plants that capture their own carbon dioxide for subsequent disposal lend themselves naturally to designs that have no emissions at all to the air and thereby avoid conventional flu-stack cleanup. Carbon dioxide capture from the air appears feasible and, if demonstrated to be economical, it would allow for the carbon neutral use of fossil fuels in cars and airplanes. With air capture it is also possible to introduce sequestration without having to abandon the existing infrastructure. Since carbon dioxide and hydrogen can be transformed into hydrocarbons, air capture of carbon dioxide combined with renewable energy resources opens the door to recycling carbon in an energy-material cycle that is analogous to the water/hydrogen cycle proposed for a hydrogen economy.

Engineered Sequestration and Advanced Power Technologies

Does Carbon Have a Future?

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New York, NY

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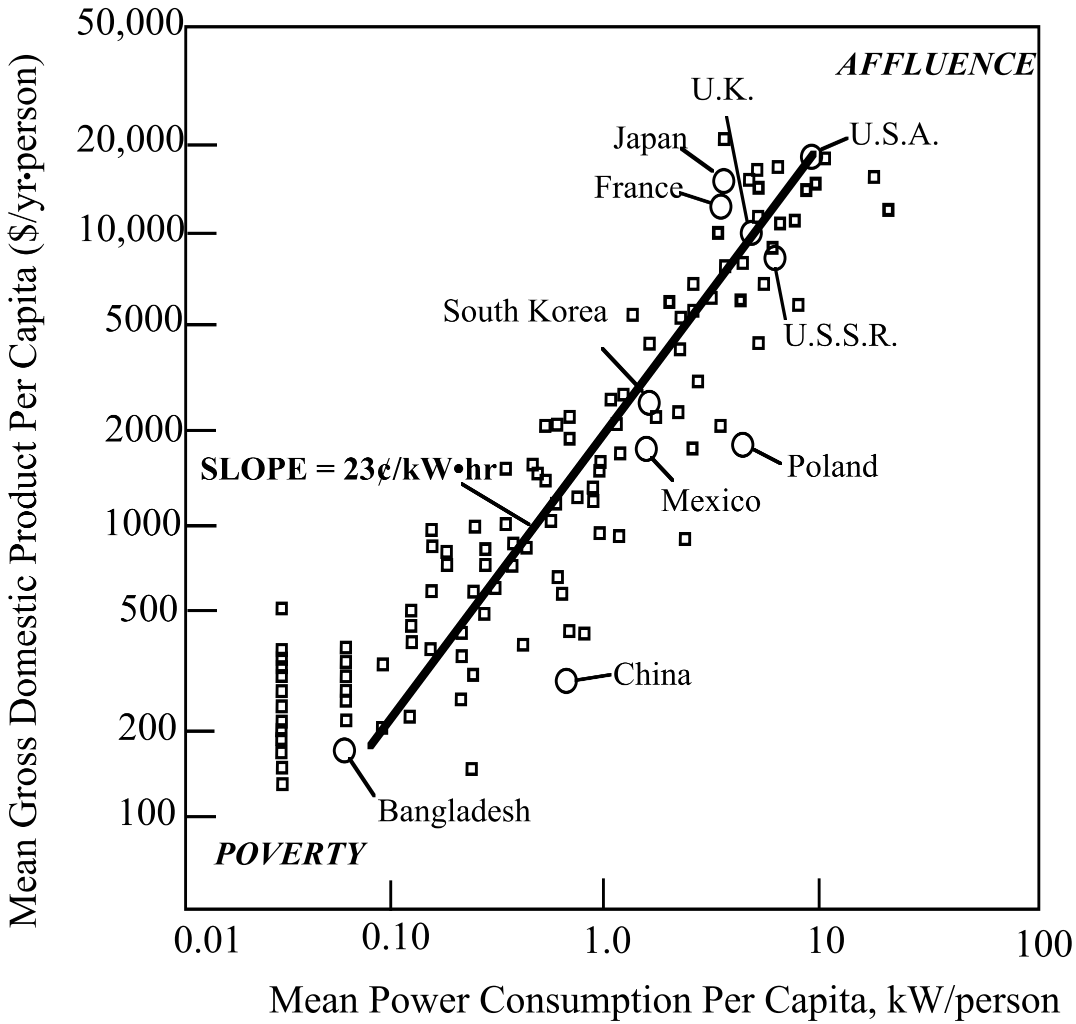
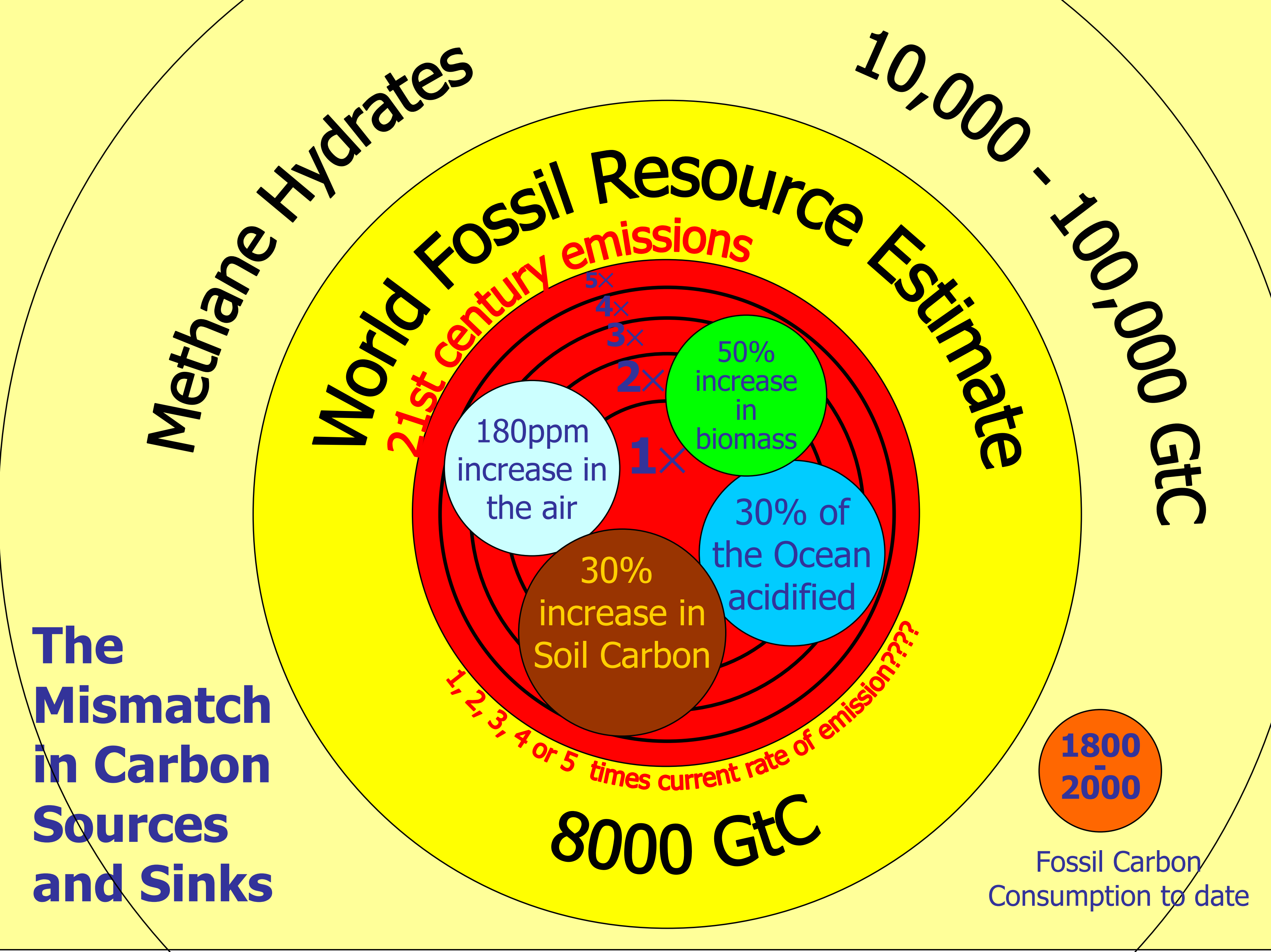
World Needs Low Cost Energy



