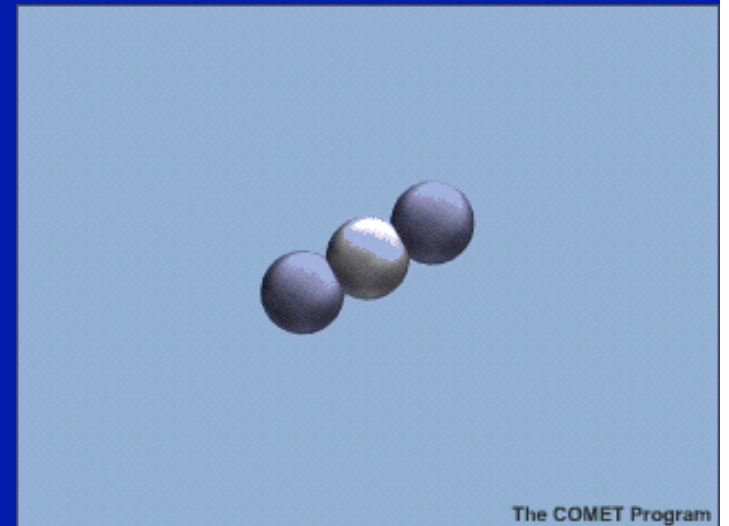


Capitalism vs. the Planet
Class 2: The Science
Facilitator: Gary Wyndarden

Jonathan F. Ormes
JFOrmes@comcast.net
Sept. 23, 2015

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



Outline: Part 2

- Population and affluence
- What new technologies are coming to help
- A tax on carbon
- What an individual can do

POPULATION & AFFLUENCE

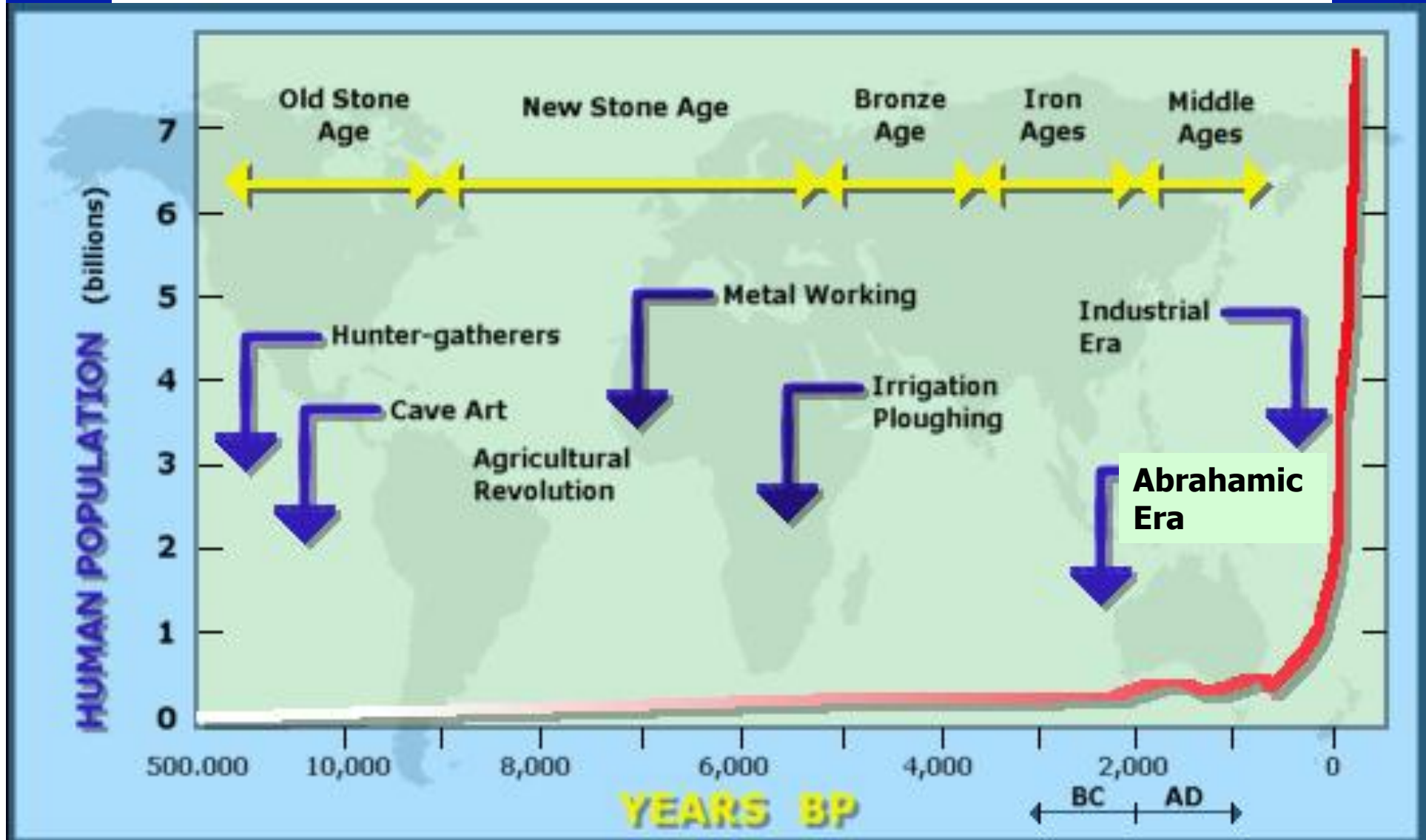
Population

Hominids first appeared in the Neogene Period, about 3.5 M years ago.

Identifiable cultures started about 11,000 years ago.



