

# Climate Change: Simple, Serious, Solvable



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**1. Simple**

**2. Serious**

**3. Solvable**

**1. Simple**

**2. Serious**

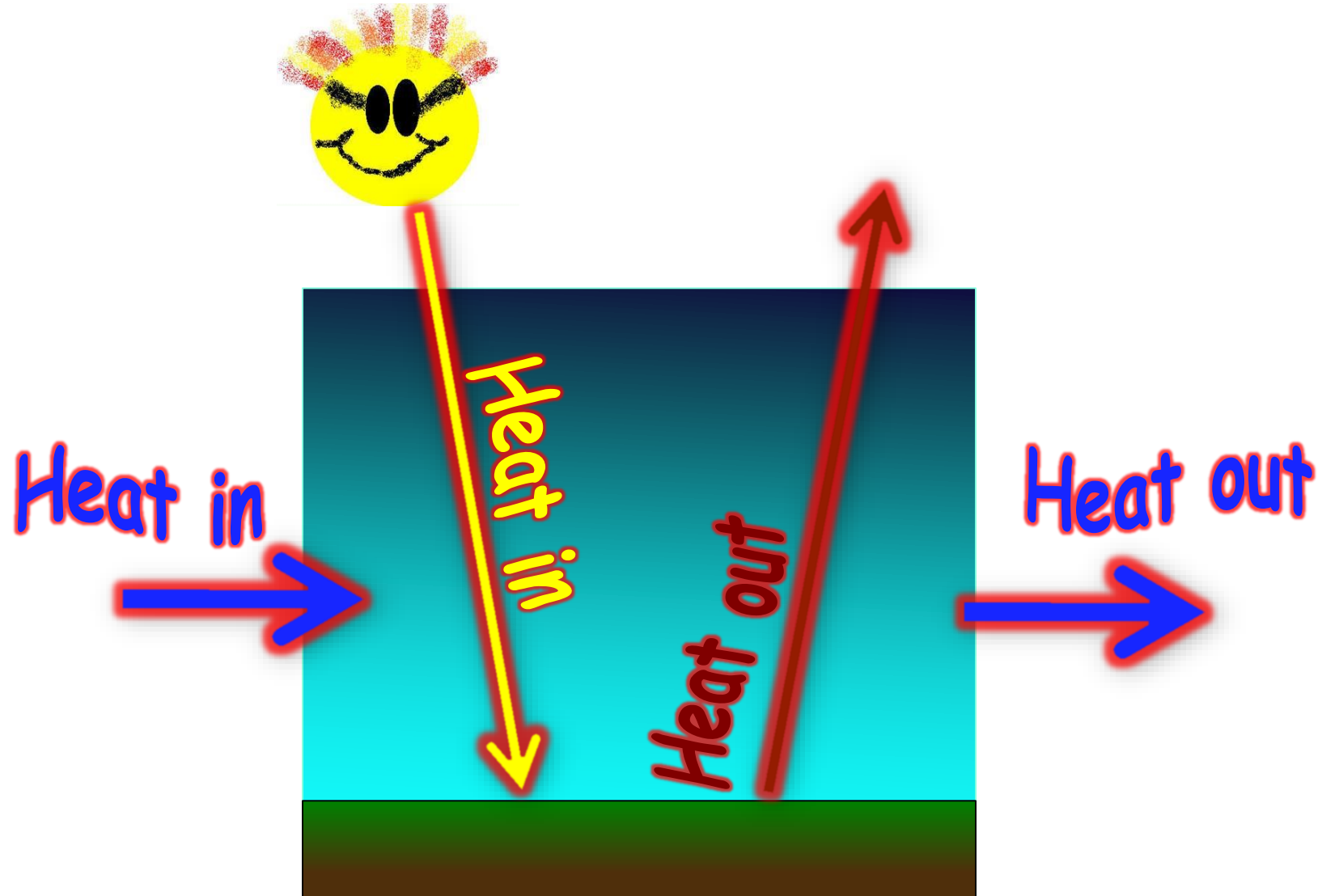
**3. Solvable**

# Ever Wonder Why?



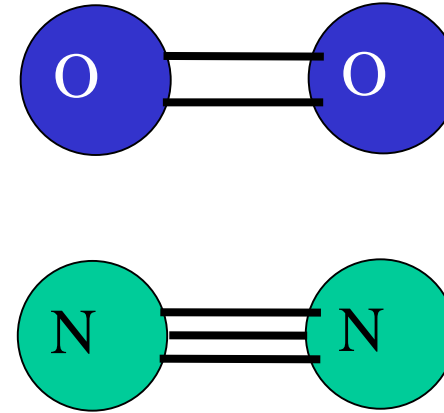
- **Day** is warmer than **night**
- **Summer** is warmer than **winter**
- **Phoenix** is warmer than **Fargo**

# Heat Budgets



# Dancing Molecules and Heat Rays!

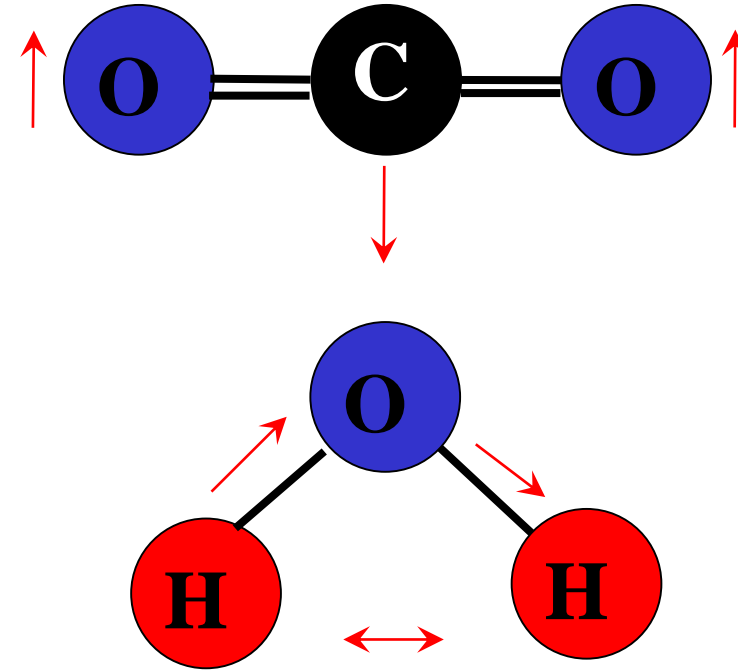
- Nearly all of the air is made of oxygen ( $O_2$ ) and nitrogen ( $N_2$ ) in which **two atoms of the same element** share electrons
- Infrared (heat) **energy radiated up from the surface can be absorbed** by these molecules, but not very well



*Diatomc molecules can vibrate back and forth like balls on a spring, but the ends are identical*

# Dancing Molecules and Heat Rays!

- Carbon dioxide ( $\text{CO}_2$ ) and water vapor ( $\text{H}_2\text{O}$ ) are different!
- They have **many more ways to vibrate** and rotate, so they are very good at absorbing and emitting infrared (heat) radiation



