Clean Energy Technology and Disinformation

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Climate Solutions Webinar
Clean Air Partnership
May 11, 2022

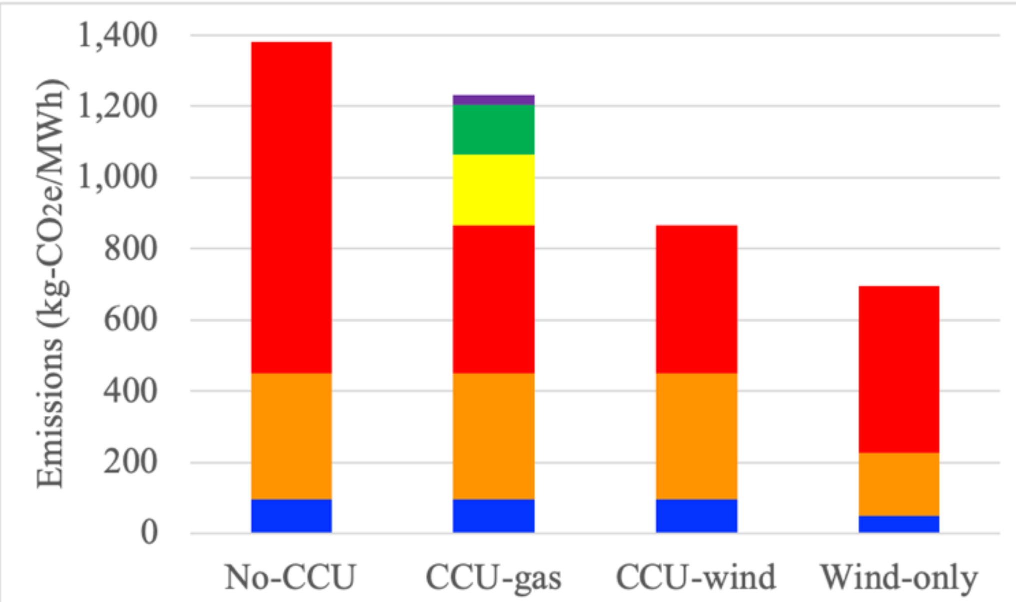
Why Not Carbon Capture?

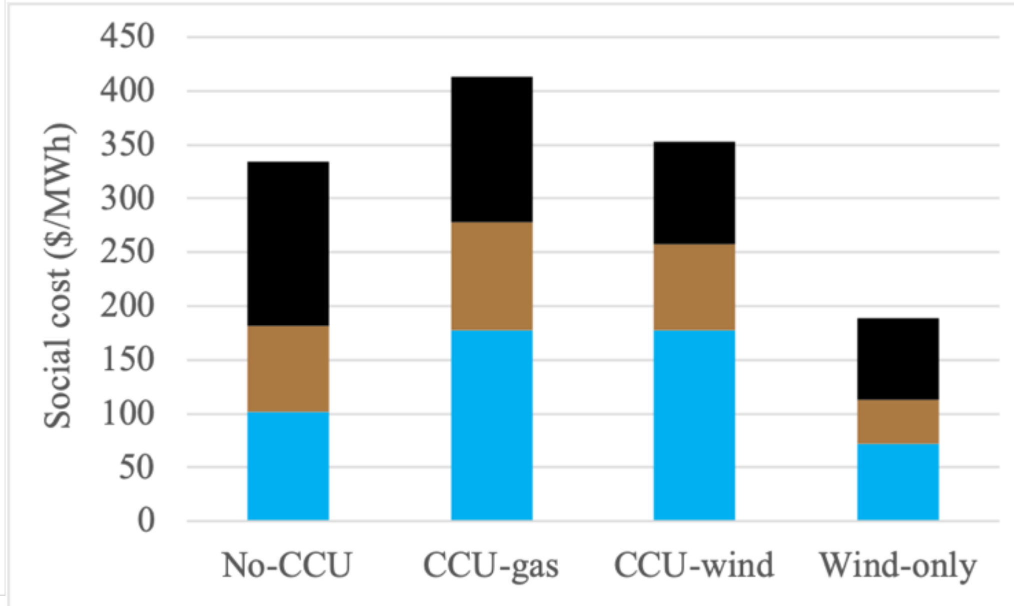
Coal Plant With CCU Powered by Natural Gas

