



# ***Our Climate: A Global Challenge***

Academy for Lifelong Learning  
Denver, CO

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<http://portfolio.du.edu/OurClimate>

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What's being done.

It's not hopeless.

We have transformed our energy before.

# Imagine it's 1859

- Oil discovered in Pennsylvania
- New England whaling industry was running out of whales
  - whaling in the arctic was a dangerous proposition
- “Peak whale” had been passed and the world stopped burning whale oil and making candles from whale blubber



# and you're in charge ...

Somebody presents you with a grand idea for transforming the world economy:

- ✓ Dig 8 billion tons of carbon out of the ground every year
- ✓ Build a system of pipelines, supertankers, railroads, highways, and trucks to deliver it to every street corner on the planet
- ✓ Build millions of cars every year, and millions of miles of roads to drive them on
- ✓ Generate and pipe enough electricity to every house to power lights & stereos & plasma TVs



... *“and here’s the bill ...”*



# Change is opportunity (peak oil will force it anyway)

- There are costs to transform our energy system
- There are costs for not transforming
- I don't think anyone can calculate the net cost



*In every crisis  
lies the seed  
of opportunity*



**Apply solutions here**



**instead of here.**

# Regulate the extraction instead of the end product

Right now we are trying to fix things at the “tailpipe”; CO<sub>2</sub> exhausts (CCS, electric cars, etc.)

EPA regulates the CO<sub>2</sub>

At the same time, the government gives out subsidies and permits for more extraction.

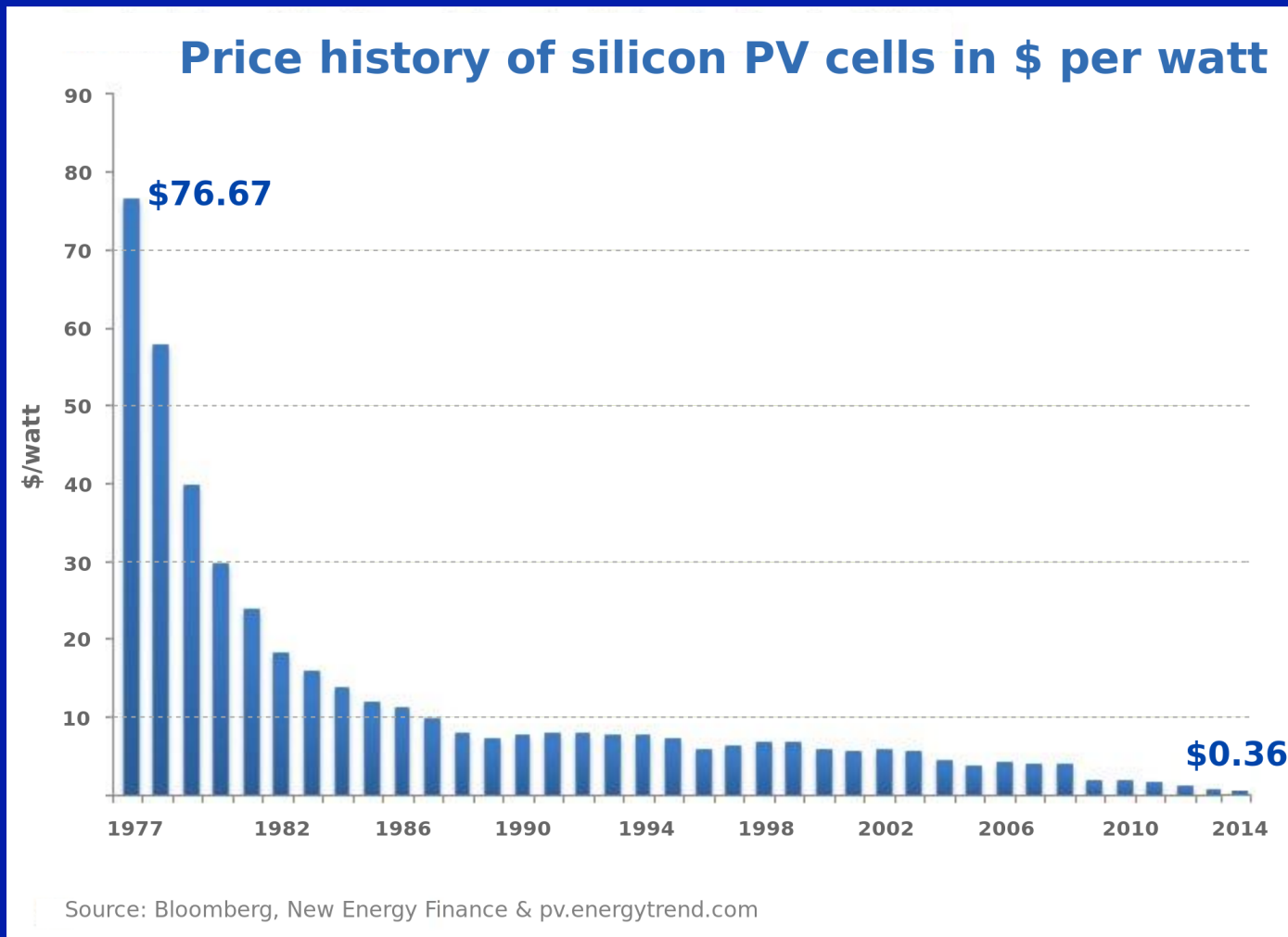
It is not just inconsistent, it's schizophrenic.

Tax carbon at the source (wellhead, minehead or port of entry) so the true cost is paid by the user. Conservative economics.