World Population Growth Through History



Current Population Situation

**20th Century growth rate was “super exponential”
until inflection point circa 1980**

Human species

0.5 billion: 1600

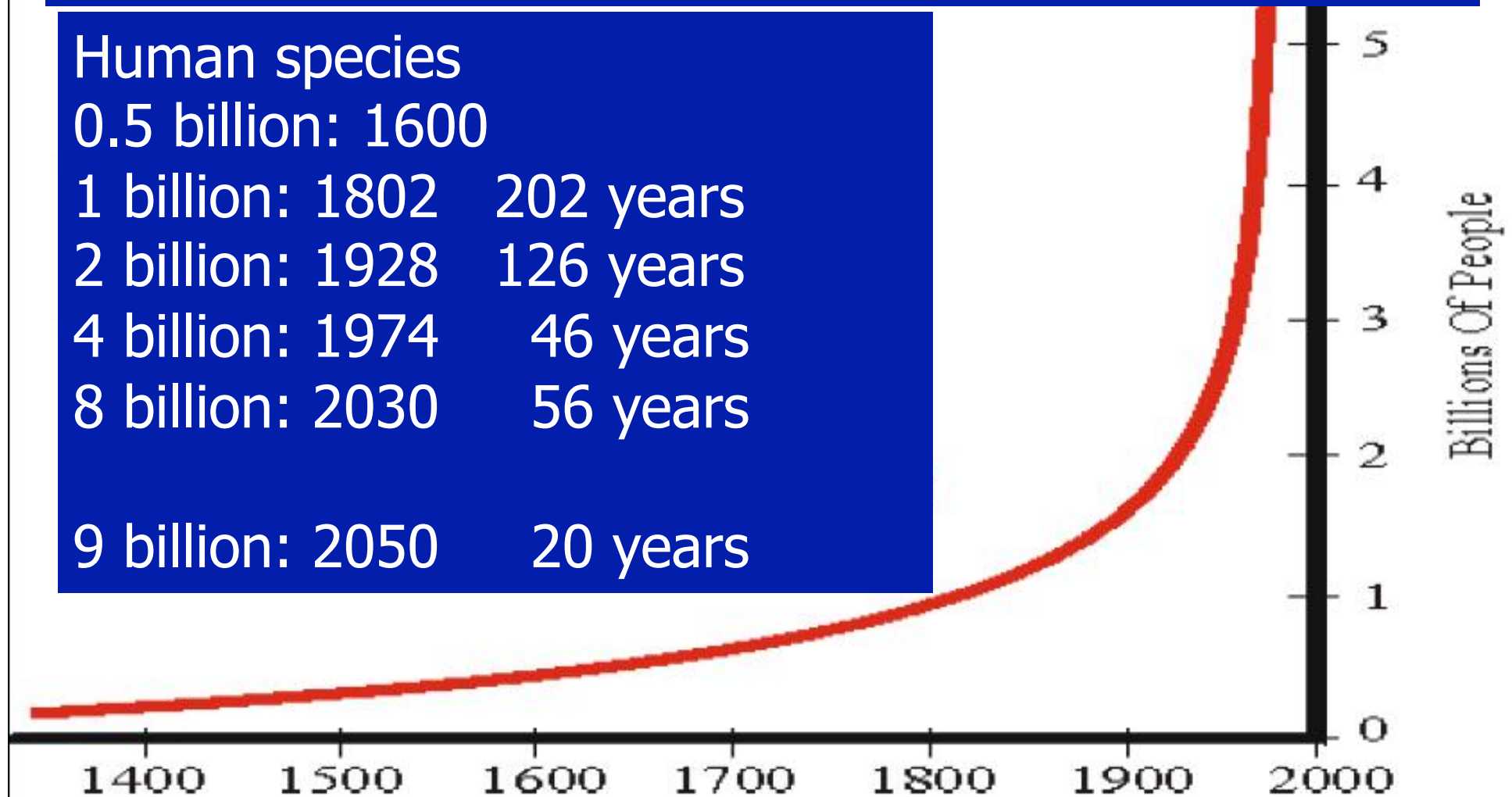
1 billion: 1802 202 years

2 billion: 1928 126 years

4 billion: 1974 46 years

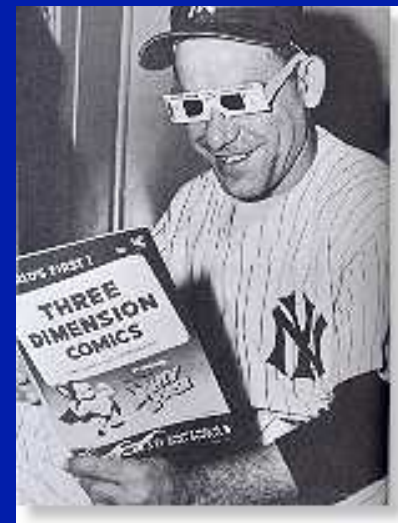
8 billion: 2030 56 years

9 billion: 2050 20 years



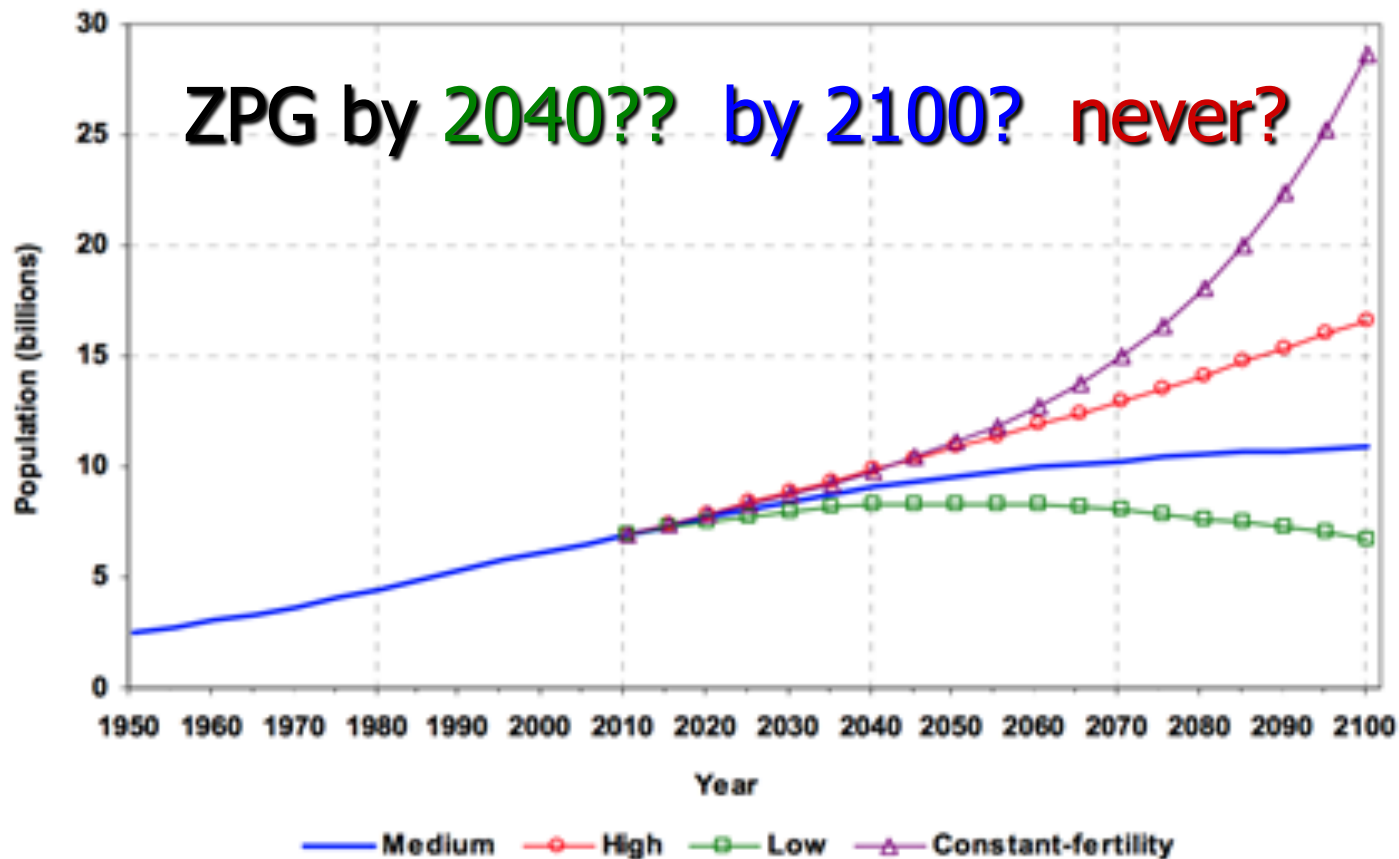
- “It’s hard to make predictions, especially about the future.”

Lawrence Peter "Yogi" Berra



UN Population projections

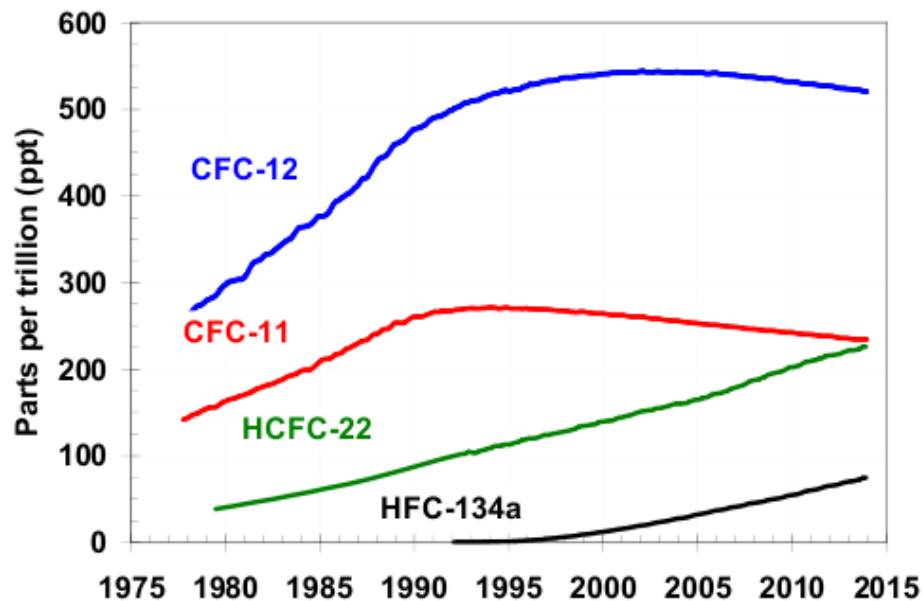
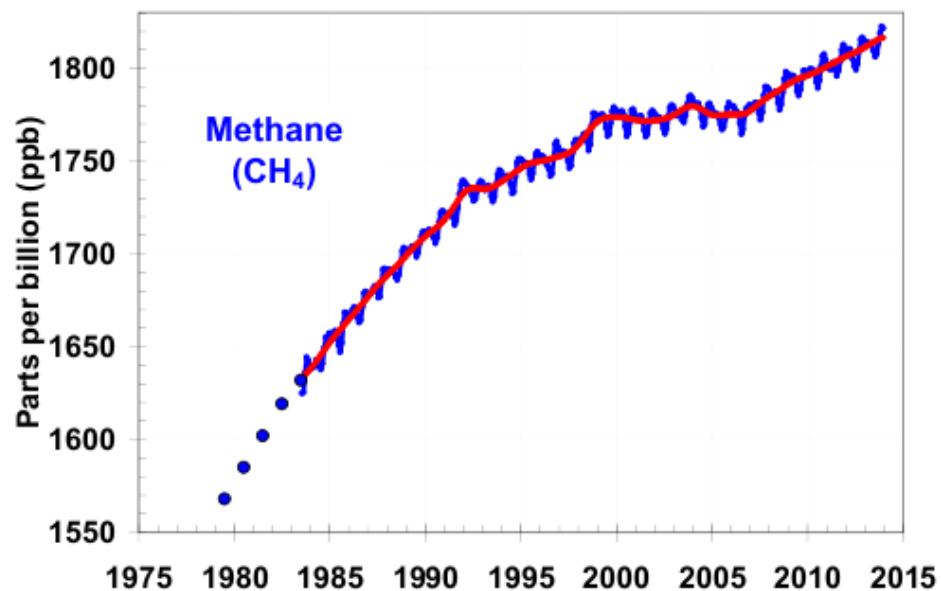
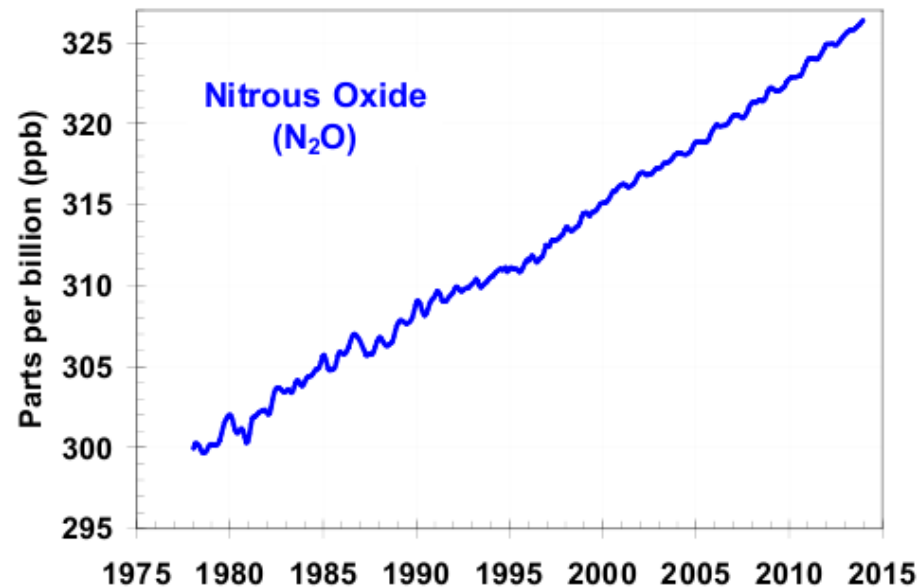
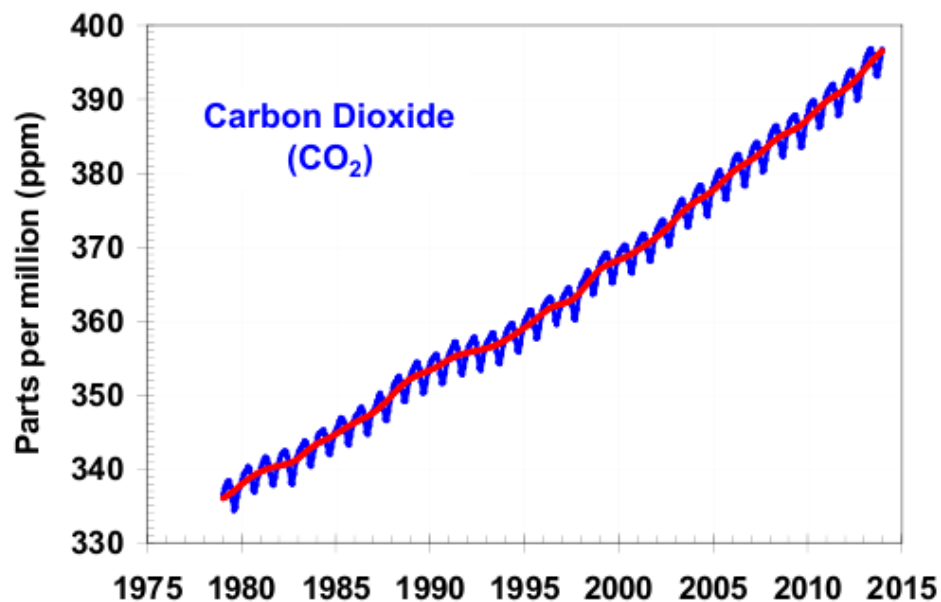
Figure 1. Population of the world, 1950-2100, according to different projections and variants



Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (2013). *World Population Prospects: The 2012 Revision*. New York: United Nations.

HANS ROSLING TED TALK ON POPULATION

Greenhouse gas (GHG) trends



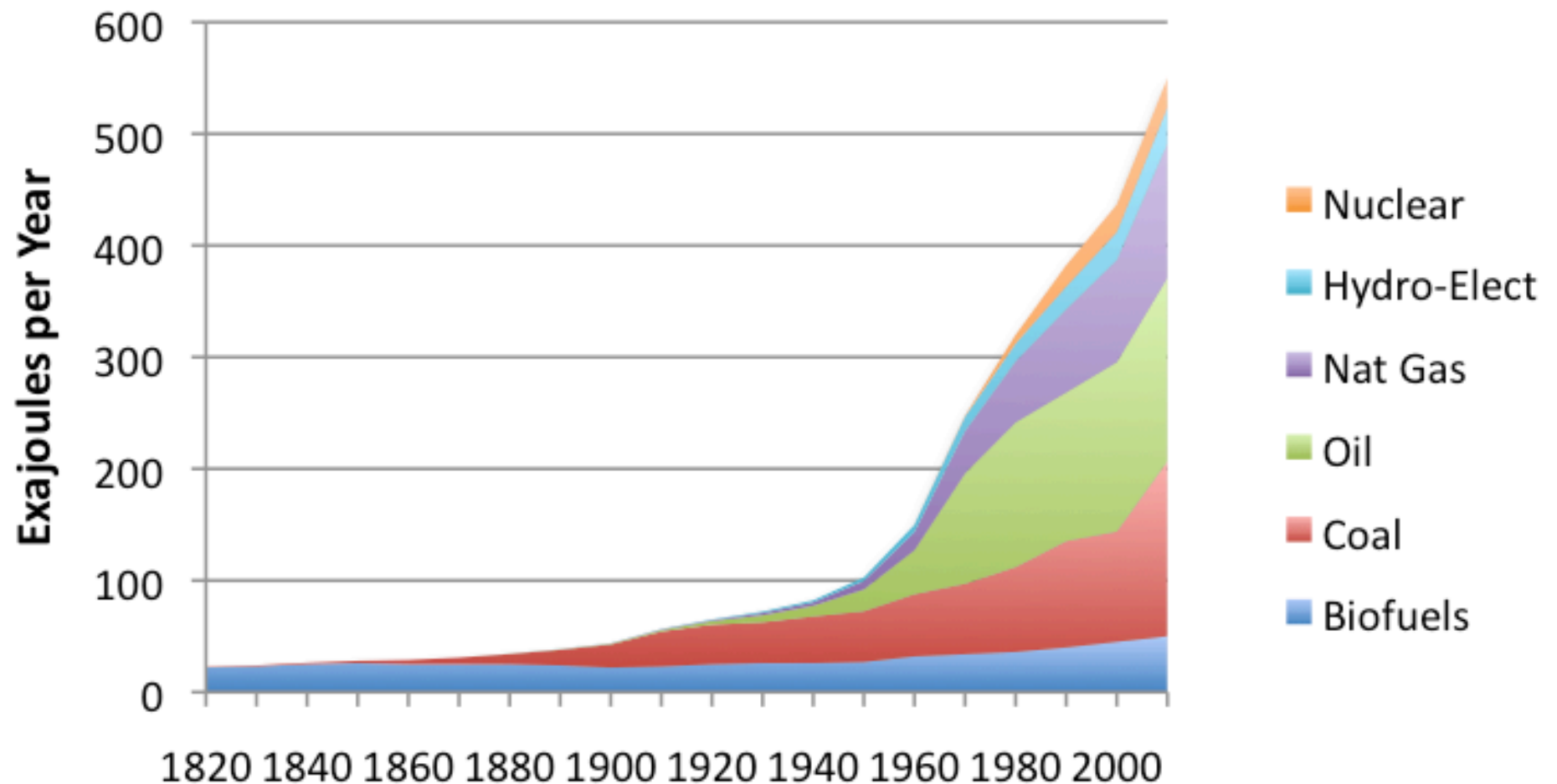


It wasn't ants, or
apes or
elephants



Energy consumption rises

World Energy Consumption

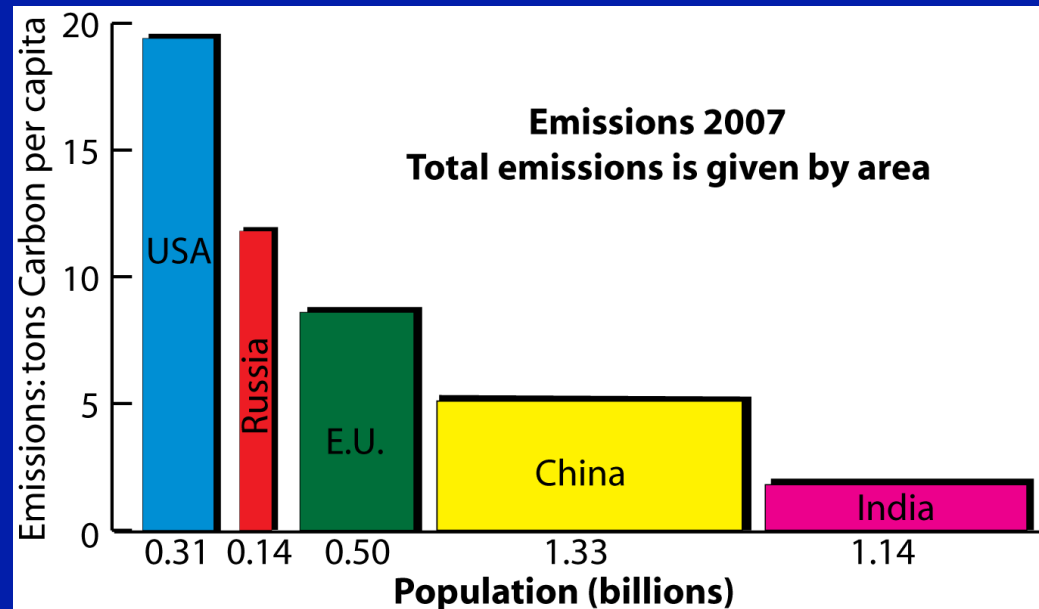


2007 emissions: Population matters!

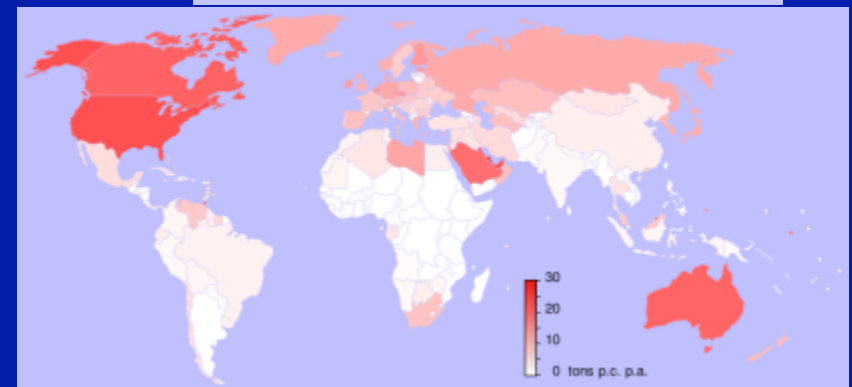
China biggest emitter

- 14% more than US

• Per capita		Pop.
U.S.:	19.4	0.31
Russia:	11.8	0.14
E. U.:	8.6	0.50
China:	5.1	1.33
India:	1.8	1.14
	tons	Billions