*Molecules that have many ways to wiggle are called "Greenhouse" molecules*

*Absorption spectrum of CO<sub>2</sub> was measured by John Tyndall in 1863*

# The Greenhouse Effect

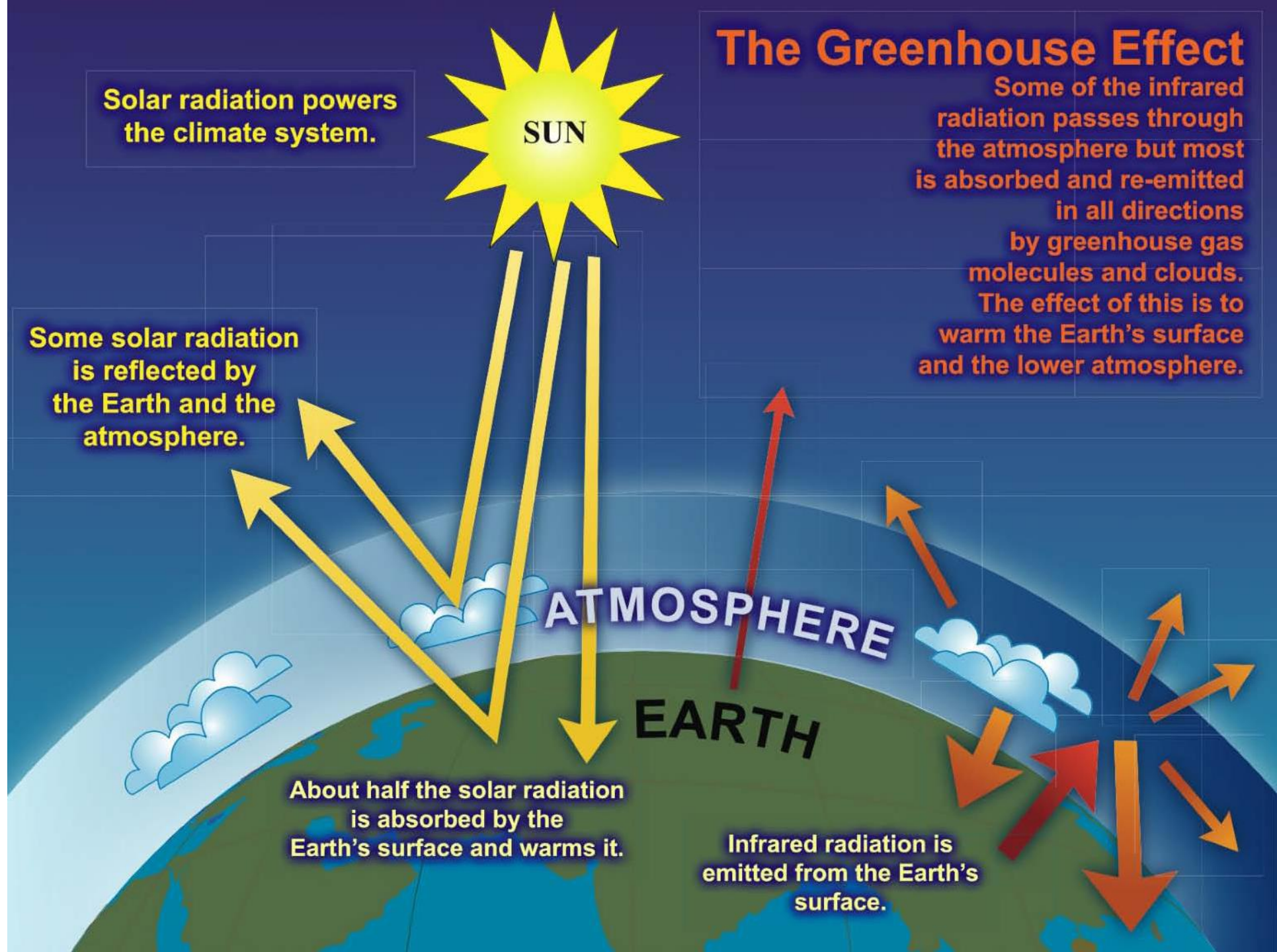
Some of the infrared radiation passes through the atmosphere but most is absorbed and re-emitted in all directions by greenhouse gas molecules and clouds. The effect of this is to warm the Earth's surface and the lower atmosphere.

Solar radiation powers the climate system.

Some solar radiation is reflected by the Earth and the atmosphere.

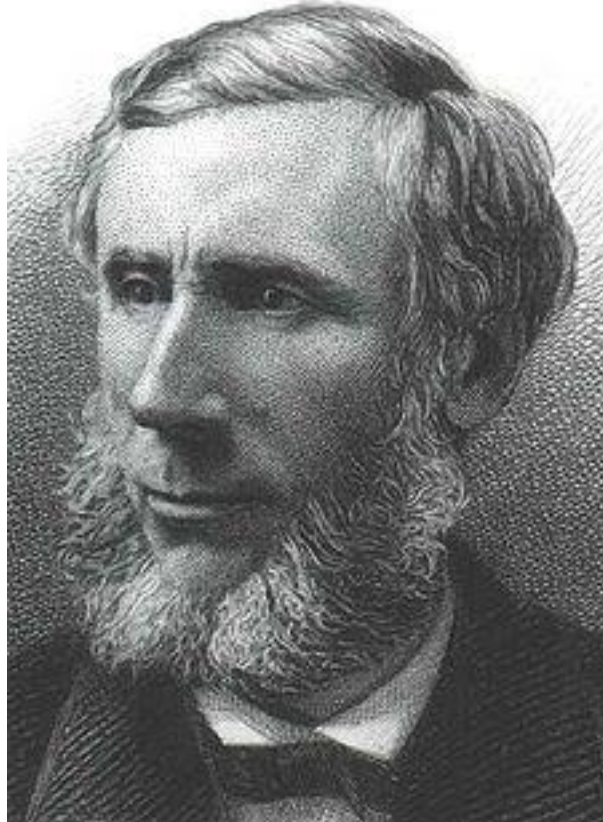
About half the solar radiation is absorbed by the Earth's surface and warms it.

Infrared radiation is emitted from the Earth's surface.