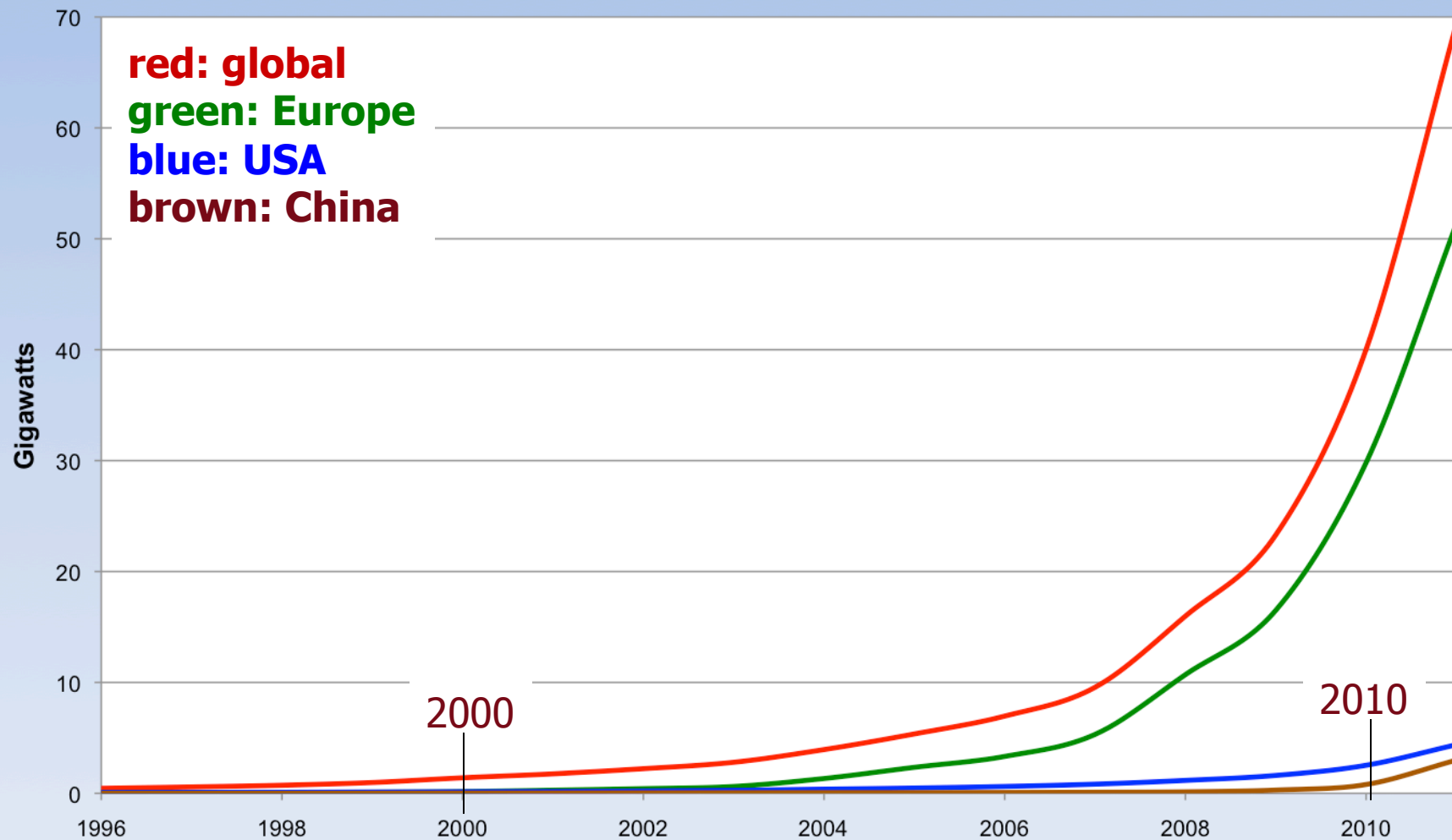
# Success stories: What we need to do has been done before.

- Reforestation in South Korea
- Rooftop solar water heating in China
- Crop residues to feed animals
  - Milk production via fodder in India
  - Feeding beef in China
- Geothermal energy in Iceland
- Wind farms in Denmark
- Soil conservation tillage in the USA (but fertilizer)
- Population stabilization in Eastern Europe, Russia
- Ozone hole treaty

