TRANSITIONING ENERGY AND TRANSPORTATION IN THE US

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SUMMARY

- A desire to reduce carbon dioxide emissions is driving change in the transportation and power generation industries.
- In what context can we view this situation?
- What options exist and how they can be evaluated?

SOME HEADLINES

California Reveals Its Plan to Phase Out New Gas-Powered Cars by 2035

If adopted, the new measures would make a dent in the state's greenhouse gas emissions and set the bar for the broader auto industry.

The New York Times

State Of Washington To Ban Gas-Powered Vehicles By 2030

BY SAM MCEACHERN — MAR 28, 2022

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New York Will Ban Sale of Gas-Engined Cars by 2035

The state rolls out ambitious goals for cars and trucks, but EV sales rates will need some serious annual gains.

BY JAY RAMEY ◆ SEP 15, 2021

U.S. government to end gas-powered vehicle purchases by 2035 under Biden order

REUTERS®

By David Shepardson and Ben Klayman

The New York Times

6 Automakers and 30 Countries Say They'll Phase Out Gasoline Car Sales

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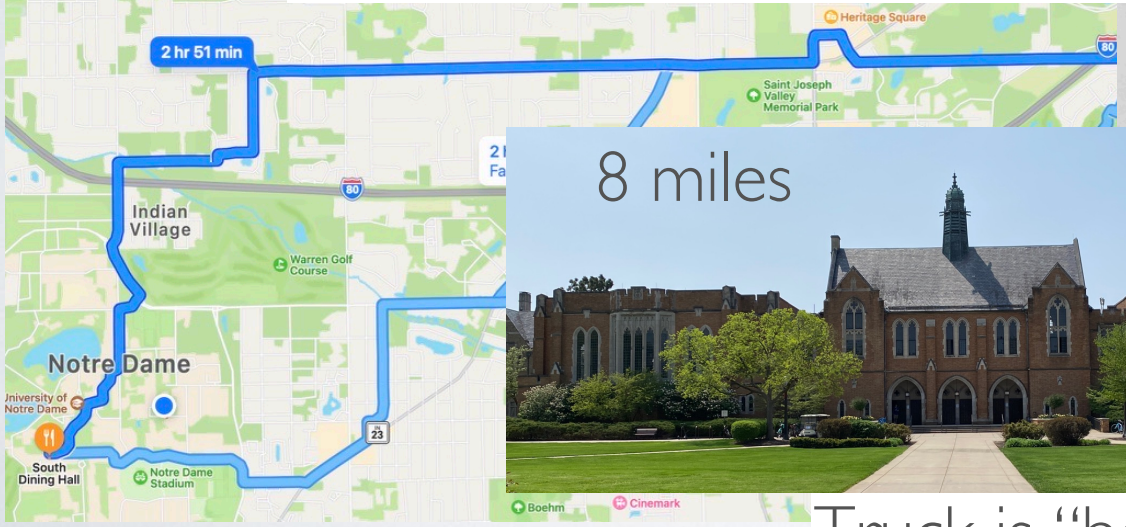
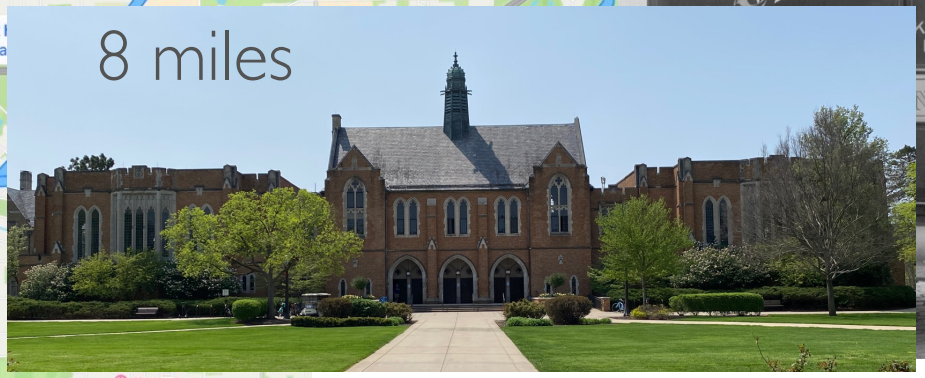
WHAT IS REASON?

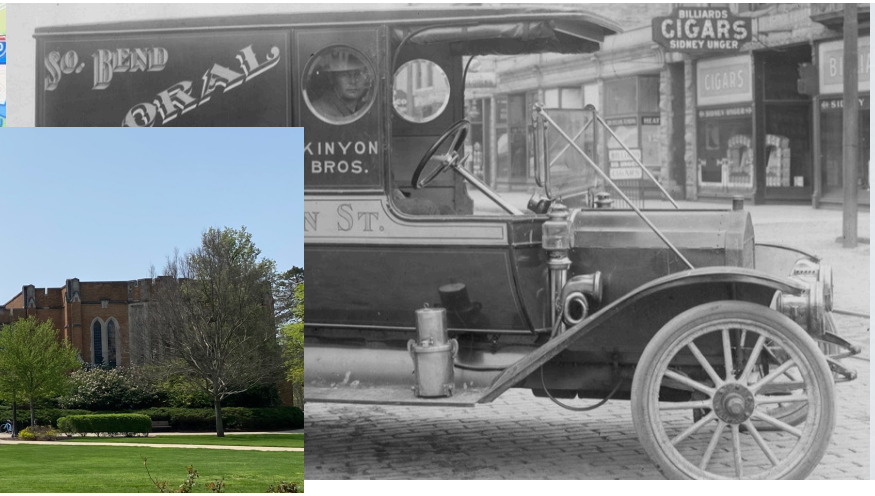
- Are “electric” cars “better”?

SOME HISTORY

Excepting the example in the John Wayne movie: "Big Jake"!







Truck is "better" than horse drawn wagon

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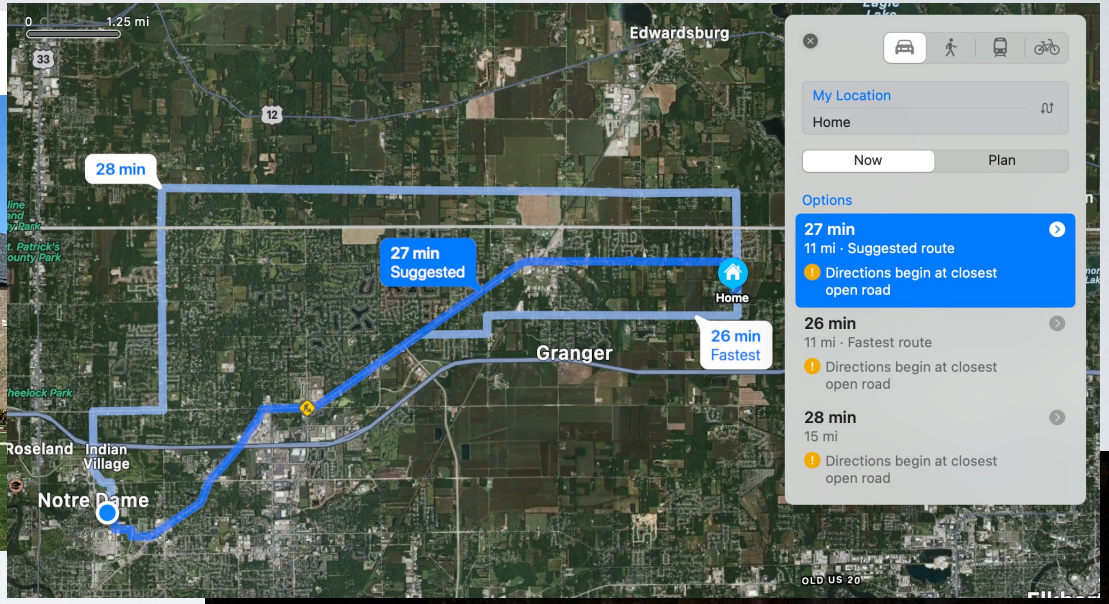
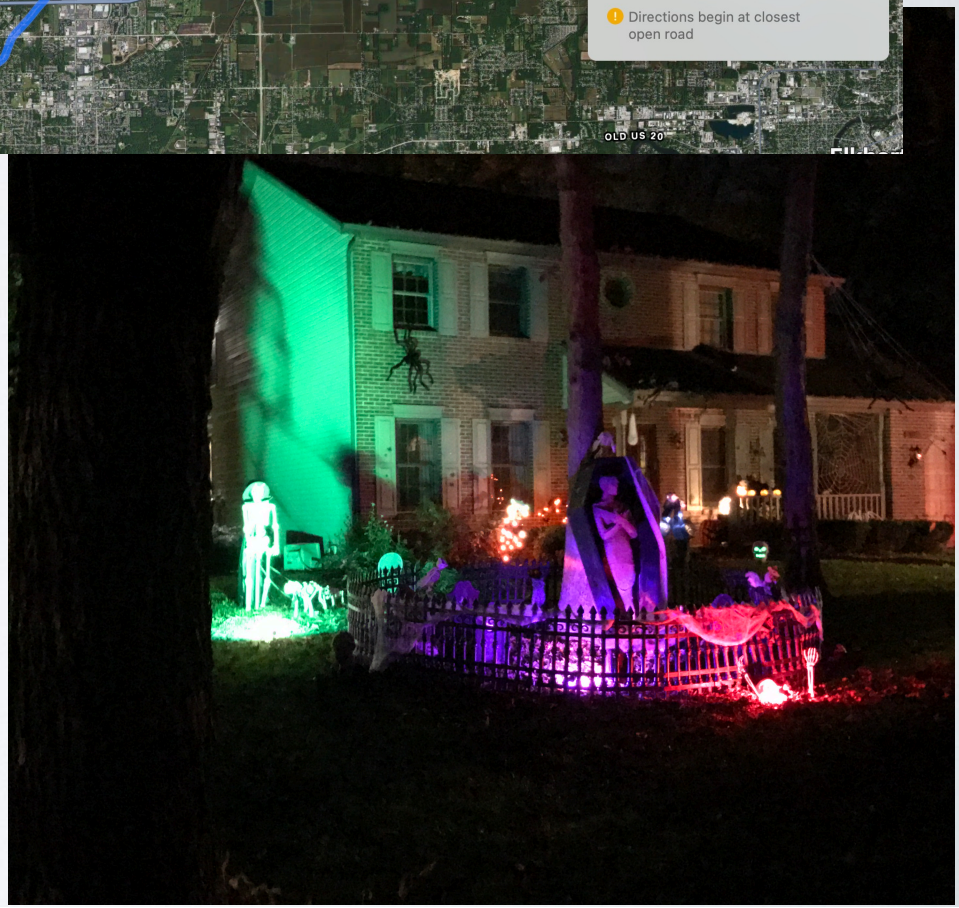
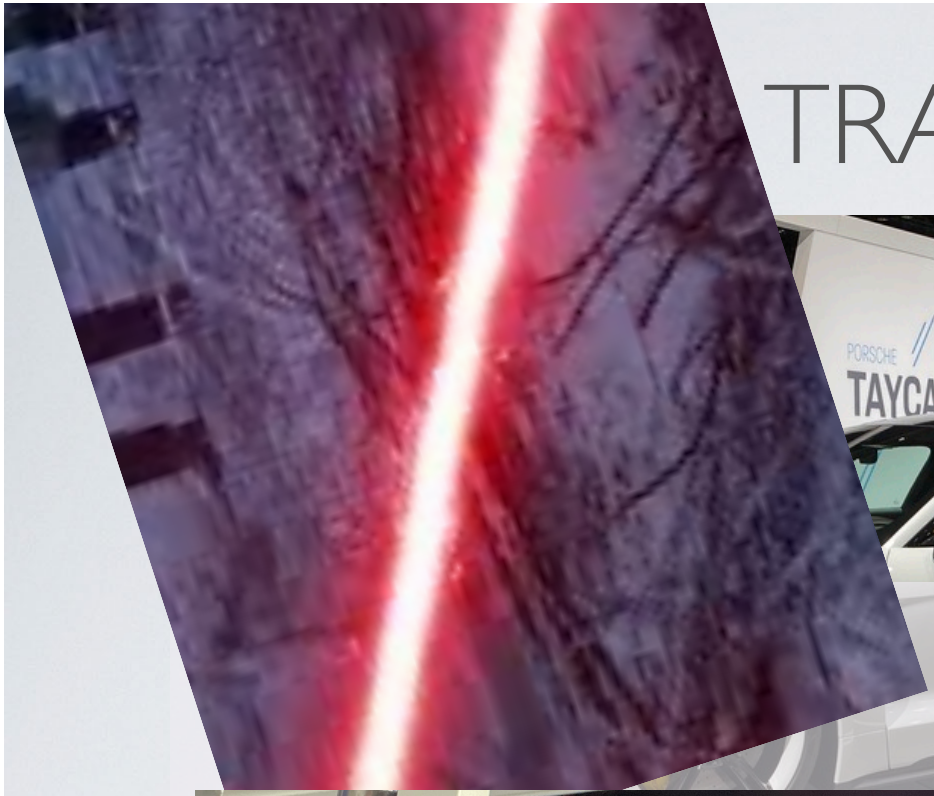
CONTEXT