# Common Sense

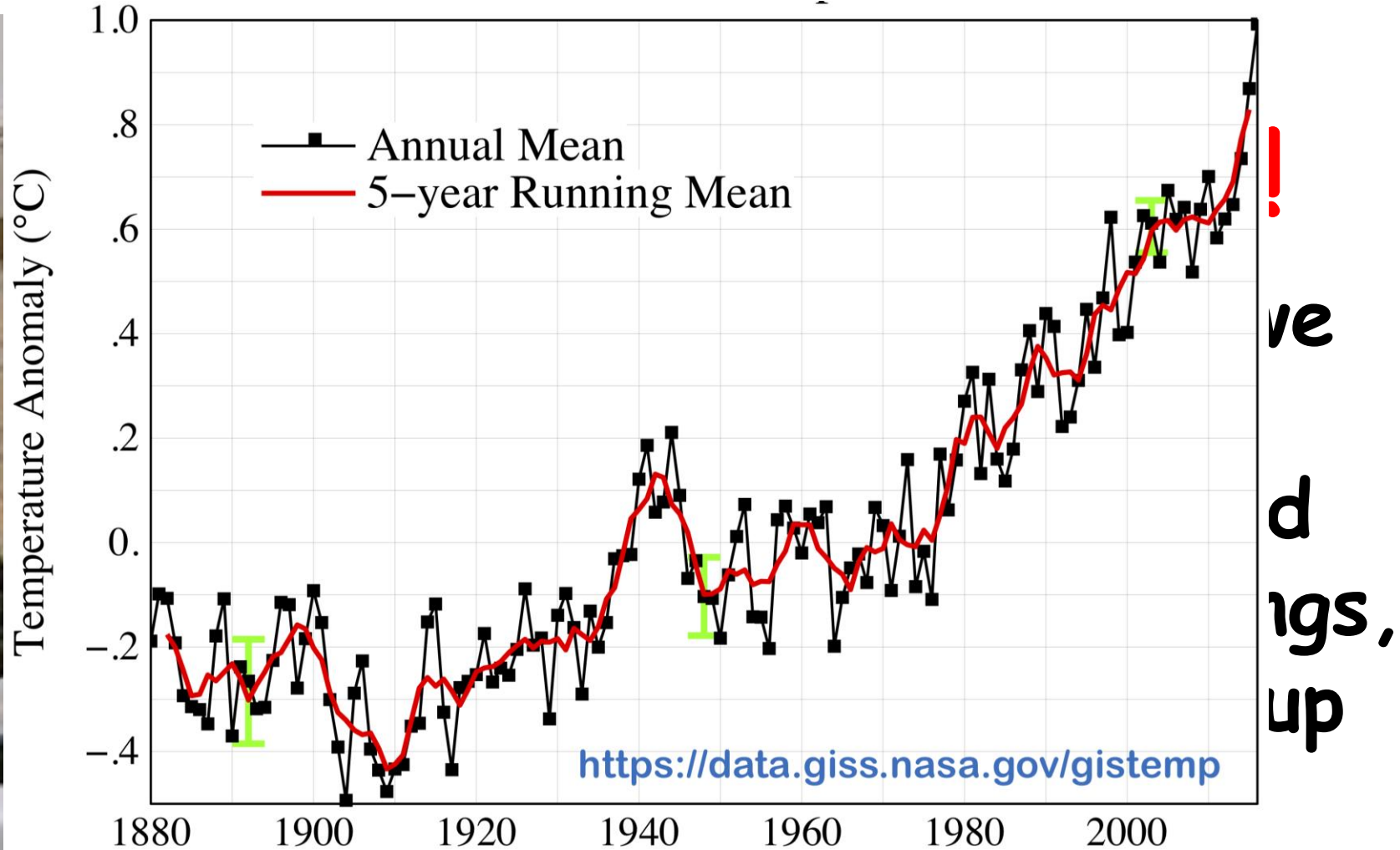
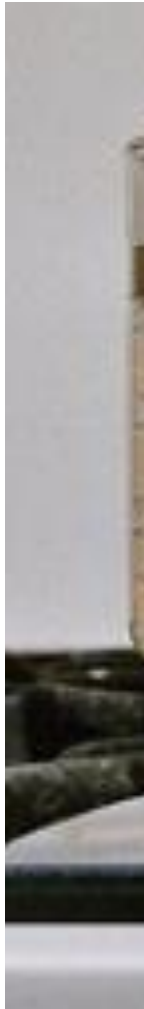


*John Tyndall, January 1863*

- Doubling CO<sub>2</sub> would add **4 watts to every square meter** of the Earth, **24/7/365**
- Doing that would make the surface **warmer**
- This was known before light bulbs were invented!

# Common Myth #1

“Scientists expect a warmer future because it’s been warming up recently”



**1. Simple**

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**3. Solvable**

# How much warmer?

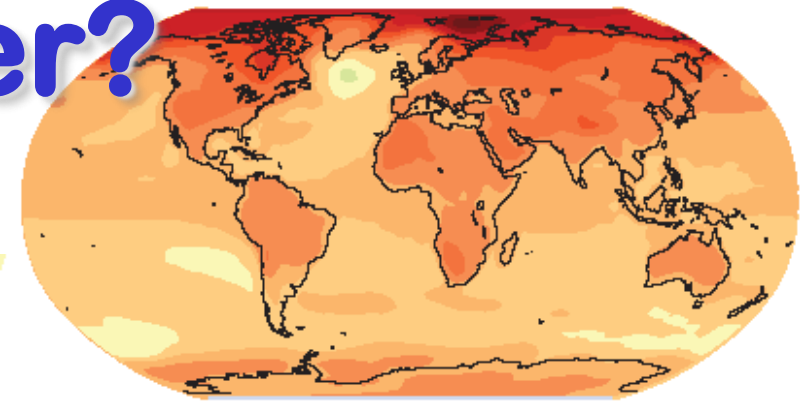
- **Land** vs ocean!
- **North** vs South
- Global mean warming of 2° to 5° C
- **North American** warming of 3° to 6° C
- = **5° to 11° F**
- Arctic warming of 8° to 14° F

***RULE OF THUMB:***

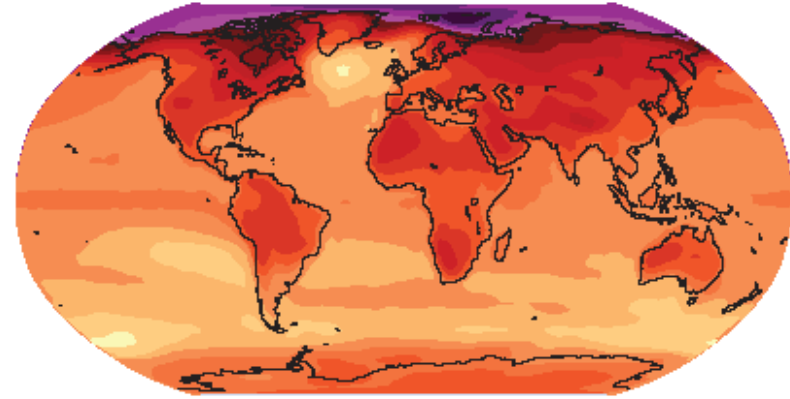
***Global Warming (Celsius)***

***x 1.6 (USA) x 1.8 = Fahrenheit***

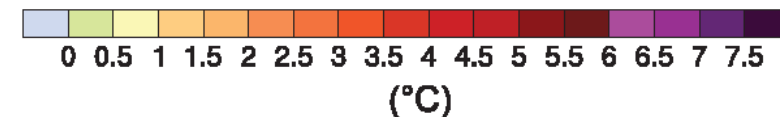
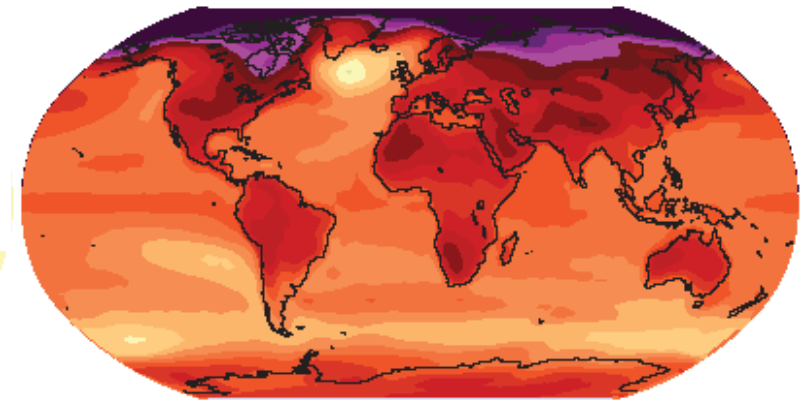
Low  
Emissions