# Photovoltaic cells: \$0.36 watt



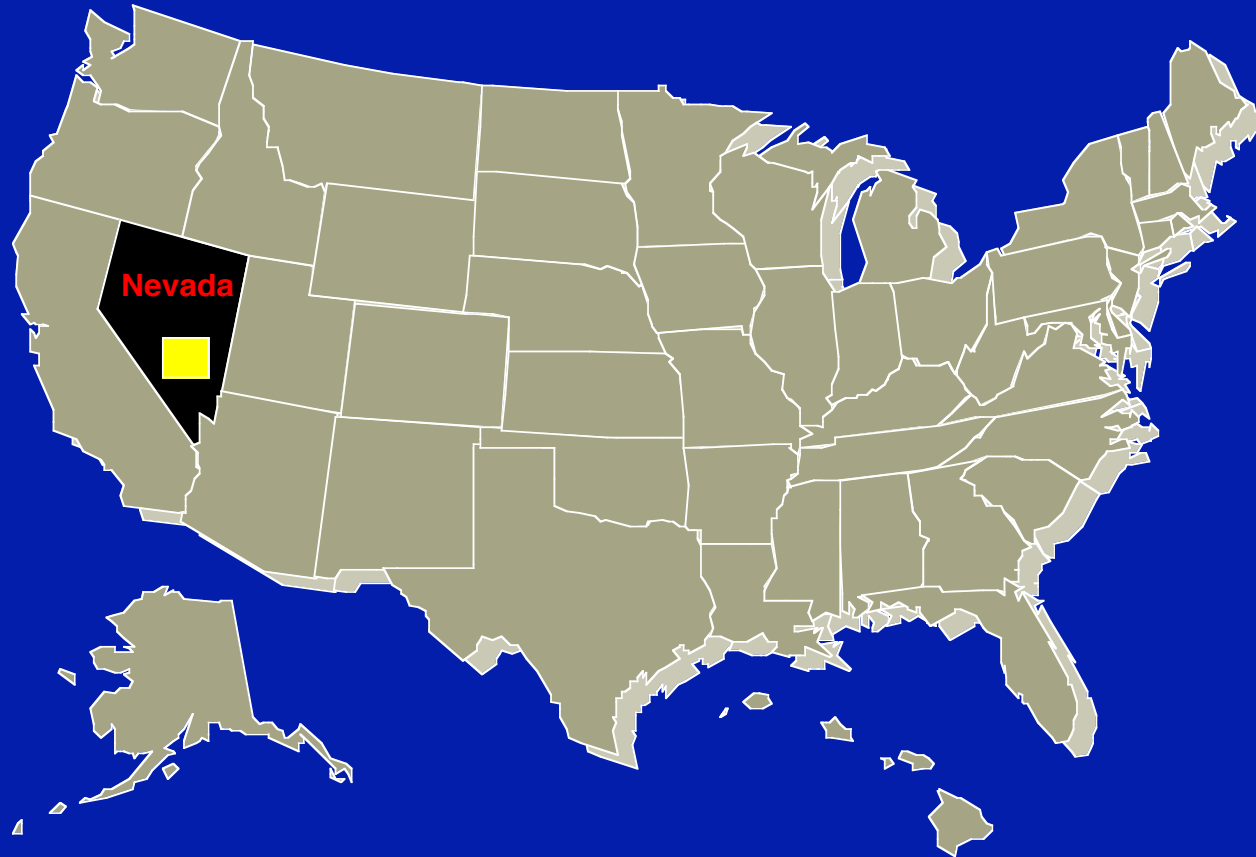
## Solar PV Capacity 1996-2011



Data source: 2012 BP Statistical Review of World Energy



# Total Area Required for a Photovoltaic Power Plant to Produce the Total U.S. Annual Electrical Demand



P109-G1055201

**J. A. Turner, "A Realizable Renewable Energy Future", Science, 285, p 5428, (1999).**

# Economist's view



# Different world views

## **Economists**

- Creative destruction
- Technology will fix everything
- Growth is essential and raises the well being of everyone

## **Biologists/ecologists**

- Everything is interrelated
- Kill one thing and the whole system will collapse
- Nature provides for free (e.g. bees)
- We must preserve it or we're all dead

# Strategies

**Mitigate:** intervene to reduce the sources or enhance the sinks of greenhouse gases

**Adapt:** Adjust in response to actual or expected climatic stimuli or their effects

**Climate Intervention:**  
Plenty of incentive

**Increase understanding:**

- Research: measure and model
- Technology development

# National Academy of Sciences

Detailed in depth look at ways for humans to cool the planet, which is being increasingly proposed for a variety of reasons

## **0. Mitigate and Adapt; first and most important**

1. Carbon Capture and removal
2. Albedo Modification

### What's In a Name

geo-engineering -> climate intervention

solar radiation management -> albedo modification

engineering implies we know how to do it well (as in bridges)

intervention is done with the intention to improve something (health)

# NAS Recommendations

- Mitigate and Adapt first and foremost
- Albedo modification at scales sufficient to alter climate should not be deployed at this time
- Research of albedo modification should continue (emergency, use by other countries, etc.)
- Carbon capture has more promise, is already in R&D, and has less down side.

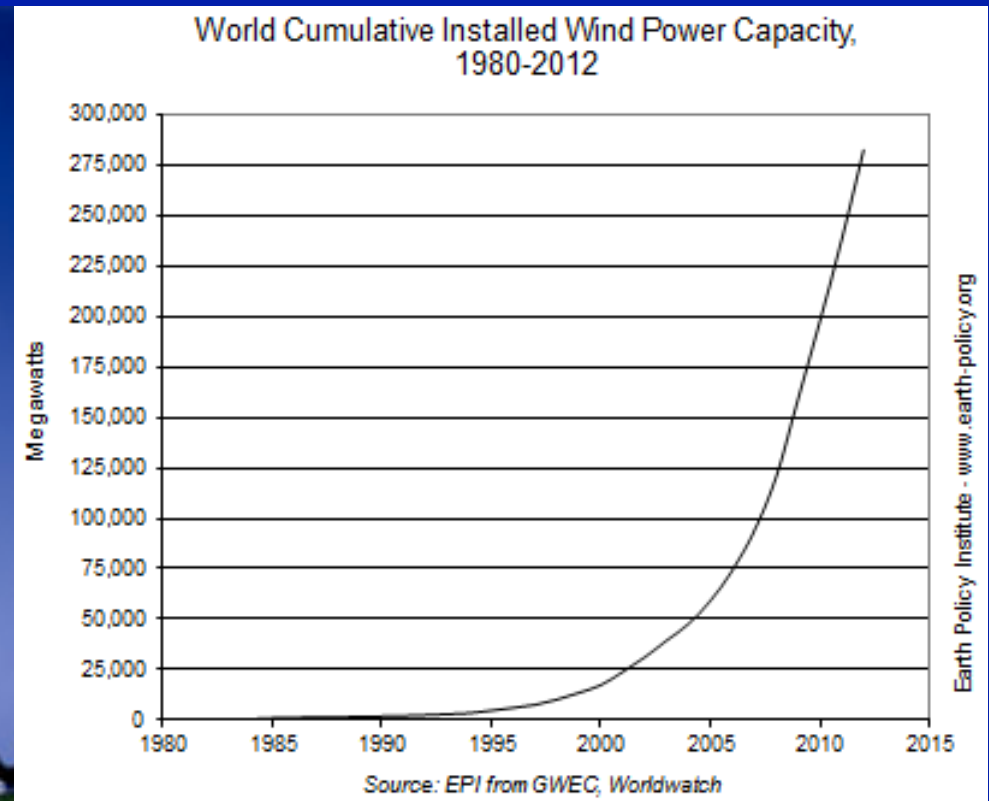
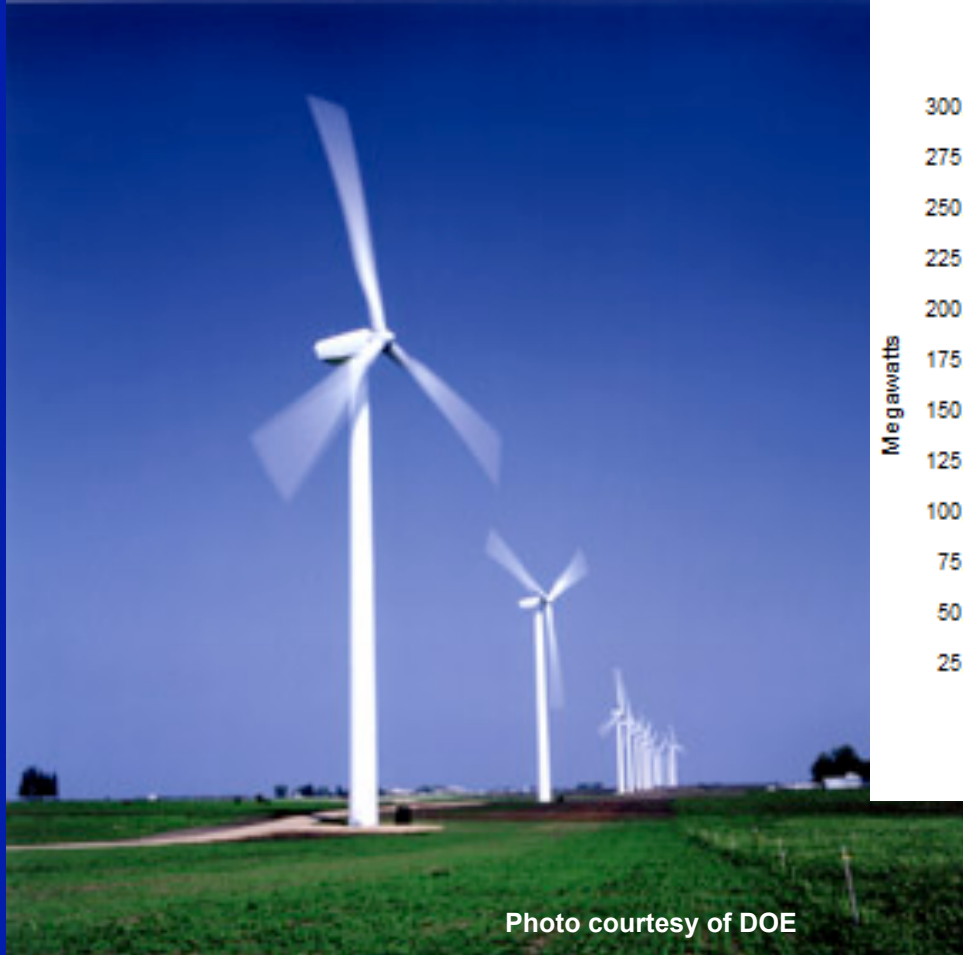
# Mitigation