Units: kg-CO_2e/MWh	20 yr	100 yr
a) Upstream CO_2 and leaked CH_4 from coal	450	237
b) CO_2 from stack	931	931
c) CO_2 captured from stack by equipment	516	516
Percent of stack CO_2 captured (c/b)	**55%**	**55%**
CO_2e emitted by natural gas mining+combustion	367	283
e) Captured CO_2e not returned to air by natgas (c-d)	149	233
Percent CO_2e reduction realized e/(a+b)	**10.8%**	**20%**

CCU attached to coal plant reduces only 11-20% of CO_2e it is expected to over 20-100 y

Change in CO_2e and Social Cost in 3 CCU Cases





1st case coal-No-CCU; 2nd: Coal-CCU powered by natural gas;

3rd : Coal-CCU powered by wind; 4th: replace coal with wind

Blue=upstream coal non-CH_4 CO_2e; Orange=coal upstream CH_4 CO_2e; Red=coal CO_2; Yellow=nat gas CO_2;

green=Natgas CO_2e from CH_4 leaks; Purple=other natgas upstream CO_2e;

Light blue=elec+CCU cost; Brown=air pol cost; Black=climate cost

Summary of CCS/U

- Using natural gas to run coal-CCU reduces CO_2e only 11.8-20% over 20-100 years while increasing air pollution and mining 25% and incurring a CCU equipment cost

- Using wind to run coal-CCU reduces CO_2e only 34-44% while keeping air pollution and mining the same, while incurring equip cost

- Using same wind to replace coal reduces CO_2 emissions, air pollution emissions, and mining 49.7% and has no CCU equipment cost

Why Not Blue or Gray Hydrogen?

Efficient Applications of Green H_2

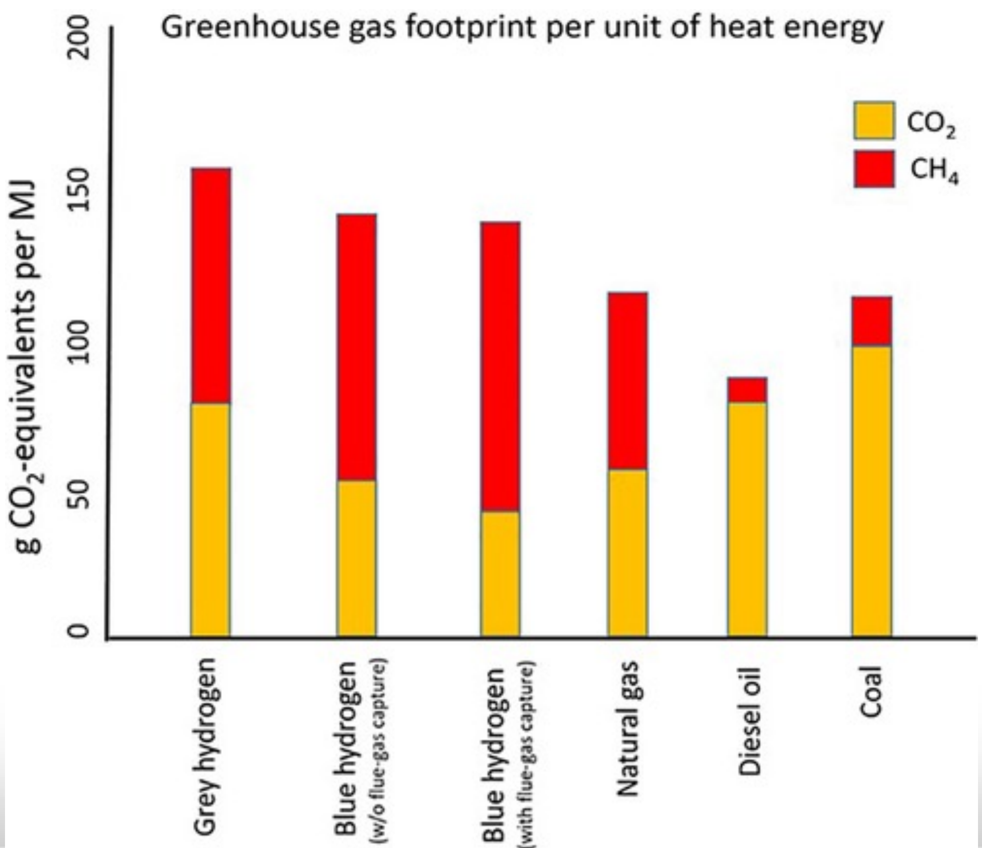
- Long-distance vehicles (airplanes, ships, trains, trucks, military vehicles)
- Steel production, some other industrial processes
- Electricity and heat in remote microgrids
- Not for stationary electricity storage, building heat, or passenger vehicles