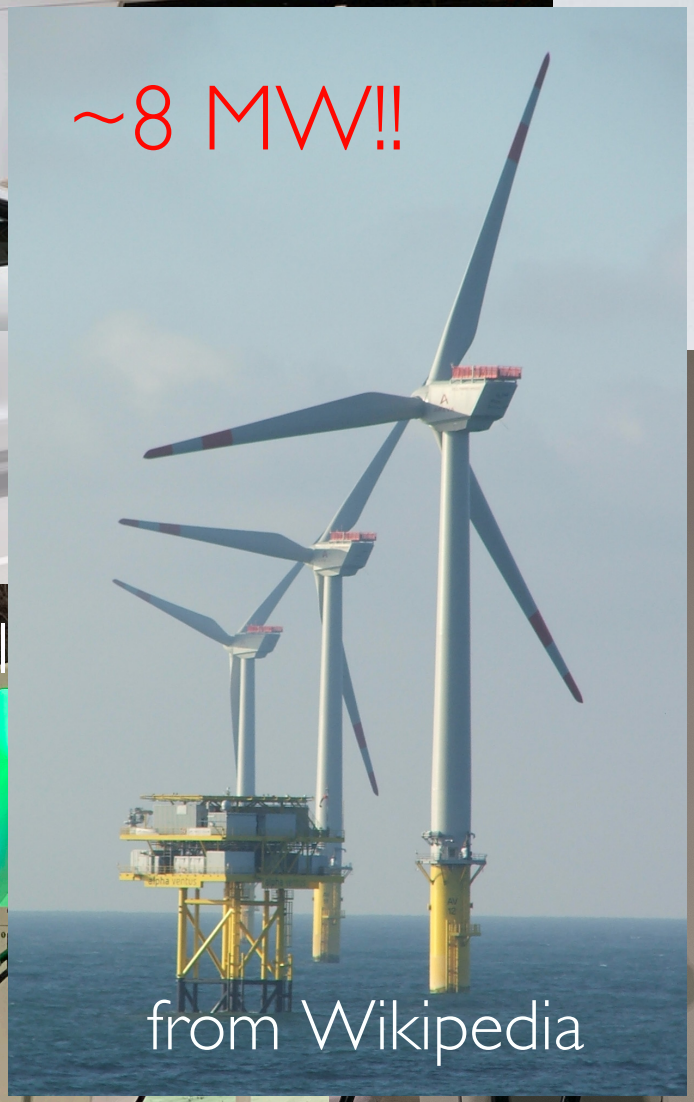


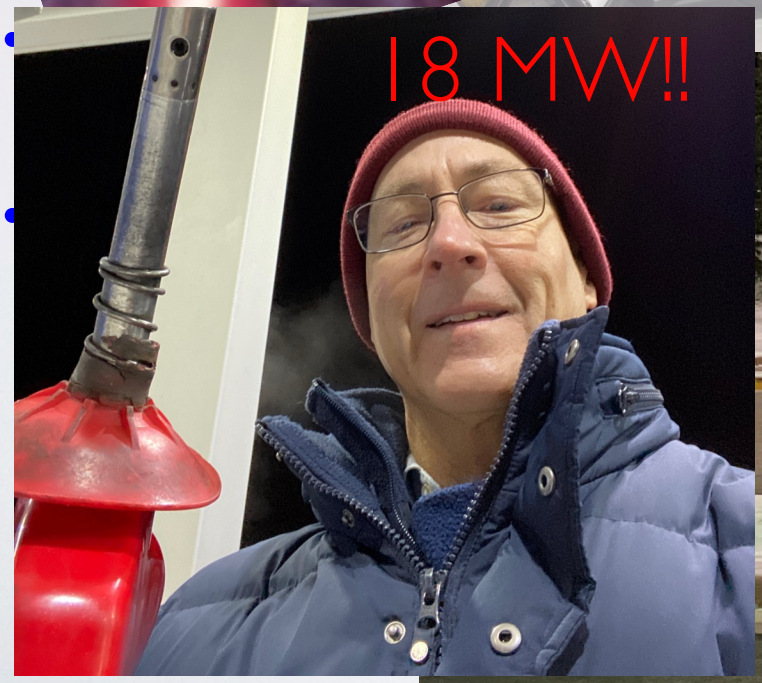
- Mazda 3, 2018 — 35 mpg — this is roughly twice what my car from graduate school, Plymouth ***Scamp*** would get.
- Range: ~400 miles, "recharge" in 3 minutes.
- Not obvious how I could get to work otherwise…

TRANSPORTATION



~8 MW!!