- **Wind energy**
- **Solar cells**
- **Solar power plants**
- **Nuclear power**
- **Energy storage**
- **Geothermal**



# Wind Electricity

Wind generated energy is cost competitive!



2012: 225,000 wind turbines

# *Solar Electricity*



Milt's attached garage



Photos courtesy of DOE Photovoltaics Program

Goal: Install 20,000 square kilometers for dedicated use by 2054  
Rooftops about 15,000 km<sup>2</sup>.

# *Xcel Energy and SunPower Corp.*

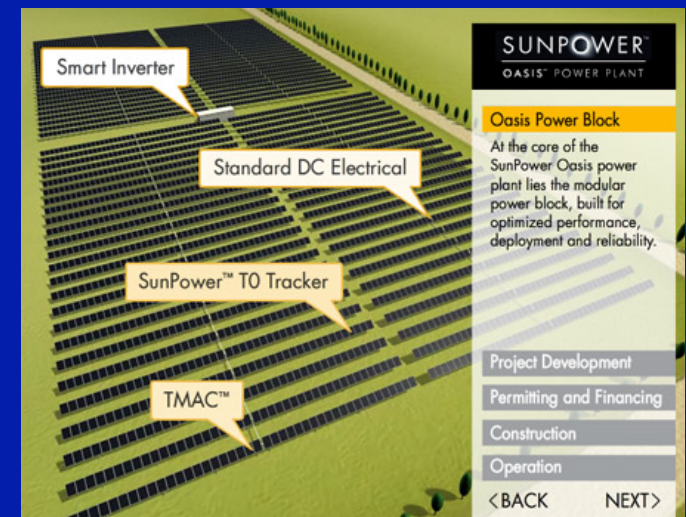
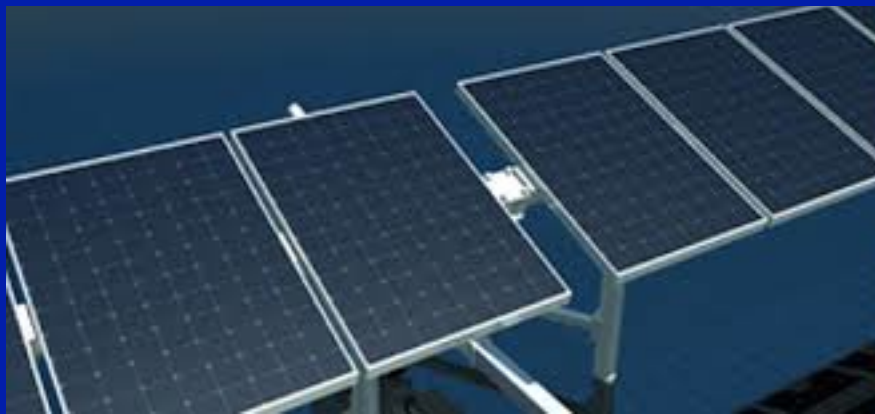
19 MW Greater Sandhill plant has been operating 2010  
30 MW San Luis Valley Solar Ranch since 2011



Building a 3<sup>rd</sup> plant in San Luis Valley 50 MW  
Construction 2015, full commercial in 2016  
all 3 support 26,500 homes (aka a Littleton, CO)

Uses photo voltaic cells with sun tracking

Need 500 for the full USA





# *California leads*

World's largest solar power plant  
392 MW Ivanpah Solar Power Facility



CA has 1.5 GW of capacity now

2 million tons of CO<sub>2</sub> avoided/year (of 30 billion tons)

0.007 % of global CO<sub>2</sub>

We would need almost 20,000 of these plants globally.

# *Nuclear Electricity*

2012: 12% world's energy  
435 reactors worldwide  
72 under construction in 15  
countries



Graphic courtesy of NRC

Expand use of small nuclear reactors such as those used on ships and satellites.

# *Energy storage*

## **Mechanical:**

- Flywheel
- Gravitational potential
- Pumped-storage hydroelectricity
- Compressed air



Highview Power  
Storage Ltd.'s pilot  
plant in Slough, UK

## **Chemical:**

- Battery
- Hydrogen
- Power to gas

## **Electromagnetic:**

- Superconducting magnet

## **Thermal:**

- Thermal
- Cryogenic
- Molten salt

Gemasolar Thermosolar Plant in Spain





# *Rooftop wind*

- Quieter systems being developed
- Vertical axis wind turbines (VAWT)



