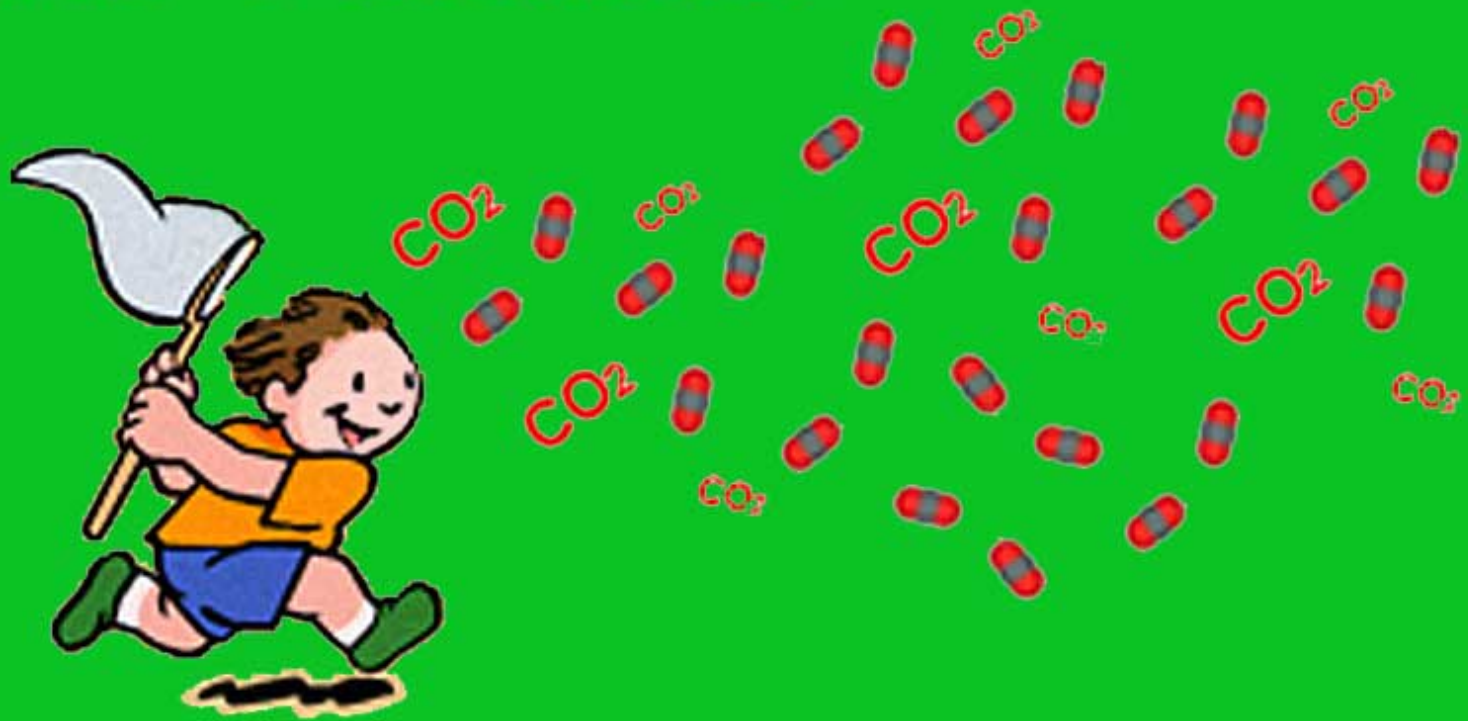
CAPTURING



GLOBAL WARMING

Using new Chinese nuclear technology to end the era of Global Warming.

A suggestion by James P. Holm, P.E. that we re-open Direct Air Capture technology investigations as a way to end Global Warming.

www.coal2nuclear.com

“A world without Global Warming.”

What needs to be accomplished?

How can it be accomplished?

This slide show is about ending Global Warming by removing it from the air.

It picks up where the MIT handout leaves off.

MIT gives up, saying while the process would work, using fossil fuel to produce the extreme heat the CO_2 extraction process demands will only make Global Warming worse.

I am suggesting using nuclear energy – *thorium, in a red-hot molten salt reactor* – instead of fossil fuels to provide the necessary extreme heat.

Thorium?

The World War II Manhattan Project identified 3 viable nuclear energy paths:

Uranium, Plutonium, and Thorium.

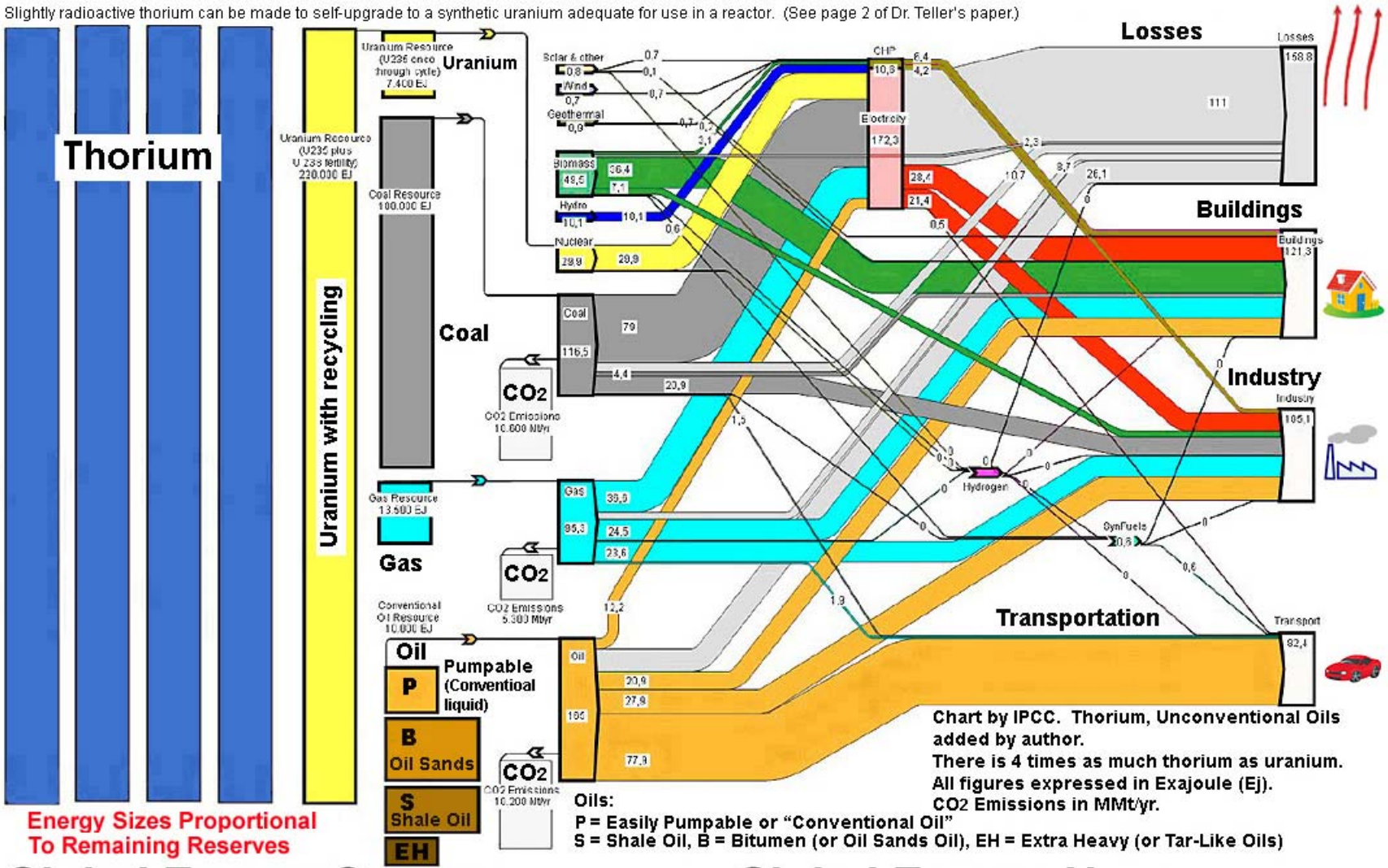
Thorium had near-zero military potential and was subsequently abandoned and forgotten.

Planet Earth has twice as much thorium energy as all the other energies combined.

Planet Earth has sufficient thorium to remove Global Warming from the air 40 times over.

Thorium is energy's untouched final frontier

There is 4 times as much thorium as uranium. There is more energy in uranium than all the energy in all the fossil fuels.
Slightly radioactive thorium can be made to self-upgrade to a synthetic uranium adequate for use in a reactor. (See page 2 of Dr. Teller's paper.)



Molten Salt Reactor?

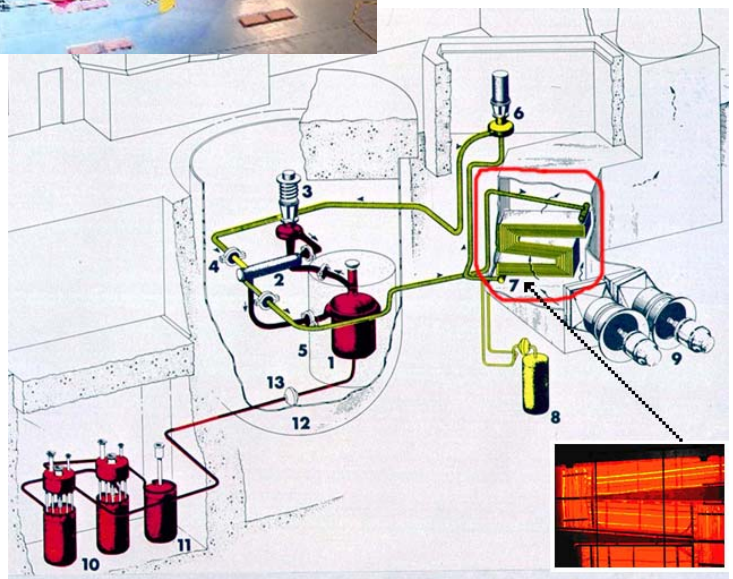
As the cold war evolved, the US Air Force developed a molten salt reactor for airplanes that would enable jet bombers to reach anywhere in the world.

Unlike the heavy solid uranium fuel rod reactor developed by the US Navy, the molten salt reactor used uranium + thorium dissolved in melted salt.

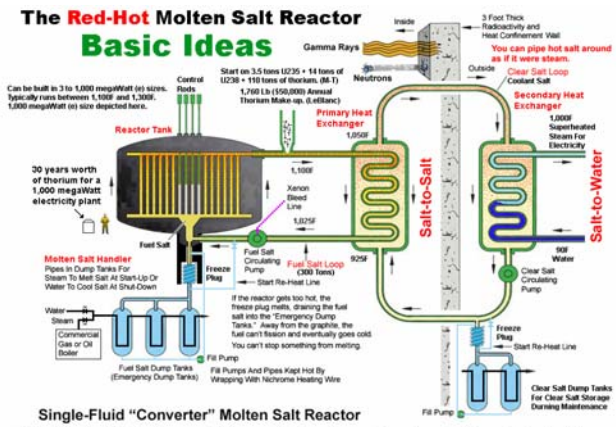
It is very light, relatively cheap, unpressurized, and, unlike solid fuel rod reactors, naturally docile.

To power a jet engine it must run red-hot.

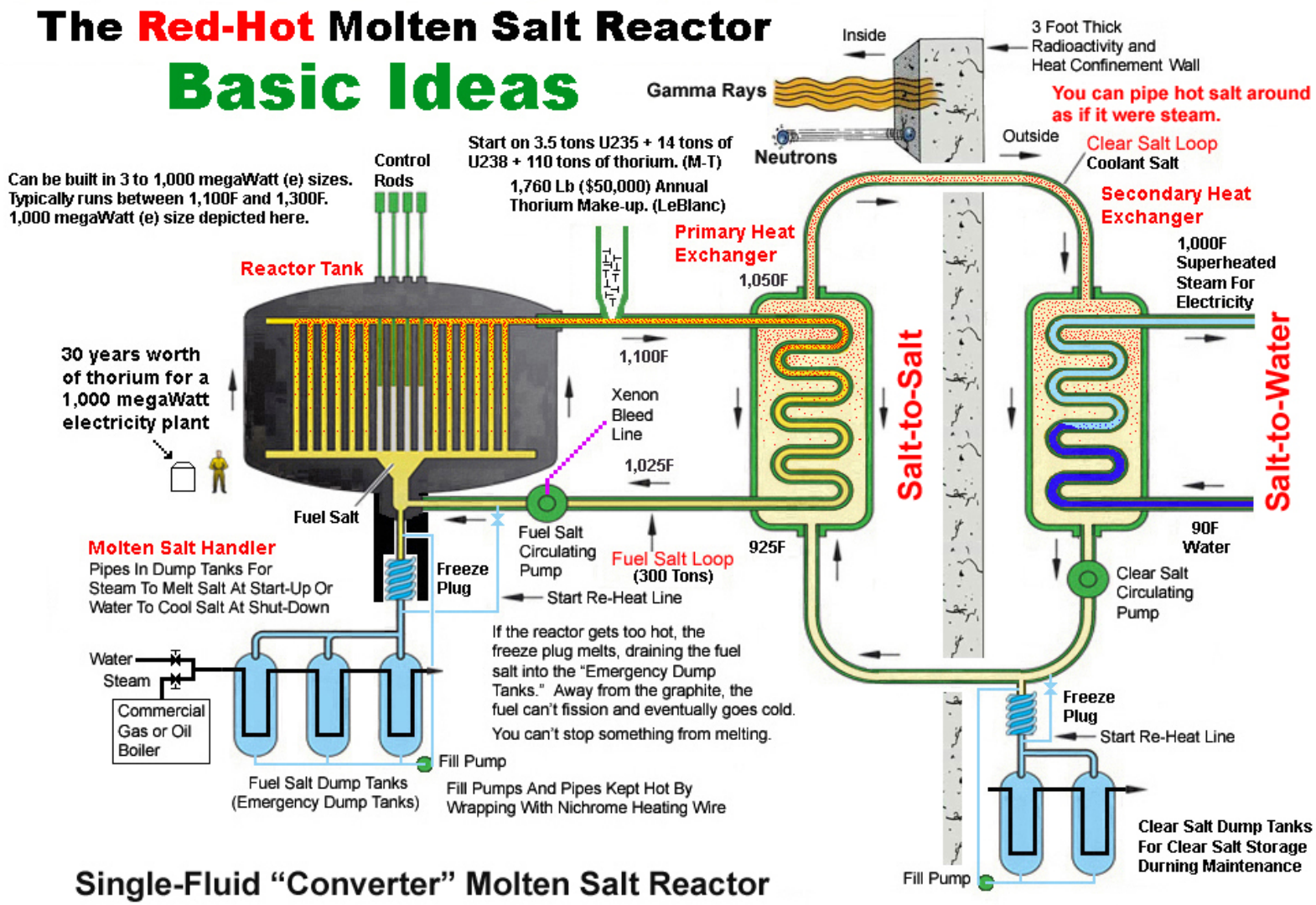
THORIUM Molten Salt Reactor? **Originally developed for a nuclear-powered 1955 airplane. Oak Ridge later built a small THORIUM Molten Salt Reactor in 1965 that ran successfully until 1970 when Nixon killed the project because thorium has no military value.**



1. Reactor Vessel, 2. Heat Exchanger, 3. Fuel Pump, 4. Freeze Flange, 5. Thermal Shield,
6. Coolant Pump, 7. Radiator, 8. Coolant Drain Tank, 9. Fans, 10. Fuel Drain Tanks,
11. Flush Tank, 12. Containment Vessel, 13. Freeze Valve.