Blue vs. Gray Hydrogen: Main Assumptions

- Use of steam methane reforming, SMR (vs. autothermal reforming, ATR)
- Leakage rate 3.5 (1.54 to 4.3)%
- Carbon dioxide capture rate for pure stream from SMR: 85 (78.8-90)%; flue gas: 65%
- 20-year GWP (100-year also examined)

Howarth and Jacobson (2021)

Base Case Results



Blue Similar to Gray H_2 Emissions; Both Greater Than Green

- Gray hydrogen (H_2 from steam reforming with no carbon capture): 153 g-CO2eq/MJ

- Blue hydrogen (H_2 from steam reforming with carbon capture) with mining, heat, and capture equipment powered by fossil fuels: 135-139 g-CO2eq/MJ

- Burning natural gas for heat: 111 g-CO2eq/MJ

- Blue hydrogen powered by renewables still emits 52 g-CO_2eq/MJ and requires natural gas mining + storing CO_2

- Green hydrogen (H_2 by electrolysis): 0 g-CO2eq/MJ and no natural gas mining or air pollution

Howarth and Jacobson (2021)

ATR Vs. SMR

- ATR produces 2 hydrogen molecules per methane; SMR produces 4
- ATR can get 2.9 by reacting waste carbon monoxide with steam, which requires more equipment and energy
- ATR requires pure oxygen to be separated from air, requiring more equipment and energy
- To reduce carbon dioxide capture needs, energy for heat and oxygen separation can be obtain with hydrogen fuel cell, requiring more equipment
- -> ATR always results in 38-100% more methane leaks and upstream pollution
- CO_2 from ATR can be captured more efficiently, but more CO_2 produced

Howarth and Jacobson (2021)

Why Not Synthetic Direct Air Carbon Capture and Storage?

Opportunity Cost of SDACCS

- WWS energy technologies do the same thing as SDACCS
  - Prevent carbon from getting into air rather than remove it

But WWS also eliminates or reduces

a) non-CO_2 air pollutants from fossil combustion
b) upstream fuel mining and pollution
c) pipeline, refinery, gas station, etc. infrastructure
d) oil spills, oil fires, gas leaks, gas explosions
e) International conflicts over energy
f) Blackout risk by decentralizing power

Direct Air Capture Powered by Natural Gas

Units: kg-CO_2e/MWh	20 yr	100 yr
a) CO_2 removed from air	825	825
b) CO_2e from natural gas upstream returned to air	334	165
c) CO_2 from natural gas combustion returned to air	404	404
d) Net CO_2e reduced due to natural gas (a-b-c)	87	256
Percent of removed CO_2e that stays removed (d/a)	11%	31%

→Natural gas-powered DAC reduces a net of only 11-31% of CO2e that is captured over 20-100 years.