Fossil Energy contributes 80 to 90% of the total World Energy

Cannot eliminate the biggest resource from the world market

10 billion people trying to consume energy as US citizens do today would raise world energy demand 10 fold



Methane Hydrates
10,000 - 100,000 GtC
World Fossil Resource Estimate
21st century emissions
5×
4×
3×
2×
1×
50% increase in biomass
180ppm increase in the air
30% of the Ocean acidified
30% increase in Soil Carbon
1, 2, 3, 4 or 5 times current rate of emission????
8000 GtC
The Mismatch in Carbon Sources and Sinks
1800 - 2000
Fossil Carbon Consumption to date

The Scale of the Problem

- The scales of C-sequastration is the challenge
  - A few million tons of CO_2 is easy
- order of magnitude implies qualitative change
  - Move from 10s of Gigawatts to 10s of Terawatts

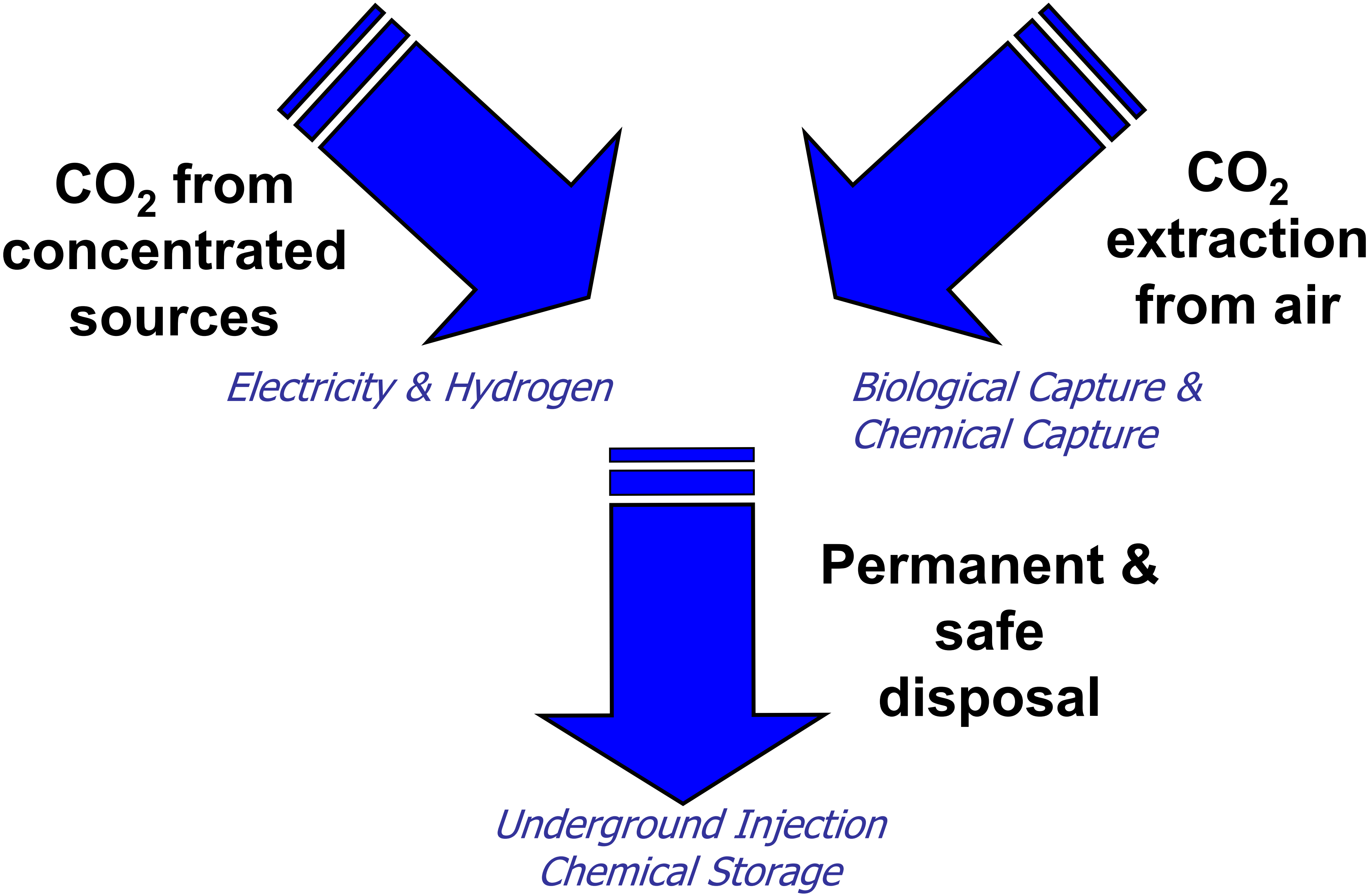
Increases by a factor of ten:

Pedestrian : Automobile : Airplane

Lake Michigan

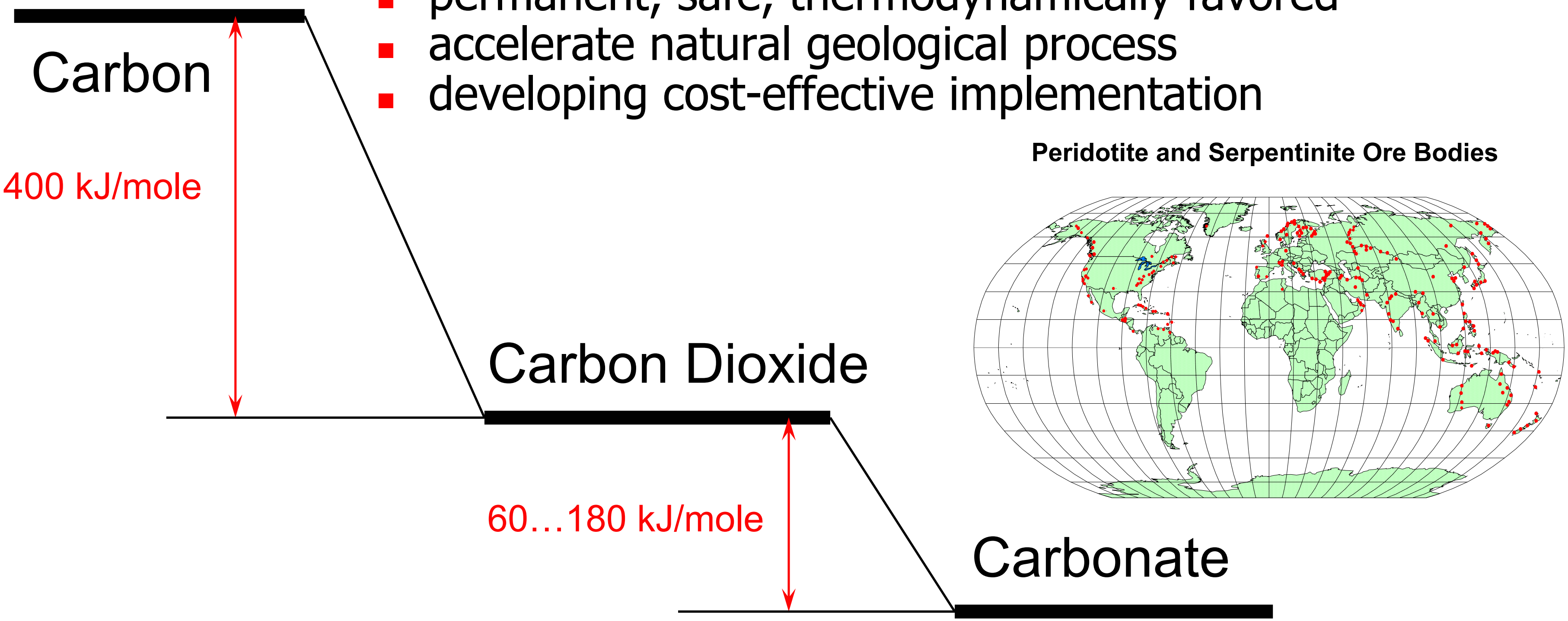
21st century carbon dioxide emissions could exceed the mass of water in Lake Michigan