Sunforce 45444  
600 Watts, 12 or 24 volts

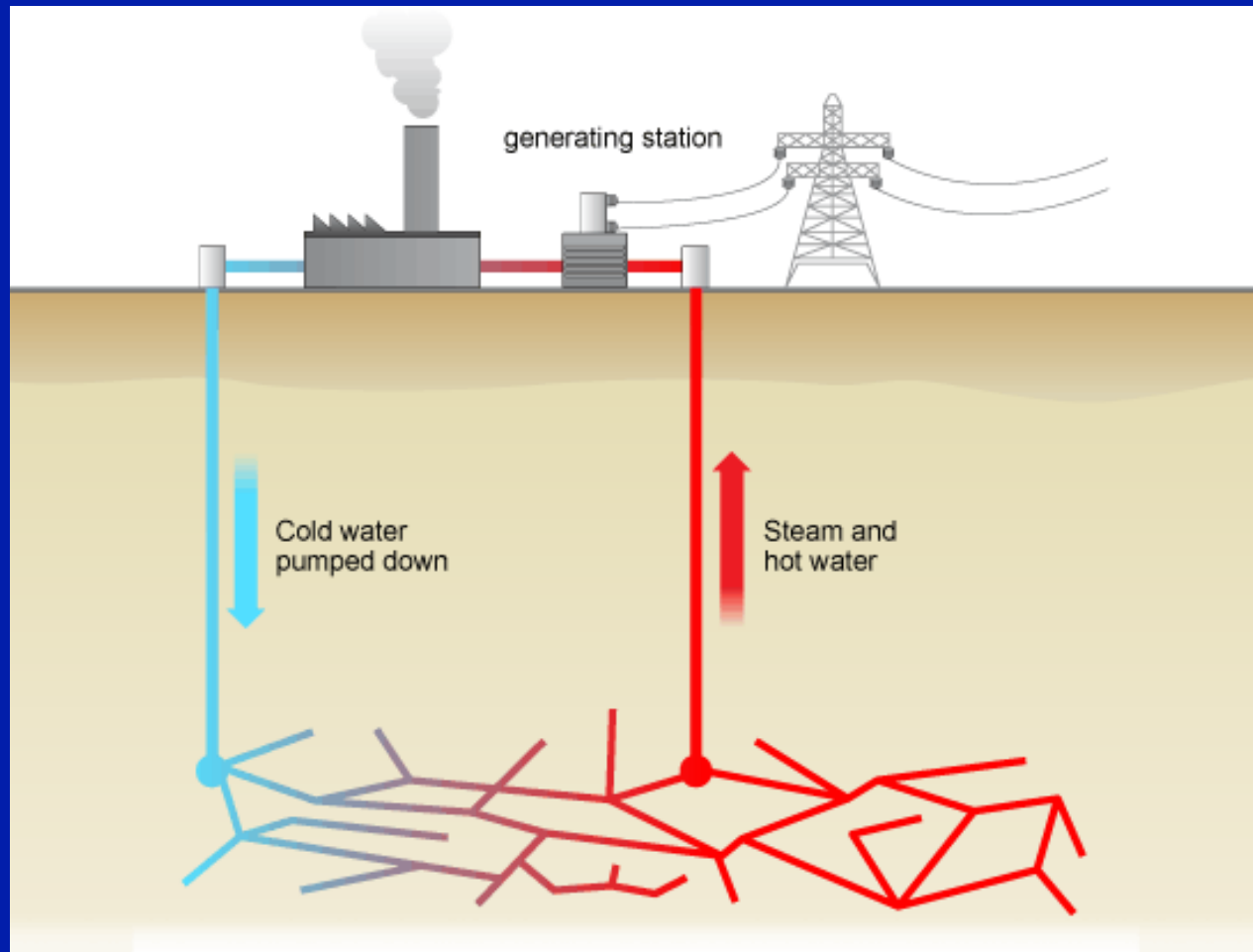


Helix Wind



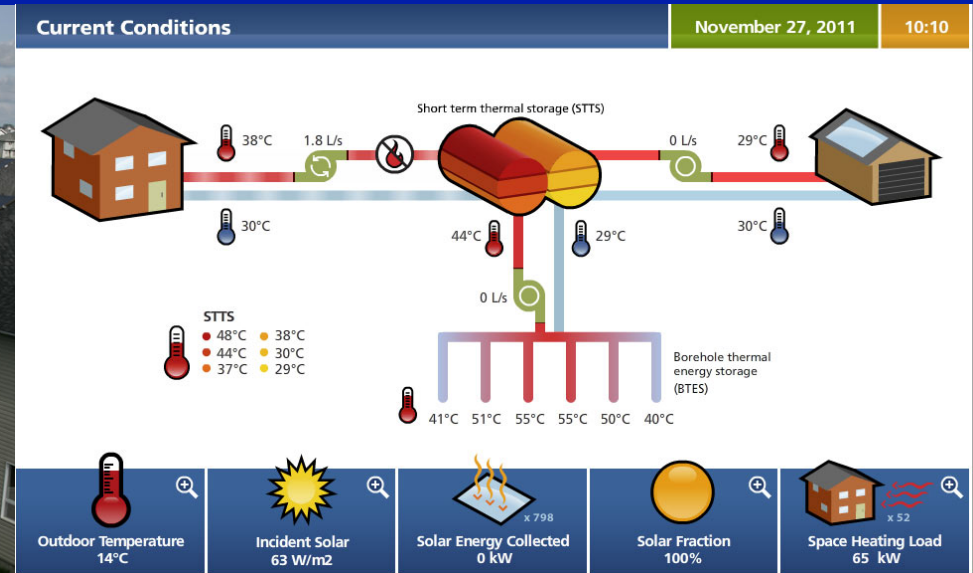


# *Geothermal*



Let's mine heat instead of oil and gas

# Drake Landing Solar Community, Alberta, Canada



52 homes  
heat capture in summer on garage roofs  
seasonal storage in the rock under a community park  
provides 97% of the community's heating energy requirements