Thorium-Fueled Molten Salt Reactor Overview



Single-Fluid "Converter" Molten Salt Reactor

Takes dissolved thorium in, converts it to a synthetic uranium, and then burns that down to almost nothing leaving almost no nuclear waste. The tiny amount of waste remains dissolved in the salt.
Goes 30 years between salt cleanings - a simple precipitation process - the salt, FLiBe, lasts forever.
Thorium heat can be 2,000 times cheaper than coal heat.

EBASCO designed but never built this 2,500 megaWatt (t) power plant version of a Molten Salt Reactor.

(70 feet in diameter, 50 feet high)

(Google: TID-26156 to download your free 250 page pdf copy)

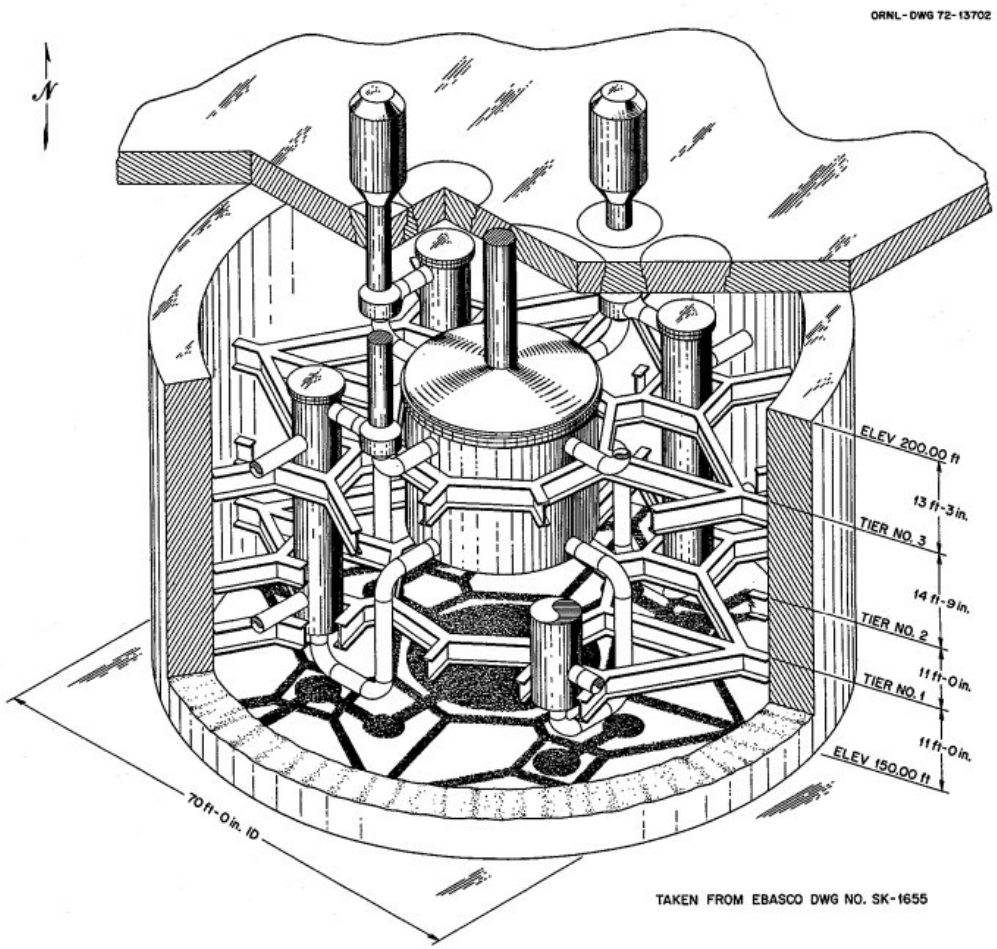


Fig. 1.3. Design study of MSBR cell.

“A world without Global Warming”

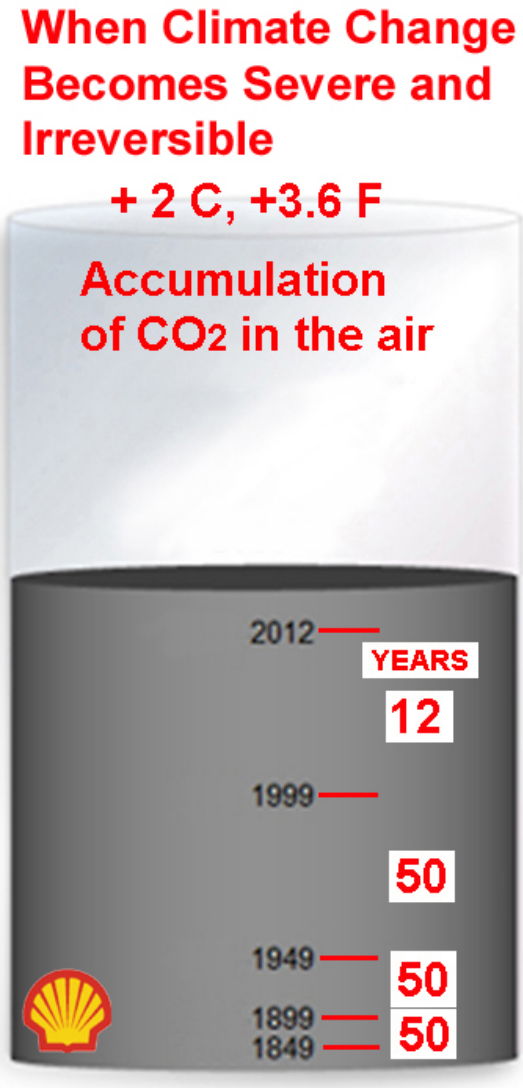
What needs to be accomplished?

How can it be accomplished?

There are two parts to Global Warming.

1. The 1.4 trillion tons of CO_2 we have already placed in the air – this is causing today's Climate Change.

2. The 35 billion tons of CO_2 we add to the air every year – making future Climate Changes even more severe.



The world is planning on burning FAR MORE, not less, coal, oil, and natural gas to stoke third world economies.

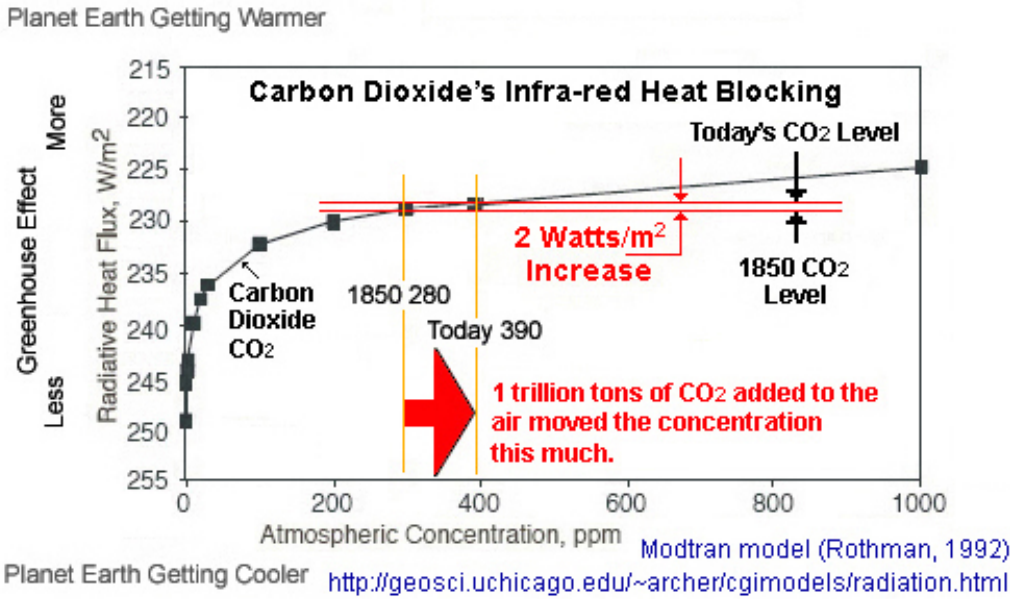
The most important thing about Global Warming.

With 1.4 TRILLION tons of CO_2 already in the air making Climate Change,

. . . it is far too late to expect that cutting back a few billion tons of new CO_2 emissions will save our children from severe Climate Change.

Carbon Dioxide is One of Planet Earth's Major Thermostat Mechanisms

Planet Earth's average temperature is 59F.
If there were no CO_2 in the air, Planet Earth would be at 0 degrees F.



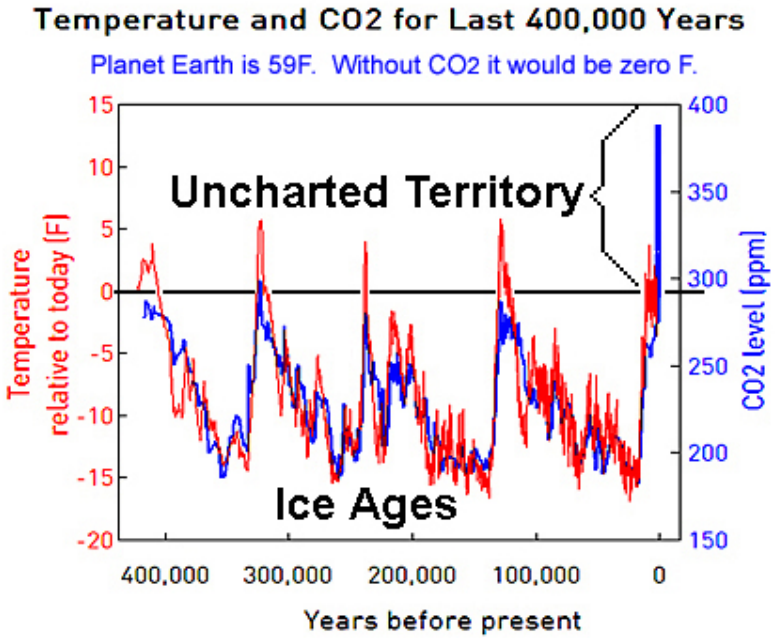
CO_2 gas in the air is a major Planet Earth THERMOSTAT. The amount of CO_2 in the air has significant control over how hot Planet Earth will be.

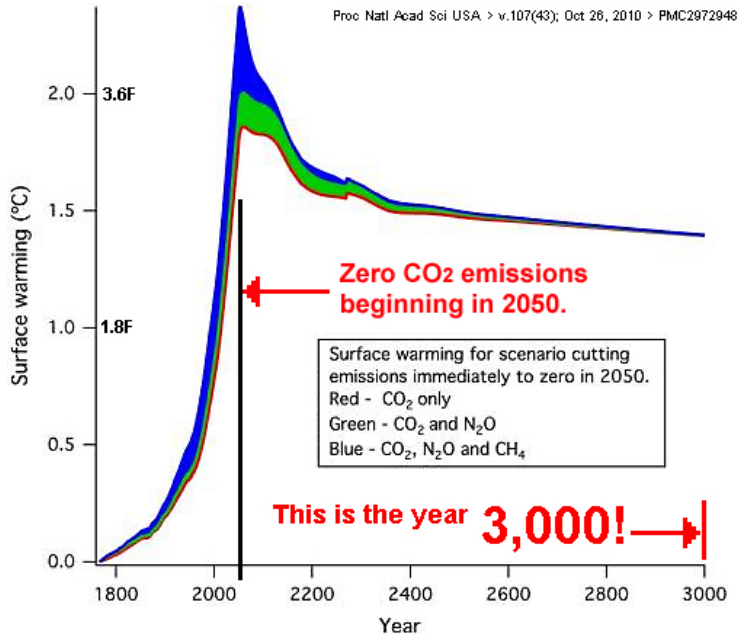
For over ½ million years this thermostat has *NEVER* been set higher than 280 parts of CO_2 per million parts of air. Man has just bumped it up to 390 ppm and our furnace, the sun, has *BEGUN* increasing Planet Earth's temperature at the rate of 30,000 Quadrillion BTUs of heat per year.

The United States produces about 100 Quadrillion BTUs of heat per year.

For over 400,000 years the CO_2 level has never been higher than 280 ppm. Now, all of a sudden, we are blowing past 400 ppm. An 80 ppm drop is enough to bring an ICE AGE.

Past ⟵ ⟶ Future





Even if we stopped all Global Warming emissions now, Global Warming would persist for over 1,000 years.

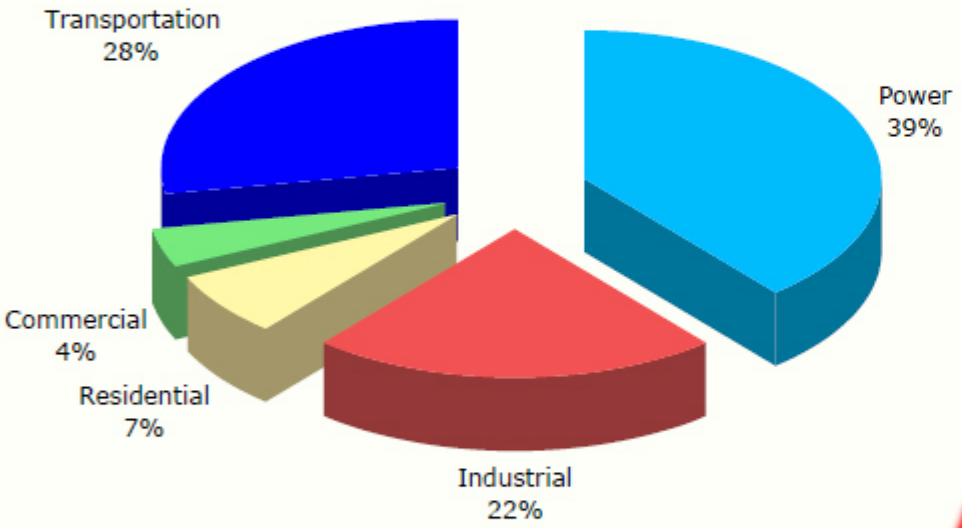
Reducing today's CO_2 emissions will have little impact on Climate Change.

Nuclear is very inconvenient. Combustion will remain a principal component of the global energy system for personal heat.

Oil, the ultimate "small energy" fossil fuel, will be used forever.

We must get good at removing CO_2 FROM the air.

Decoupling CO_2 emission from CO_2 mitigation



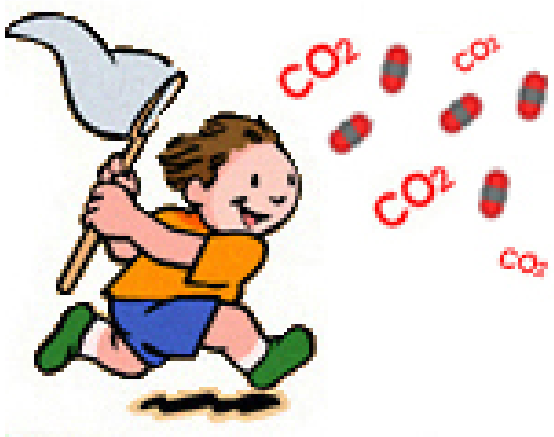
- Distributed and/or mobile sources
- Existing Infrastructure ill suited to retrofit
- Challenging CO_2 transportation scenarios
- Driving capture to or above 100%

“A world without Global Warming”

What needs to be accomplished?

How can it be accomplished?