Net Zero Carbon Economy



Mineral Carbonation
A safe and permanent disposal option
Transforming plentiful mineral rocks into carbonates

- permanent, safe, thermodynamically favored
- accelerate natural geological process
- developing cost-effective implementation



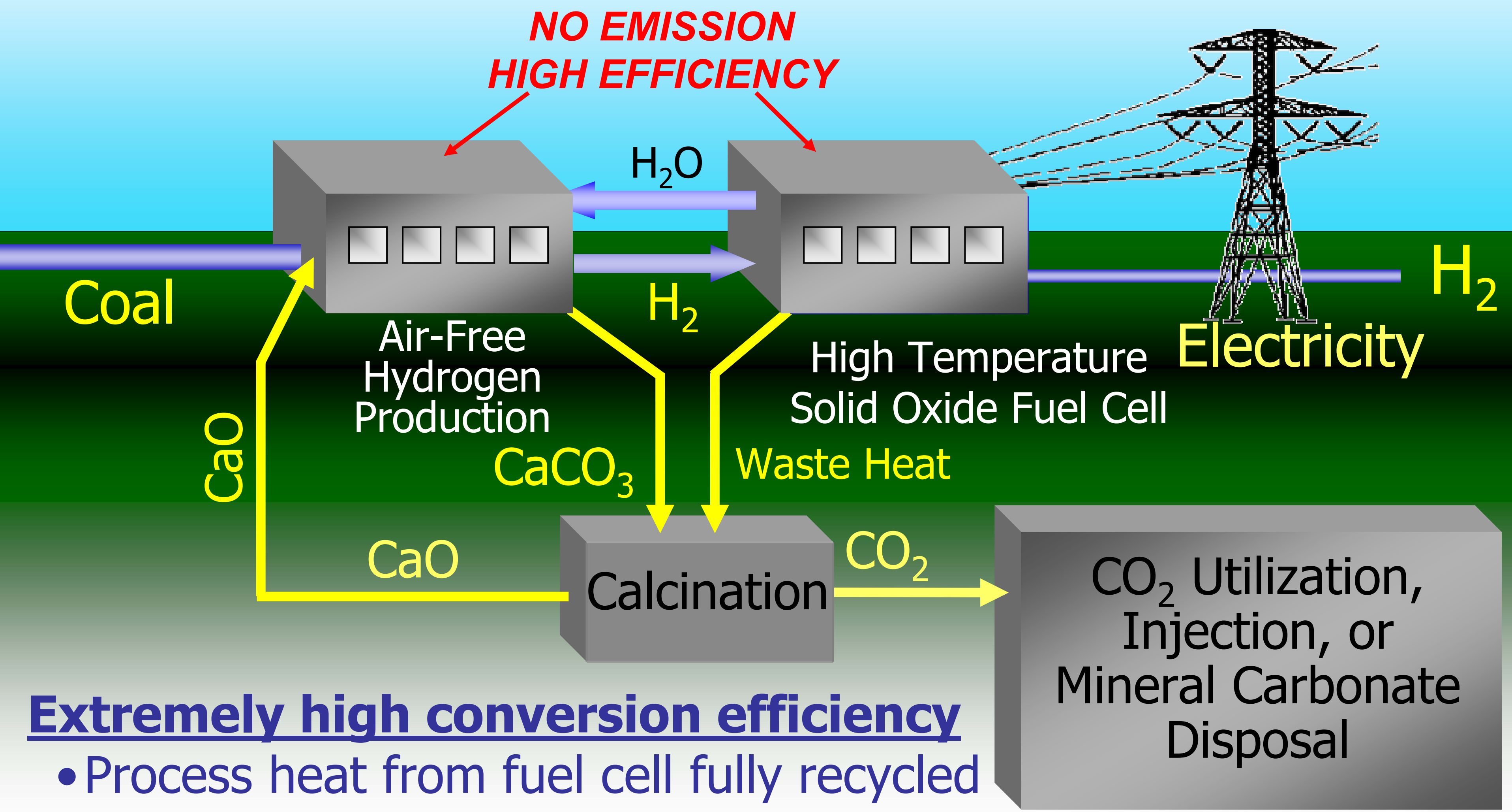
Serpentine carbonation:

$Mg_3Si_2O_5(OH)_4 + 3\ CO_2(g) \rightarrow 3MgCO_3 + 2\ SiO_2 + 2H_2O(l) + 190$ kJ/mol