Direct Air Capture Powered by Wind

Units: kg-CO_2e/MWh	20 yr	100 yr
a) CO_2 removed from air	825	825
b) CO_2e from running equipment returned to air	0	0
c) CO_2e reduction due to wind (a-b)	825	825
Percent of removed CO_2e that stays removed (c/a)	100%	100%

→Wind-powered DAC reduces 825 kg-CO_2e/MWh, but it does not reduce air pollution or mining of coal, and it incurs both a DAC equipment and wind equipment cost.

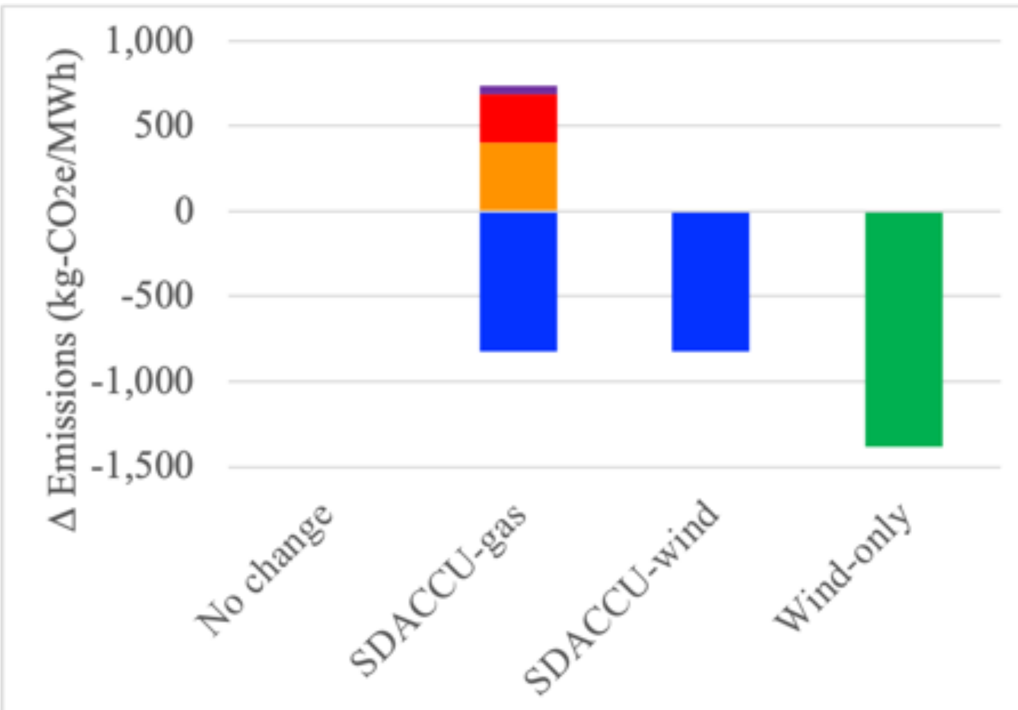
Wind replacing coal, removes more CO_2e as well as air pollution and mining…