Tons of CO₂ per capita



Netherlands Environmental
Assessment Agency 2008

Human production of CO₂

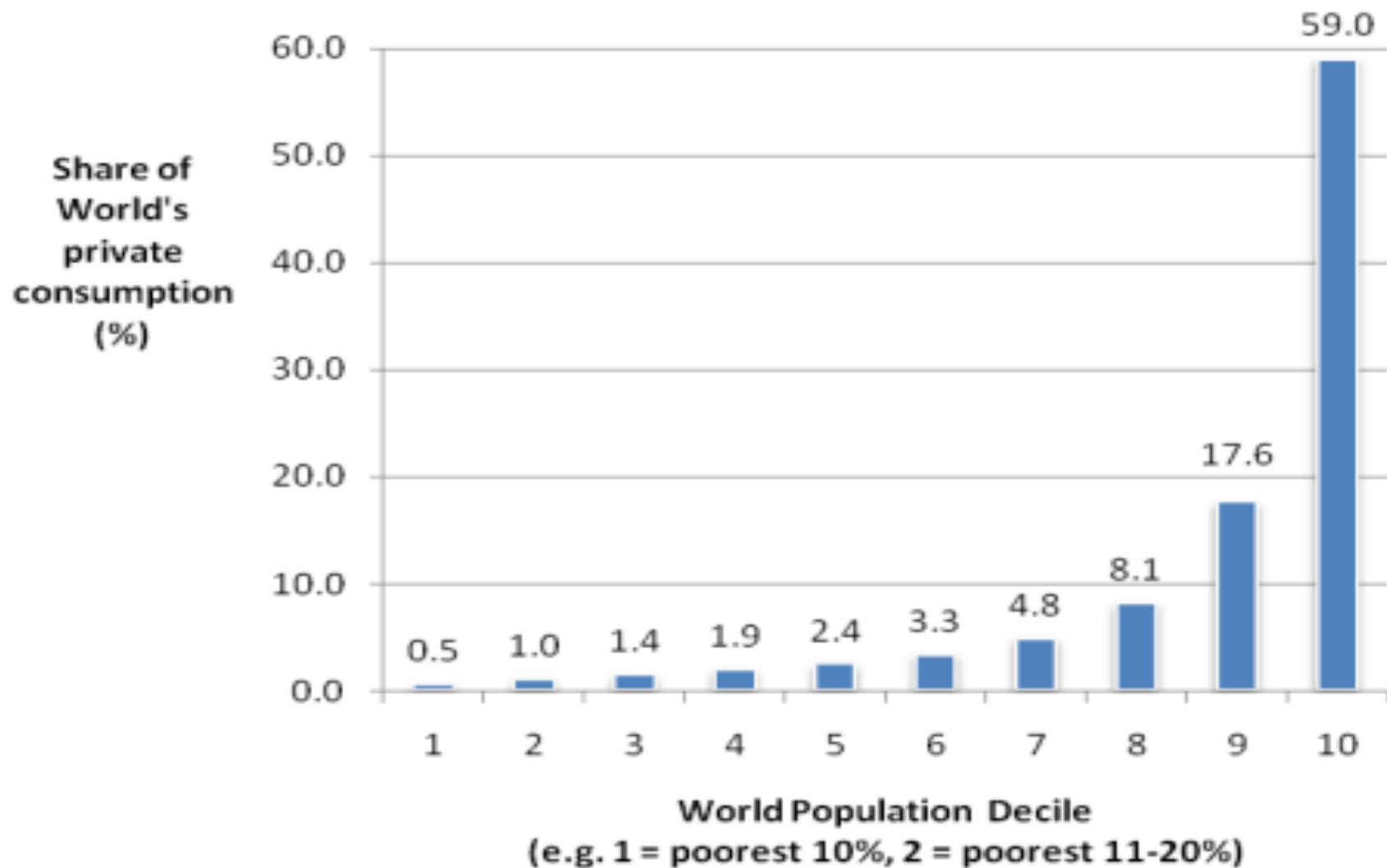
- Atmosphere as a waste dump
- Solid waste produced annually about 1 billion metric tons
- Fossil fuel burning -> 30 billion metric tons/year
- By mass in the USA (20x)
 - 250 M tons of trash to landfills (not including the recycled waste 87 M tons)
 - 5200 M tons of CO₂ emitted from burning fossil fuels

Coal and oil drove an amazing expansion of human possibilities



Gotta' love 'em: These fuels have supported an exploding population and a fantastic lifestyle for many (but not all).

Inequality of Consumption, 2005



Source: World Bank Development Indicators 2008

NEW TECHNOLOGY

A lot is happening, finally

Timeliness

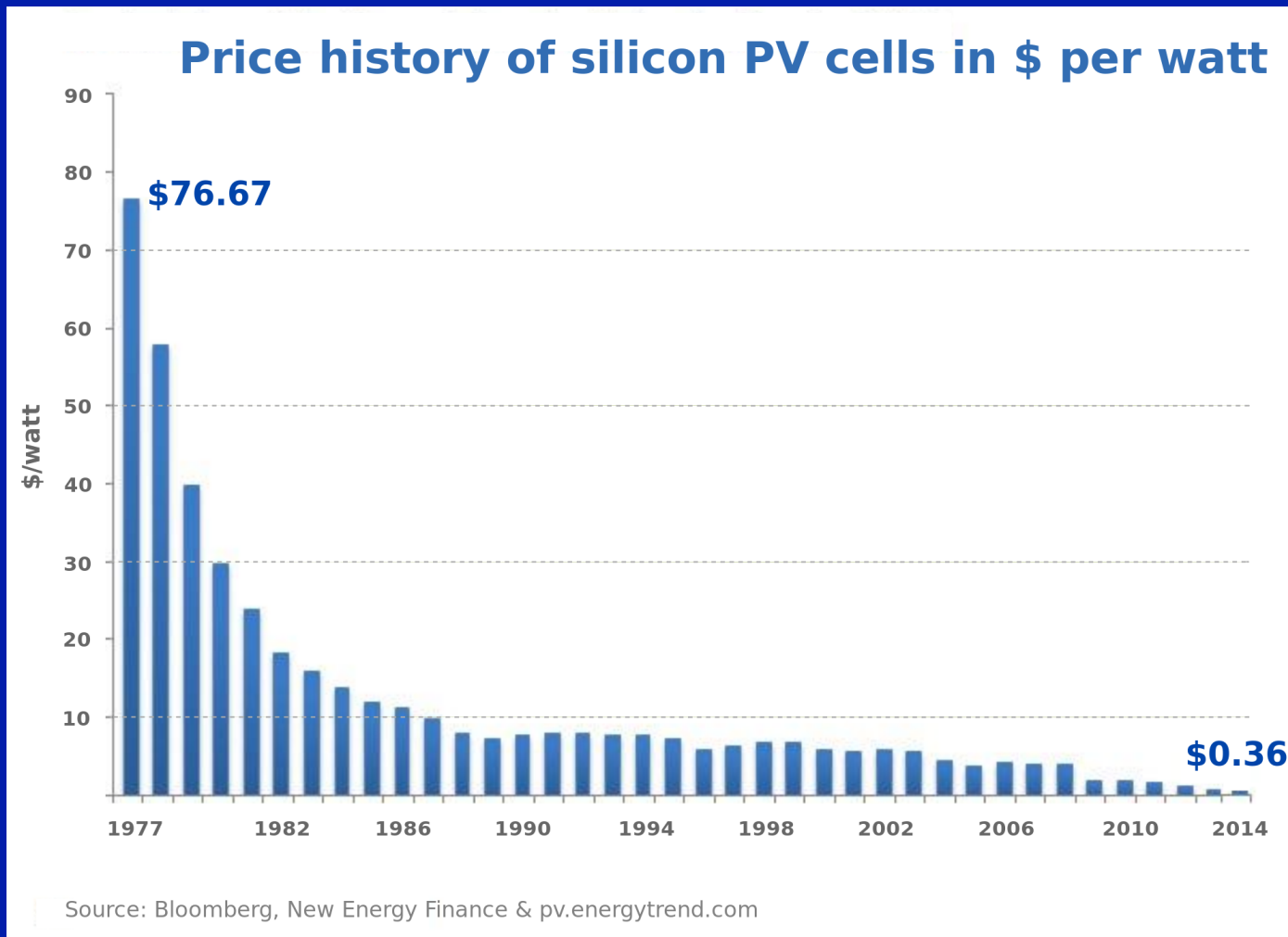
- 5th IPCC report, March 28, 2014
- National Climate Assessment Report, May 6
- May 12, 2014: news from West Antarctica
- US & China agree on climate, Nov. 20, 2014

- Laudato si' – Pope's encyclical, May 24, 2015
- Power plant rules, Aug 3
- UN conference in Paris, Dec., 2015

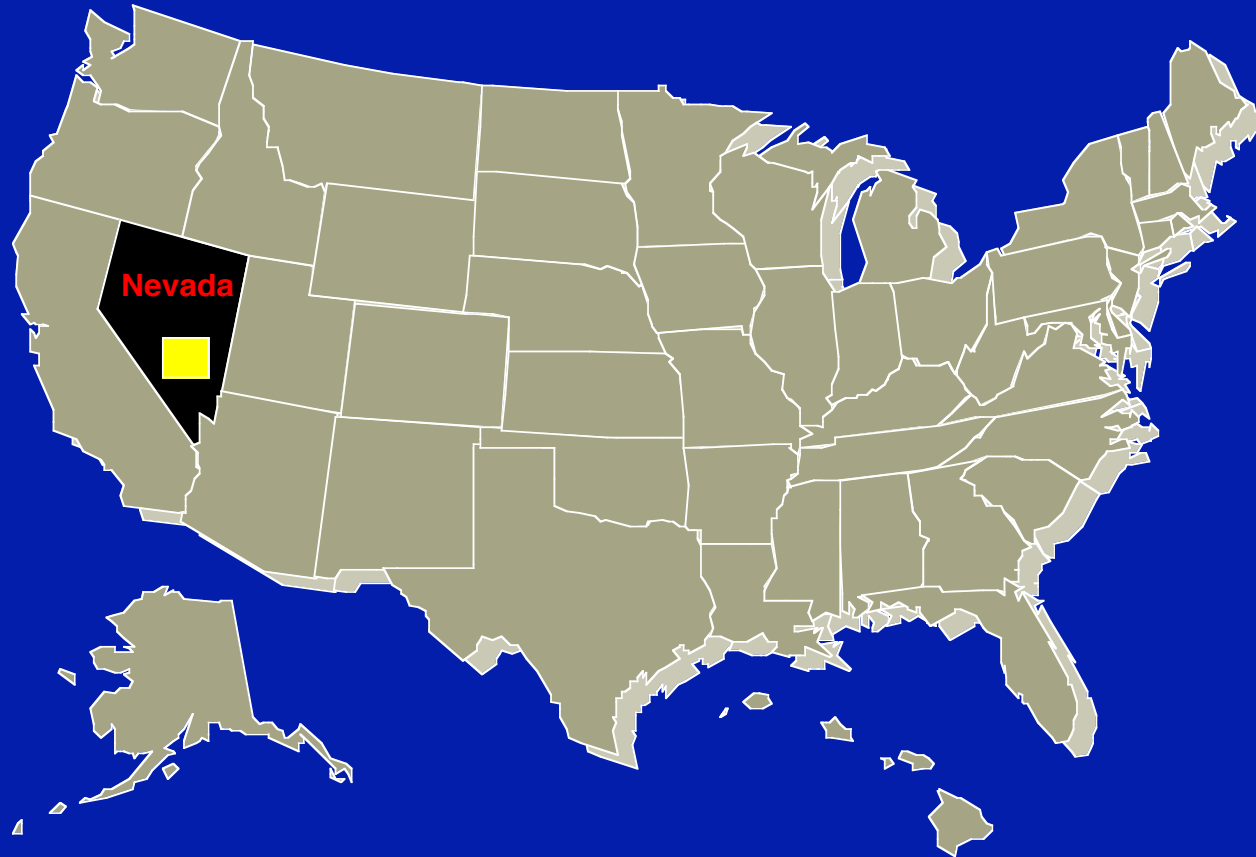
Success stories: What we need to do has been done before.