Experimentally demonstrated

Maintains access to vast fossil fuel reservoirs

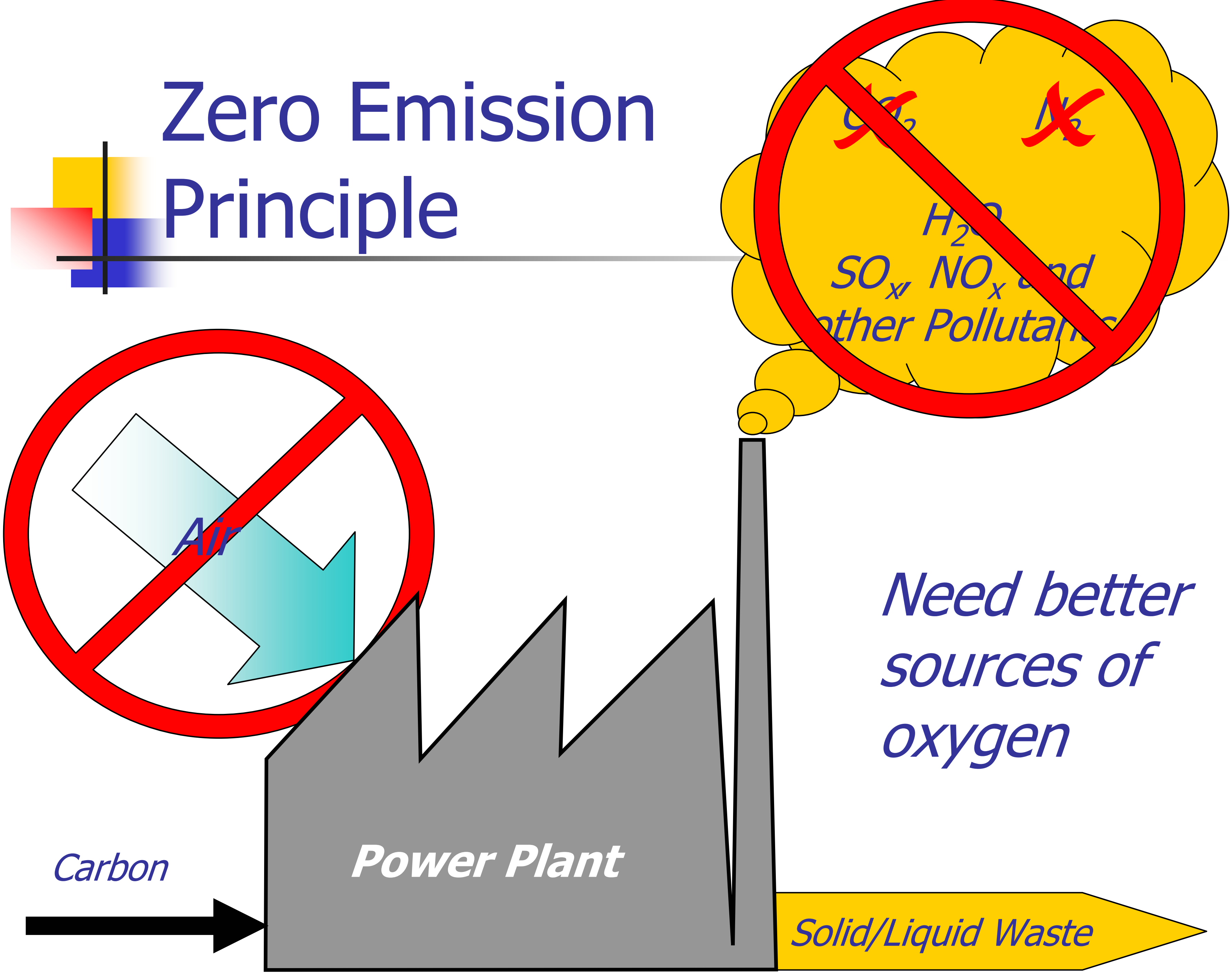
ZECA's Hydrogen and Electricity Production



Extremely high conversion efficiency

- Process heat from fuel cell fully recycled
- 50% less CO_2 even without disposal
- Capture all emission products

Zero Emission Principle



Need better sources of oxygen

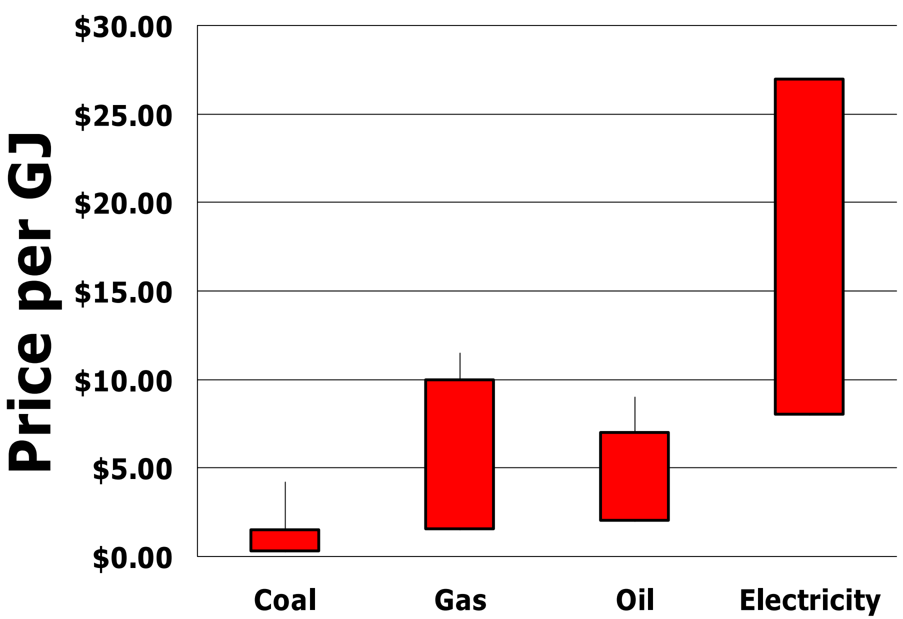
Hydrogen economy cannot run on electricity, yet

There are no hydrogen wells

Tar, coal, shale and biomass could support a hydrogen economy.