Moderate  
Emissions

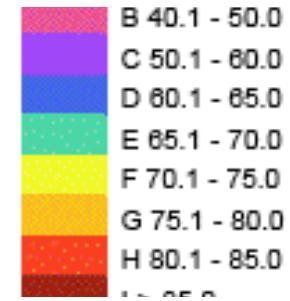
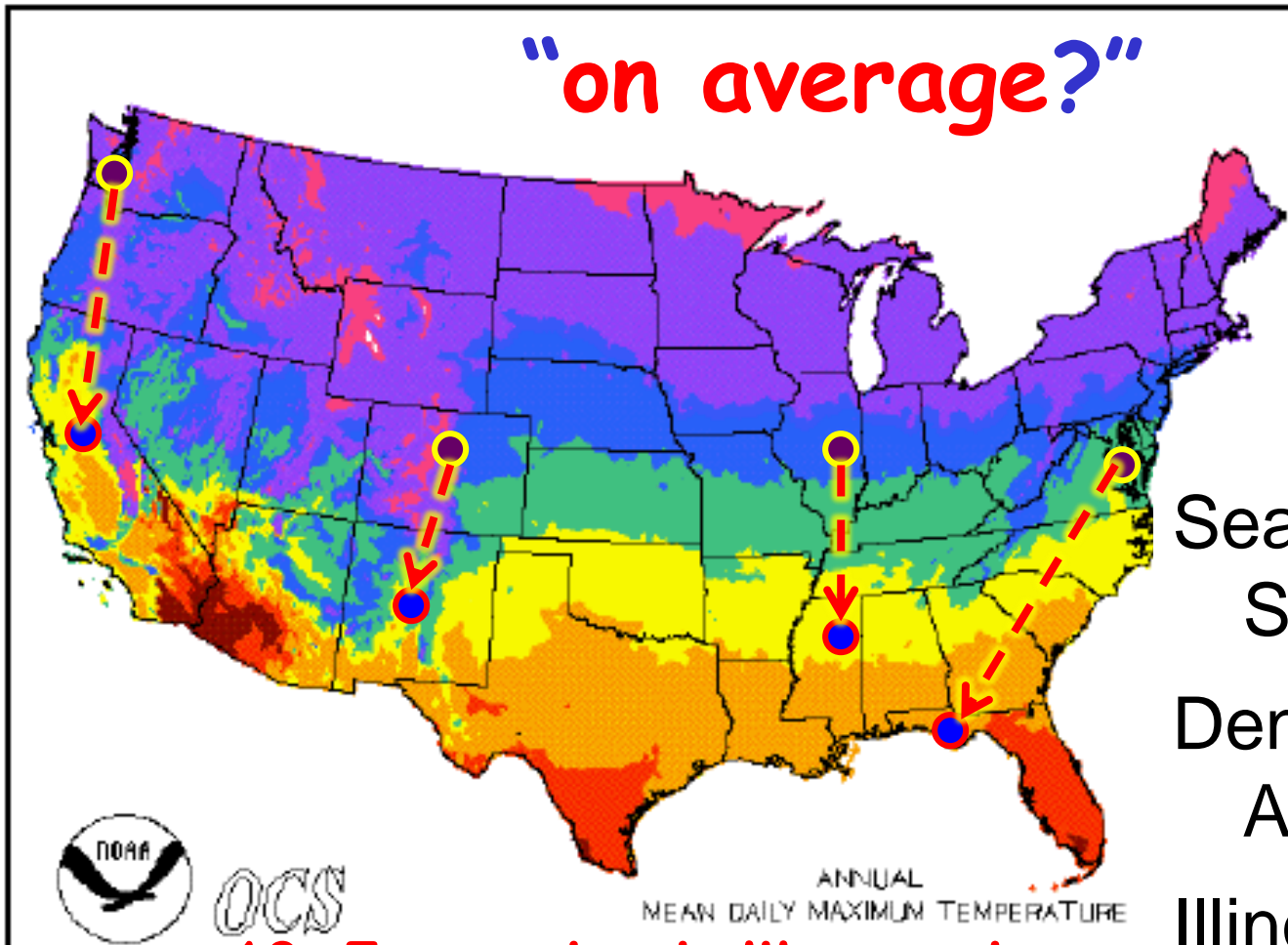


High  
Emissions



# Where is it 10° F Warmer

"on average?"