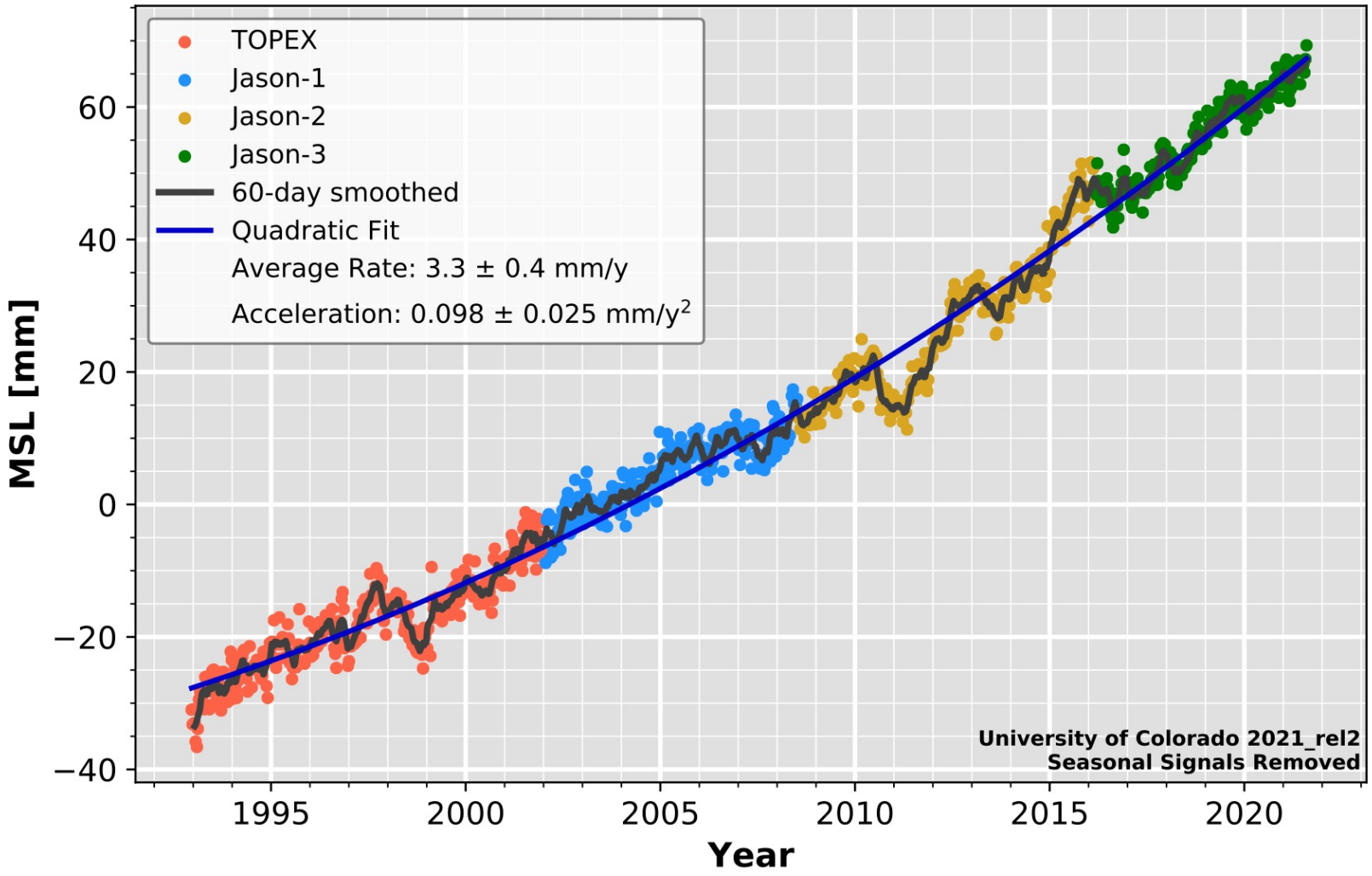
18 MW!!

We have l

from Wikipedia

SO WHAT OTHER REASONS COULD JUSTIFY A CHANGE?

GLOBAL SEA LEVEL



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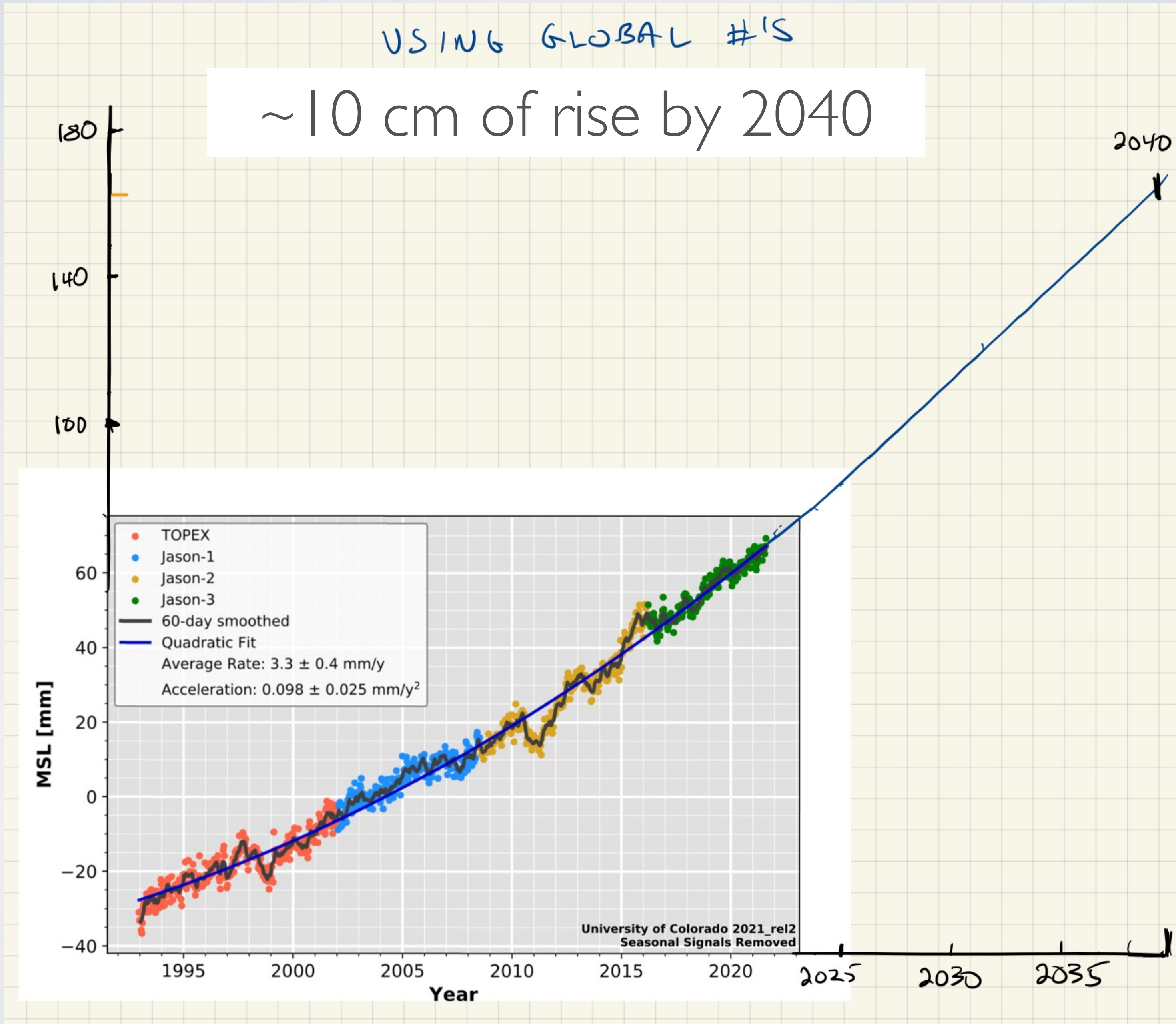
AN ESTIMATE OF SEA LEVEL RISE

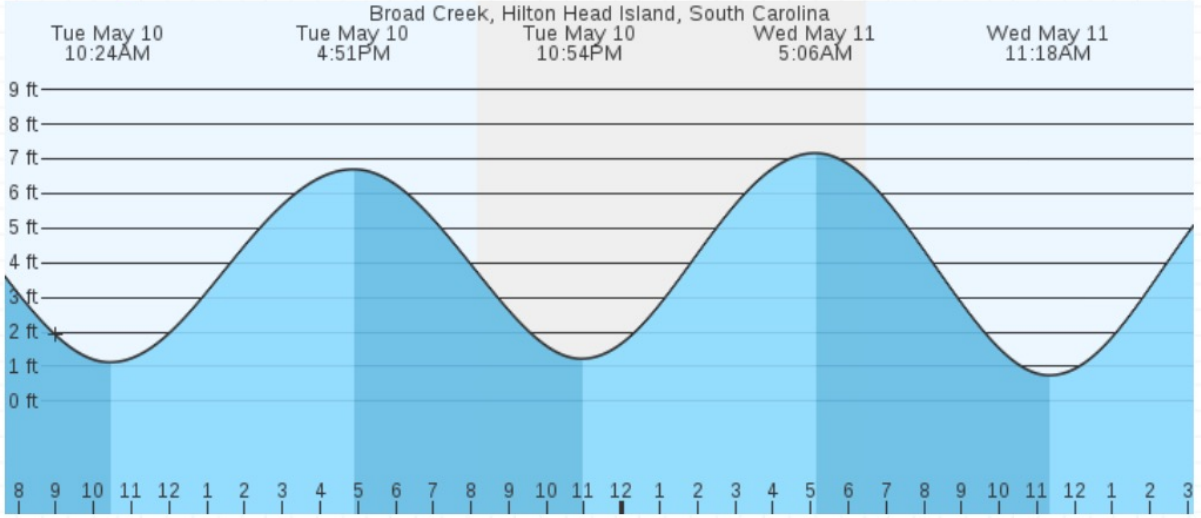


YOUR TIDAL RANGE

Broad Creek, Hilton Head Island, SC Tides

Marine Forecast: Edisto Beach to Savannah

TIDES



Date	Time	Feet	Tide
Tue May 10	10:24am	1.12 ft	Low Tide
Tue May 10	4:51pm	6.70 ft	High Tide
Tue May 10	10:54pm	1.23 ft	Low Tide