- 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



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).

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

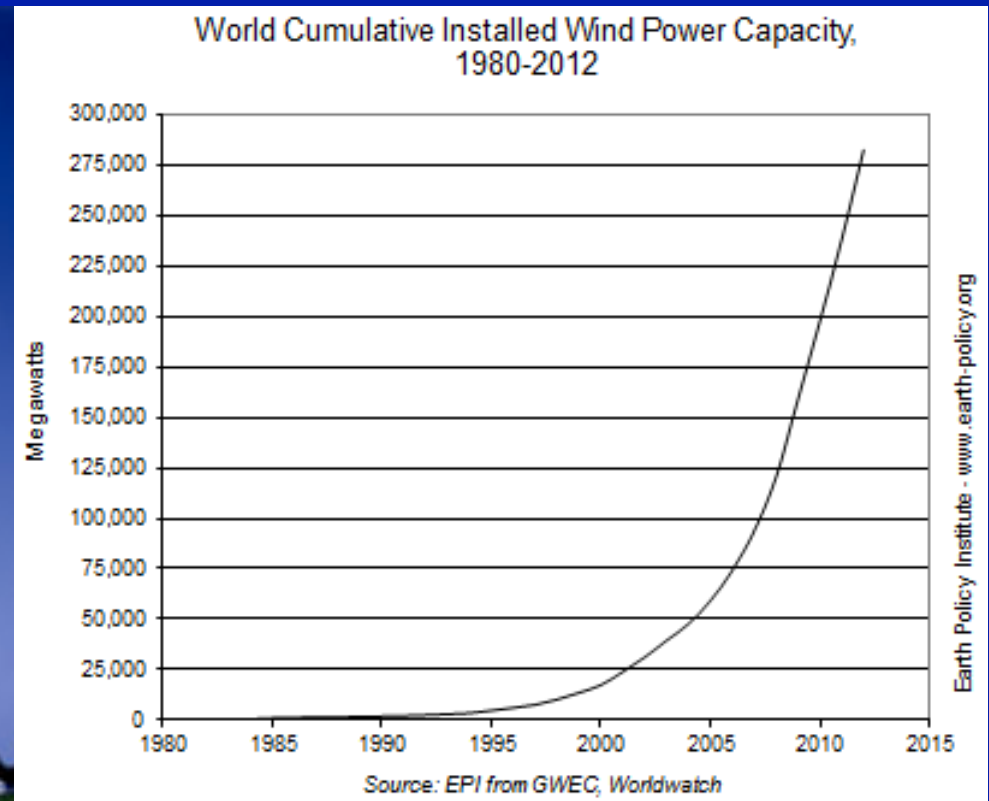
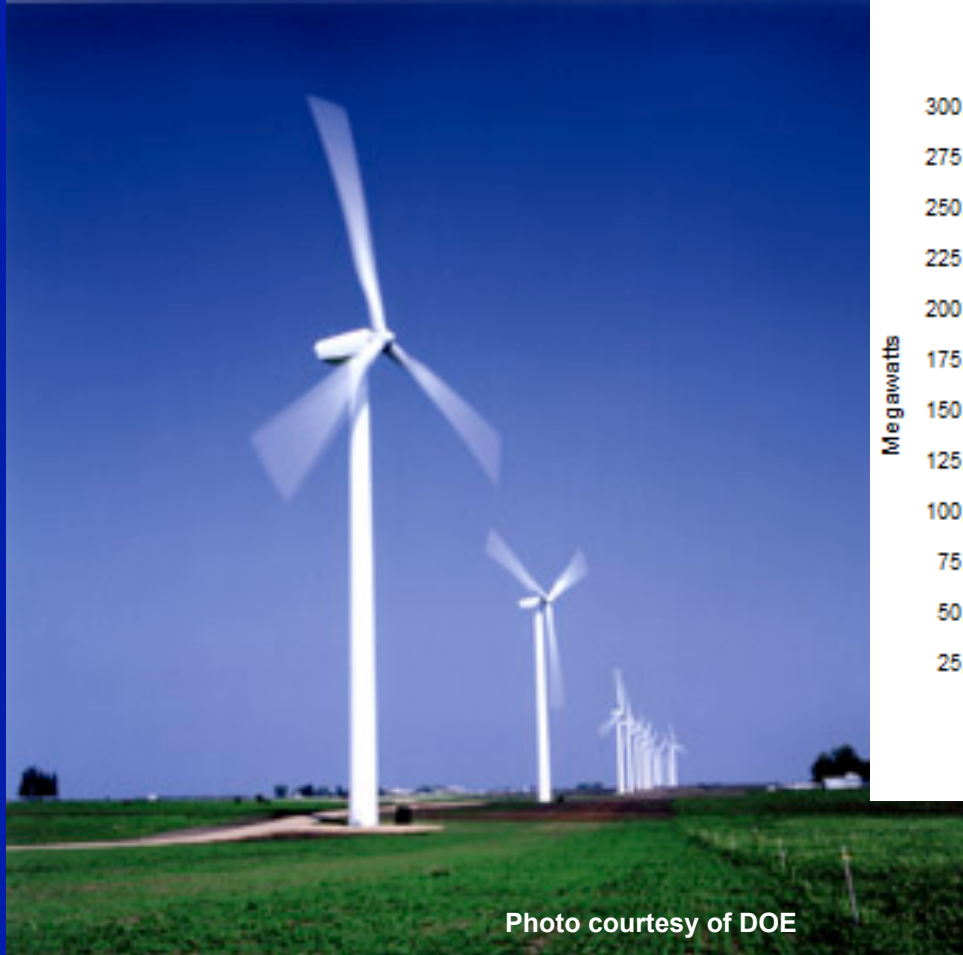
- Mitigate and Adapt first and foremost
- Albedo modification at scales sufficient to alter climate should not be deployed at this time
- Research of albedo modification should continue (emergency, use by other countries, etc.)
- Carbon capture has more promise, is already in R&D, and has less down side.

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 km².

Xcel Energy and SunPower Corp.

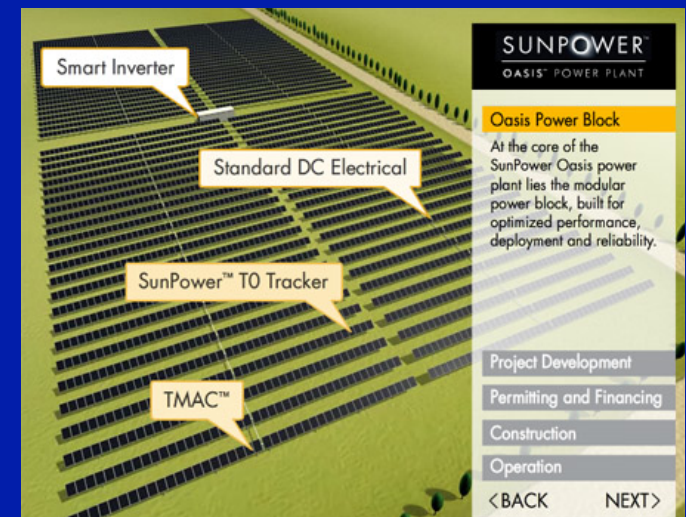
19 MW Greater Sandhill plant has been operating 2010
30 MW San Luis Valley Solar Ranch since 2011



Building a 3rd 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 CO₂ avoided/year (of 30 billion tons)

0.007 % of global CO₂

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)