OCS

**10 °F warming is like moving  
600 – 800 miles South!**

*Water?      Crops?  
Real Estate?      Health?*

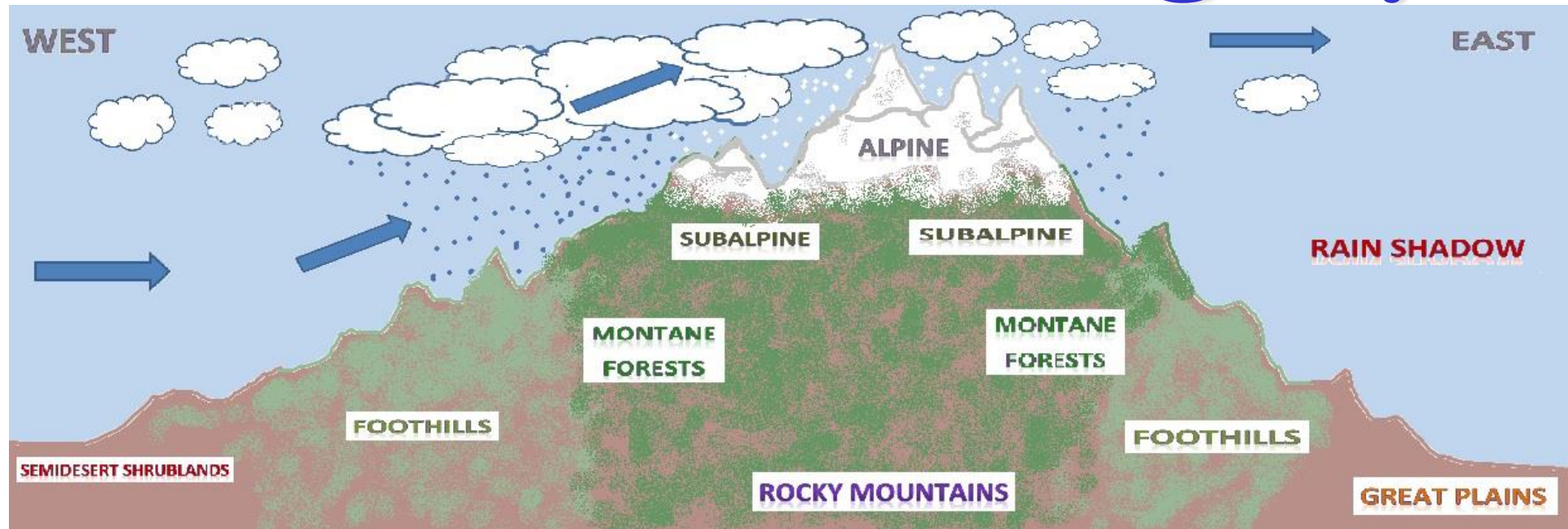
Seattle →  
Sacramento

Denver →  
Albuquerque

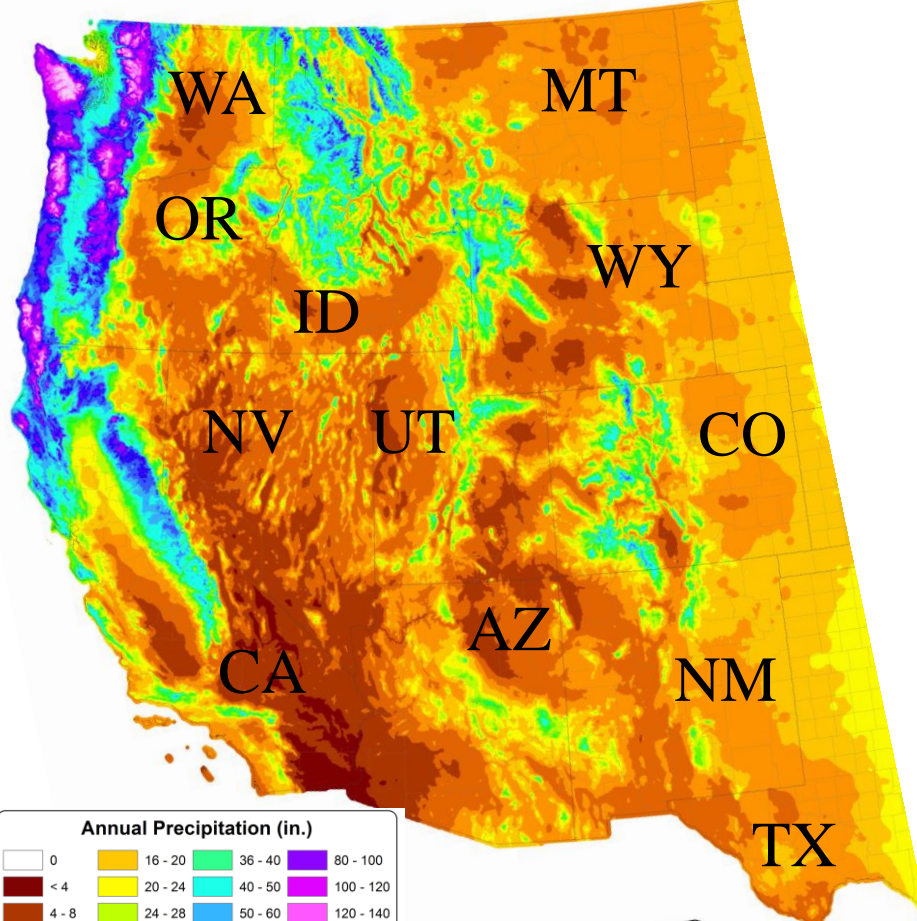
Illinois →  
Mississippi

Washington DC →  
Tallahassee

# Zones Marching Up



- In Colorado, temps drop about 10 F for each 3000 feet of elevation
  - Denver -> Estes Park
  - Estes Park -> Trail Ridge Road
- But in 100 years instead of 100 centuries!



Annual Precipitation (in.)			
0	16 - 20	36 - 40	80 - 100
< 4	20 - 24	40 - 50	100 - 120
4 - 8	24 - 28	50 - 60	120 - 140
8 - 12	28 - 32	60 - 70	140 - 160
12 - 16	32 - 36	70 - 80	> 160



# A Region On the Edge

**75 million people** in the western US live in a region with **marginal precipitation**

**Just enough snow** to support forests and reservoirs

**Just enough irrigation water** to support farming

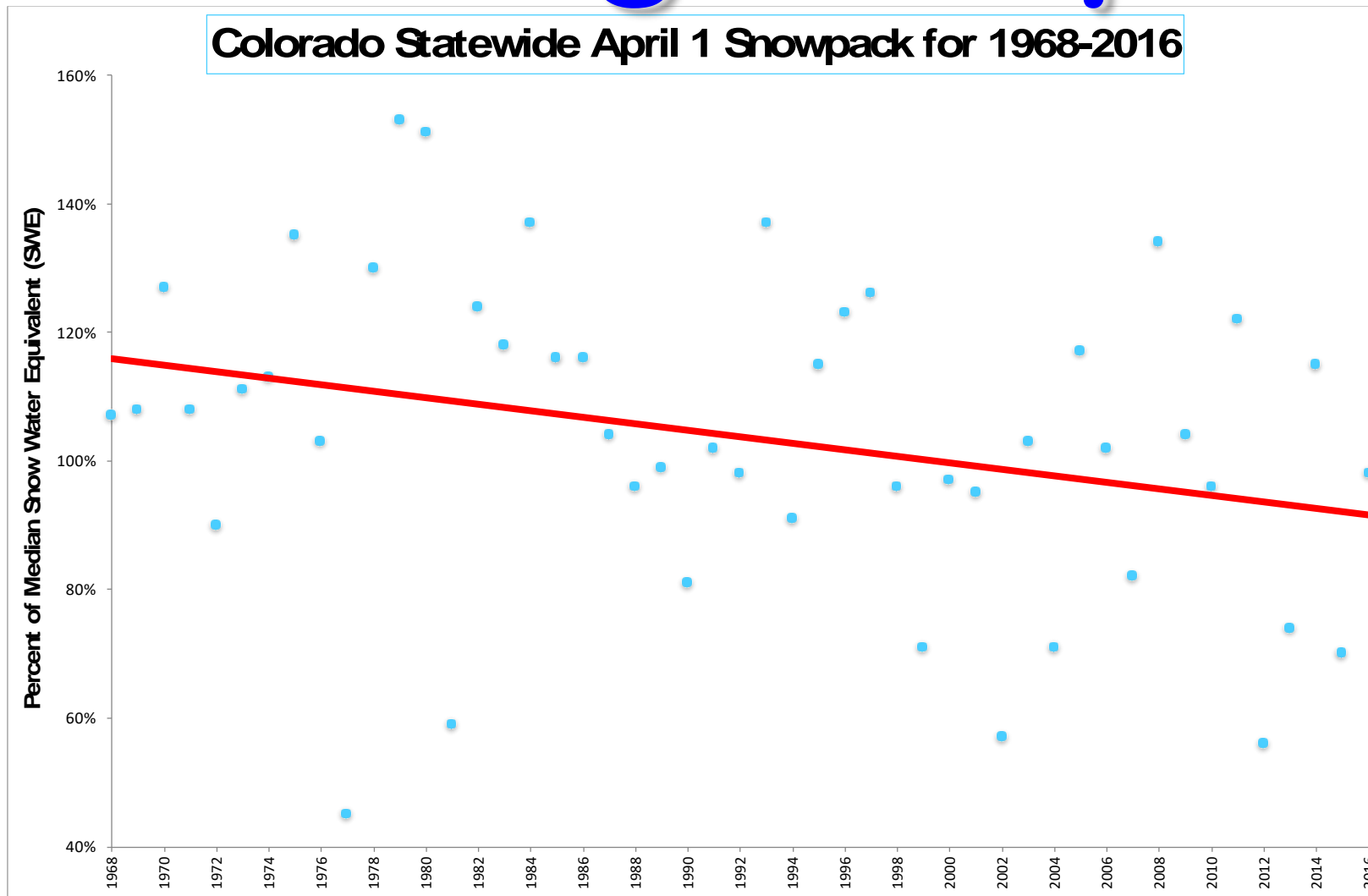
**Just enough water for cities and towns**