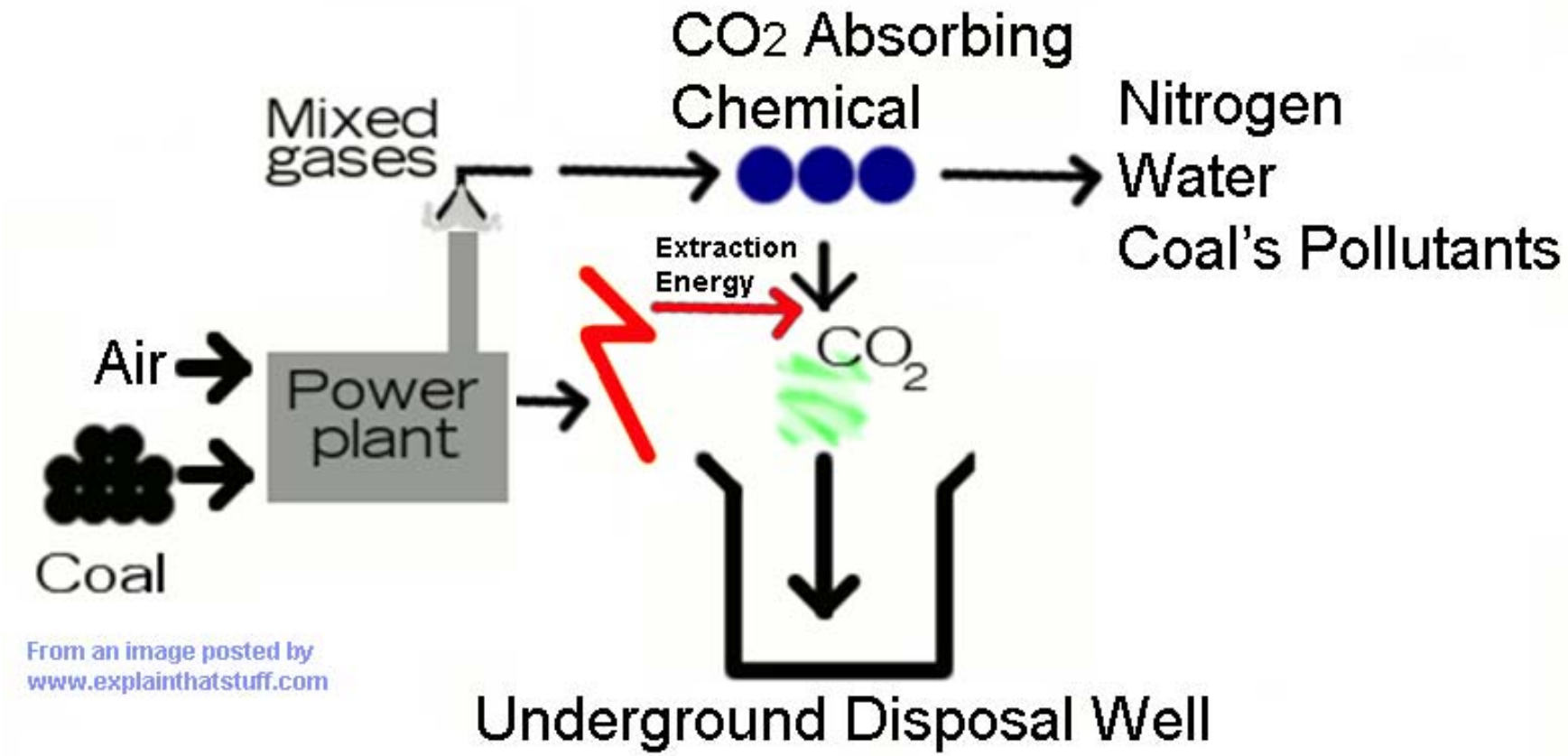
We can capture CO_2 from either smokestacks or ambient air.



carbon capture journal

A pilot plant for capturing 10 tons of stack CO_2 per day at a Japanese power plant.

The US DOE National Energy Technology Laboratories (NETL) estimates the US alone has the capacity to sequester 2.4 trillion tons of CO_2. (2012 DOE Atlas.)

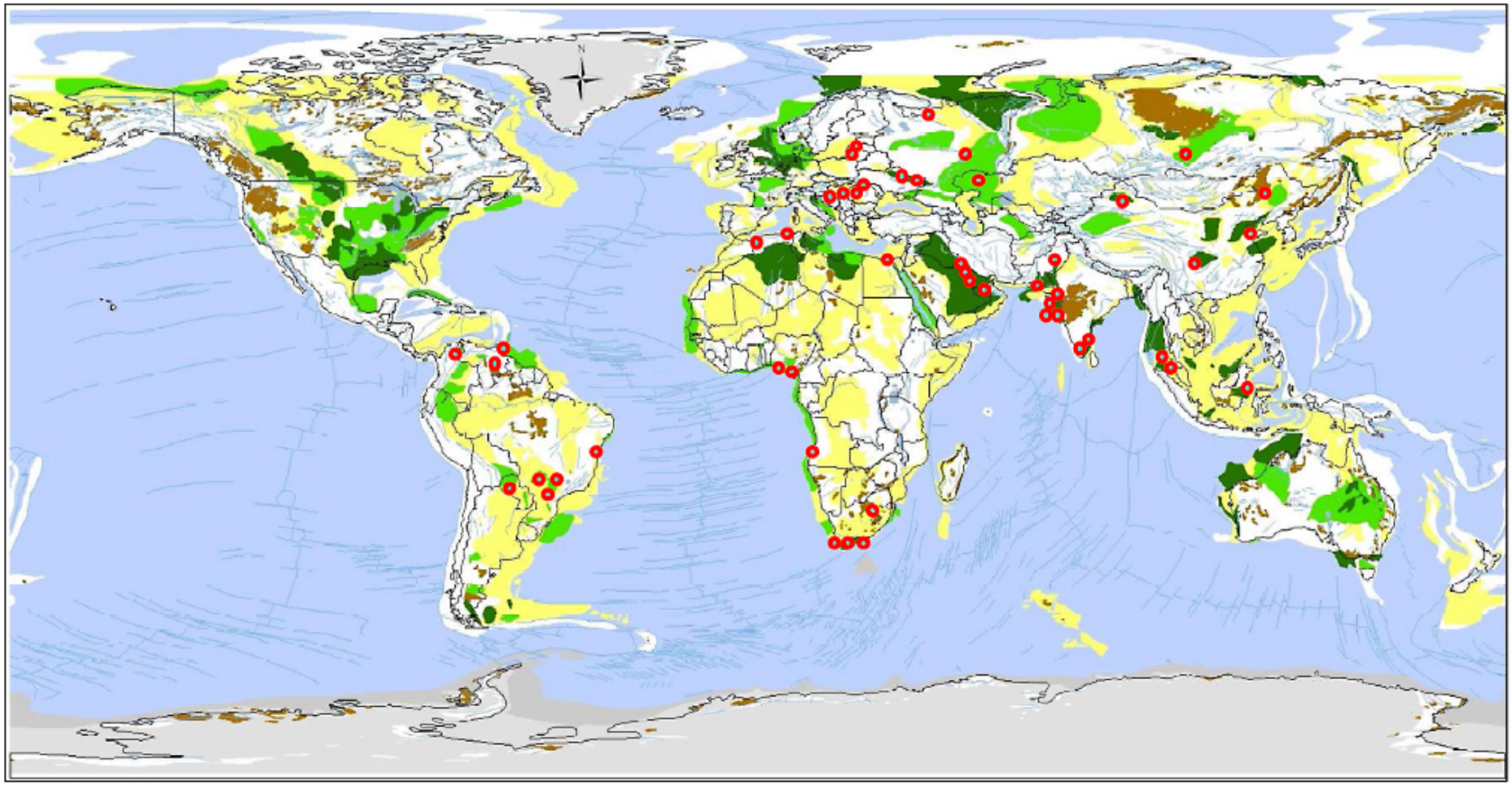


How Carbon Capture and Storage (CCS) works

About 70% of the CO_2 is captured,
about 25% of the plant's power is consumed.
So coal consumption would have to increase substantially.

CLEAN COAL

The US alone can safely store all of Planet Earth's Global Warming CO_2 2.4 times over. And just look at how many other good places there are.



World Geological Storage Suitability
March 2011

Highly Suitable, Sedimentary Basins or Continental Margins

Suitable, Sedimentary Basins or Continental Margins

Possible, Sedimentary Basins or Continental Margins

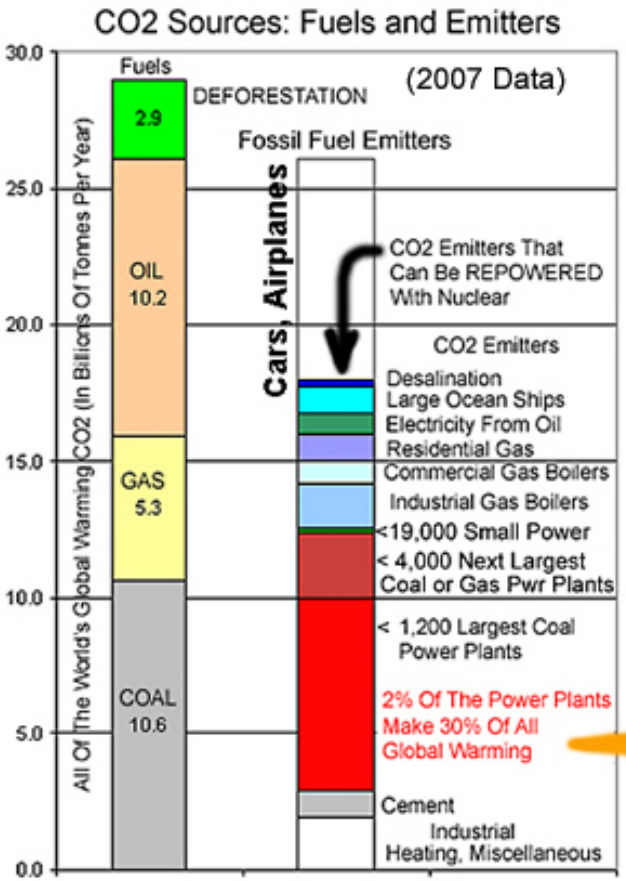
Unproven, Extrusive volcanic rocks

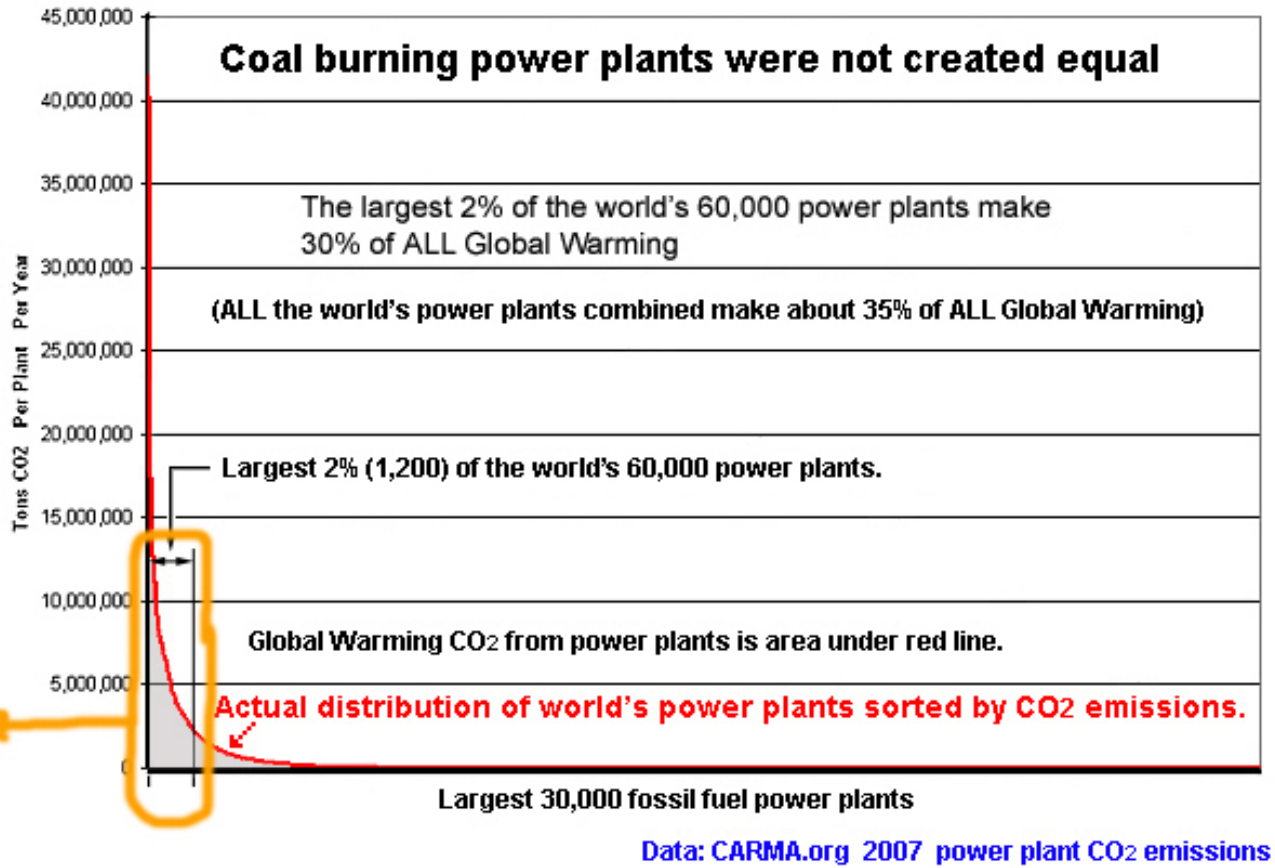
Main Faults

Early Opportunity

0 2,000 4,000 6,000 8,000 10,000 Km

Power plants are, by far, the biggest emitters of CO_2. They make about 35% of all Global Warming





Interestingly, only a few power plants – 1,200 out of 30,000 -- produce most of the power plant CO_2.

Here come 1,026 additional NEW coal power plants !

The New York Times
Sunday, December 2, 2012

Summary of Proposed Coal-Fired Plants

RANK	COUNTRY	TOTAL INSTALLED CAPACITY (MW)	NUMBER OF PROJECTS	Average Project
1	China	557,938	363	1,540 mW
2	India	519,396	455	1,140 mW
3	Russia	48,000	48	1,000 mW
4	Turkey	36,719	49	750 mW
5	Vietnam	34,725	30	1,160 mW
6	South Africa	22,633	8	2,830 mW
7	United States	20,236	36	562 mW
8	Ukraine	14,000	14	1,000 mW
9	Poland	12,086	13	930 mW
10	Germany	12,060	10	1,206 mW
			Total = 1026	

World Resources Institute

The lion's share of new coal plants planned worldwide would be built in China and India.

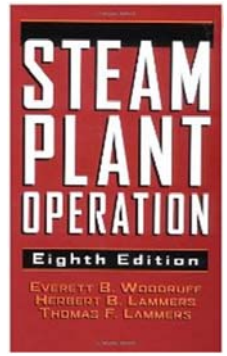
We can end Global Warming by fixing old coal power plants:

1. We can fix those 1,200 old coal power plants by replacing their coal boilers with nuclear boilers.

2. By using 2.5 times over-powerful *EBASCO* reactors, we can add "Air Capture" equipment that will capture the remaining new Global Warming CO_2 being made by everything else.

3. Build any new power plants with over-powerful EBASCO reactors and carbon capture equipment to dig into our trillion ton CO_2 backlog.

Modifying old coal power plants to capture Global Warming:



The average electricity generator in those 1,200 coal power stations consumes 970 megaWatts (thermal) of heat to produce 350 megaWatts (e) of electricity (36% efficient).

I suggest replacing the 970 mW (thermal) coal burning boilers with 2,500 mW (thermal) EBASCO thorium nuclear boilers.

(The above is the key idea of this slide show.)