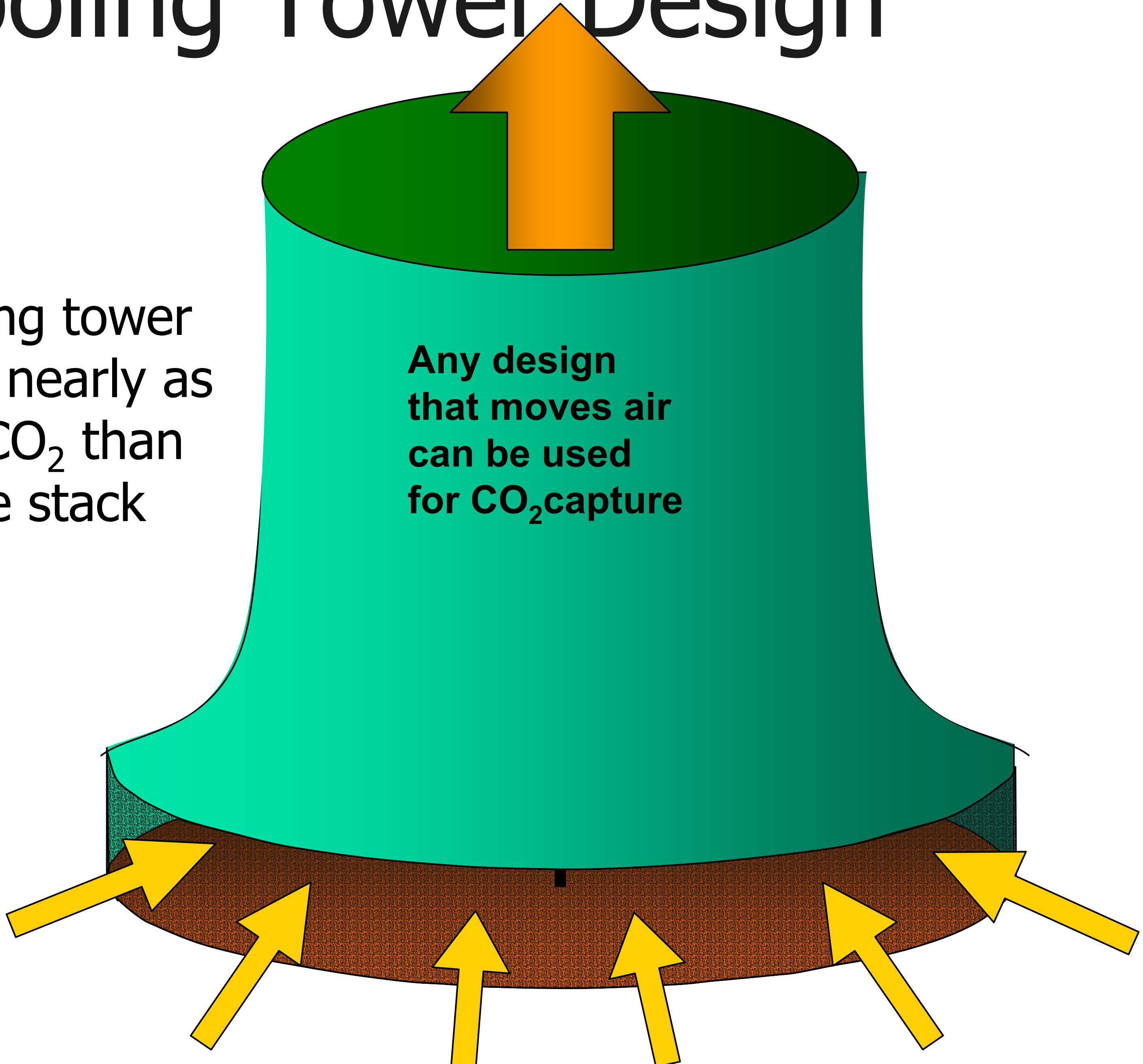
Wind, photovoltaic, and nuclear energy cannot.