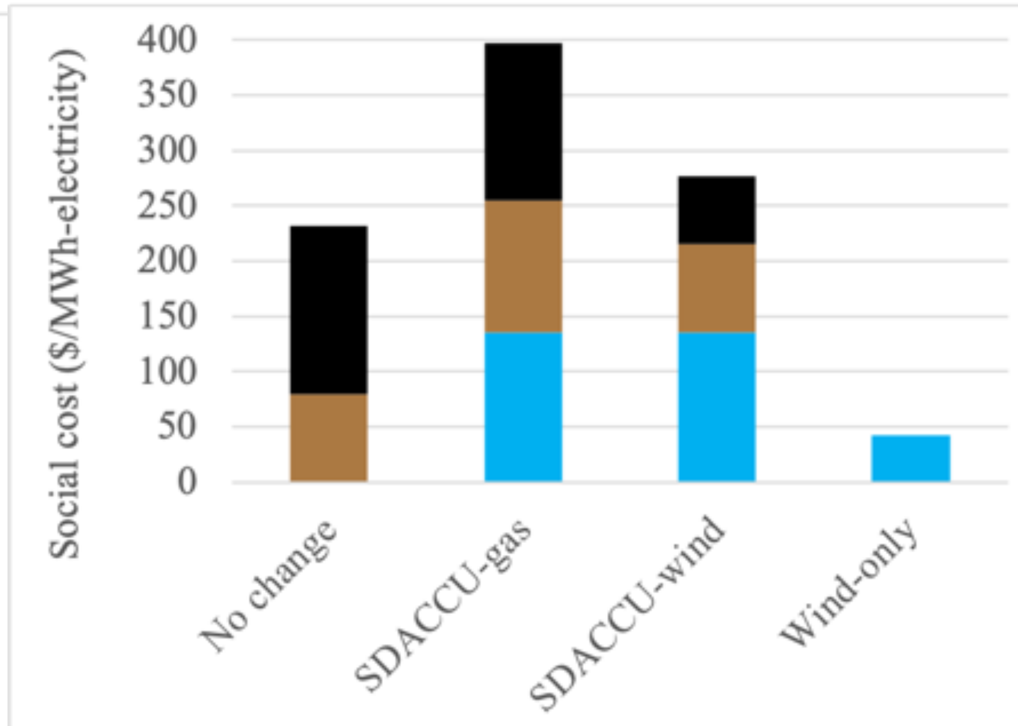
Replacing 100% of Coal Plant w/Wind (no DAC)

Units: kg-CO_2e/MWh	20 yr	100 yr
a) Upstream+stack coal CO_2e before replacing	1,381	1,168
b) Upstream+stack coal CO_2 after replacing	0	0
c) CO_2e reduction due to wind (a-b)	1,381	1,168
Percent of CO_2e reduction realized c/a	100%	100%

→ Replacing coal with wind reduces more CO_2e (1,381 to 1,168 versus 825 kg-CO_2e/MWh) than using DAC powered by wind and also reduces coal air pollution and mining at no DAC equipment cost (same wind cost).

Change in CO_2e and Social Cost in 3 DAC Cases





1st case: no change; 2nd: Use SDACCU powered by natural gas;

3rd : Use SDACCU powered by wind; 4th: replace coal with wind

Why Not New Nuclear Power?

Issues With Nuclear

1) Produces 9-37 times more CO_2e and pollution per kWh than wind
2) Takes 10-19 yrs between planning & operation vs 0.5-5 yrs for wind/solar
3) Costs 4-5 x that of onshore wind/utility PV
4) →Takes 2-38 times longer to obtain 1/4rd to 1/5th the CO_2 savings per dollar than wind/solar.
5) IPCC 2014: P. 517. "Robust evidence, high agreement" that increased use of nuclear leads to more
   (a) Weapons proliferation risk
   (b) Meltdown risk
   (c) Waste risk
   (d) Mining risk

Nuclear Planning-to-Operation Times

	Construction Time (years)	Plan-to-Operation Time (years)
Olkiluoto 3 (Finland)	17	22
Hinkley Point (UK)	8-9	18-19
Vogtle 3 and 4 (US)	10-11	17-18
Flamanville (France)	16	19
Haiyang 1 and 2 (China)	9	13-14
Taishan 1 and 2 (China)	10-11	12-13
Ringhals (Sweden)		10-18

Nuclear Versus Wind CO_2e Emissions

	Nuclear (g-CO_2e/kWh)	Onshore Wind (g-CO_2e/kWh)
Lifecycle	9-70	7-10.8
Opportunity cost	64-102	0
Anthropogenic heat	1.6	-1.7 to -0.7
Anthropogenic water vapor	2.8	-0.5 to -1.5
Weapons proliferation risk	0-1.4	0
Covering land	0.17-0.28	0.0003
Total	**78-178**	**4.8-8.6**

Ratio of nuclear to wind 9-37:1

Why Impossible for Nuclear to Solve Warming

1) We can allow 500 GT-CO_2 after 2020 to stay below 1.5 ^{o}C warming

2) Eliminating 80% emissions by 2030; 100% by 2050 emits ~340 GT CO_2

3) This requires reducing today's emissions ~10%/year from 2023-2030

4) A new nuclear plant proposed today requires 10-19 yrs until it operates. Wind/solar need 0.5-3 years.