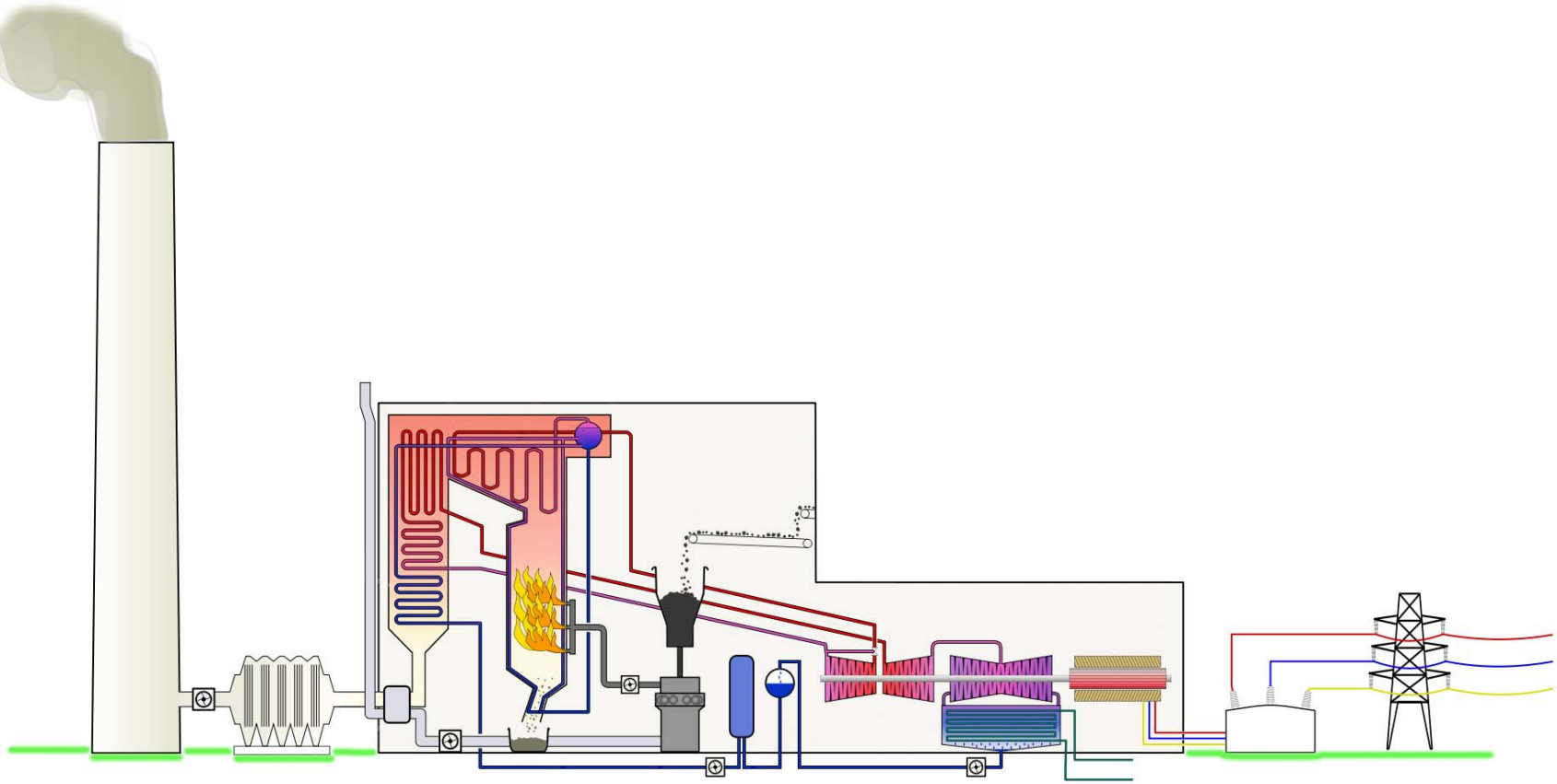
1. This will immediately end about 1/3 of all Global Warming.

2. The remaining 1,530 mW (thermal) of energy can then be used to capture the rest of Global Warming being made by everything else – cars, airplanes, etc.

The three steps to ending Global Warming

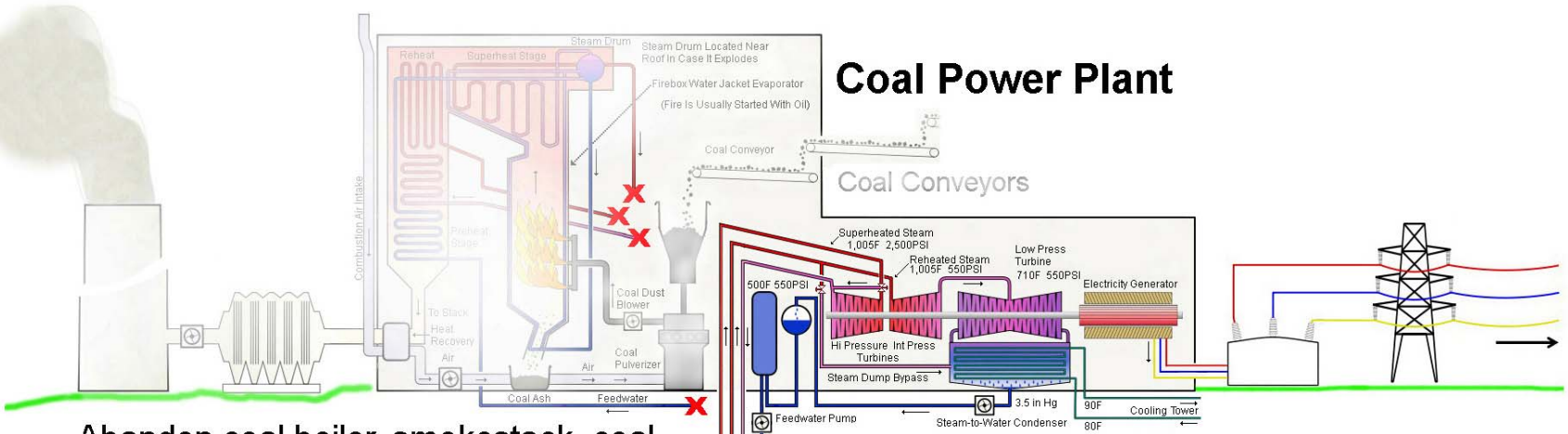
(Typical 1,200 mega-coal power stations will have at least 4 generating units.)

1. Obtain a standard coal burning power station generating unit with a 970 megaWatt (t) boiler.



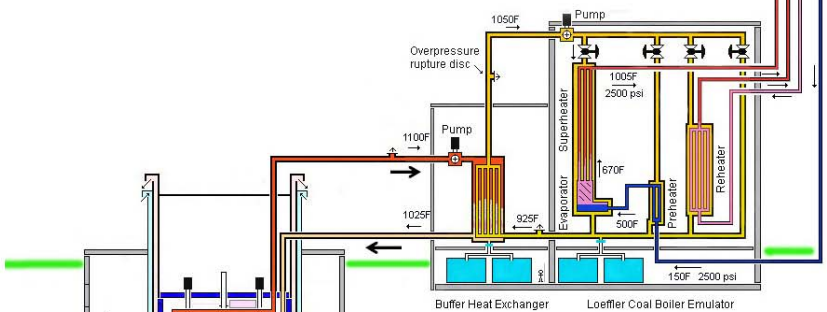
Standard Coal Burning Power Station

2. Disconnect the 970 mW (t) coal power plant boiler, reconnect the steam turbine to a 2,500 mW (t) underground thorium reactor.



Abandon coal boiler, smokestack, coal pulverizers, coal conveyors (all faded).

Original Steam Turbine



New steam generators

Think co-axial sheet metal fireplace chimney

Convection Air Cooled Underground Reactor

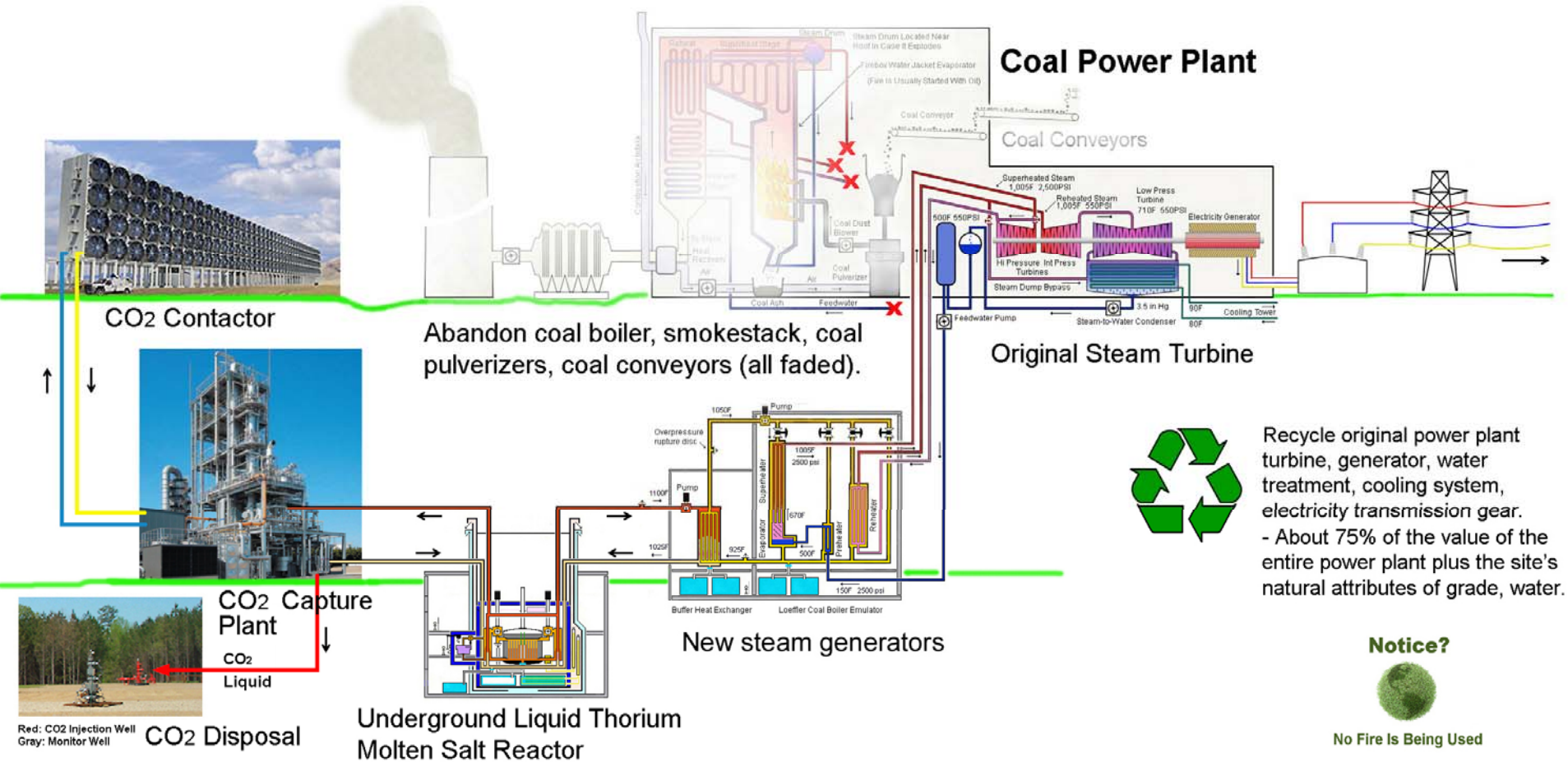
Recycle original power plant turbine, generator, water treatment, cooling system, electricity transmission gear.
- About 75% of the value of the entire power plant plus the site's natural attributes of grade, water.

Notice?

No Fire Is Being Used

3. Add CO_2 capture equipment (see photos) to remove CO_2 from the air.

Use the reactor's spare 1,530 mW (t) to power the capture equipment.



Old coal burning power plants have the "Right Stuff" for scrubbing CO_2 out of the air.

Large coal storage yard for CO_2 canals.
Ample adjacent land.
Cooling water access.
Local, state, and federal permits.
Proven team of skilled trades workers.
Strong local support.
Already paid for.
Basic site construction completed.
Hazardous waste storage in place.
Railroad access.
Road access.
Electric switchyard in place, grid access.
Computer and telecommunications in place.
Sewage and wastewater in place.
Electricity + CO_2 capture doubles the value of the plant.

Big Bend, 4 x 450 mW, Apollo Beach, FL

Well over 50% are on navigable water.

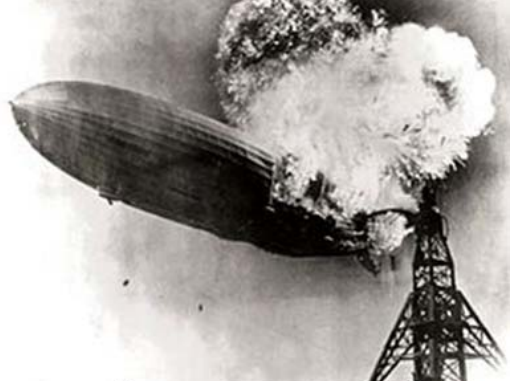
Big enough to damage air, big enough to repair air.

Why coal power plants are so bad.

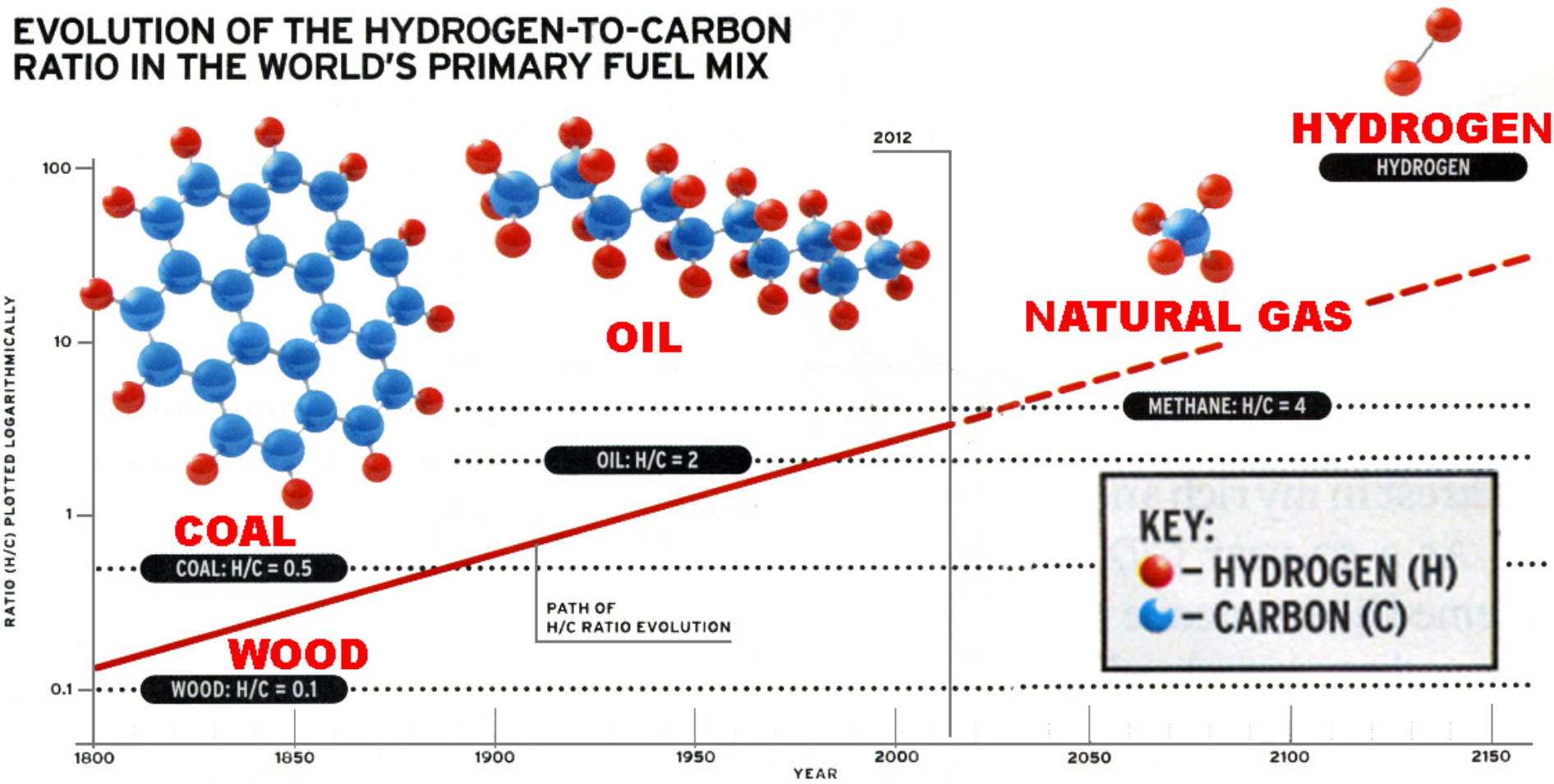
Blue = Carbon, Red = Hydrogen

Energy is carried by the hydrogens.