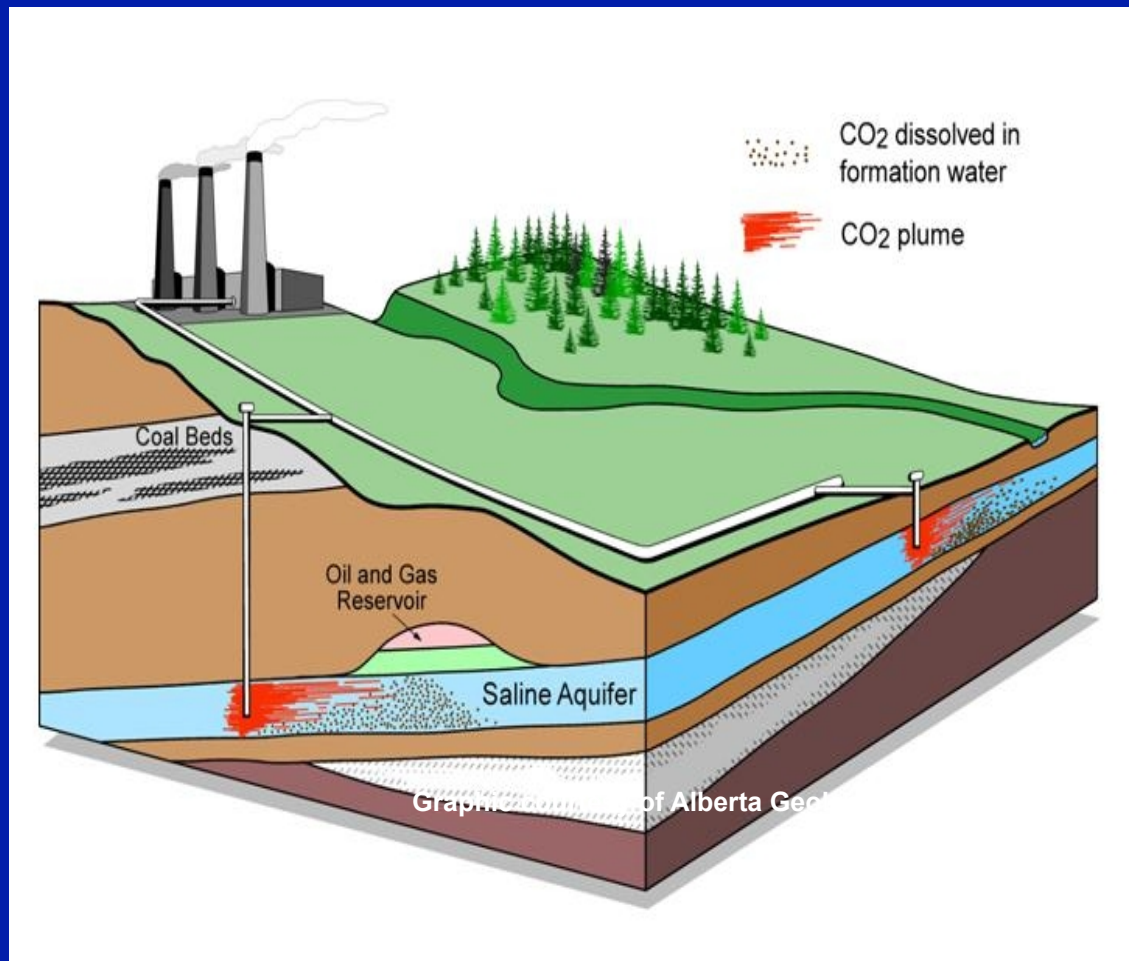
# Adaptation

- **Dikes, sea walls, artificial reefs**
- **Electric cars**
- **Paint roofs white**
- **Recycle, recycle, recycle**
- **Buy boat and generator**
- **Move north, buy sweater**

# Carbon Capture & Storage

There are currently three storage projects that each inject 1 million tons of CO<sub>2</sub> per year.

**Well, they're trying.**



# *Manage the sea*

## Dikes in the Netherlands



Windmills of Holland pump water from behind the dikes.



Netherlands lies primarily on the river delta of the Rhine (and the Meuse) river

27 percent of the Netherlands is actually below sea level

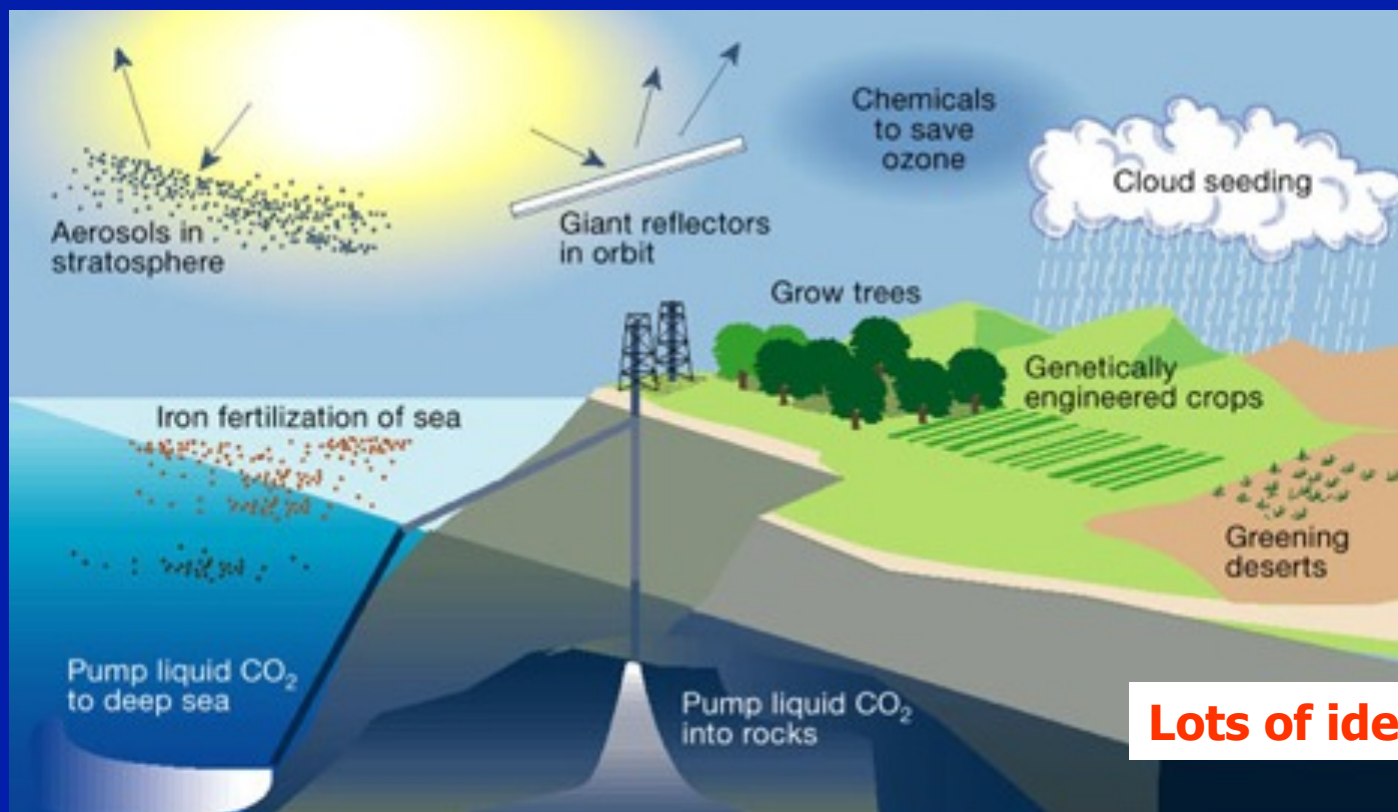
60 percent of the country's (15.8 million people) live below sea level

# **Climate Intervention: Planetary scale**

[http://earthobservatory.nasa.gov/  
Features/Aerosols/](http://earthobservatory.nasa.gov/Features/Aerosols/)



‘Climate Intervention’ is the deliberate modification of an element of the climate system on a large scale to avoid dangerous impacts of climate change.