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CURRENT (HIGH) HIGH WATER

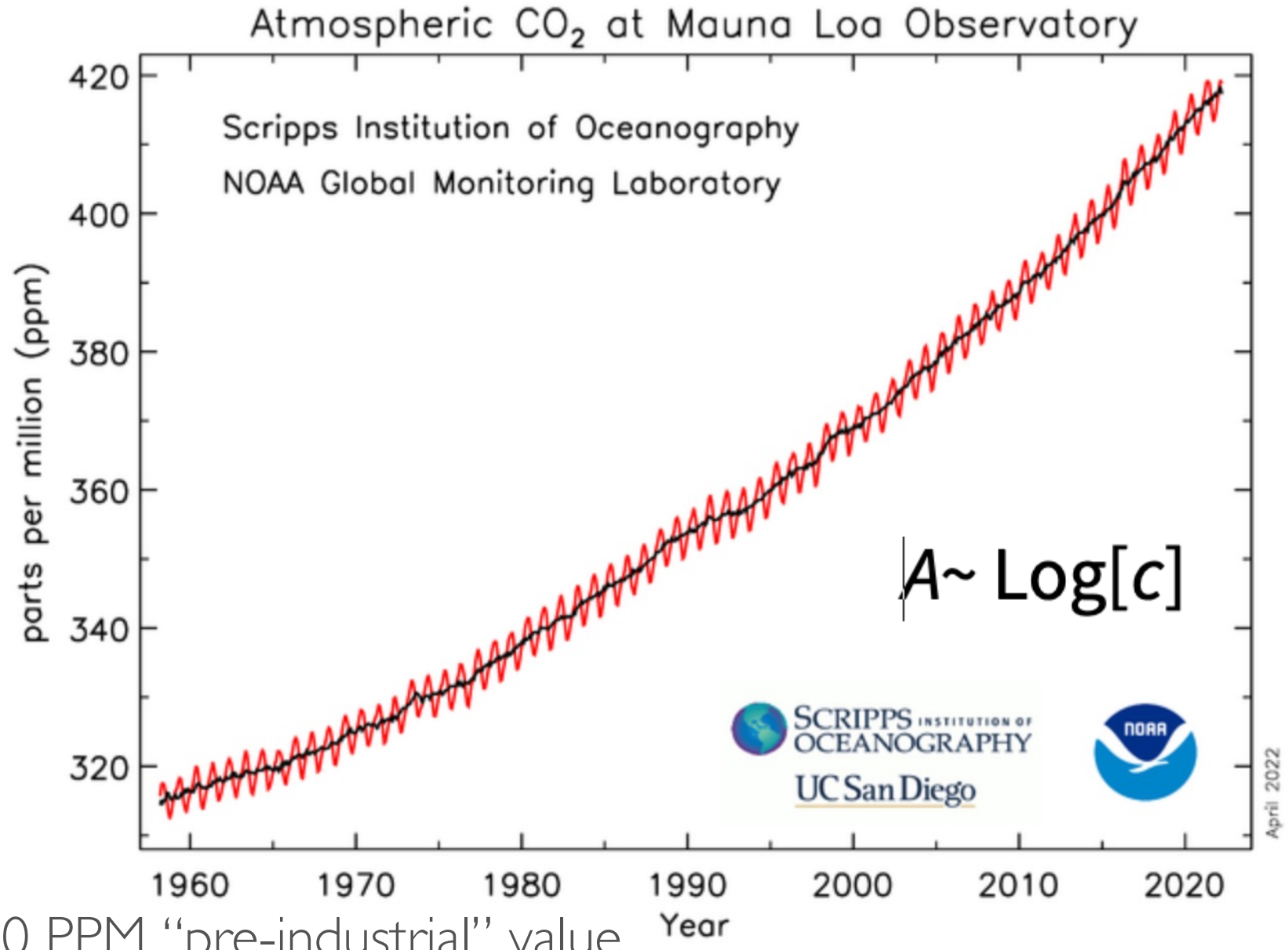
1 FOOT RISE IN LEVEL

SEA LEVEL RISE

- A single family house usually does not last more than a century
  - Other residential housing probably even less
  - You can judge the level of concern for you

MORE GENERALLY

- Carbon dioxide concentration in the atmosphere
- Average and fluctuating temperature



280 PPM "pre-industrial" value

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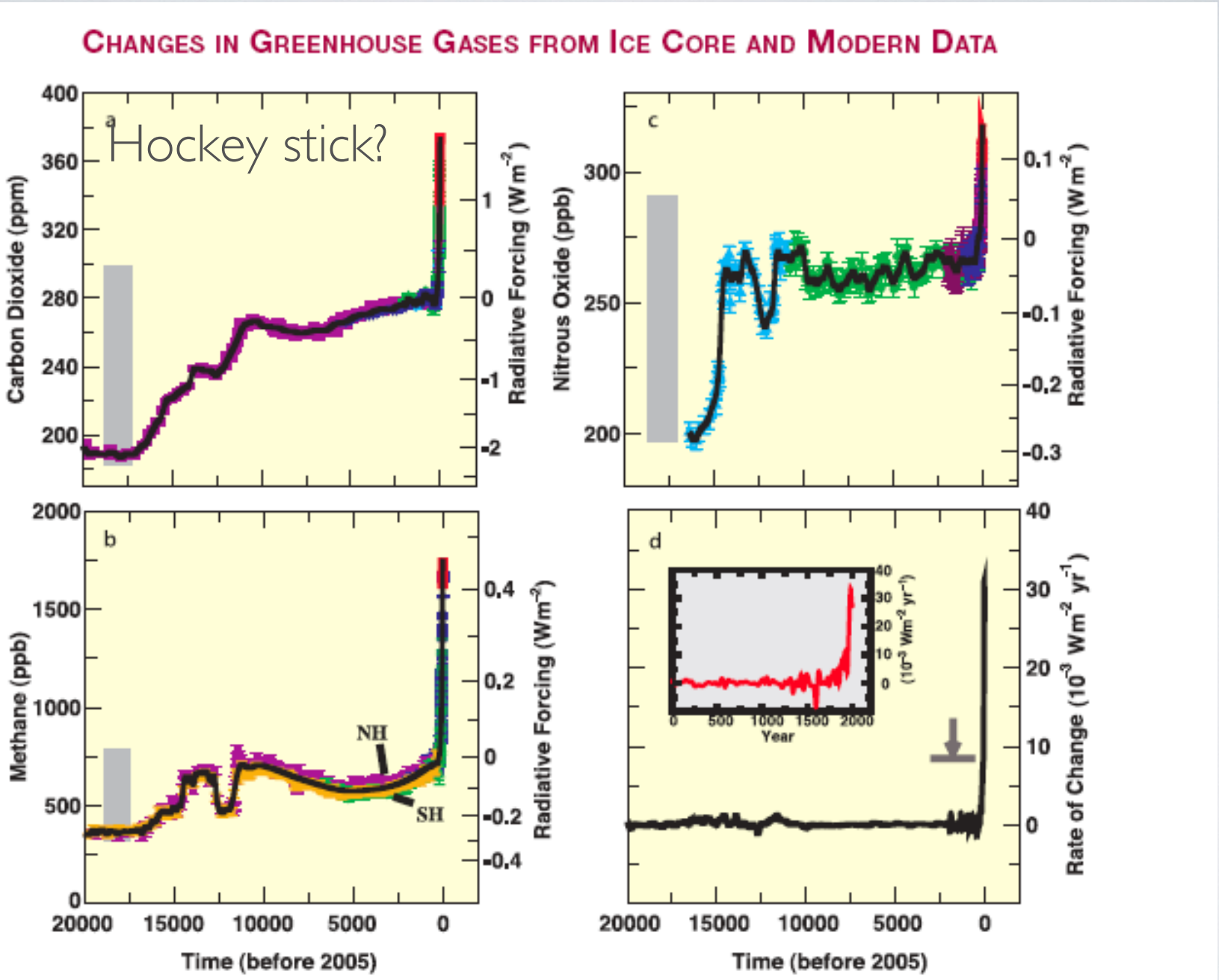
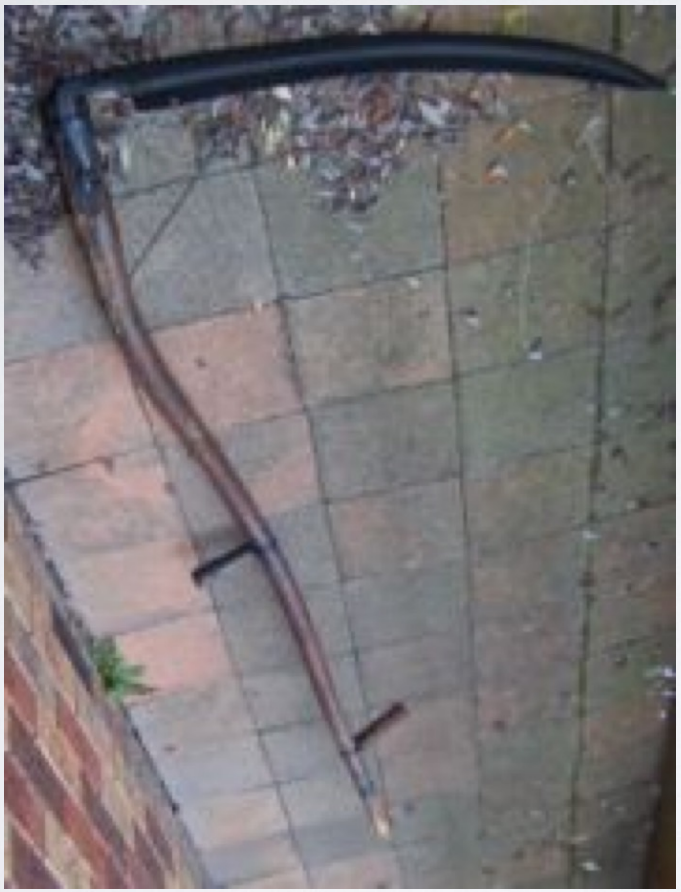
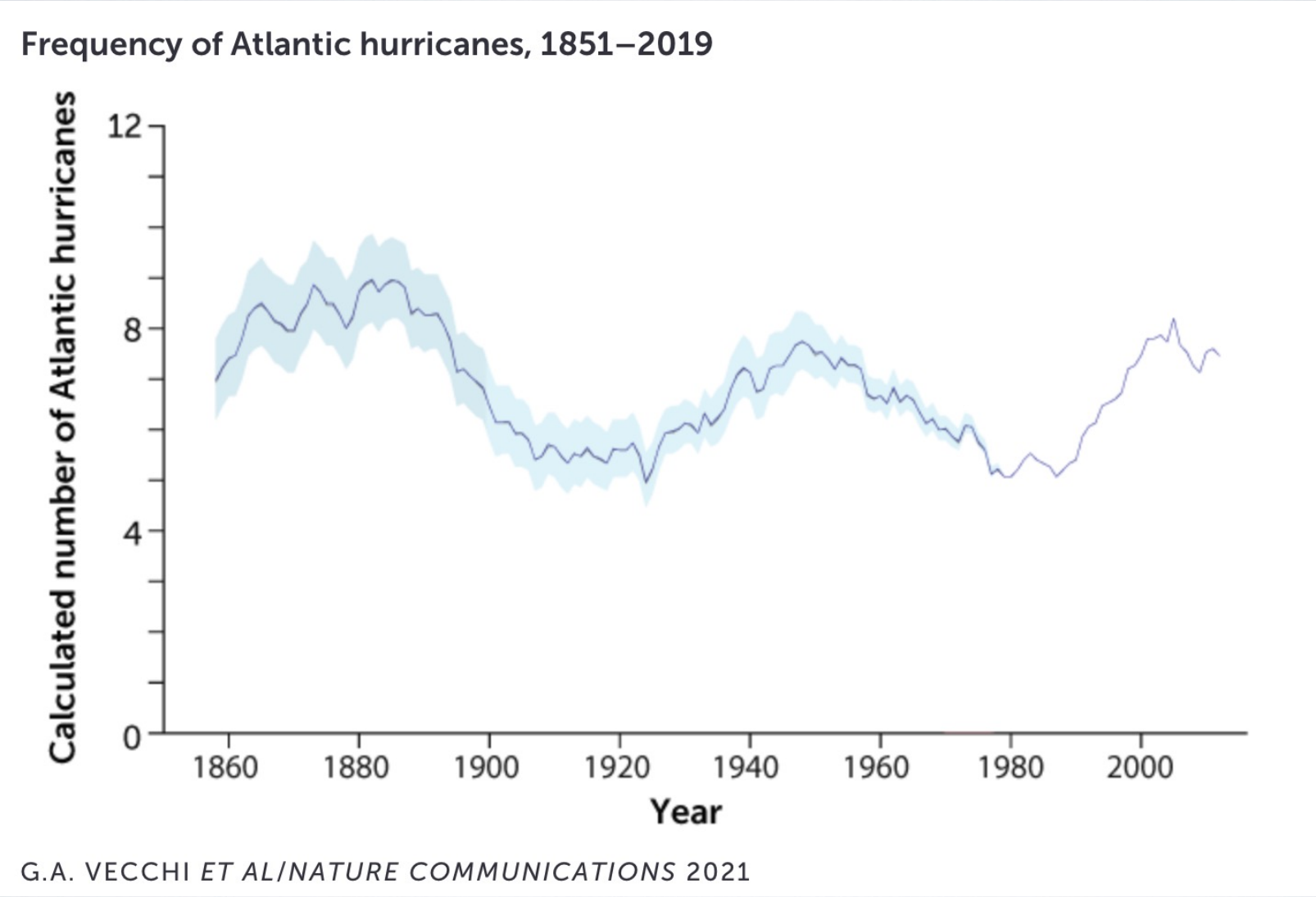