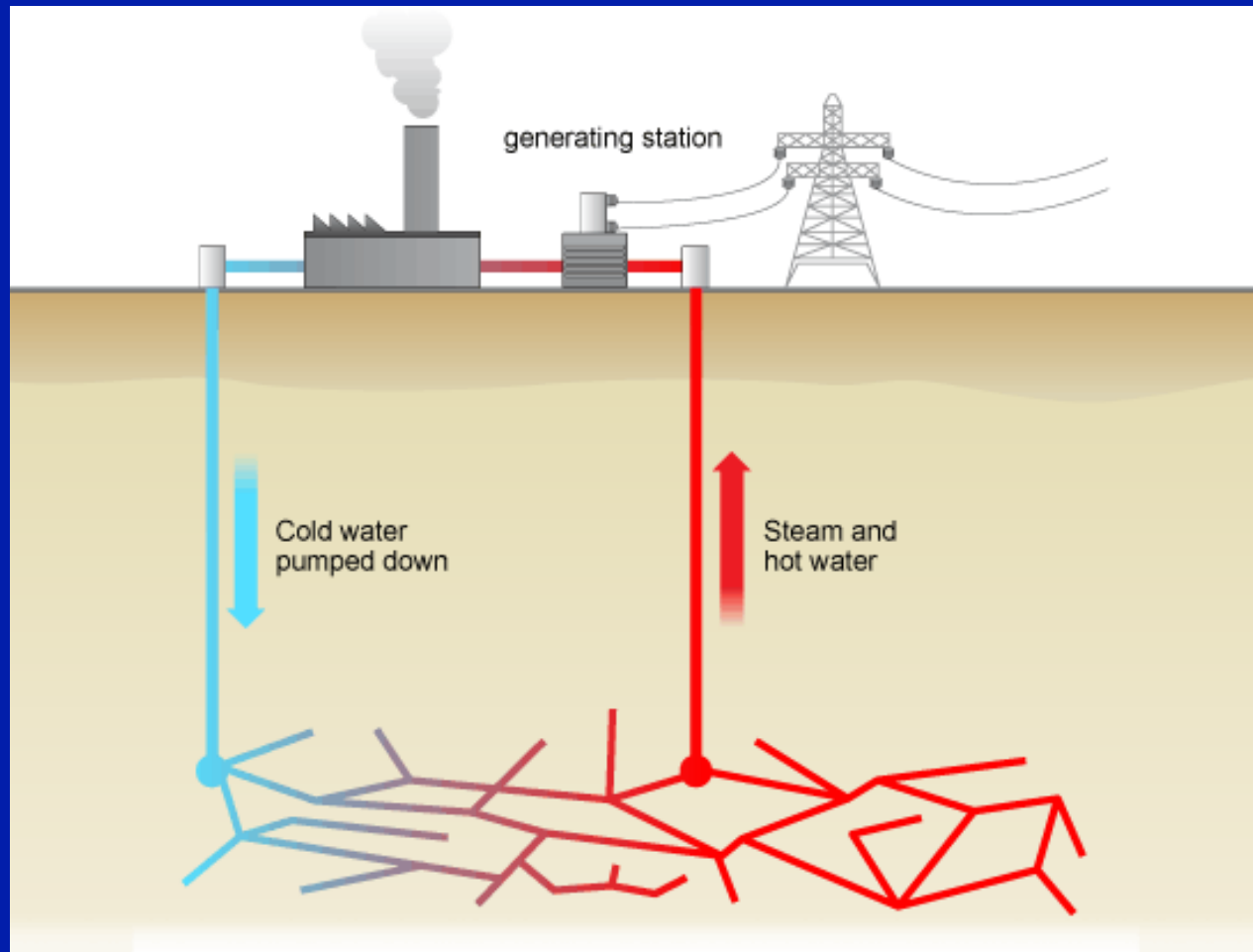
Sunforce 45444
600 Watts, 12 or 24 volts



Helix Wind

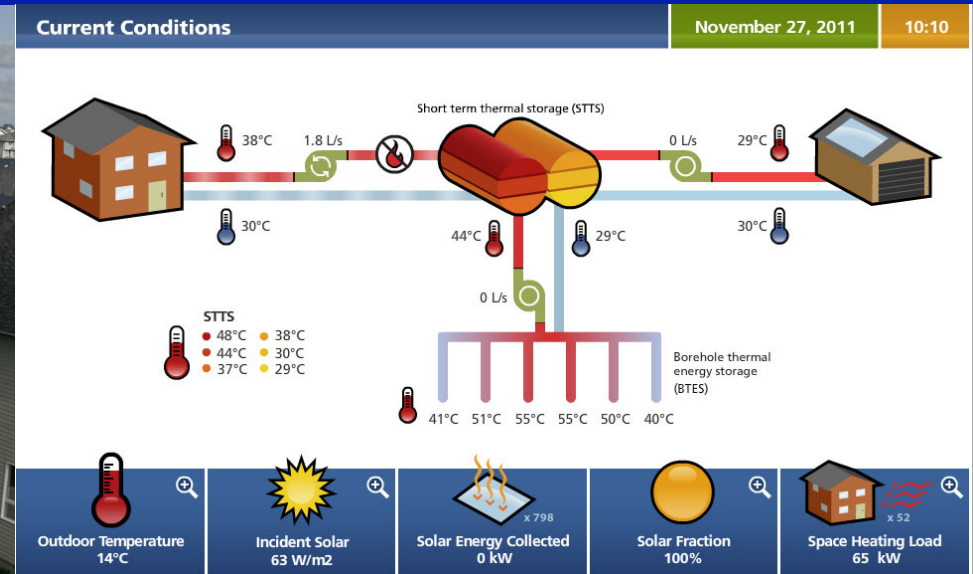


Geothermal



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**

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

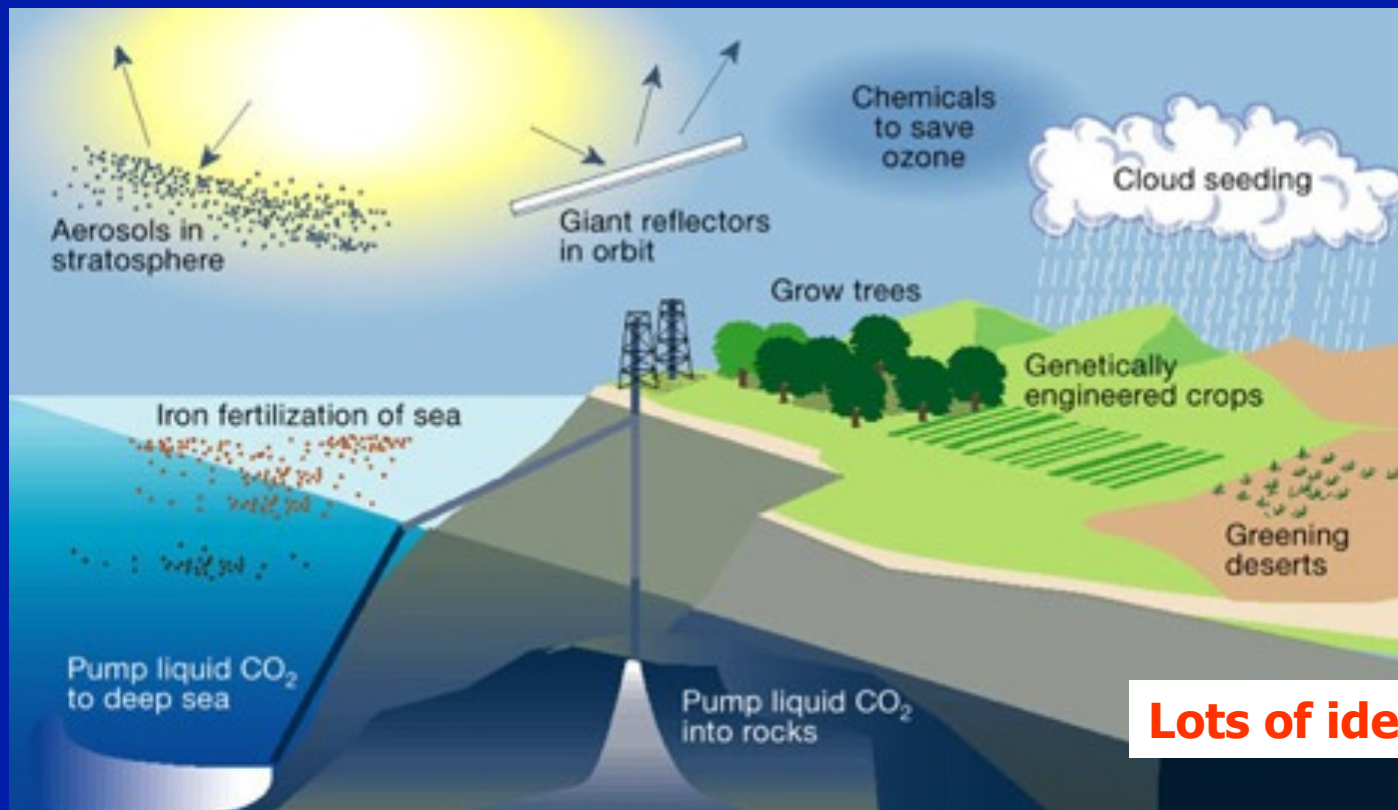
27 percent of the Netherlands is actually below sea level

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!!

CO₂ Removal

Bio-removal:

- Plant trees and other land management

- Wetland restoration and sustainable agriculture

- Use biofuel (e.g. algae), burn and recycle the CO₂

- BECCS (bio energy, carbon capture storage)