# Our Water Supply





# Declining Snowpack

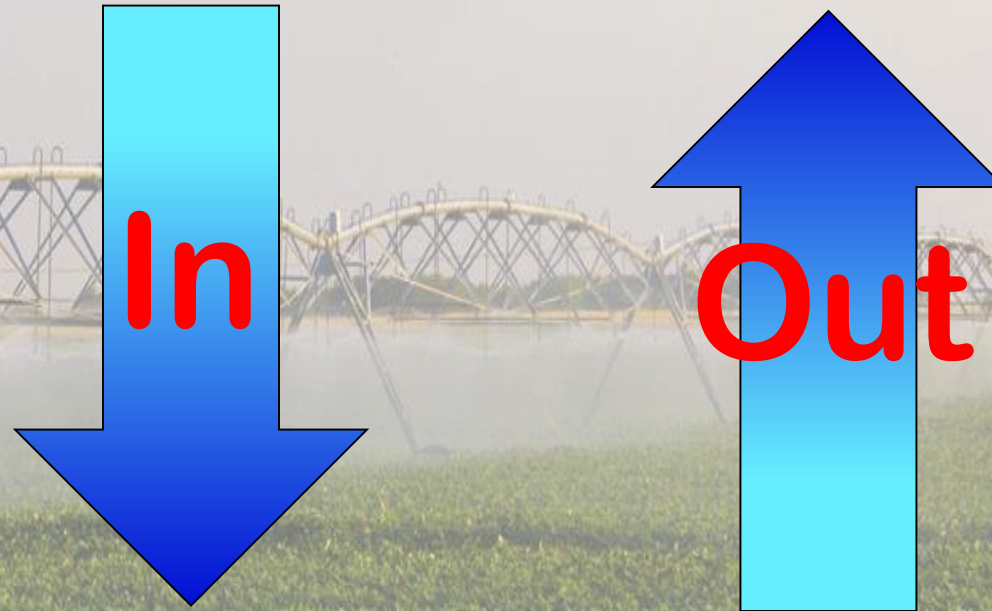


**20% less snowpack over 49 years**

**Less than 2 Fahrenheit average warming**

# Water Budgets

Evaporative demand increases w/ temperature



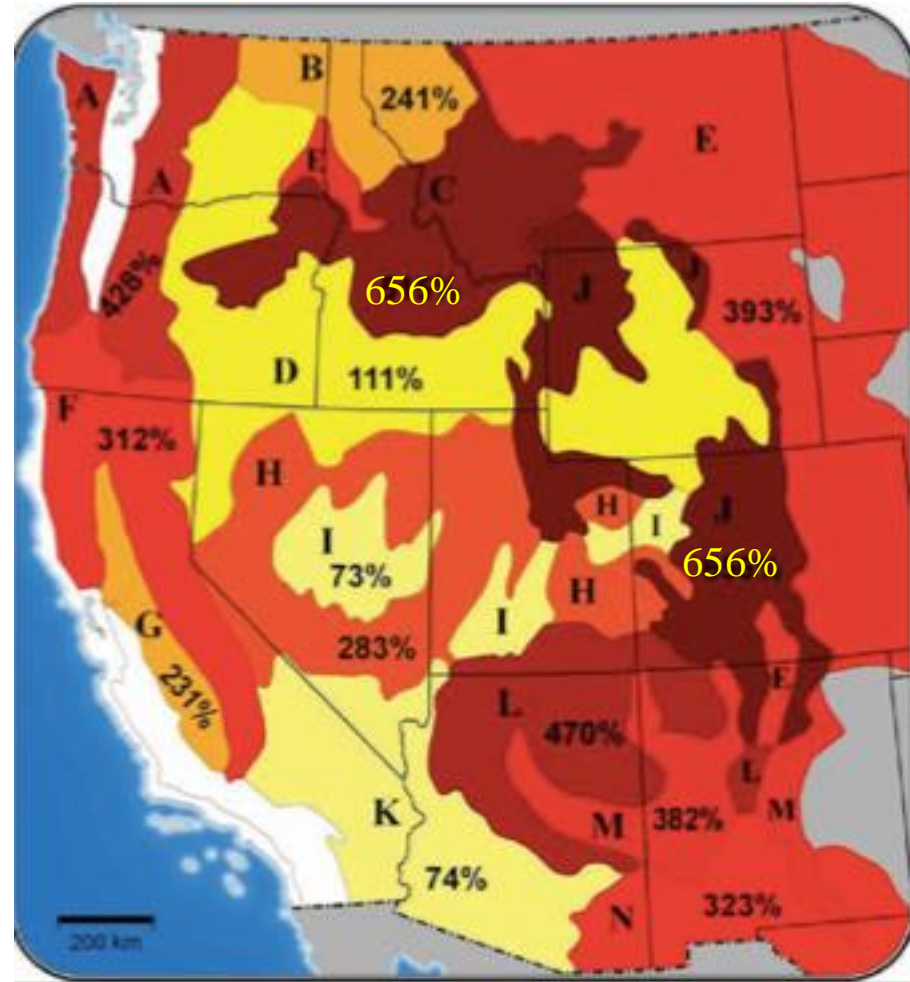
Drought is the *running sum* of water out minus water in

# Warming Promotes Wildfire

1. Warmer air increases **evaporative demand** on forests
2. Longer **warm season** depletes soil moisture
3. More frequent **extremely hot, dry, windy days** when fires are uncontrollable



*Projected Increase in Area Burned*



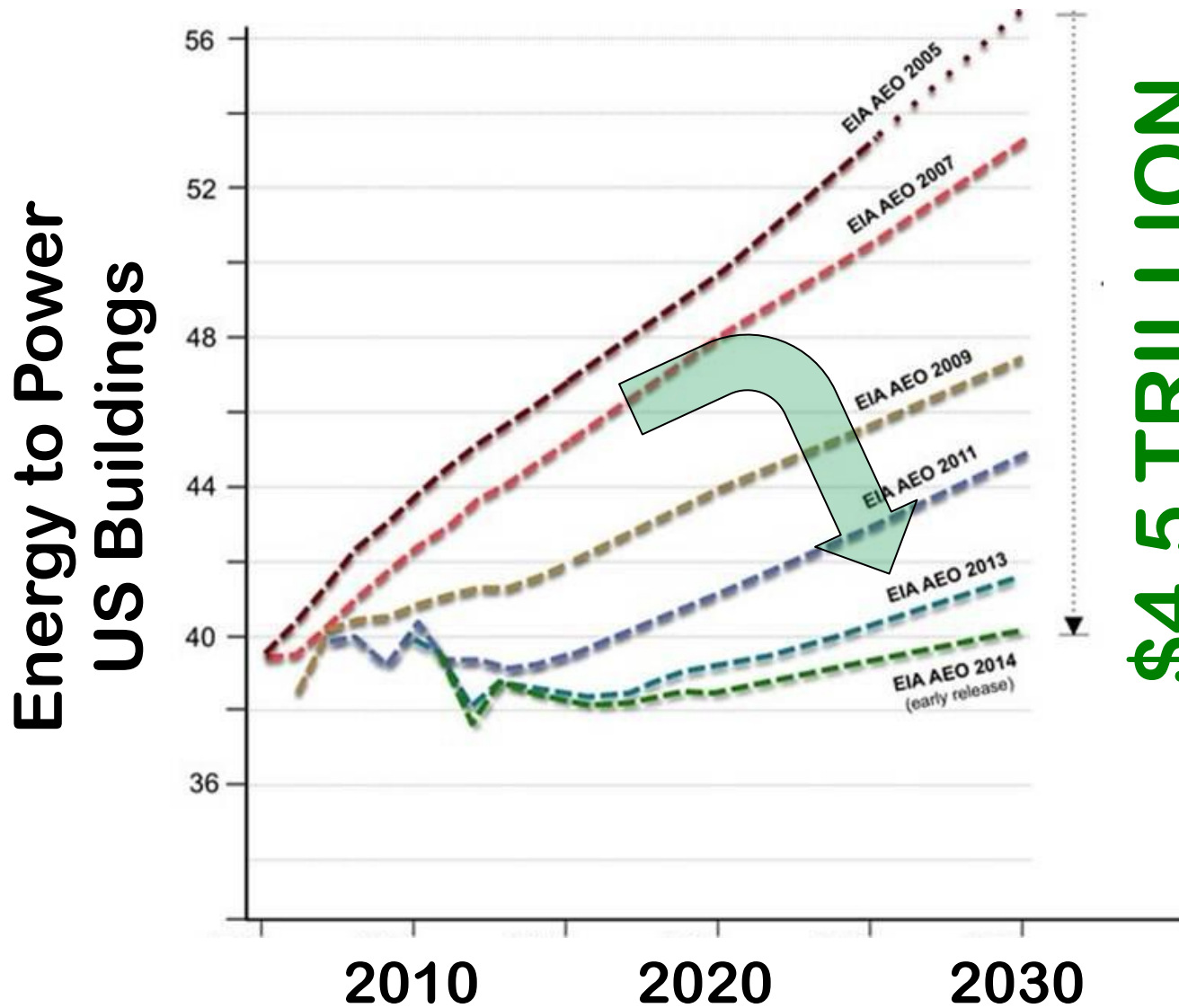
*NRC 2011*

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# Efficient Buildings!