CHANGES IN GREENHOUSE GASES FROM ICE CORE AND MODERN DATA
a
Hockey stick?
Carbon Dioxide (ppm)
Radiative Forcing (W m-2)
c
Nitrous Oxide (ppb)
Radiative Forcing (W m-2)
b
Methane (ppb)
NH
SH
Radiative Forcing (Wm-2)
Time (before 2005)
d
Year
Rate of Change (10-3 Wm-2 yr-1)
Time (before 2005)

IPCC 2007

NOW IT'S A SCYTHE!



NO CHANGE IN NUMBER OF HURRICANES



May be some increase in rainfall and windspeed

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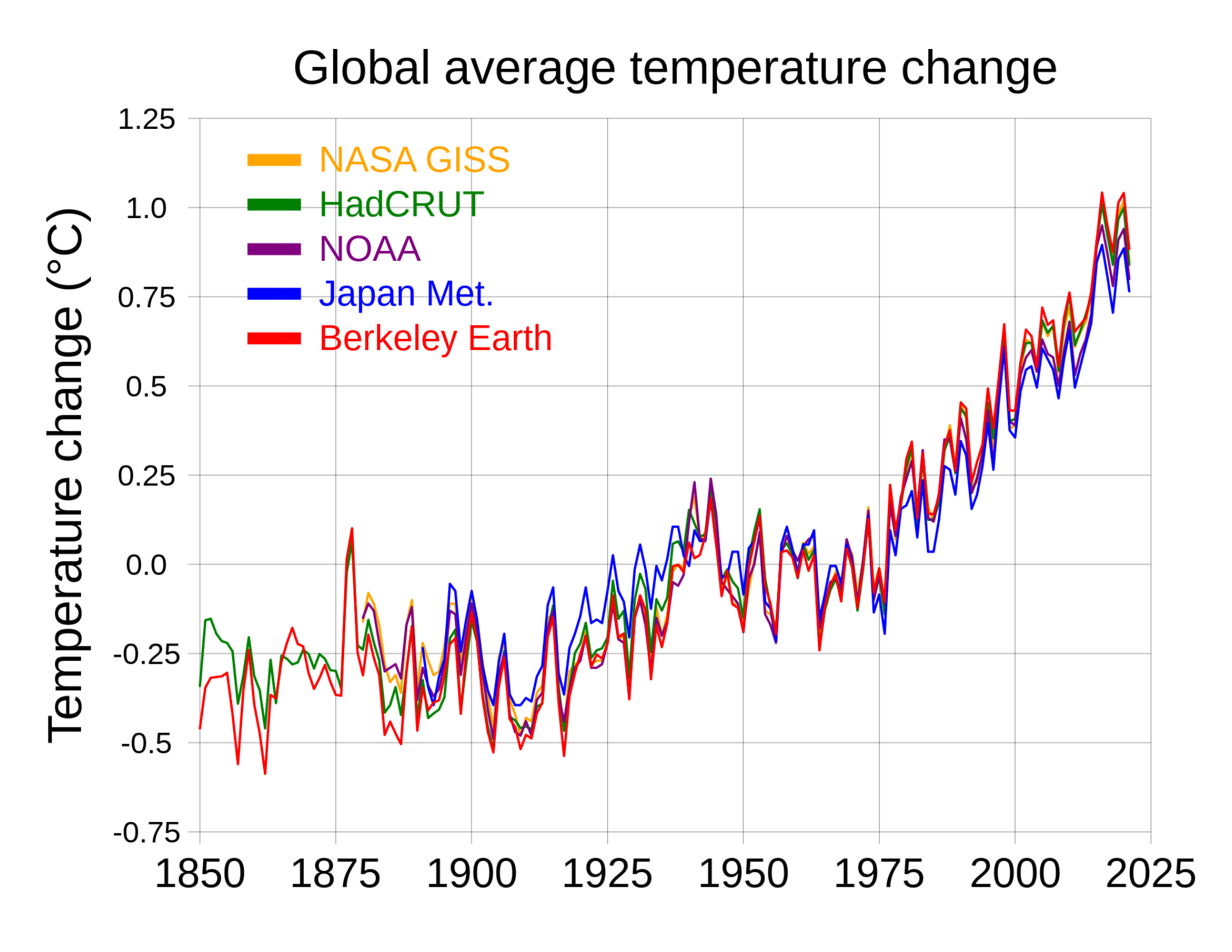
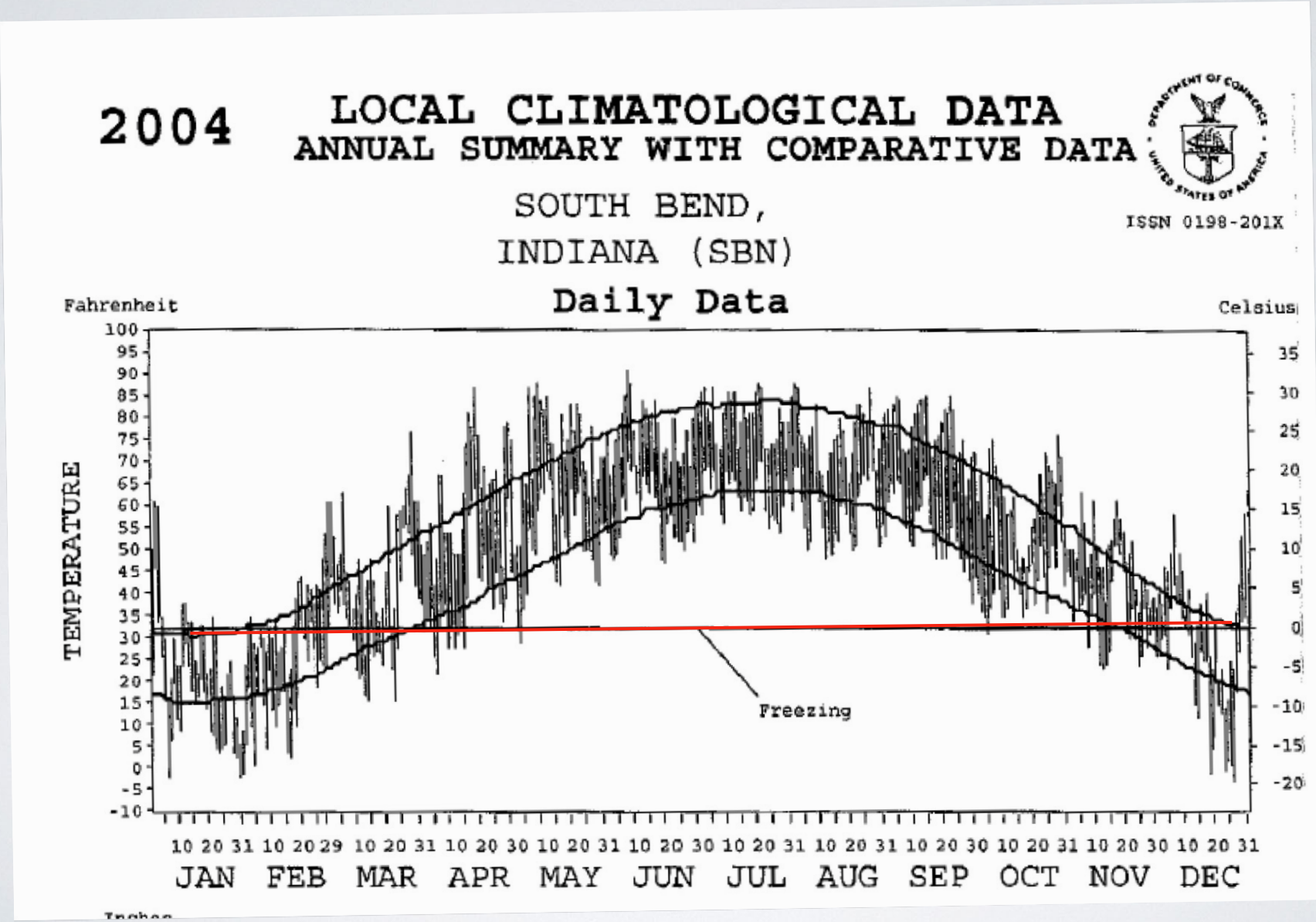
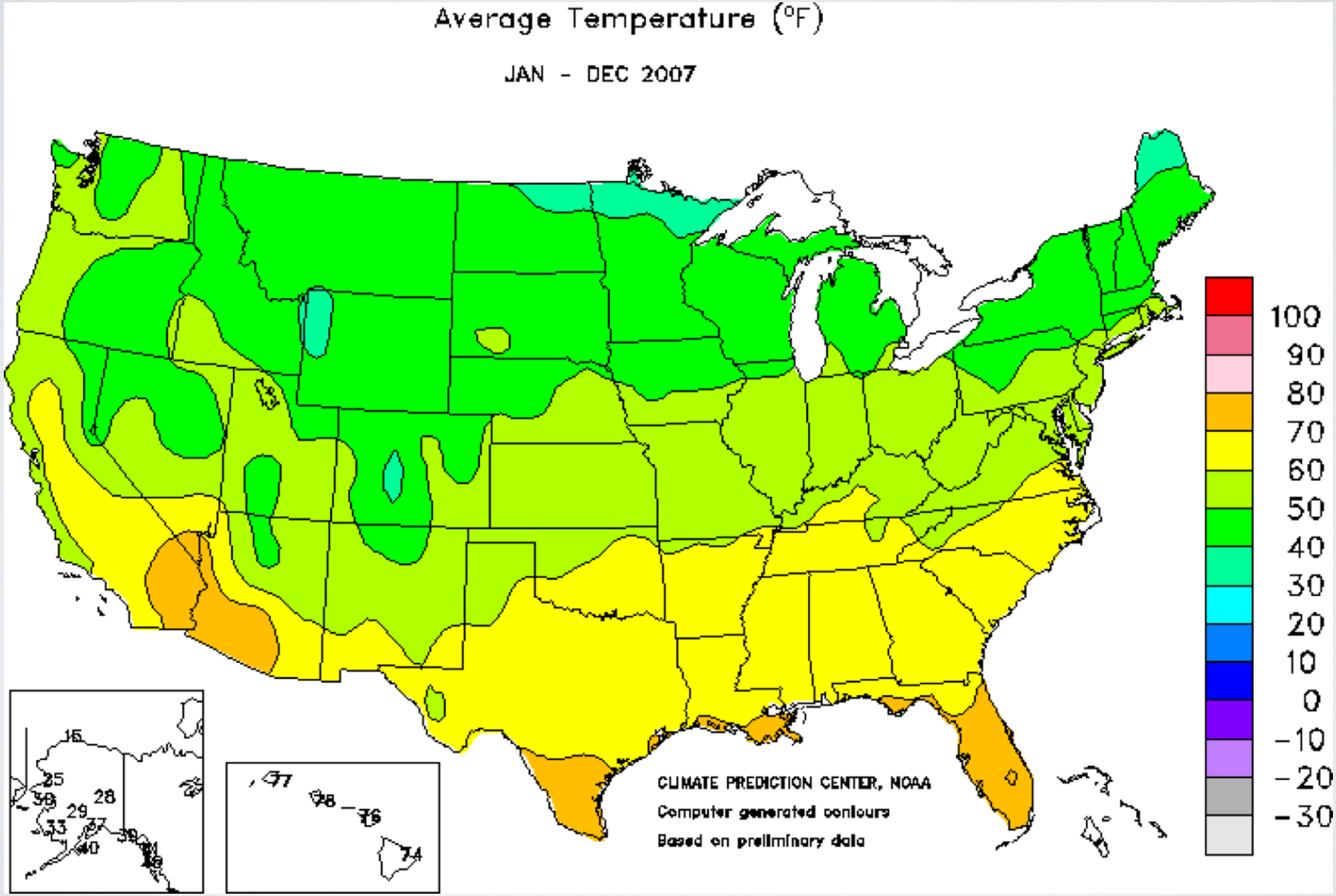