5) →Impossible for nuclear to avoid 1.5 ^{o}C warming; possible for WWS

Why Not Biomass For Electricity or Heat?

Sources of Biomass Energy

- Agricultural residues – e.g., straw, livestock waste
- Forestry residues – e.g., bark, woodchips, forest thinning logs
- Energy crops
  - Dry wood crops – e.g., willow
  - Herbaceous crops – e.g., switchgrass
  - Oil energy crops – e.g., sugar beet
  - Starch energy crops – e.g., corn
- Wood, food industry residues – e.g., sawdust
- Park and garden waste – e.g., grass
- Contaminated waste – e.g., municipal waste

Biomass Versus Wind CO_2e Emissions

	Biomass (g-CO_2e/kWh)	Onshore Wind (g-CO_2e/kWh)
Lifecycle	43-1,730	7-10.8
Opportunity cost	36-51	0
Anthropogenic heat	3.4	-1.7 to -0.7
Anthropogenic water vapor	3.2	-0.5 to -1.5
Covering land	0.09-0.5	0.0003
Total	**86-1788**	**4.8-8.6**

Ratio of biomass to wind 10-373

Bioenergy With Carbon Capture & Storage (BECCS)

Requires 25 to 50 percent more energy

→25 to 50 percent more air pollution

Air pollution already high from biomass combustion

Need CO_2 pipelines

Few storage locations available

→Coupled with enhanced oil recovery

Increases fertilizer use by removing agricultural residues

High cost → opportunity cost

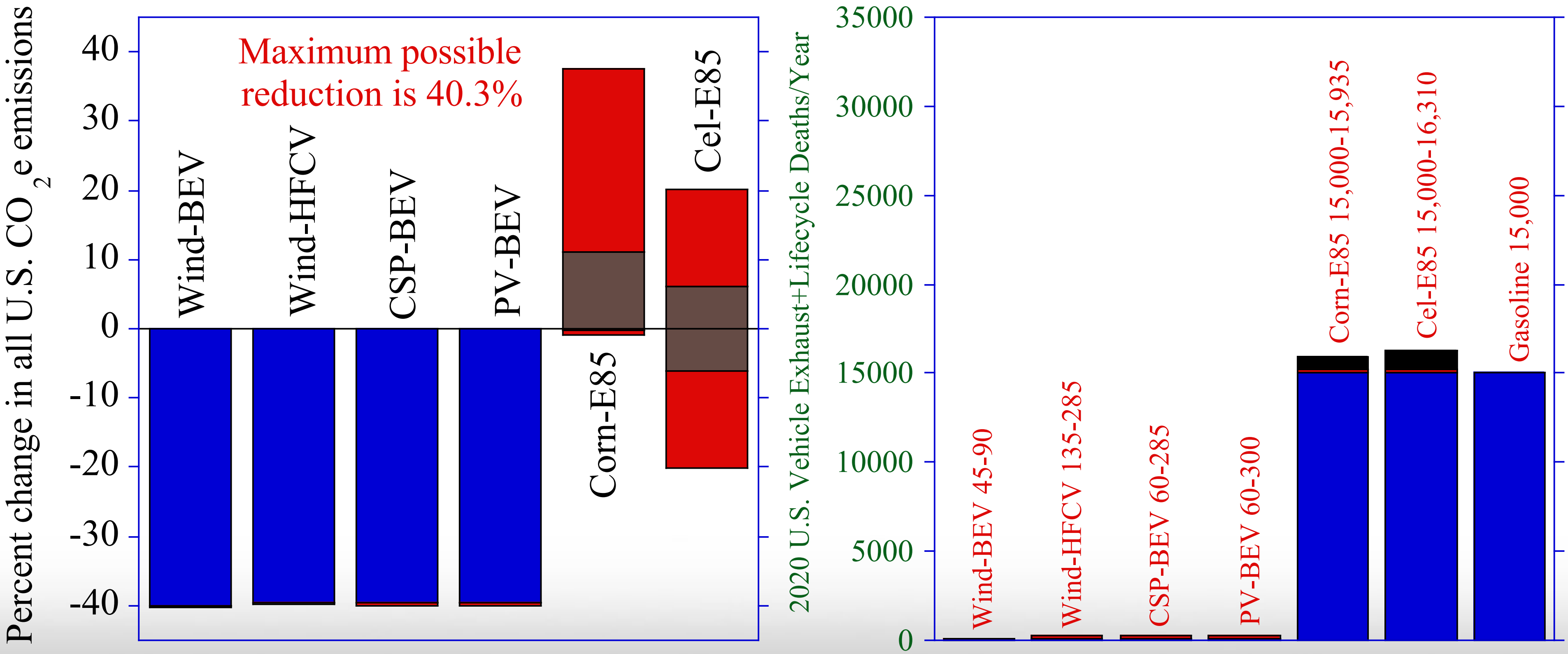
Biomass combustion efficiency only 20-27%