Price Ranges for Raw Fossil Energy Resources

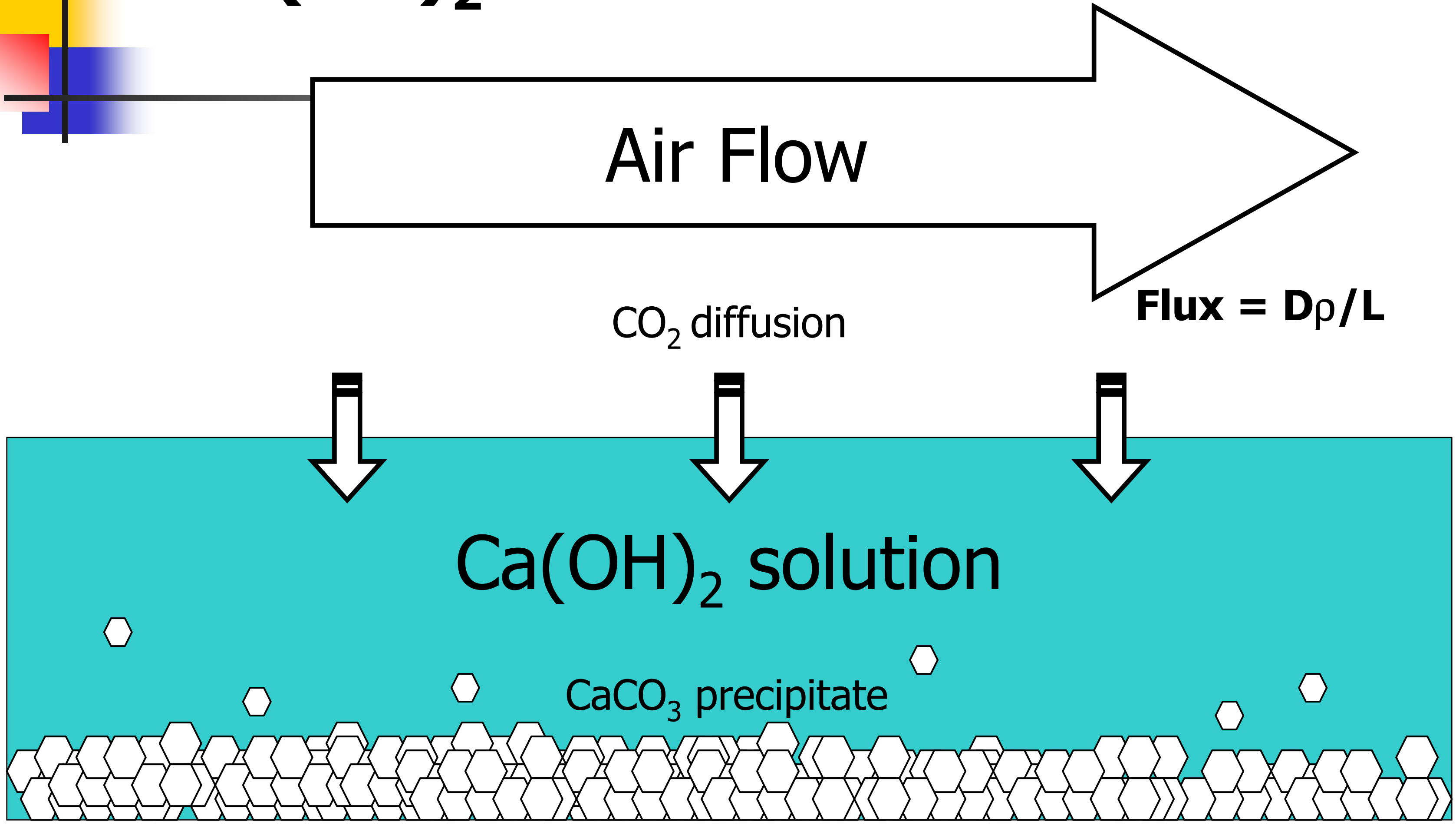


Cooling Tower Design

A cooling tower passes nearly as much CO_2 than the flue stack



$Ca(OH)_2$ as an absorbent



CO_2 mass transfer is limited by diffusion in air boundary layer

How much wind?

(6m/sec)