Think Hindenburg.

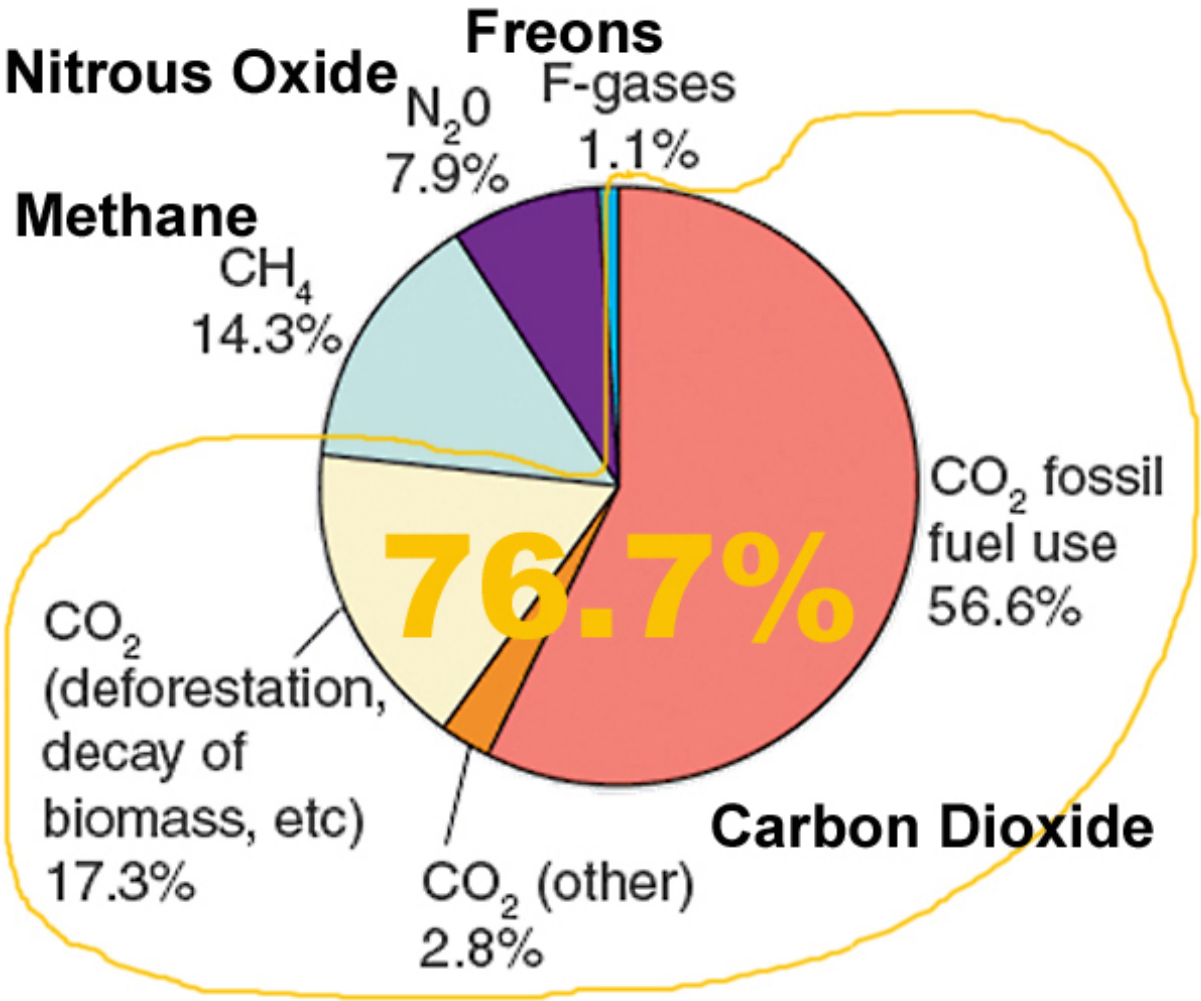


EVOLUTION OF THE HYDROGEN-TO-CARBON RATIO IN THE WORLD'S PRIMARY FUEL MIX



ILLUSTRATIONS *by* BRYAN CHRISTIE DESIGN

Global Warming is a chemical process. Chemistry can also undo Global Warming.



Reference: IPCC [4th Assessment Report:Climate Change 2007]

Using FIRE-HOT nuclear heat to CAPTURE GLOBAL WARMING FROM THE AIR

The three basic Methods for Air Carbon Capture:
1) Liquid Absorbents
2) Solid Sorbents
3) Membranes
Liquid absorbents + heat appear well-suited for nuclear heated DIRECT AIR CAPTURE of CO_2.

(Right) Mono Lake in California.

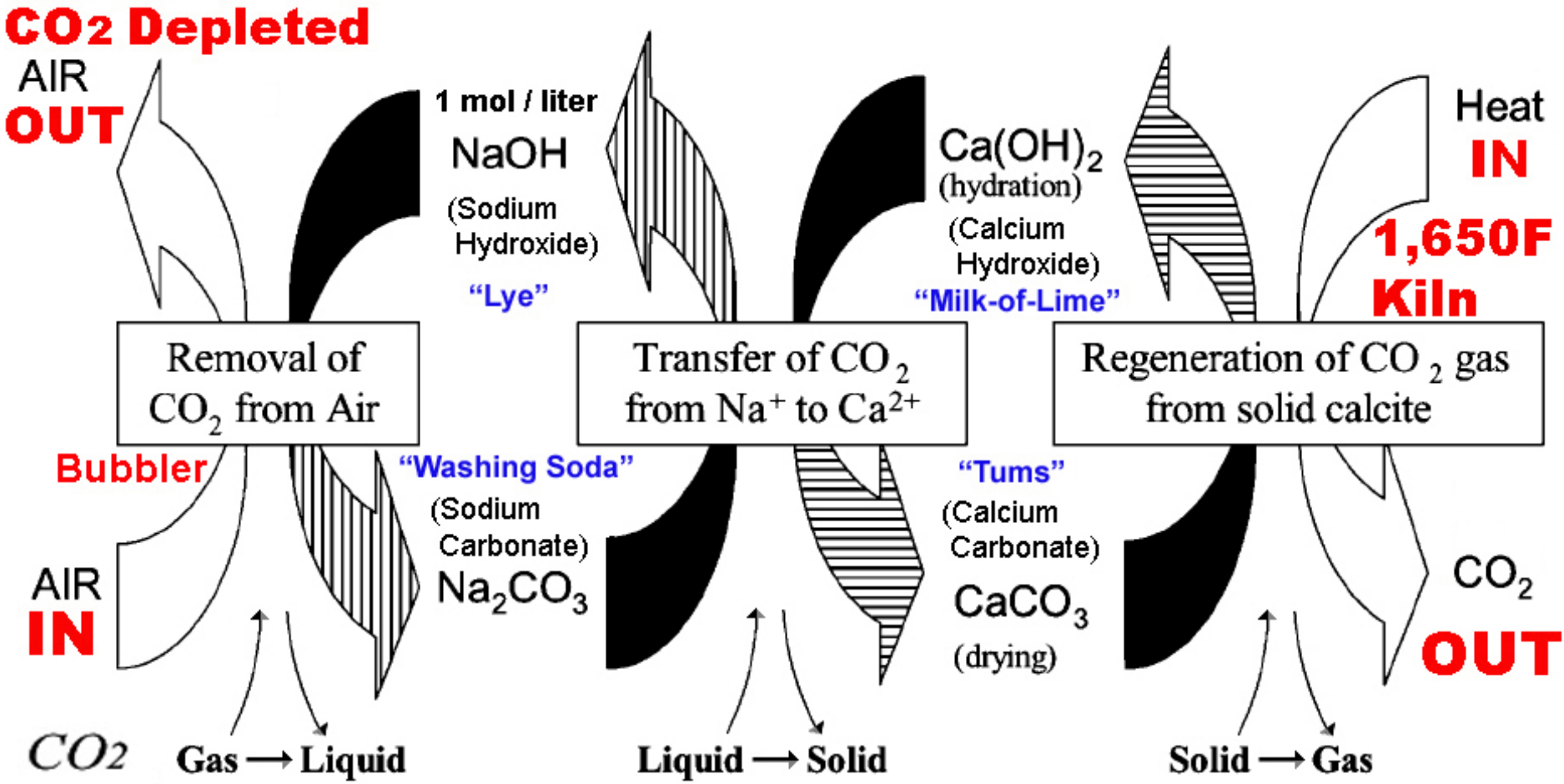
Simple, cheap, and abundant natural chemicals are involved.

It is possible to build canals with the alkaline chemistry of Mono Lake, use air bubblers to bring the air's CO_2 into contact with the chemicals, extract the CO_2 from the chemicals, and then return the chemicals to the canals to absorb more CO_2 from the air.

This process is known as:
"Direct Air Carbon Capture."

An alkaline lake absorbs CO_2 at an estimated rate of ~450 ton per acre per yr

Modeled after the "Kraft" process common in the paper industry, this is perhaps the most suggested chemical process for capturing CO_2 from the air.

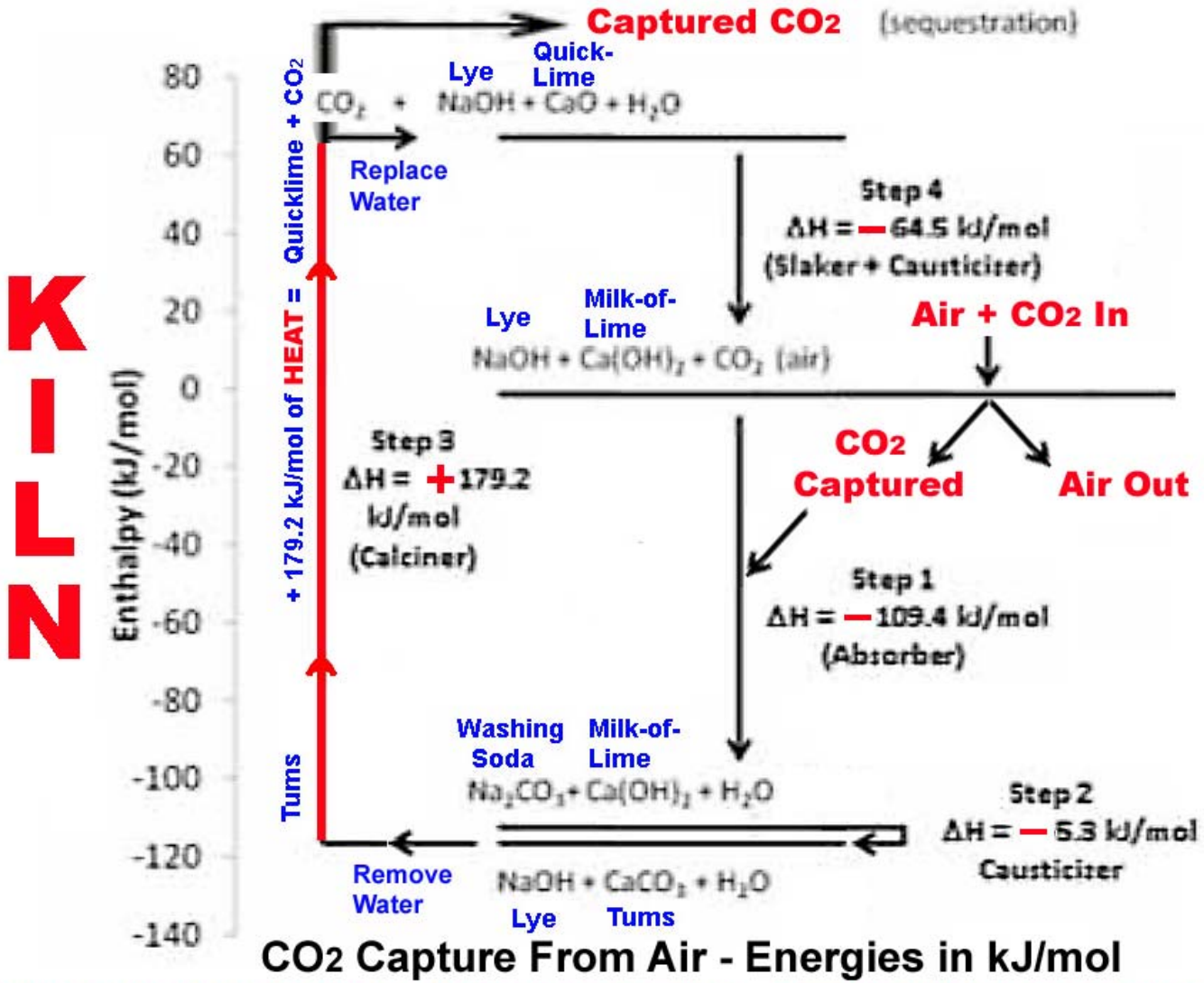


Schematic overview of air capture process.

Frank S Zeman, ENVIRONMENTAL SCIENCE & TECHNOLOGY / VOL.41, NO. 21, 2007, p 7558 - 7563

To drive the CO_2 out of the solid calcite (Tums) you need a 1,650°F kiln.

Extreme heat is the key to ending Global Warming.