Global average temperature change
Temperature change (°C)
1.25
1.0
0.75
0.5
0.25
0.0
-0.25
-0.5
-0.75
1850
1875
1900
1925
1950
1975
2000
2025
NASA GISS
HadCRUT
NOAA
Japan Met.
Berkeley Earth

EFFECT OF TEMPERATURE ON GROWING SEASON



US AVERAGE TEMPS



SORRY TO BE CONTROVERSIAL

- It is not apparent to me that locally, around the US or even for almost all of the world, that the increasing CO2 levels will lead to any catastrophic outcomes.

- Thus any actions that cause changes in technologies, (that are not obviously technically better) should be "political decisions", made with consideration of all factors, (including economic and social issues), by elected officials.

  - There is no single "Science" to follow.

  - Will a prescribed action actually achieve the intended outcome?

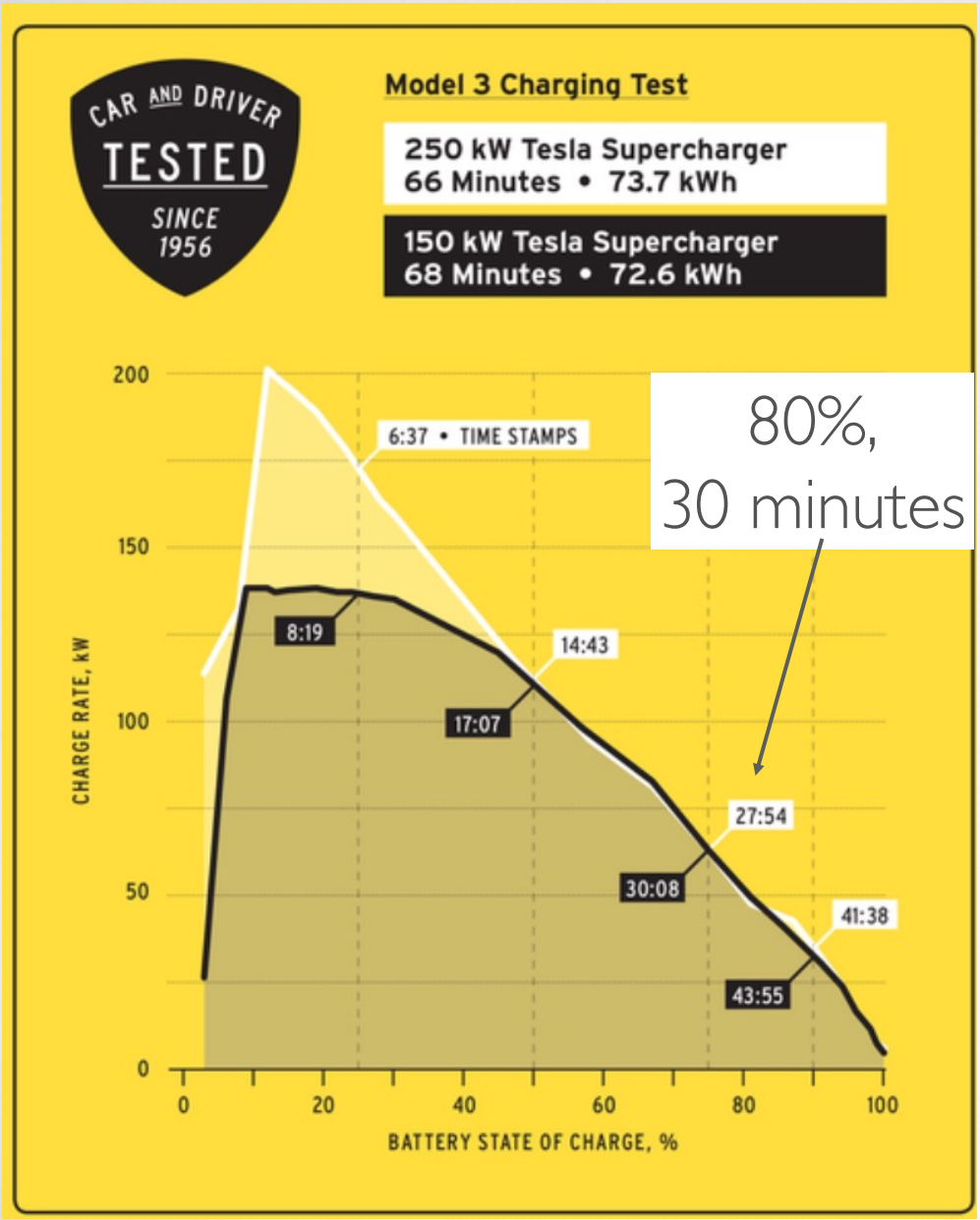
WHAT ARE THE ISSUES RELATED TO ELECTRIC VEHICLE ADOPTION?