Wind area that carries 10 kW

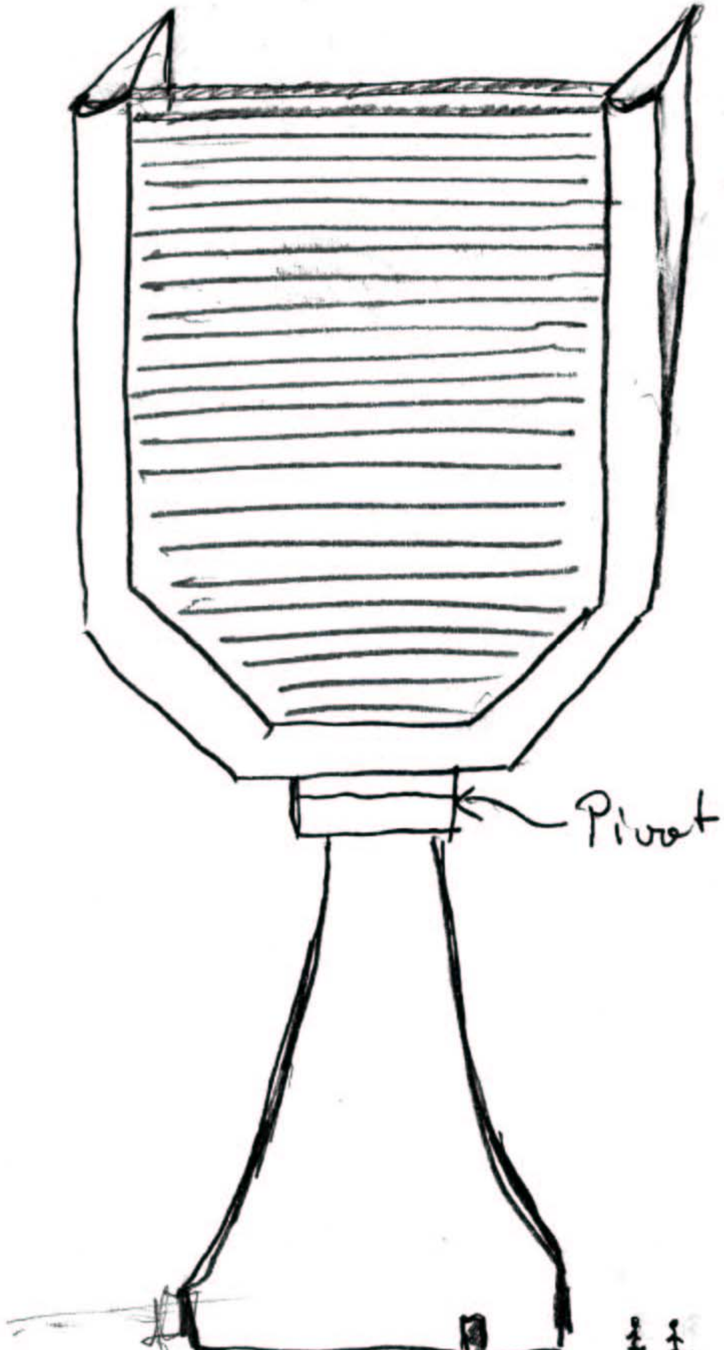
0.2 m^2

for CO_2

Wind area that carries 22 tons of CO_2 per year

80 m^2

for Wind Energy



60m by 50m

3kg of CO_2 per second

90,000 tons per year

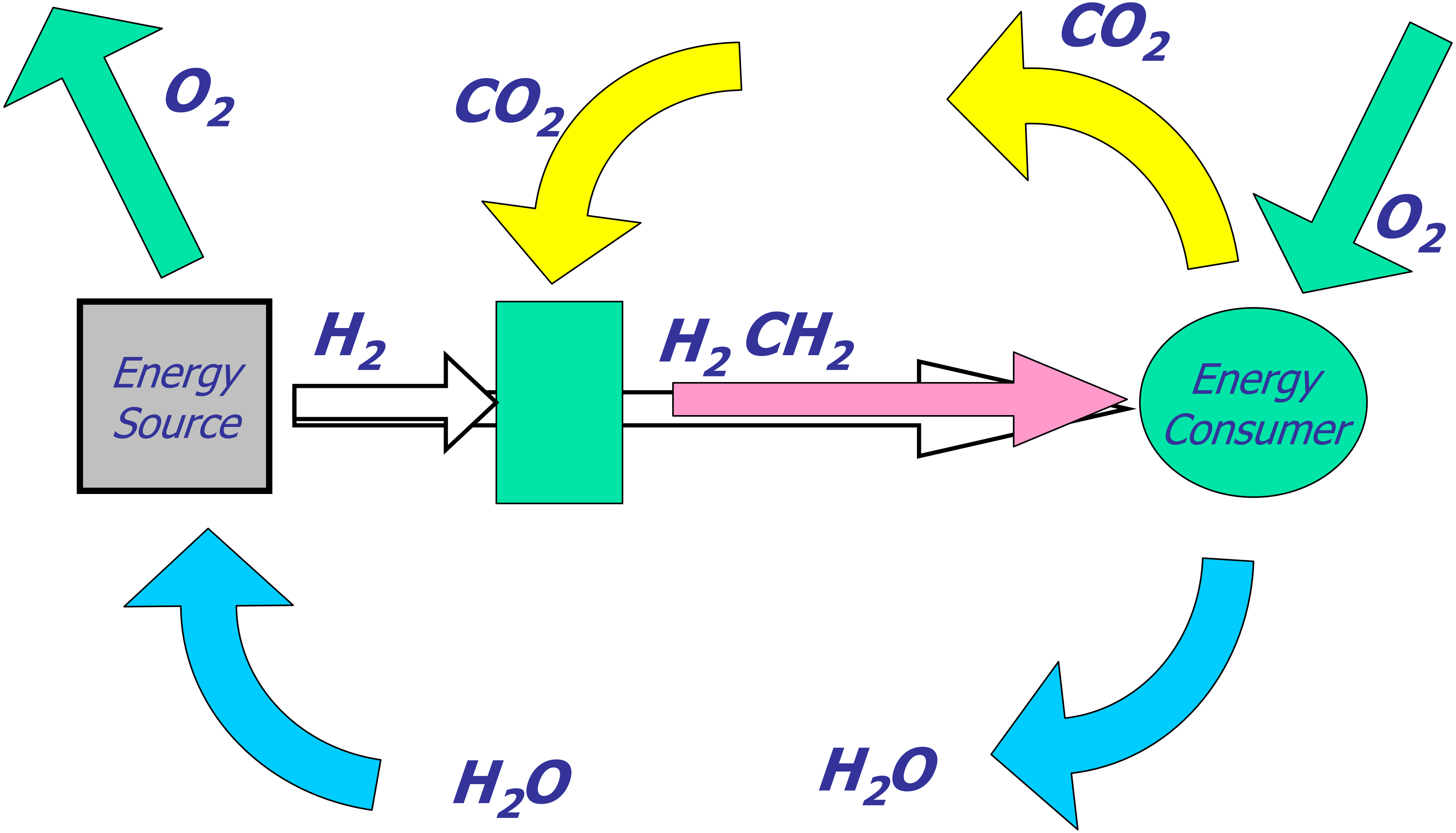
4,000 people or

15,000 cars

Would feed EOR for 800 barrels a day.

250,000 units for worldwide CO_2 emissions

Materially Closed Energy Cycles



Take Back The Empties

CH_n CH_n CH_n CH_n

CO_2 CO_2 CO_2 CO_2