Why Not Liquid Biofuels For Transportation?

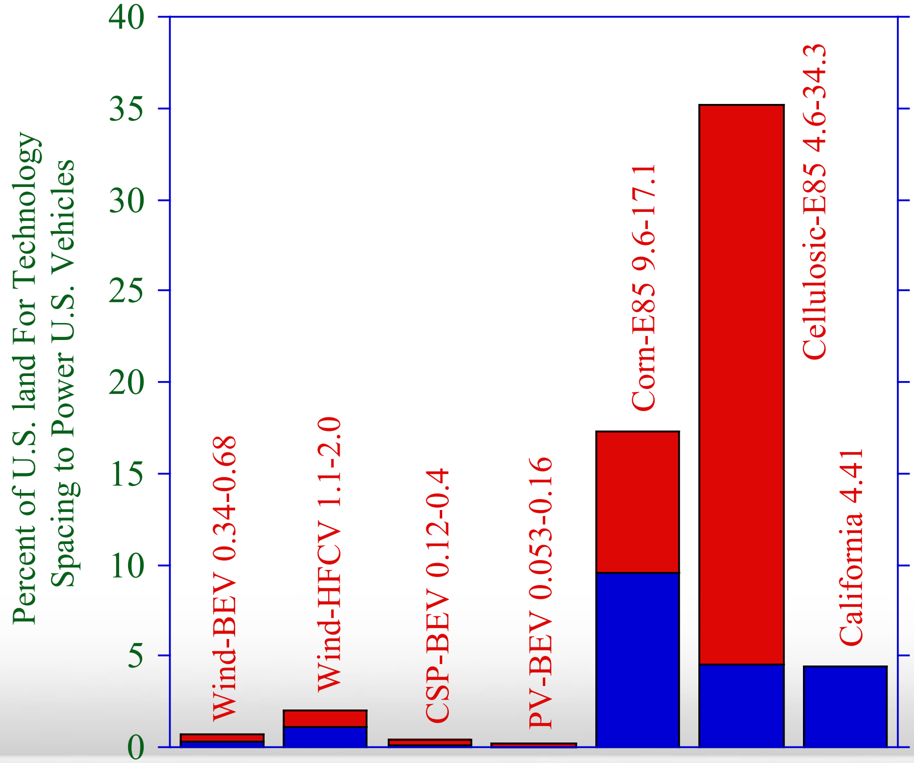
Types of Biofuels

- Ethanol (E10, E85, E100)
  - Corn
  - Sugarcane
  - Cellulosic
- Butanol
- Biodiesel (B100)
  - Soy
  - Algae