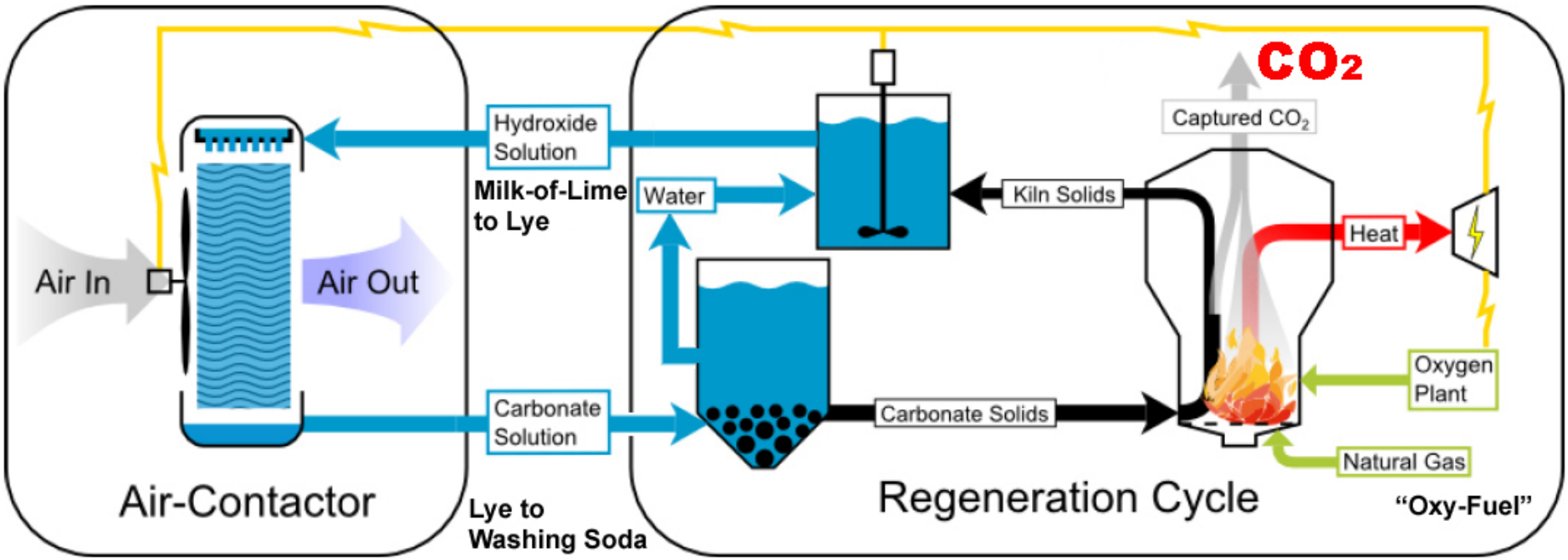
CO_2 Capture From Air - Energies in kJ/mol

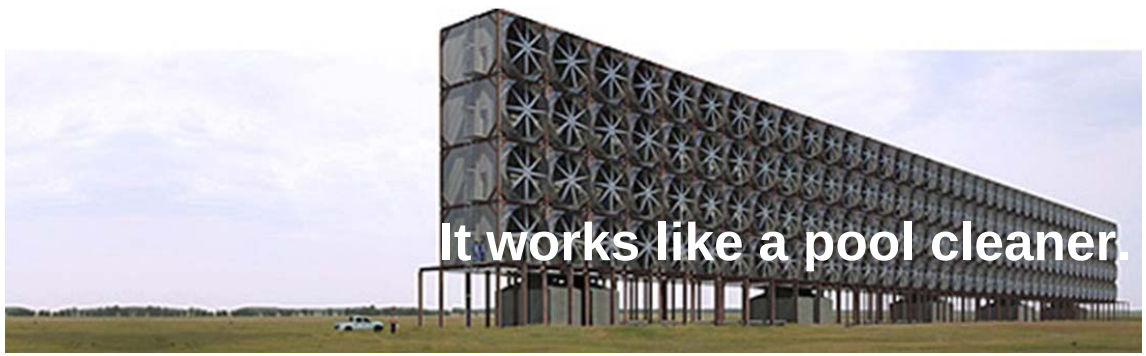
A kiln's 1,650F heat is needed to power the reactions

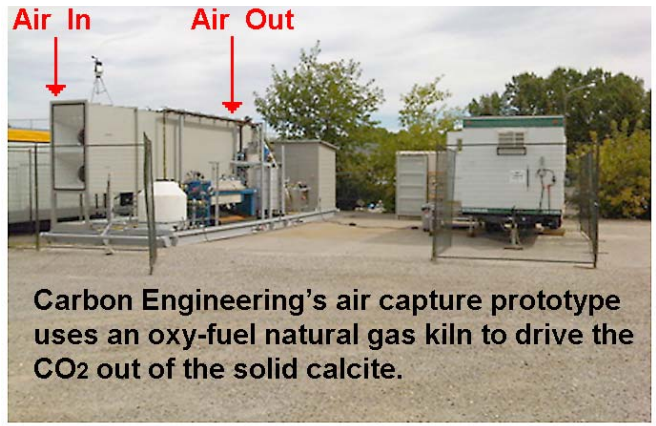
Like batteries, the chemicals have to be carrying the energy necessary to make the chemical reactions happen. The kiln provides the energy.

1,650F is needed to provide a "Full Charge" of energy.

Companies have been formed to develop the Direct Air Capture of CO_2 process.
The capture process itself needs fire-hot heat.
Here, the heat is obtained by combusting natural gas with oxygen diluted by some of the captured CO_2. This process, "Oxy-fuel," also produces a stream of CO_2.

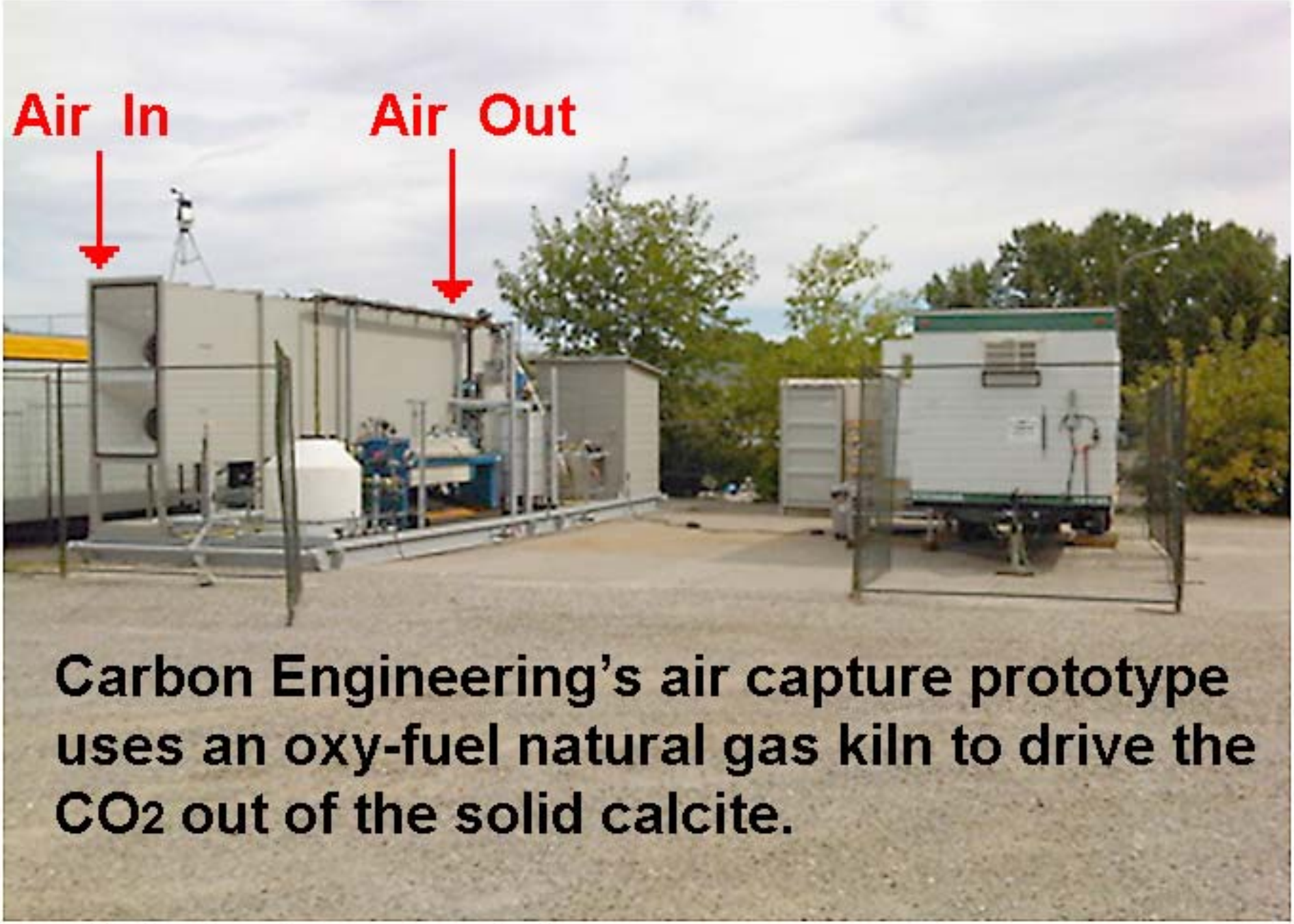




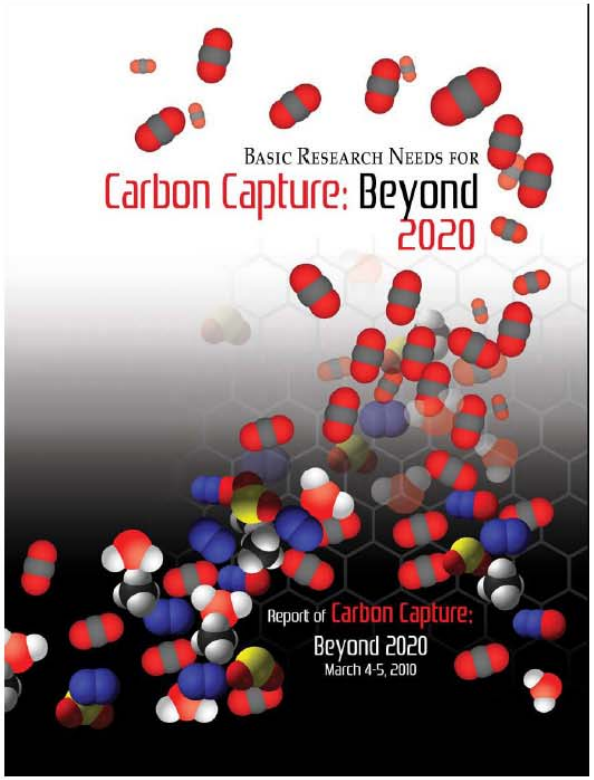


The CE Outdoor Contactor work-site.

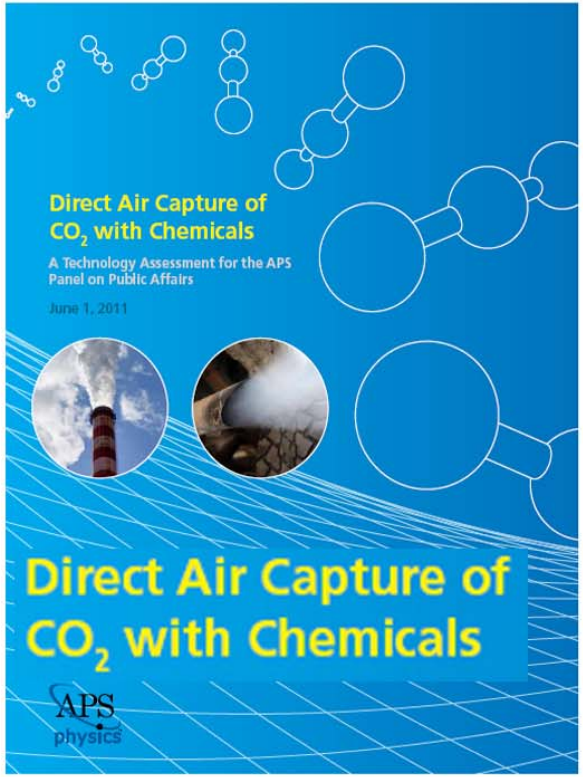
Much more at: **http://www.CarbonEngineering.com**



The CE Outdoor Contactor work-site.



Lawrence Berkeley National Labs
Oak Ridge National Laboratory
March 4-5, 2010 200 pages



American Physical Society
June 1, 2011 100 pages

MIT Sep 14, 2011, 6 pages

MIT's Gas Dynamics Lab is a global carbon capture research center.

Many teams of experts have concluded fossil fuels can't be used to end Global Warming.

MIT's analysis:

"Specifically, our analysis of existing gas separation systems suggests that, unless air capture significantly outperforms these systems, it is likely to require more than 400 kJ of work per mole of CO2, requiring it to be powered by CO2-neutral power sources in order to be CO2 negative." – MIT's Sep 14, 2011, report.

(400 kJ per mole means: A 100 watt light bulb's hour worth of energy gets you 1.4 oz of CO2)

So, using fossil fuel fire to remove CO_2 from the air would

1) Cost too much and

2) Make Global Warming worse.

What about using nuclear heat?

Conventional 550F nuclear heat isn't nearly hot enough. To remove CO_2 from the air you need a 1,650F hot kiln.