- Biochar (burning in O₂ 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

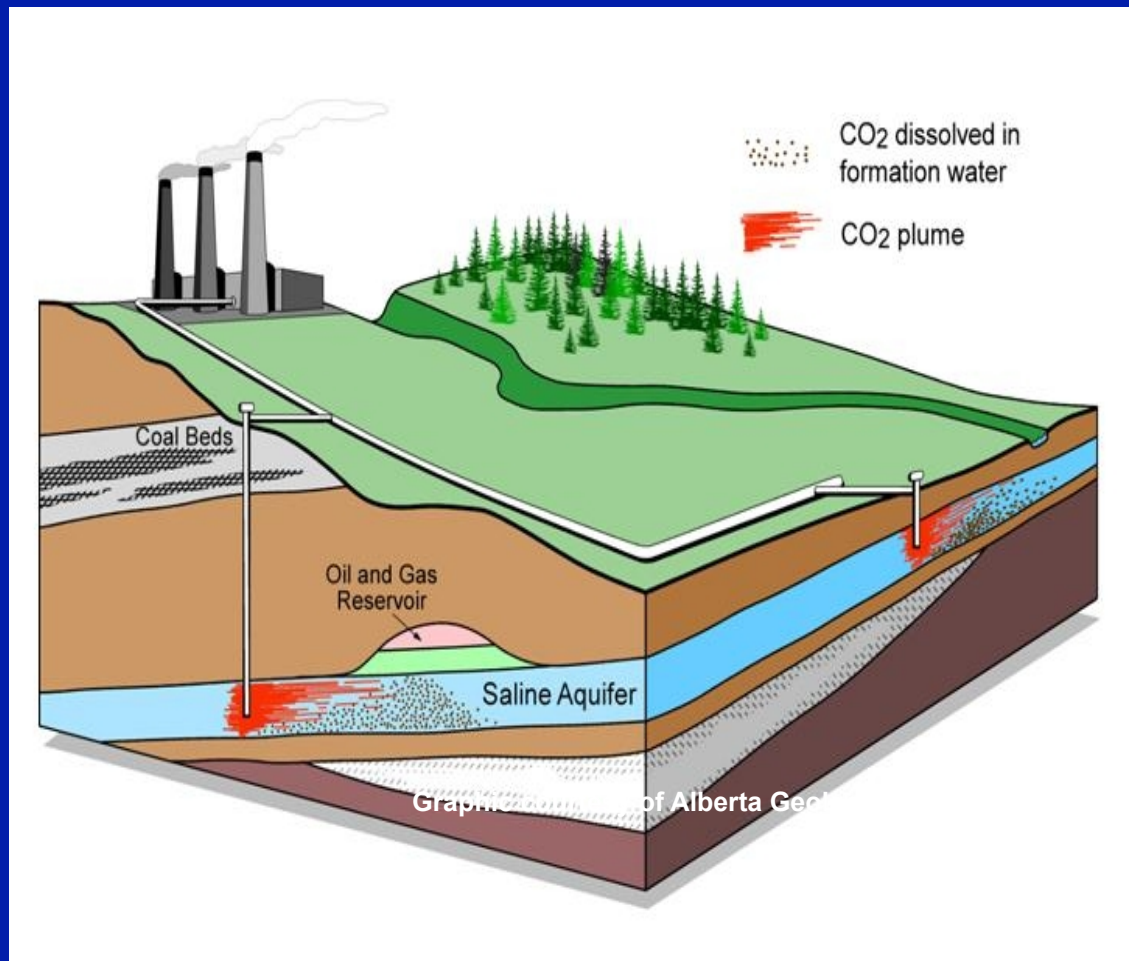
Artificial weathering

Many other ideas

Carbon Capture & Storage

There are currently three storage projects that each inject 1 million tons of CO₂ per year.

Well, they're trying.



Mineral Carbonation of CO₂

Eric H. Oelkers¹, Sigurdur R. Gislason² and Juerg Matter³

Artificial weathering

TABLE 1 SOME POTENTIAL SOURCE MINERALS
FOR CARBON MINERALIZATION

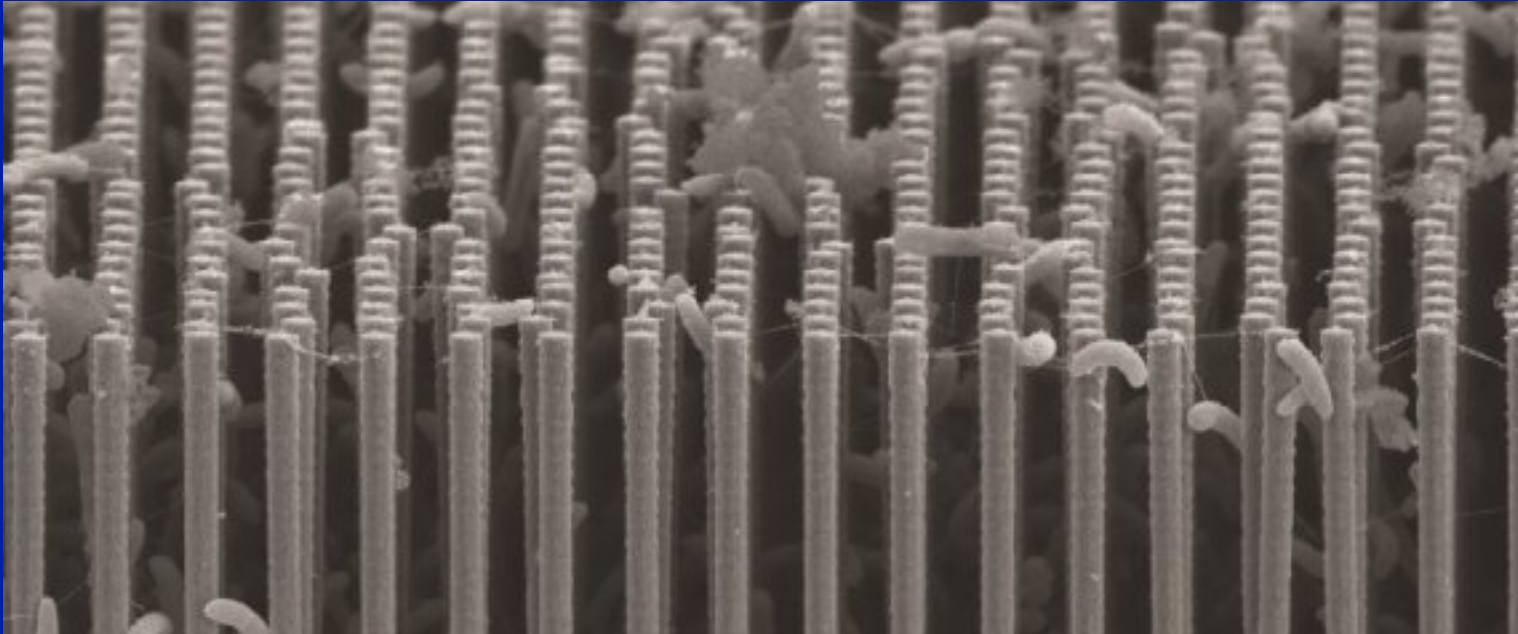
SOLID	CHEMICAL FORMULA	Tons required to sequester 1 ton of carbon
Wollastonite	CaSiO ₃	9.68 ^a
Forsterite	Mg ₂ SiO ₄	5.86 ^b
Serpentine/ chrysotile	Mg ₃ Si ₂ O ₅ (OH) ₄	7.69 ^b
Anorthite	CaAl ₂ Si ₂ O ₈	23.1 ^a
Basaltic glass	Na _{0.08} K _{0.008} Fe(II) _{0.17} Mg _{0.28} Ca _{0.26} Al _{0.36} Fe(III)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

^a as calcite; ^b as magnesite; ^c assuming all Ca, Mg and Fe are converted into calcite, magnesite and siderite

Costs:

1. Collect and transport CO₂
2. Grind the mineral to increase binding sites
3. Dispose of store the CO₂ rich mineral that results.

Artificial photosynthesis



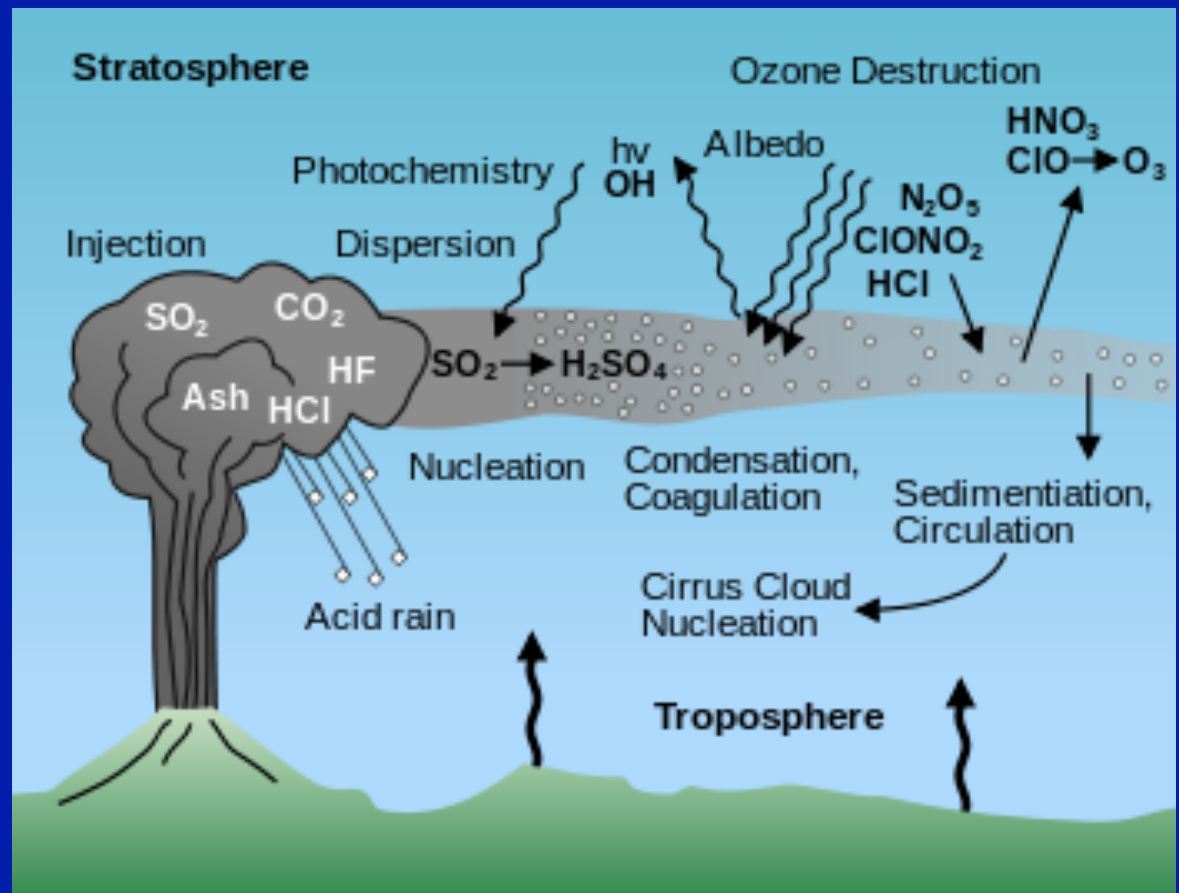
A system that can capture carbon dioxide emissions before they're released into the atmosphere and convert them into fuels, pharmaceuticals, plastics, and other valuable products.

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 H_2S and SO_2 into the stratosphere: artillery shells, aircraft or stratospheric balloons.