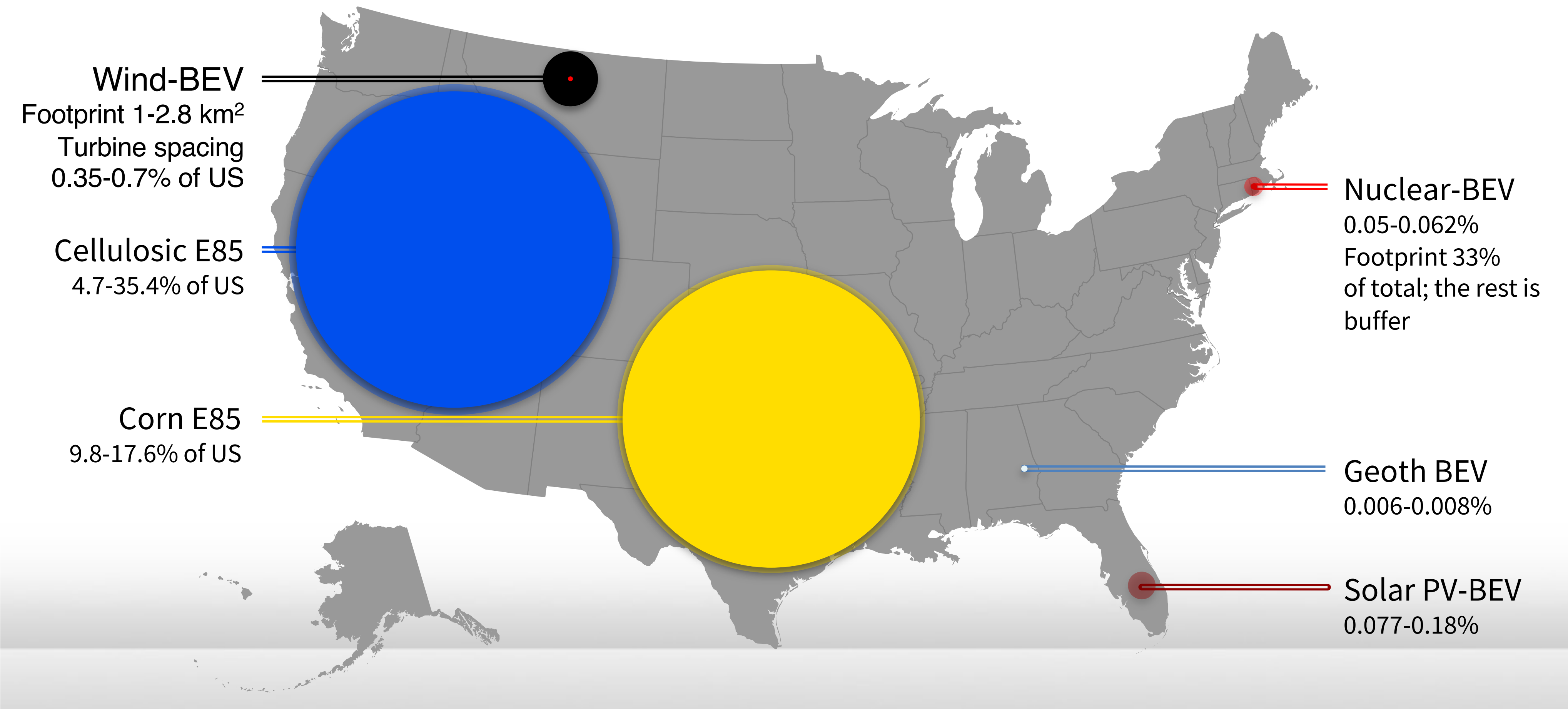
CO_2 Emissions and Air Pollution Deaths BE/HFC Vehicles Versus E85 Vehicles



Spacing Area For BE/HFC Vehicles Versus E85 Vehicles



Area to Power 100% of U.S. On-road Vehicles



Book on 100% WWS

https://web.stanford.edu/group/efmh/jacobson/WWSBook/WWSBook.html

Paper on Carbon Capture and Direct Air Capture

https://web.stanford.edu/group/efmh/jacobson/Articles/Others/19-CCS-DAC.pdf

Paper: How Green is Blue Hydrogen

https://onlinelibrary.wiley.com/doi/full/10.1002/ese3.956

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