**Lots of ideas!!**



# *CO<sub>2</sub> Removal*

## Bio-removal:

- Plant trees and other land management

- Wetland restoration and sustainable agriculture

- Use biofuel (e.g. algae), burn and recycle the CO<sub>2</sub>

- BECCS (bio energy, carbon capture storage)

- Biochar (burning in O<sub>2</sub> free environment)

## Carbon capture and sequestration (CCS)

(popular with energy giants like Shell)

- There are 2-3 pilot CCS plants now

- It will take thousands of plants to make a difference

Artificial weathering

Many other ideas

# Mineral Carbonation of CO<sub>2</sub>

Eric H. Oelkers<sup>1</sup>, Sigurdur R. Gislason<sup>2</sup> and Juerg Matter<sup>3</sup>

## *Artificial weathering*

**TABLE 1** SOME POTENTIAL SOURCE MINERALS  
FOR CARBON MINERALIZATION

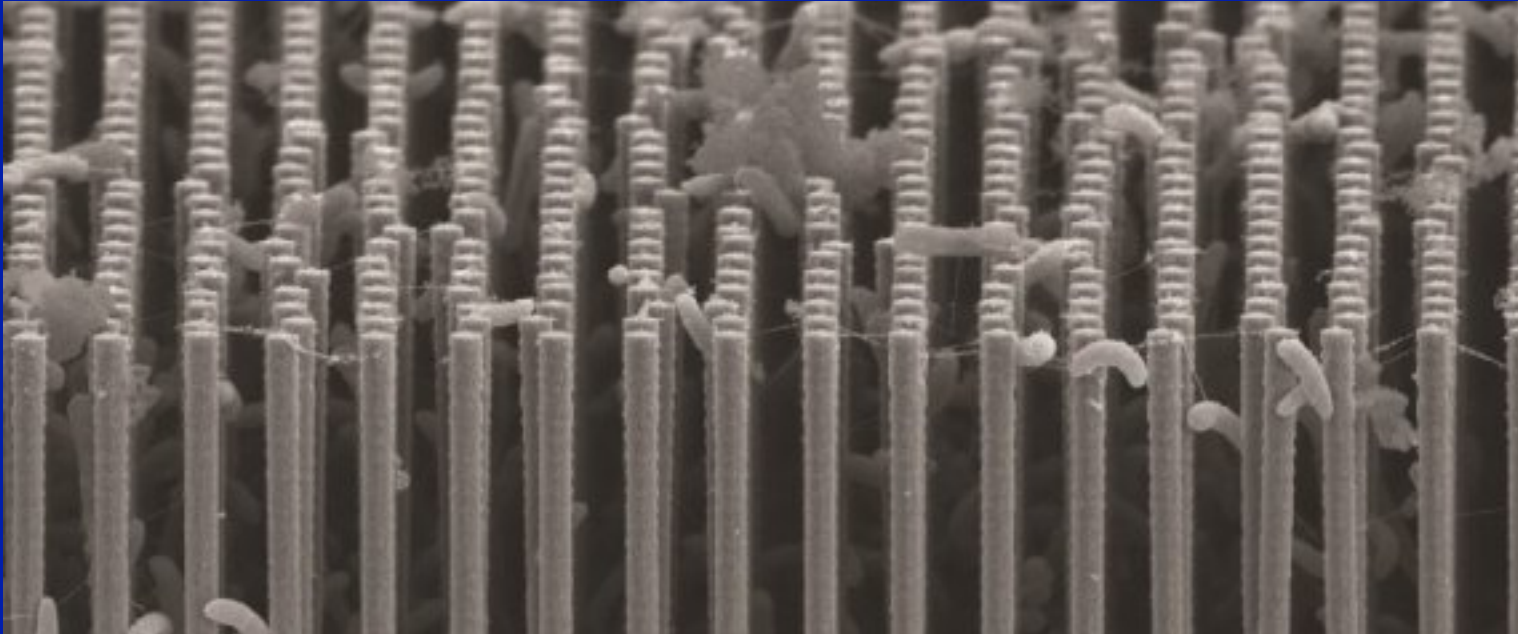
SOLID	CHEMICAL FORMULA	Tons required to sequester 1 ton of carbon
Wollastonite	CaSiO <sub>3</sub>	9.68 <sup>a</sup>
Forsterite	Mg <sub>2</sub> SiO <sub>4</sub>	5.86 <sup>b</sup>
Serpentine/ chrysotile	Mg <sub>3</sub> Si <sub>2</sub> O <sub>5</sub> (OH) <sub>4</sub>	7.69 <sup>b</sup>
Anorthite	CaAl <sub>2</sub> Si <sub>2</sub> O <sub>8</sub>	23.1 <sup>a</sup>
Basaltic glass	Na <sub>0.08</sub> K <sub>0.008</sub> Fe(II) <sub>0.17</sub> Mg <sub>0.28</sub> Ca <sub>0.26</sub> Al <sub>0.36</sub> Fe(III) <sub>0.02</sub> SiTi <sub>0.02</sub> O <sub>3.45</sub>	8.76 <sup>c</sup>

<sup>a</sup> as calcite; <sup>b</sup> as magnesite; <sup>c</sup> assuming all Ca, Mg and Fe are converted into calcite, magnesite and siderite

Costs:

1. Collect and transport CO<sub>2</sub>
2. Grind the mineral to increase binding sites
3. Dispose of store the CO<sub>2</sub> rich mineral that results.