Do not use

- Artificial blocking of the sun
 - Pollution from burning causes cooling
 - Management issues (air does not respect boundaries)
 - Space based mirrors might be ok but prohibitively expensive and difficult
- Seeding clouds or dumping iron into the oceans

CARBON FEE AND DIVIDEND

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
CO₂ at wellhead
or port of entry
[fee rises \$10/yr]

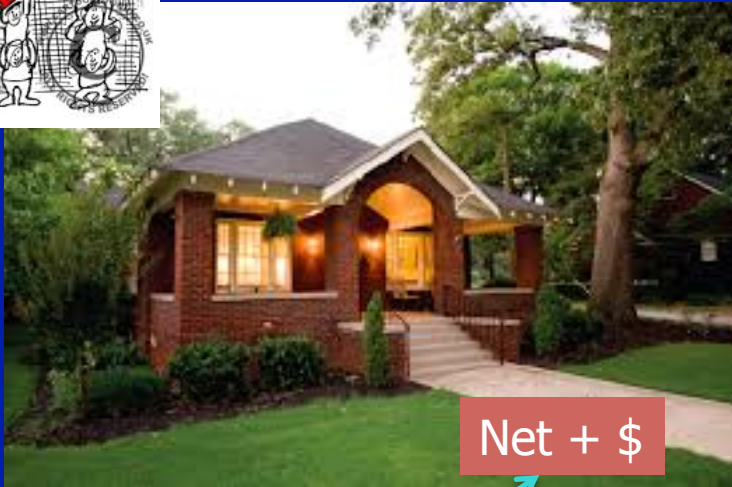


\$\$\$

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 \$.

CO₂ emissions are reduced



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



PERSONAL PLANS

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 (CO is 49th - lots of room for improvement)

Sea level rise: Maldives, Miami and me



Better build some sea walls.

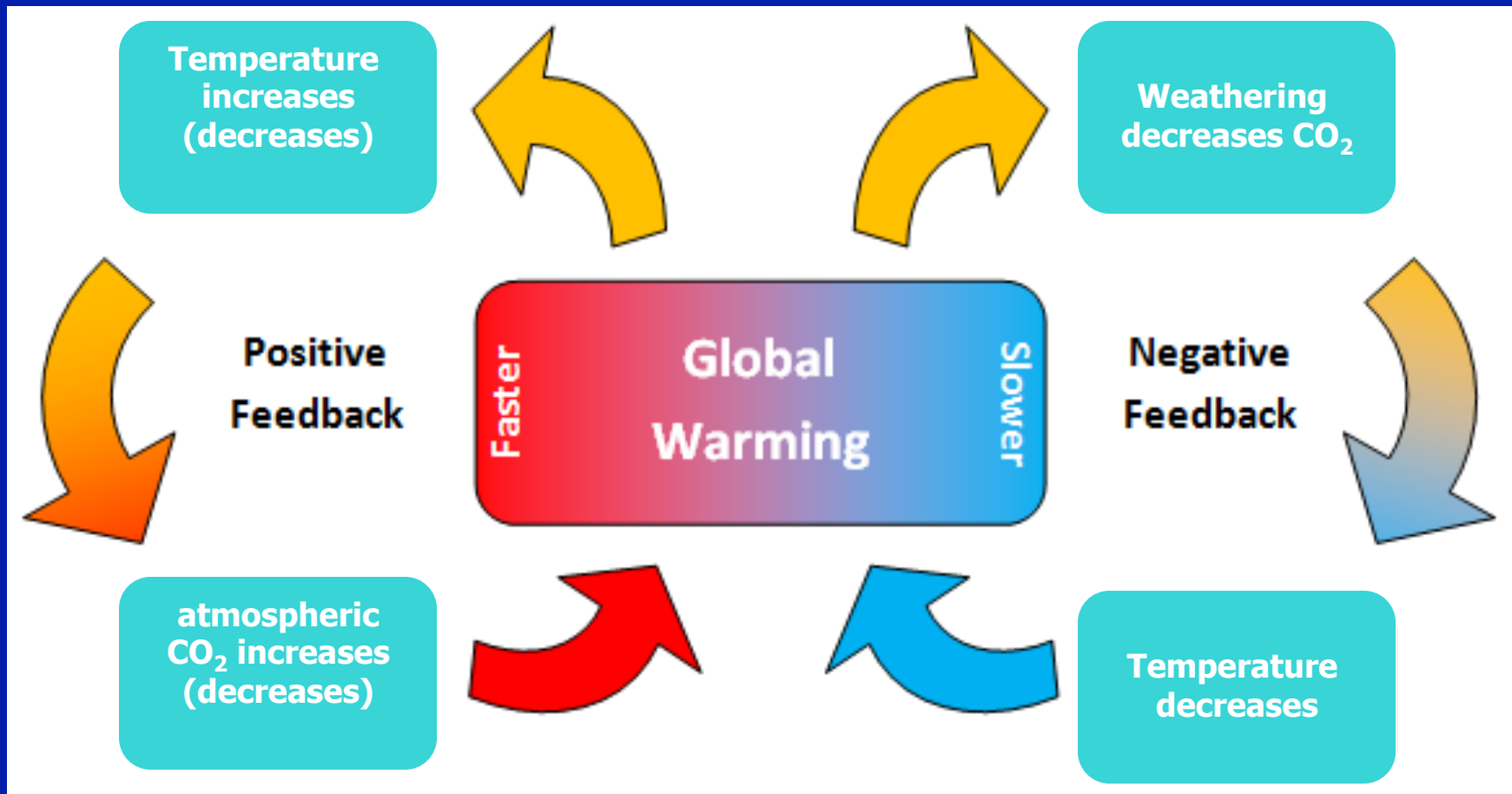
All this is happening far away to people we don't know.

Why should a Coloradan be concerned?

Feedbacks

Vicious circle

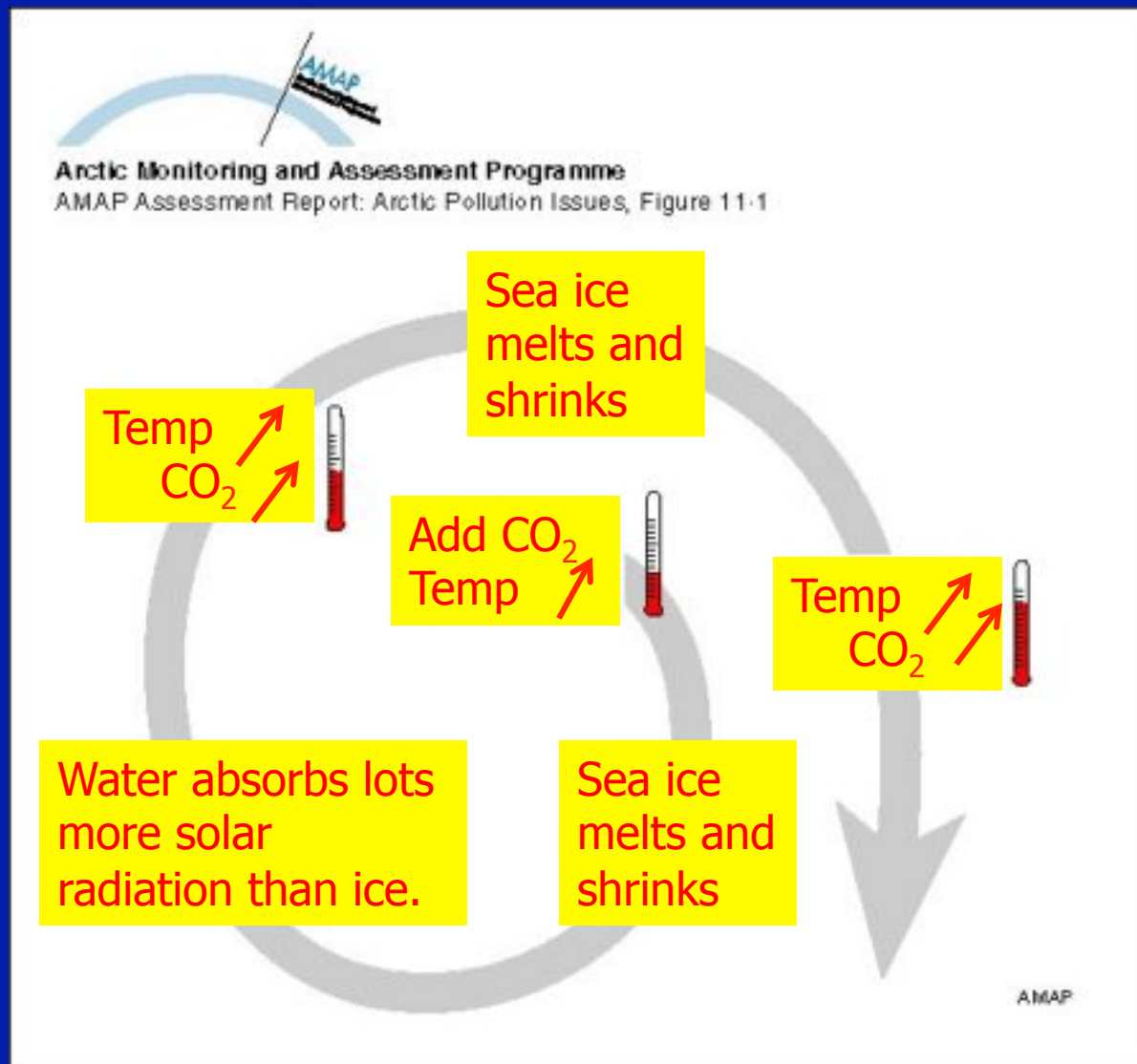
**Virtuous circle
Thermostat**



100s of years

millions to billions of years

Positive Feedback is most serious in the Arctic.



Summary

- That CO₂, methane, other greenhouse gases are warming the planet is well established.
 - Keep an eye on news about Greenland and West Antarctica
 - ** if the ice sheets on these land masses disappear, we will have significant rise in sea level.
 - Aerosols, clouds and the carbon cycle are poorly understood and require more study.
- Improved management of water and land resources is essential.
- There are things we can do if we have the will.
- Expect the unexpected:
 - Predictions and planning are adiabatic (e.g. slow cookin')
 - Consequences tend to be catastrophic (e.g. Katrina, Sandy)
- We're in this for the long haul.
 - There won't be instant gratification.

Comments that struck me

- wicked problems “require systems thinking”
- Most of us in a “state of fantasy”
 - Different degrees
- Institutions designed to deal on few year time scales
 - Damage done will take centuries to fix
- Morality requires an input from Mother Nature
 - Ignoring her needs will doom us all
 - Gives new meaning to “If momma ain’t happy, nobody’s happy.” or maybe it’s “If momma ain’t happy nobody lives.”