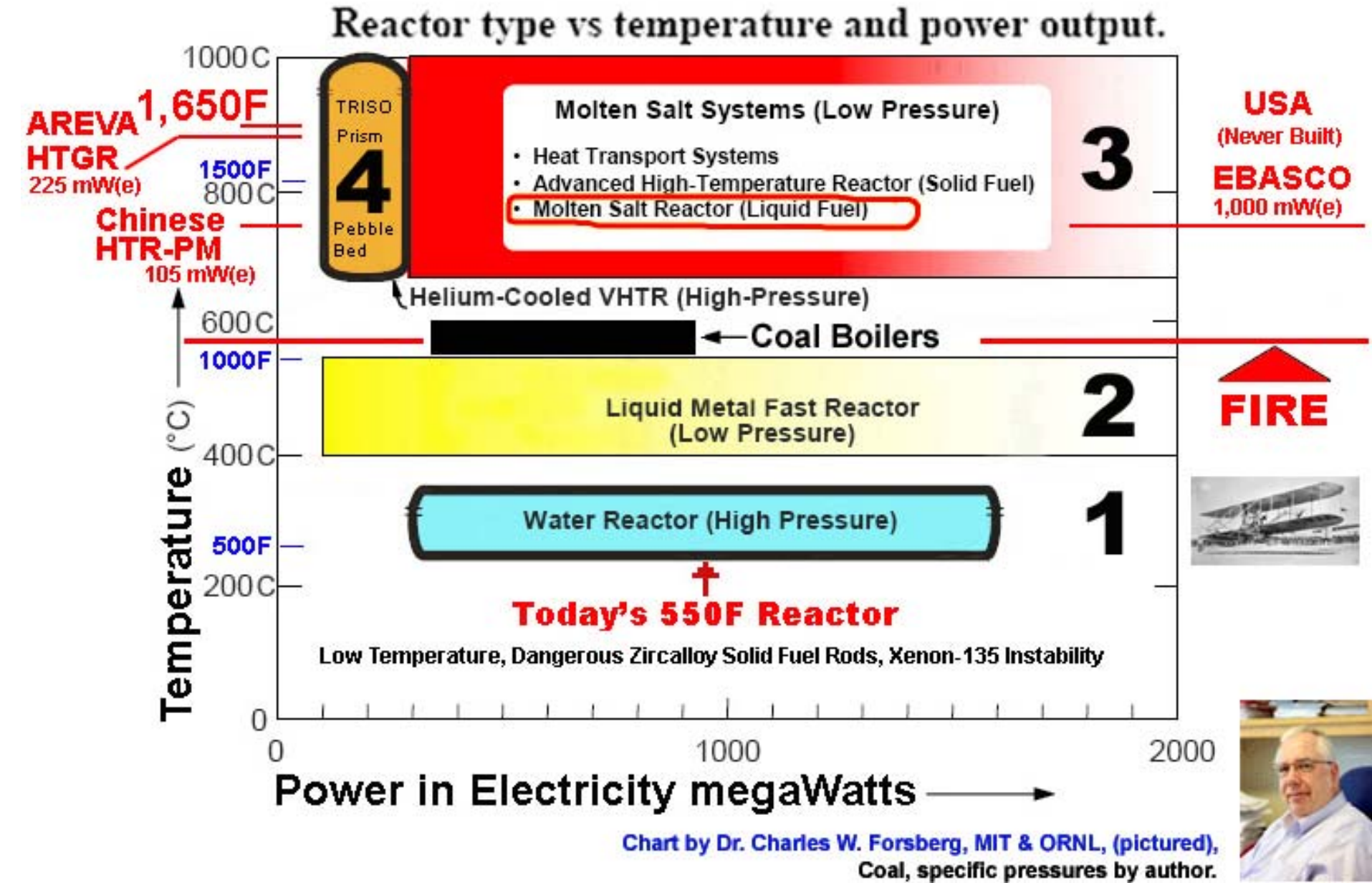
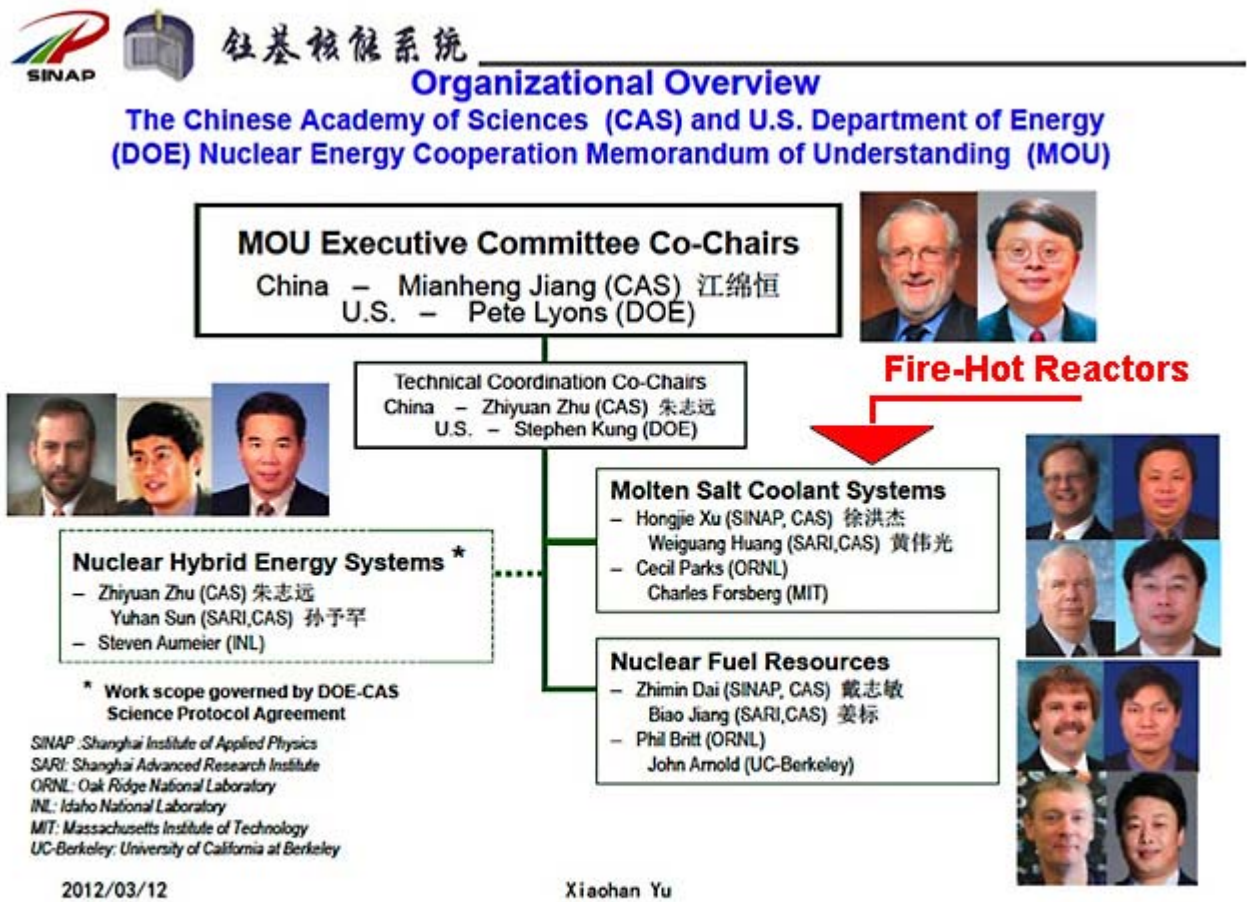


Chart by Dr. Charles W. Forsberg, MIT & ORNL, (pictured),
Coal, specific pressures by author.

No longer in the nuclear game, the United States has become ossified around the first nuclear technology – 550°F Low Temperature Steam. China is using 4 different nuclear technologies now.
2 ARE hot enough to end Global Warming.

Dr. Jiang Mianheng

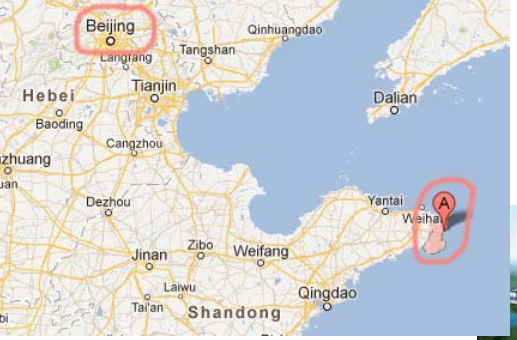
1. **Pebble Bed (U + Th)**
2. **Molten Salt (Thorium)**
3. Fast Breeder (U or Pu)
4. Conventional Uranium



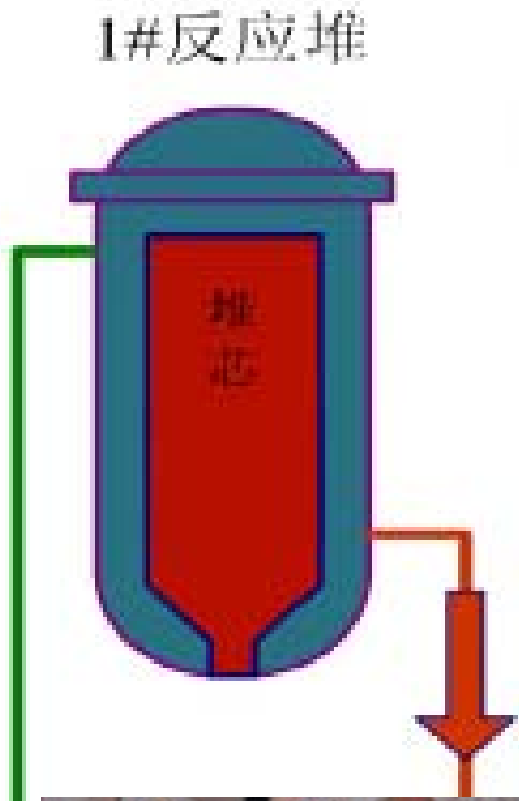
The names, faces and structure of the U.S. Department of Energy's nuclear collaboration with the Chinese Acaden of Sciences.

Photos and chart: Jiang/Clinton, from David Scull via Wikimedia. All others from page 27 of Chinese Academy of Science's March 12 presentation on thorium molten salt reactors, "TMSR Project of CAS."

How advanced is China?

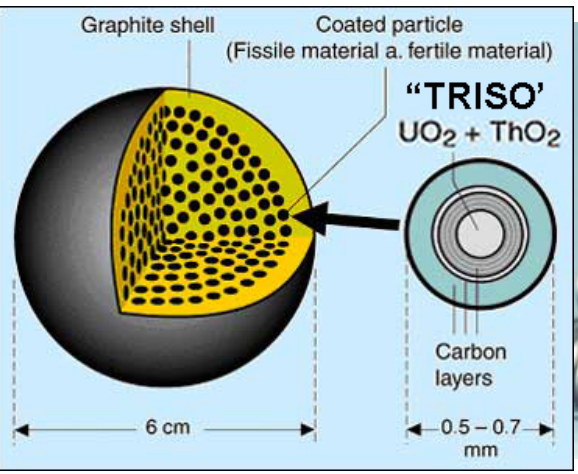


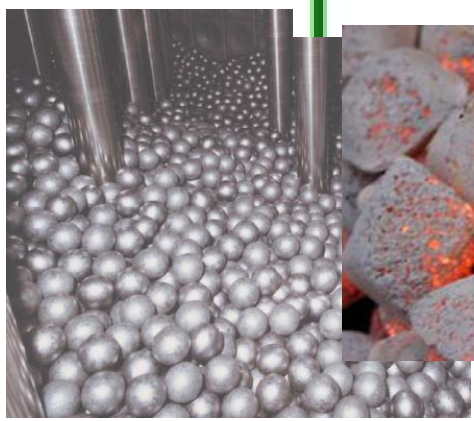
HTR-PM Helium cooled pebble bed reactor



Example: China is installing 40 FIRE-HOT 105 mW(e) HTR-PM high temperature pebble bed reactors at their Rongcheng electricity complex. We have none.

This is important because the HTR-PM is hot enough and powerful enough to power a small carbon-capture pilot plant NOW!





Many countries are working on hotter reactors

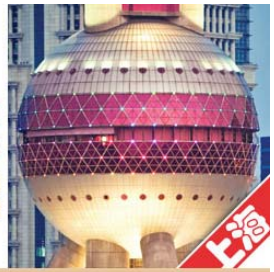
Canada, China, India, Finland, France, Japan, Korea, Russia, South Africa, UK.

	neutron spectrum (fast/ thermal)	coolant	temperature (°C)	pressure*	fuel	fuel cycle	size(s) (MWe)	uses
Gas-cooled fast reactors	fast	helium	850	high	U-238 +	closed, on site	1200	electricity & hydrogen
Lead-cooled fast reactors	fast	lead or Pb-Bi	480-800	low	U-238 +	closed, regional	20-180** 300-1200 600-1000	electricity & hydrogen
Molten salt fast reactors	fast	fluoride salts	700-800	low	UF in salt	closed	1000	electricity & hydrogen
Molten salt reactor - Advanced High-temperature reactors	thermal	fluoride salts	750-1000		UO_2 particles in prism	open	1000-1500	hydrogen
Sodium-cooled fast reactors	fast	sodium	550	low	U-238 & MOX	closed	30-150 300-1500 1000-2000	electricity
Supercritical water-cooled reactors	thermal or fast	water	510-625	very high	UO_2	open (thermal) closed (fast)	300-700 1000-1500	electricity
Very high temperature gas reactors	thermal	helium	900-1000	high	UO_2 prism or pebbles	open	250-300	hydrogen & electricity

** high = 7-15 Mpa*
\+ = with some U-235 or Pu-239
*** 'battery' model with long cassette core life (15-20 yr) or replaceable reactor module.*

ThEC
THORIUM ENERGY CONFERENCE 2012

Shanghai, China
Oct 29 - Nov 1 2012
Hope Hotel
No. 500 ZhaoJiaBang Road



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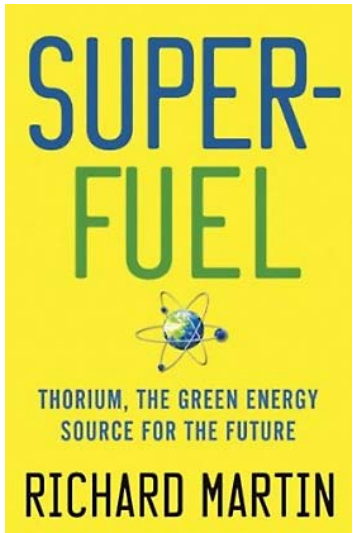


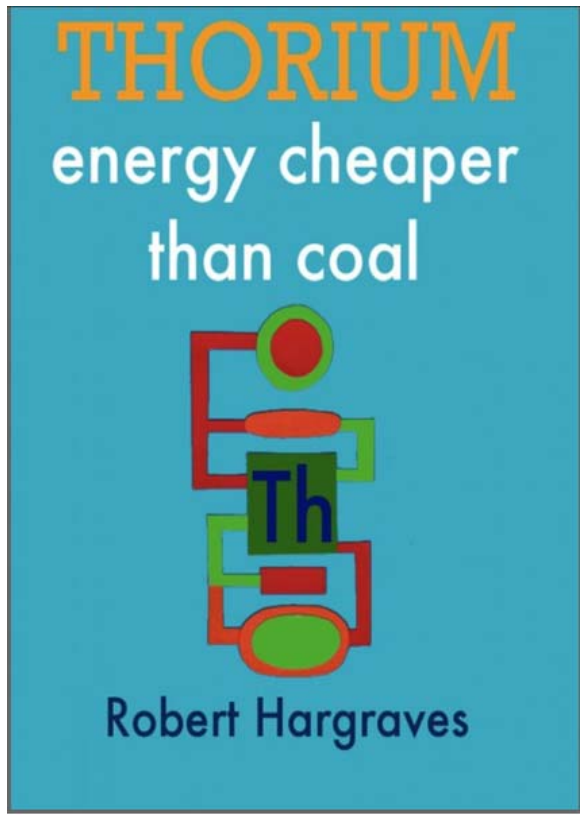
The objective is ending Climate Change, not saving money. Thorium will do both.

For now, I accept MIT's conclusion that it will take at least 400 kiloJoules (110 watt light bulb for 1 hour) to capture a 44g (1.55 oz) mole of CO_2 from ambient air.

I will use MIT's numbers but use thorium nuclear energy.

Extreme heat from thorium can be 2,000 times cheaper than extreme heat from coal.

The US DOE's goal is less than $25 per ton of delivered CO_2.



Doing it.

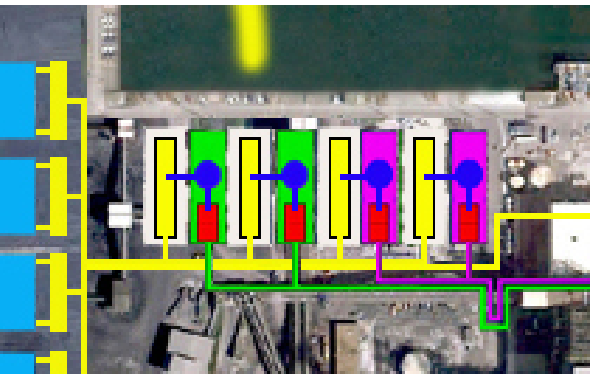
Capturing Global Warming CO_2 from the air.

Ending the Era of Global Warming.

The Russians are making barge mounted nuclear power plants for their remote Siberian mining towns on the Arctic Ocean.
Serial production in shipyards to drive down costs and drive up quality.
- FNPS Lomonosov is both a nuclear power plant and a desalinator.