- Can the key challenge be overcome?
- Where is the electricity going to come from?
- Will this transition be affordable?

KEY CHALLENGE

- The 12 gallons of gas in my Mazda 3 gives a range of 400 miles. Refueling takes 3 minutes
- A lithium battery pack of the same weight (32 kg) would have a range of about 40 miles.
    - Thus a Tesla or other electric car has a battery pack that weighs substantially more than the equivalent gasoline.
        - Not likely to see battery powered airplanes anytime soon!
- Recharging is also an issue.

KEY CHALLENGE



- For a maximum range of 300 miles, you could get to about 250 miles in 30 minutes
  - The "super-duper" charger doesn't change this much

ELECTRIC CARS

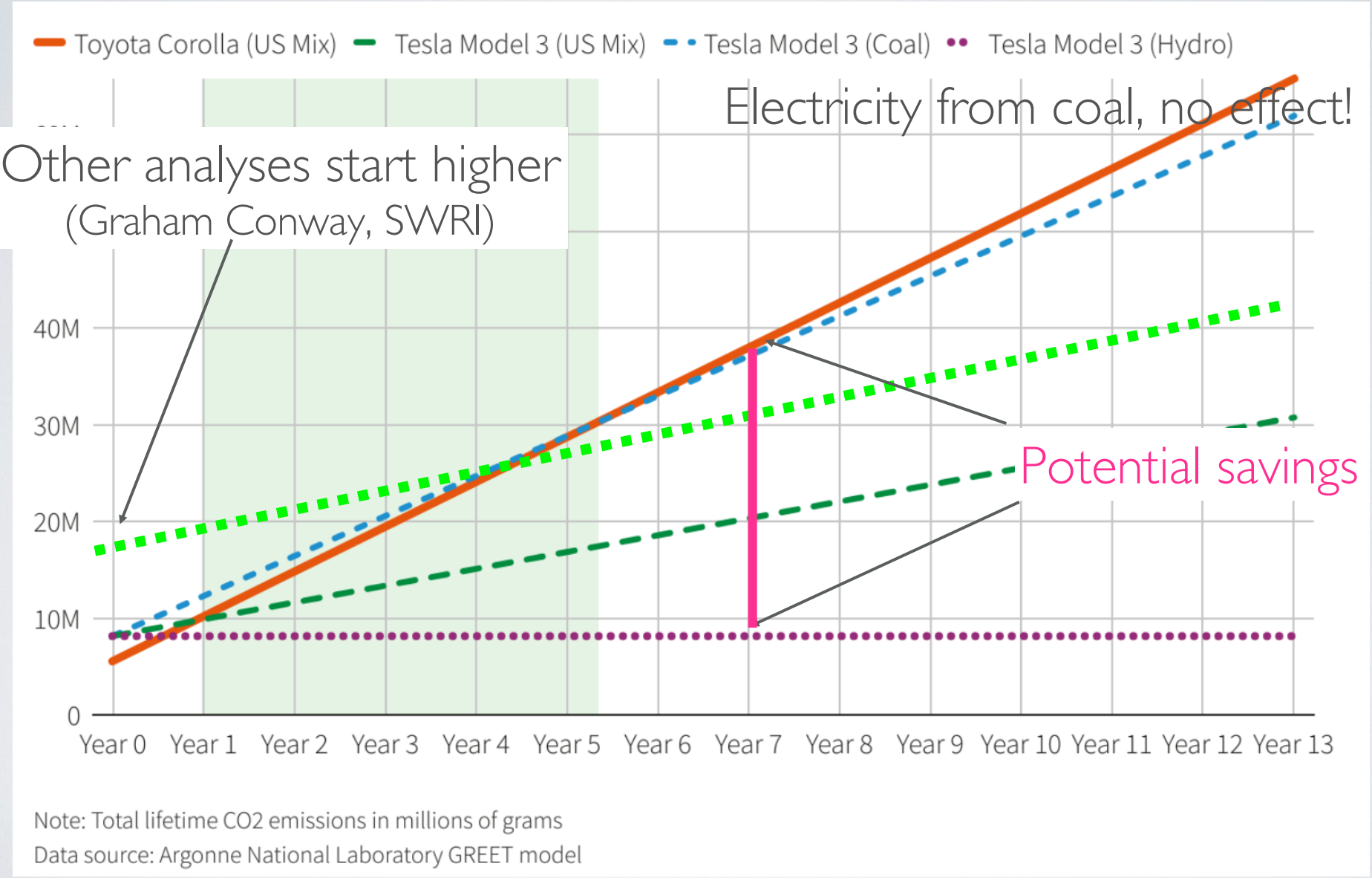
- The difference in range, cold weather performance or charging time will be reduced over time.
- (Unsubsidized) cost differential will be reduced over time.
- Key materials (availability, extraction techniques) will probably remain a concern.

RECHARGING

- Indiana Toll Road + Ohio Turnpike, 392 miles, about 6 hours to drive
- On a really busy travel day, the 11 travel plazas will have backups at the gasoline pumps.
  - While there is some lost time, it takes only about 3 minutes to fill up.
  - One tank will provide enough fuel so on average, each car will stop for gas only 1 time.
- What if all cars were electric?
  - Today, a Tesla supercharger can give a car <300 miles of range in 20-30 minutes.
  - We need to provide about 9 times more charging capacity — meaning each plaza would need 144 charging ports. (OK, so every space!)
  - **Total power needed for this: 650MW! (Where from?)**

EFFECT ON CO_2

ELECTRIC CAR: EFFECT ON CO2



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ELECTRICITY GENERATION

- Almost all of the "hydro" available in the US has been tapped.
    - Significant environmental pain to get more.

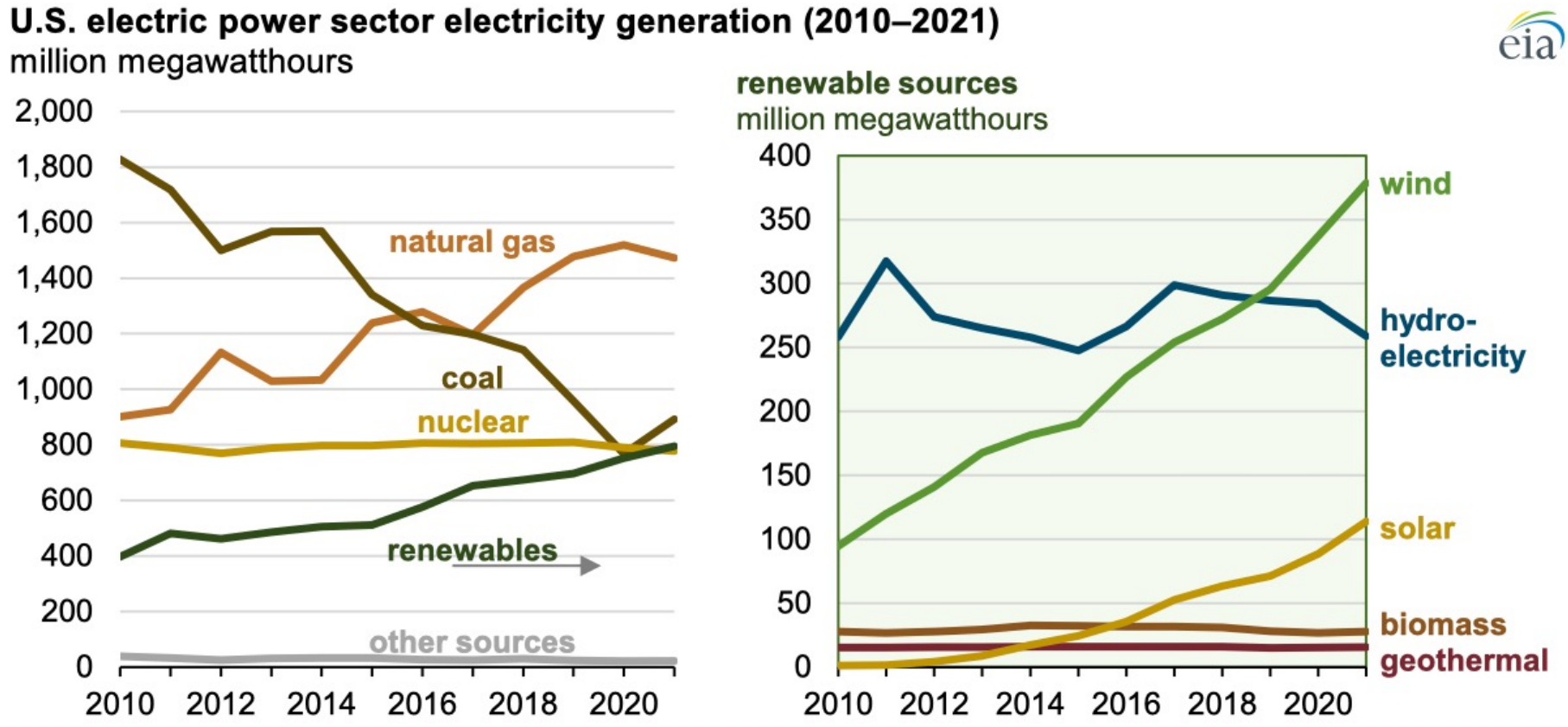
RENEWABLE POWER SOURCES

- Biofuels (ethanol is just barely CO2 positive compared to natural gas and diesel needed for farming)
- Wind (intermittent, location dependent, birds?)

$$\text{Power} \sim V^3_{\text{wind}}$$

- Solar (intermittent, location dependent)
- Geothermal (location dependent, expensive)

ELECTRICITY GENERATION: RENEWABLES HAVE MADE GAINS….