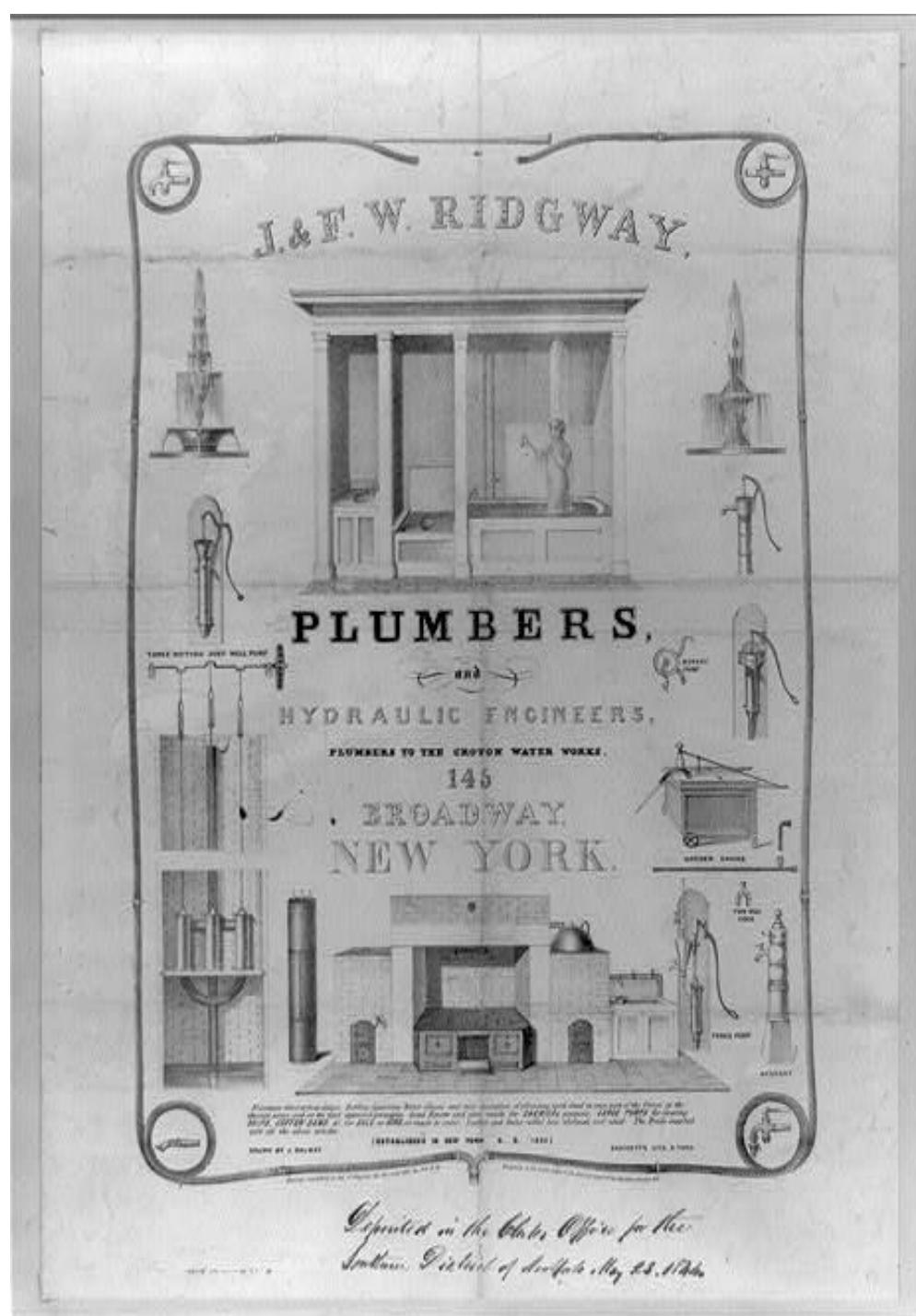


**\$4.5 TRILLION  
SAVINGS!**



# Costs

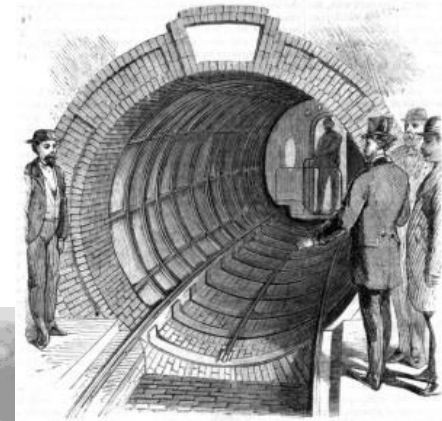
- Conversion to 100% noncarbon energy will cost about **1% of GDP**
- That's about **what it cost to retrofit all the world's cities with indoor plumbing a century ago ...**
- It was **SO worth it!**