# *Artificial photosynthesis*



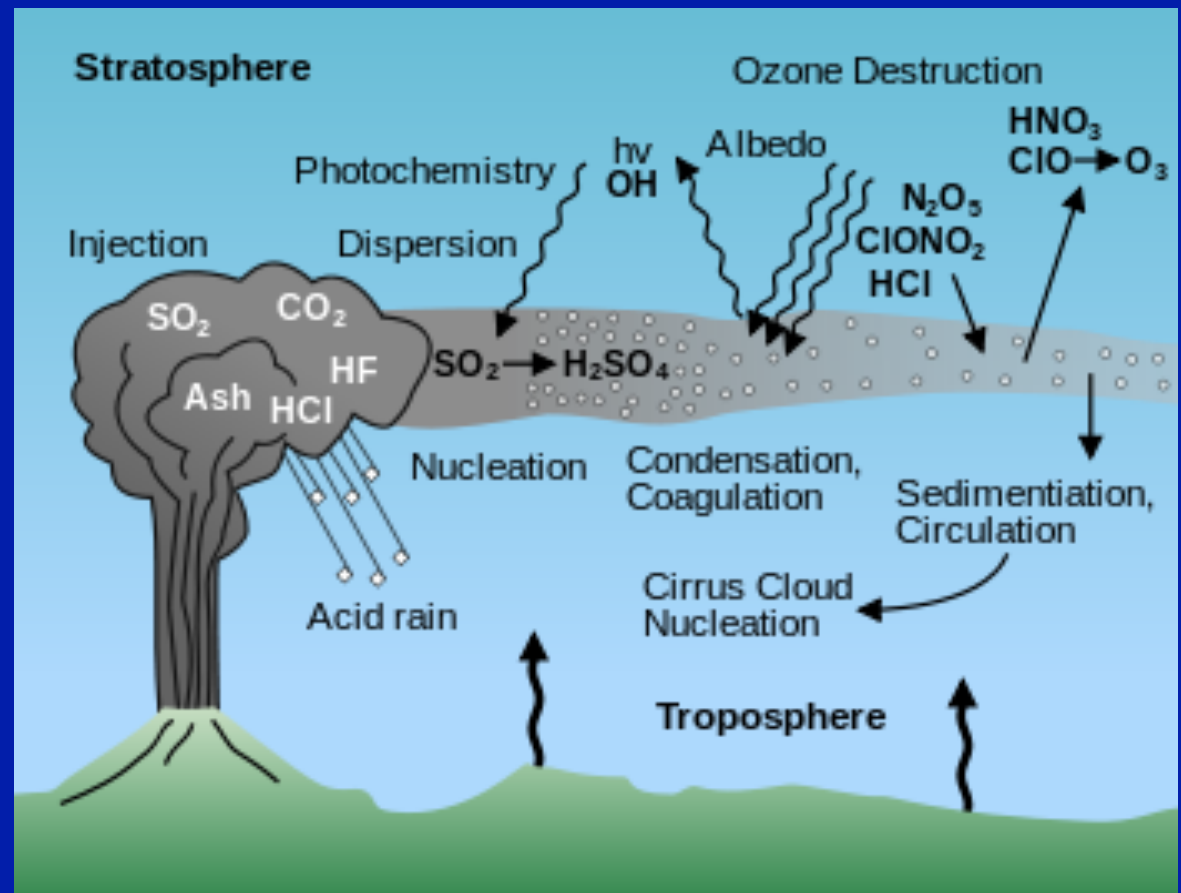
A system that can capture carbon dioxide emissions before they're released into the atmosphere and convert them into fuels, pharmaceuticals, plastics, and other valuable products.

# Artificial volcanoes

Volcanic sulfates end up here as sulfuric acid droplets and have a strong cooling effect (aka global dimming) on the planet until they fall out over a few years.



Mt. Pinatubo, June 1991



Poorly understood:

Imitate the natural volcanic action by shooting  $\text{H}_2\text{S}$  and  $\text{SO}_2$  into the stratosphere: artillery shells, aircraft or stratospheric balloons.

# Trash gas

- We pay fees to put our waste into sewers.
- We pay fees to have our solid waste disposed of.
- Why should we not pay a fee for dumping waste gases into the atmosphere?



# Citizens Climate Lobby **Proposal**



Collect fee  
\$15 per ton of  
CO<sub>2</sub> at wellhead  
or port of entry  
[fee rises \$10/yr]

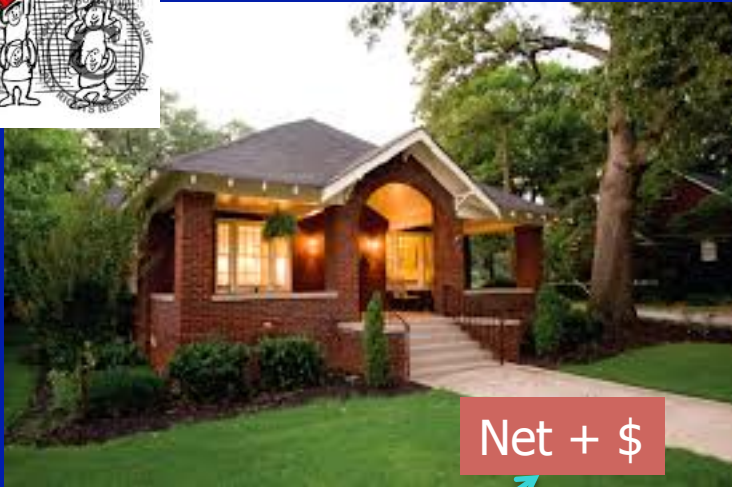


\$\$\$

U S Dept. of the Treasury: Trust Fund

All monies returned to households  
1 share per adult  
0.5 shares per child <18yrs  
maximum 3 shares per family





Net + \$



Net - \$



Net +\$

2 of 3 households have net gain of \$.

CO<sub>2</sub> emissions are reduced



Renewable energy sources  
are stimulated.  
Market will choose  
the best.





# Citizen's Climate Lobby

During the break

Lesley Lefevre

A major push for a bipartisan  
carbon fee and dividend

# Personal



# My own "to do" list

- 40 year old house with shake roof (not good)
  1. insulate
  2. new roof (wait for the hail storm from hell?)
  3. rooftop solar cells (solar shingles?), wind?
- Divest of ancient hydrocarbon fuel stocks
- Buy an electric car
- Replace old appliances
- Continue giving "global warming" talks
- Continue recycling