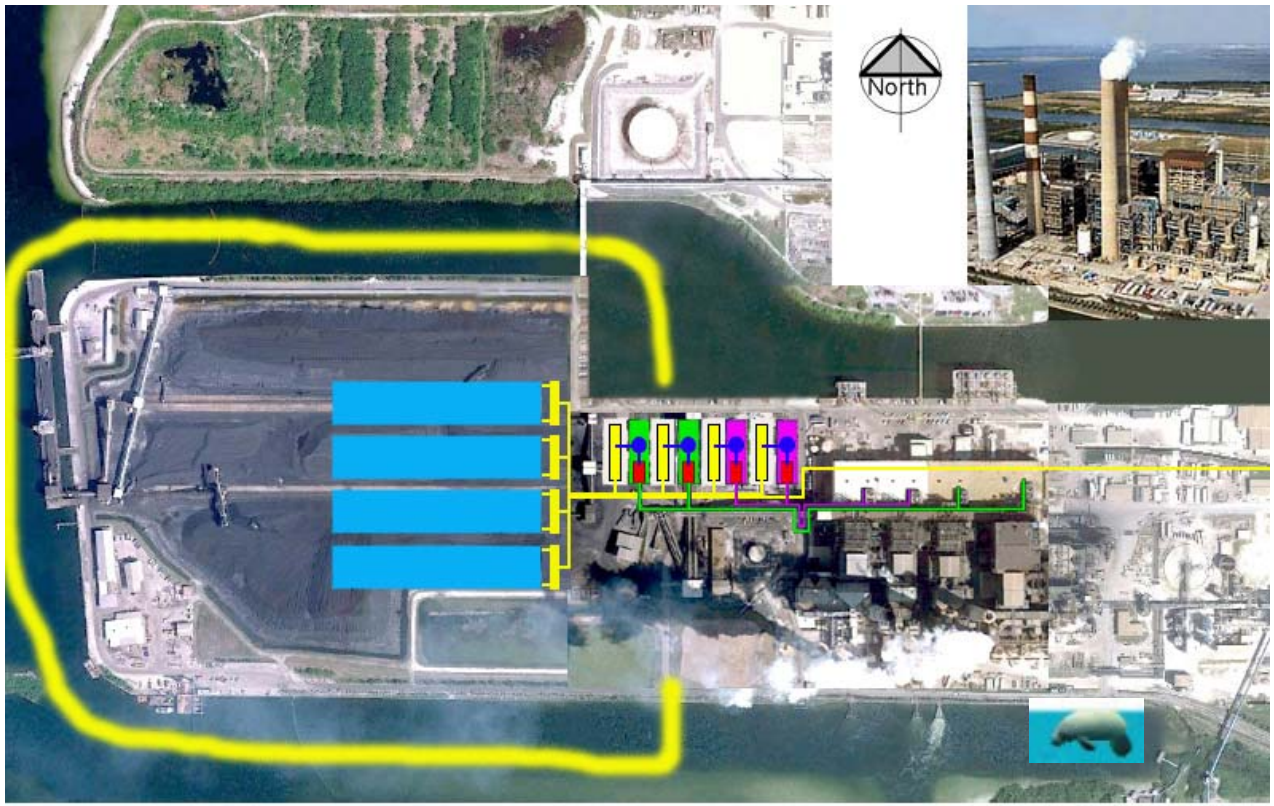
How it all would come together.
Using Big Bend, Tampa, Florida, as an example.

(Well over half of the world's largest coal power plants are on navigable water.)



Lt Blue = Air Contactors
Yellow = CO2 Capture System
Green, Vi. = Concrete Barges
Dk Blue = EBASCO Reactors
Dk Blue = Molten Salt Pipes
Red = Steam Generators

Violet, Green = Steam Pipes
Yellow = CO2 Disposal Pipe



Big Bend, near Tampa, Florida

Big Bend is a large coal burning power plant having 4 445 megaWatt (e) generators.
This sketched-up drawing shows how 4 reactor barges with steam generators (red) mounted on them could be floated next to the power plant's turbine gallery. Steam lines would be run to the existing turbines to repower them with the thorium-fueled molten salt reactors (blue dots) in the reactor barges.

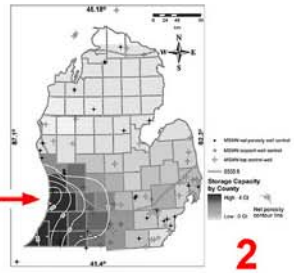
The reactor's extra power would be used to power 4 Air Capture systems to suck CO_2 from the air. 4 air bubbler canals located in the now-uneeded coal yard would bring air into contact with a 1 mole solution of sodium hydroxide (lye) to extract the CO_2 from the air. The yellow pipeline would take the CO_2 to a suitable geological area for disposal.

The time to begin a PILOT PLANT is now.

There is nothing, absolutely nothing, that has to be invented or developed to end Global Warming. We could begin construction drawings on a pilot plant now.

Russian nuclear reactor barge used to power remote Siberian Arctic Ocean towns.

1

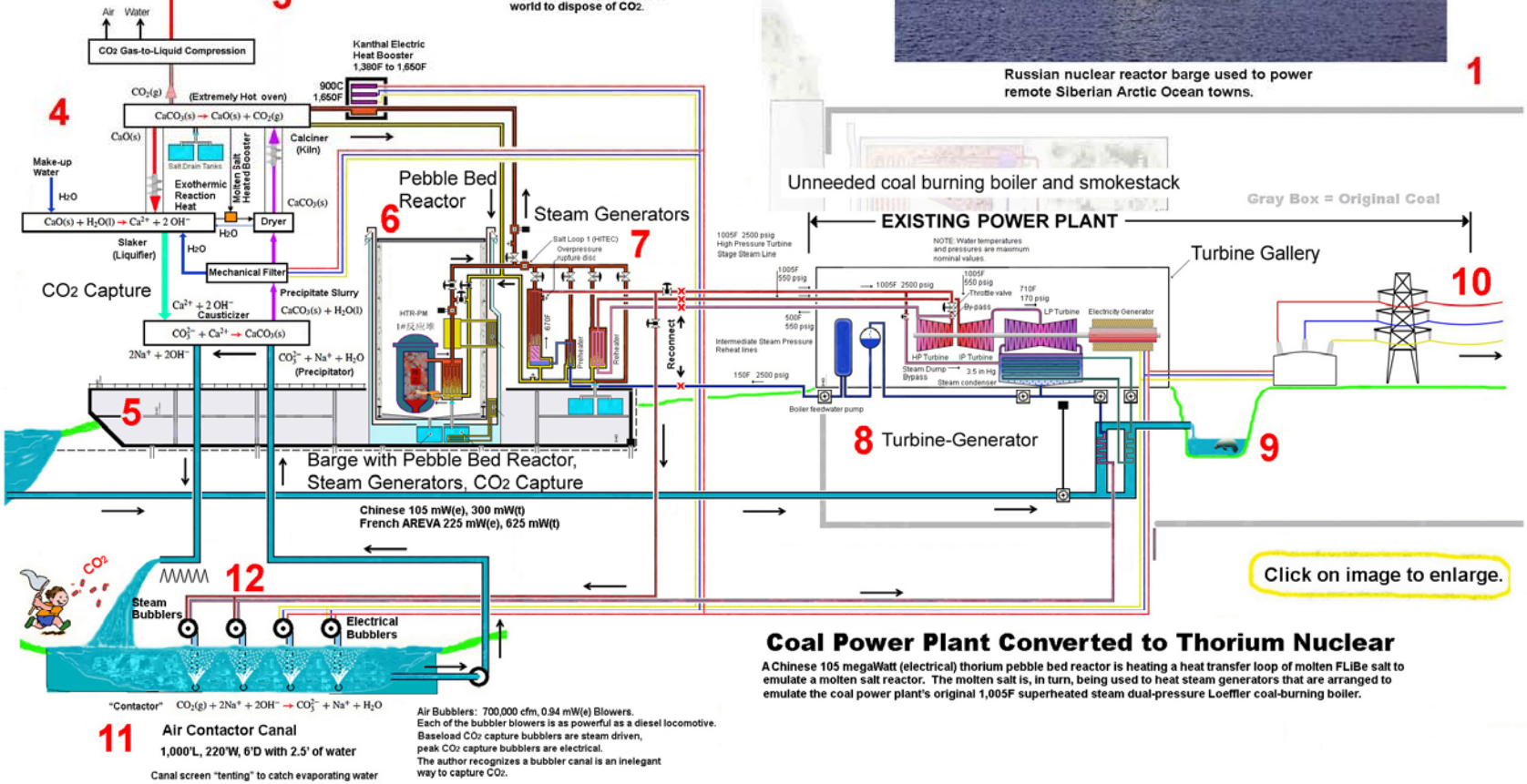


One of the best places in the world to dispose of CO_2.

2

Red: CO2 Injection Well Gray: Monitor Well

3



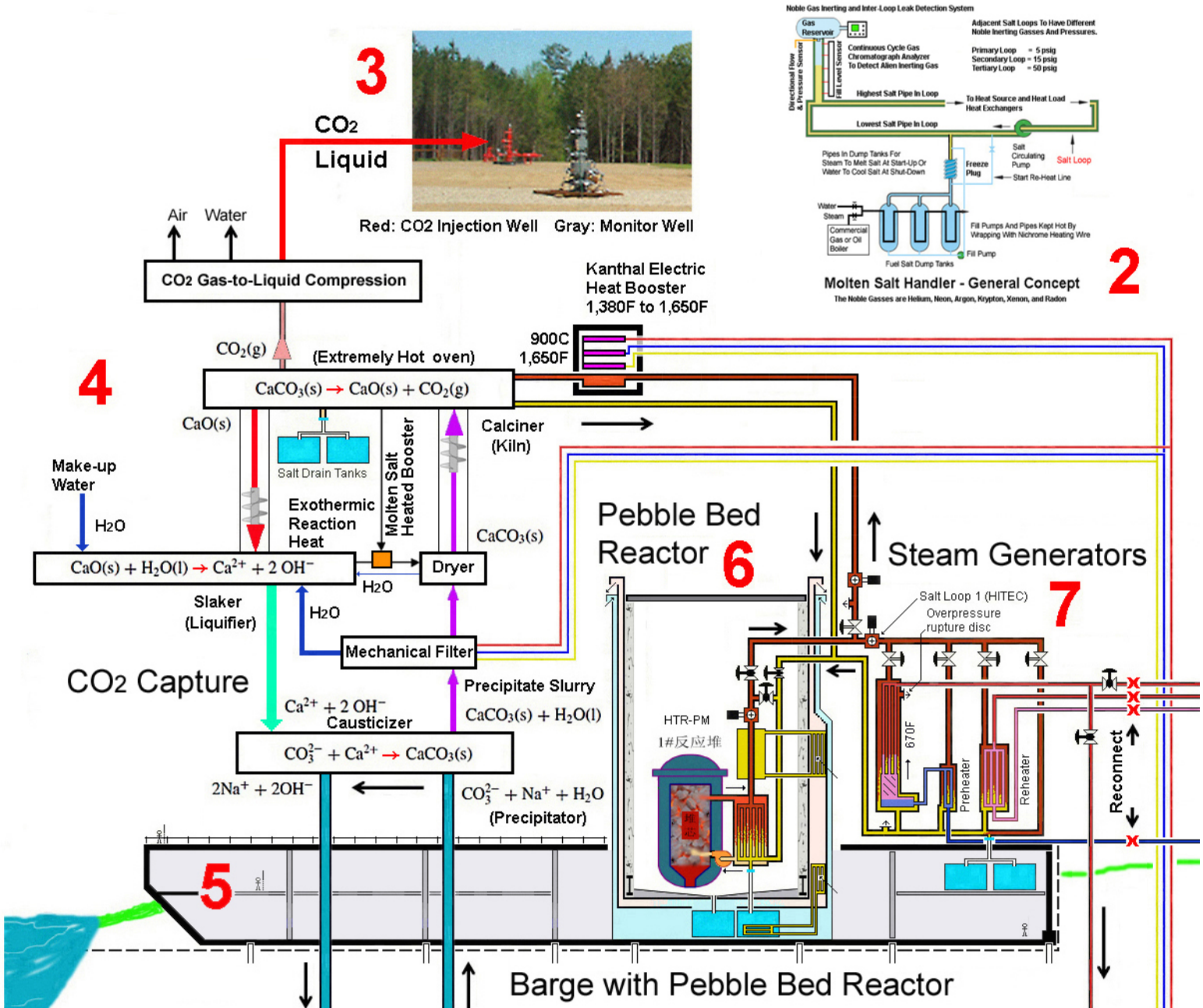
Click on image to enlarge.

Coal Power Plant Converted to Thorium Nuclear

A Chinese 105 megaWatt (electrical) thorium pebble bed reactor is heating a heat transfer loop of molten FLiBe salt to emulate a molten salt reactor. The molten salt is, in turn, being used to heat steam generators that are arranged to emulate the coal power plant's original 1,005F superheated steam dual-pressure Loeffler coal-burning boiler.

Atmospheric CO_2 Scrubber to Roll Back Global Warming

Closer view of pilot plant barge.



What are the best results we might expect?
(Man put 35 billion US tons of CO2 into the air during 2011.)

- **Immediately end 10 billion tons per year of Global Warming emissions by converting 1,200 large power plants from coal to thorium.**
- **Remove 27.8 billion tons of CO2 from the air per year by air capture equipment added to the 1,200 large existing power plants.**
- **That's a total of 37.8 billion tons compared to the 35 billion tons of CO2 made by man during 2011.**

- **The author thinks 50% to 80% of the above figure is a realistic expectation.**

- **For the 1 trillion tons of CO2 backlog in the air, there are the 1,000 new mega-power plants being planned by China, India, etc., which could be built as CO2 capture plants.**

Calculations:

(Using MIT's 400 kJ (380 BTU or 112 watt-hours thermal) of work per 44g mole (1.55 oz) of CO2 captured.)
The EBASCO reactor is rated at 2,500 megaWatts (thermal) at 1,300°F.

The average mega-coal power plant generating unit, rated at 350 megaWatts (electrical), consumes 970 mW(t), this leaves 1,530 mW(t) for CO2 capture.
Recall, this calculation is at peak electrical load, delivered CO2 would be higher.

1,530 million W(t)/h / 112 Wh/mole = 137 million moles. Times 1.55 oz CO2/mole = 21.2 million oz or 1.32 million lb or 660 tons / hour.
660 tons/hr * 24 hr/day = 15,840 tons/day, * 365 days/yr = 5.8 million tons/yr / generating unit.
There are 1,200 mega-coal power plants * 4 generating units per plant = 4,800 units.
5.8 million tons/yr times 4,800 units total = 27.8 billion tons of CO2 per year at 100% efficiency.

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9) "**Capturing carbon dioxide directly from the atmosphere."** Zeman, F. S.; Lackner, K.S., *World Resour*. Rev. 2004, 16,157-172. [45.048]

Thank you for your interest.

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What might repairing the air cost?

Guesstimating the order of magnitude costs.

(We say two numbers have the same order of magnitude of a number if the big one divided by the little one is less than 10.)

The average old coal mega-power plant has 4 x 350 megaWatt electrical generating units.
The CO2 revenue stream would be based upon mine mouth and well head carbon taxes.
(11 tons of carbon dioxide equals 3 tons of carbon, and a price of $30 per ton of carbon dioxide equals a price of $110 per ton of carbon. The ratio is 44/12 or 3.6 to 1.)

Revenue: The current EU price for carbon is $7.75 per ton or $2.15 per ton of CO2. It is estimated that a price of $180/ton carbon or $50 per ton CO2 will be necessary to reduce Global Warming emissions to 1990 levels. (Yvo de Boer, UNFramework Convention on Climate Change, Dec 2, 2012.) **US DOE wants captured CO2 at no more than $25 / ton CO2.**

USING DOE $25 / ton CO2: At = 5.5 million tons CO2/yr / generating unit, times $25 / ton CO2, that's $138 million / year per generating unit. Times 4 generating units per power station = $550 million / yr.

Construction Cost: My educated GUESS to add the 10th EBASCO reactor produced to an old large coal power plant would cost $500 million. To add the 10th air capture facility at the same time would also cost $500 million. Per unit total would be $1 billion. Times 4 generating units per power station = $4 billion.

Times 1,200 generating stations = $4.8 trillion. This buys sucking up ALL of the world's current CO2 emissions.
(The world's GDP is about $70 trillion/yr.) Disposal of the captured CO2 would be local and is extra.
Digging into the 1 trillion tons of CO2 backlog that is already in the air would take converting some of the 4,000 regular sized old coal burning power plants.

Fuel cost savings - Coal to thorium: 4 - 350 mW(e) units = 1.4 gigaWatts(e). At 3 million tons of coal per gW/yr = 4.2 million tons of coal. At $40 per ton of coal = $170 million/yr. At $50 thousand per gW/yr for thorium = $70 thousand/yr for 4 350 mW(e) thorium units or a savings of 169.93 million/yr. - - (Dr. David LeBlanc)