# My Grandparents



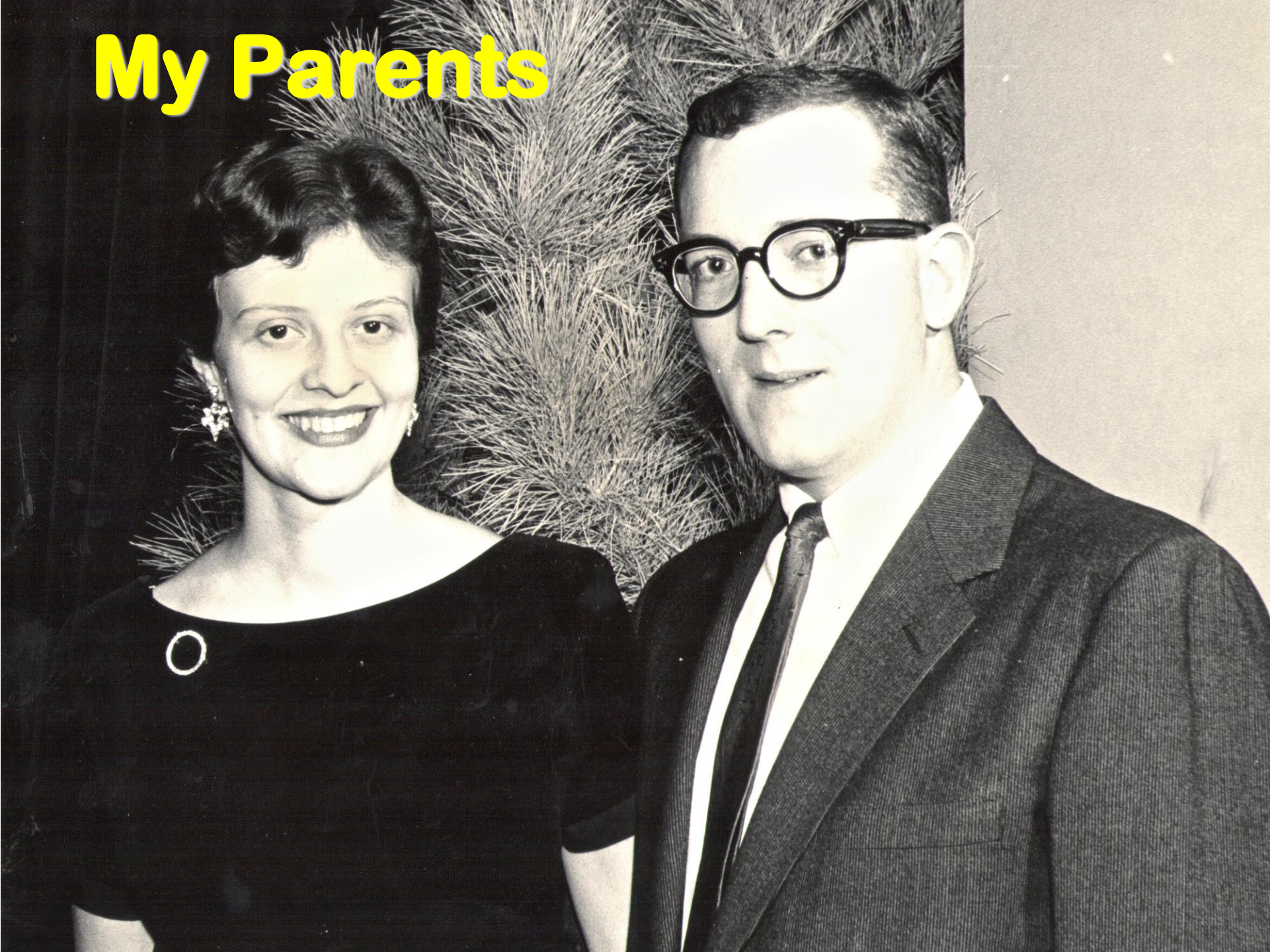
# My Grandparents' Generation



**Built subways, sewers,  
the electrical grid, defeated the Nazis**



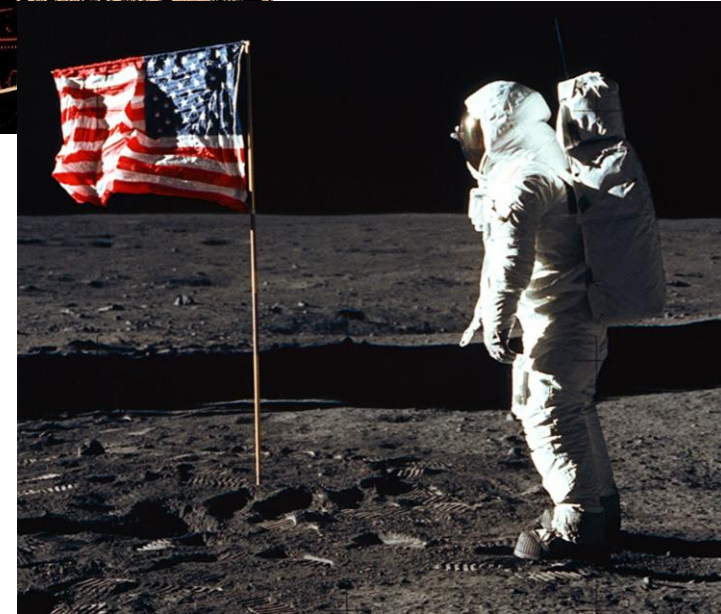
# My Parents



# My Parents' Generation



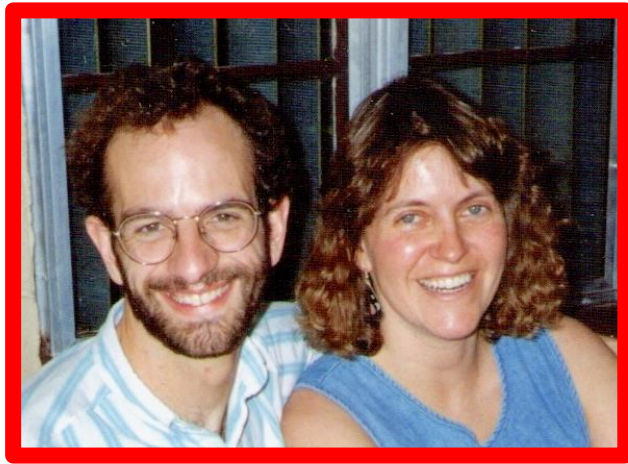
Ribbon-cutting ceremony along the first portion of Interstate highway to be completed in Wisconsin on September 4, 1958—I-94 in the Waukesha area. (Photo courtesy Wisconsin Historical Society Archives.)



**Built the Interstate Highways,  
fought the cold war, landed on the Moon!**

# Jennifer & Me





# My Generation

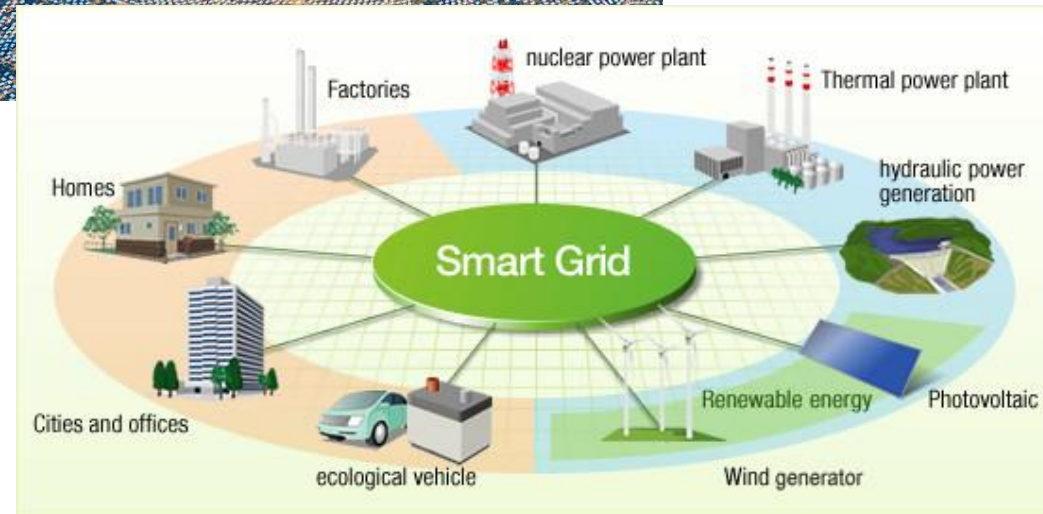
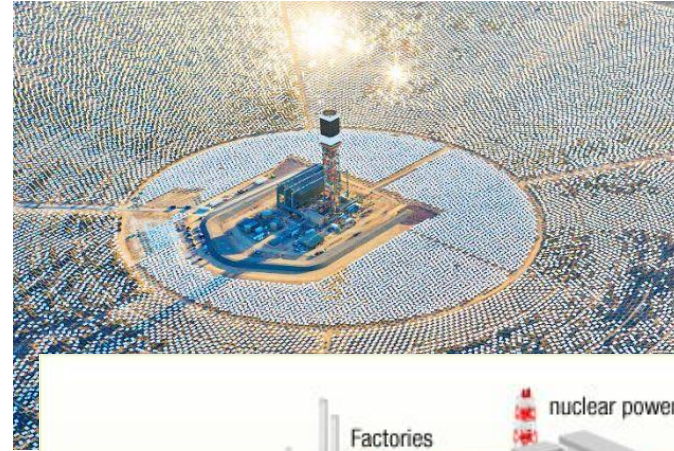


**Invented the PC, Built the internet,  
replaced billions of land-lines with cell phones**

# My Kids



# My Kids' Generation



Will replace the world's energy system *again!*



# Choose Your Future

Many people think:

“Our well-being is based on  
stuff we extract from the ground”

When we stop burning coal, will our  
descendants shiver in the dark?

# Choose Your Future

A diverse group of people, including men and women of various ethnicities, are shown in a state of high energy and celebration. They are smiling broadly, laughing, and raising their arms in the air. The background is bright and slightly blurred, emphasizing the people in the foreground.

I prefer:

“We create our well-being through creativity, ingenuity, and hard work”

**The future is bright!**