Source: U.S. Energy Information Administration, *Electric Power Monthly*

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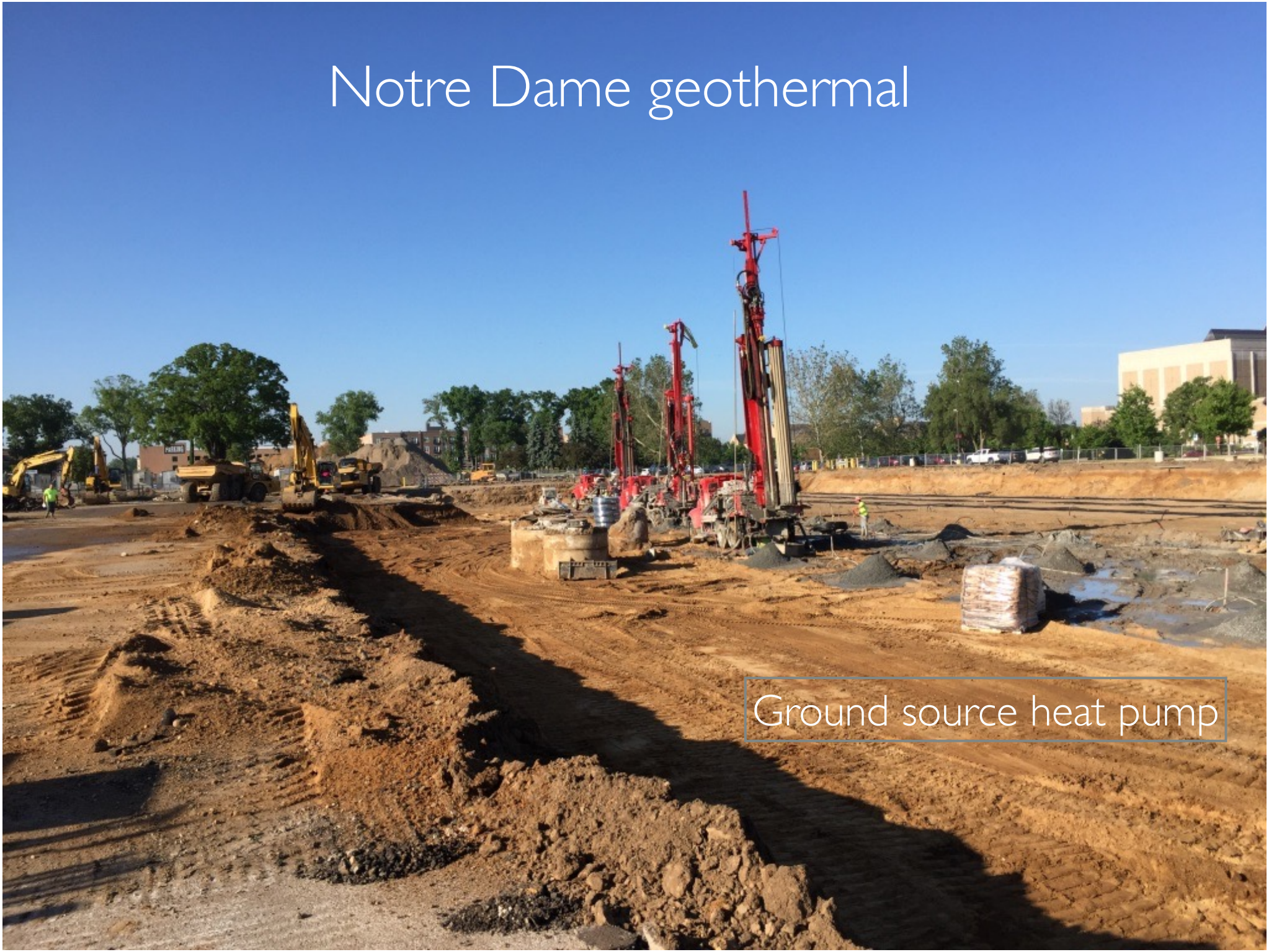
CHALLENGES OF RENEWABLES

- If we work out the numbers, the power density of wind is about
  - 0.004 MW/acre
- What could we compare this to (Engineers always want to make comparisons!)
- How about solar flux?
  - We can capture only part of the solar flux for useful heat, much less for electricity
    - What are these numbers?
- Solar flux averaged over the earth is ~350 W/m^2
- While nothing more energetic than a tree “runs” directly on solar, this gives a value of about
  - 0.3 MW/acre

ON A 100 ACRE SITE

- Coal to Electricity: 1000 MW
- Solar to Electricity: 30 MW
- Wind to Electricity: 0.4MW
- Corn to liquid fuel: 0.1 MW
- 10 oil wells (surface footprint): 10 GW

Notre Dame geothermal



GEOTHERMAL

- If you want high grade "heat"
- Drilling is expensive!
  - From a 6 inch well
  - 1 MW of "heat" (really stretching the values..)
  - 2000 MW of chemical energy! (If an oil well)

GRID SCALE ENERGY STORAGE

- At the present time this is infeasible!
  - Lithium Ion:
    - way too expensive, hard to get the needed Lithium
  - Multiple other battery systems are being studied:
    - Nothing is close to commercialization
  - "Pumped-hydro" is doable where you have excess water and a working hydroelectric plant — that is not at capacity….
- Until this can be solved. It will be hard to get the fraction of "renewables"much higher.

CO2 SEQUESTRATION

- We will never remove CO2 directly from the atmosphere with any sort of technology process!

$$\text{work}_{min} = \Delta G = -R\,T \sum_{i}^{\square} x_i \,\text{Log}[x_i]|$$

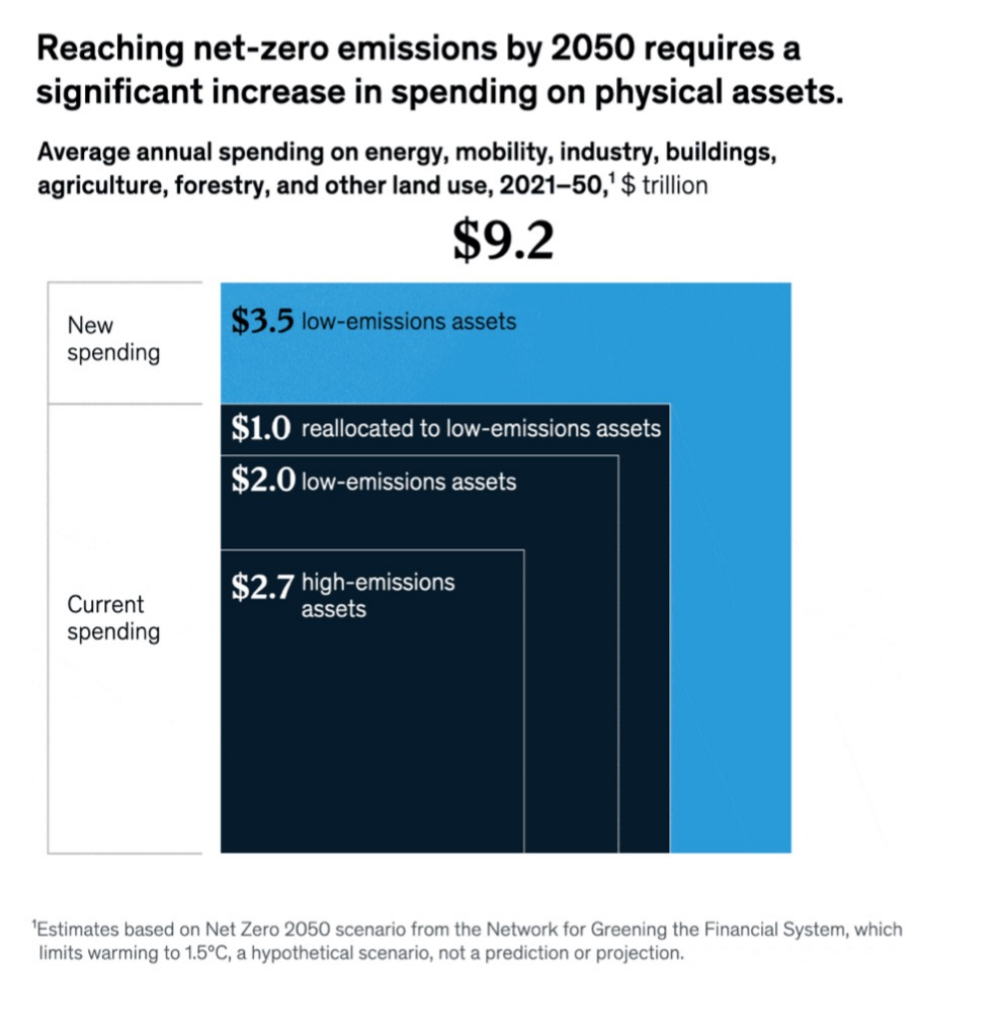
- If you start with an exhaust stream of a coal or natural gas plant, technologies exist to absorb the CO2, which can be compressed and pumped into some sort of long term storage.
  - This could be accomplished with ~20% of the electricity from the power plant!
  - Plus a capital cost that is 30-40% higher.
  - Approximate doubling of wholesale electricity price.

SOLUTIONS…

- For now:
  - Natural gas is the best "bridge" fuel
    - Saves more than 1/2 of emissions of coal
  - Should seriously consider building nuclear power plants…

HOW MUCH WILL NET-ZERO COST?

- McKinsey: An extra $3.5 Tril/year from now until 2050.



SUMMARY

- While we have technologies that ***could*** allow substantial reductions in the emission of carbon dioxide into the air from the transportation and power generation sector, these are not "better" in the sense that there is a direct economic payback by using them.
  - Thus the costs would be substantial to achieve reductions that would match the predicted 2C temperature increase.
  - It is hard to see where a complete "game-changer" would come from to change this assessment. ("fusion"… still 20 years?)
- Thus an informed discussion of <u>all</u> of the issues needs to be had by society to decide a path forward.

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