Comparative Effects of Vehicle Fuels and Technologies on Air Pollution and Climate

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Controlling Global Warming and Local Air Pollution
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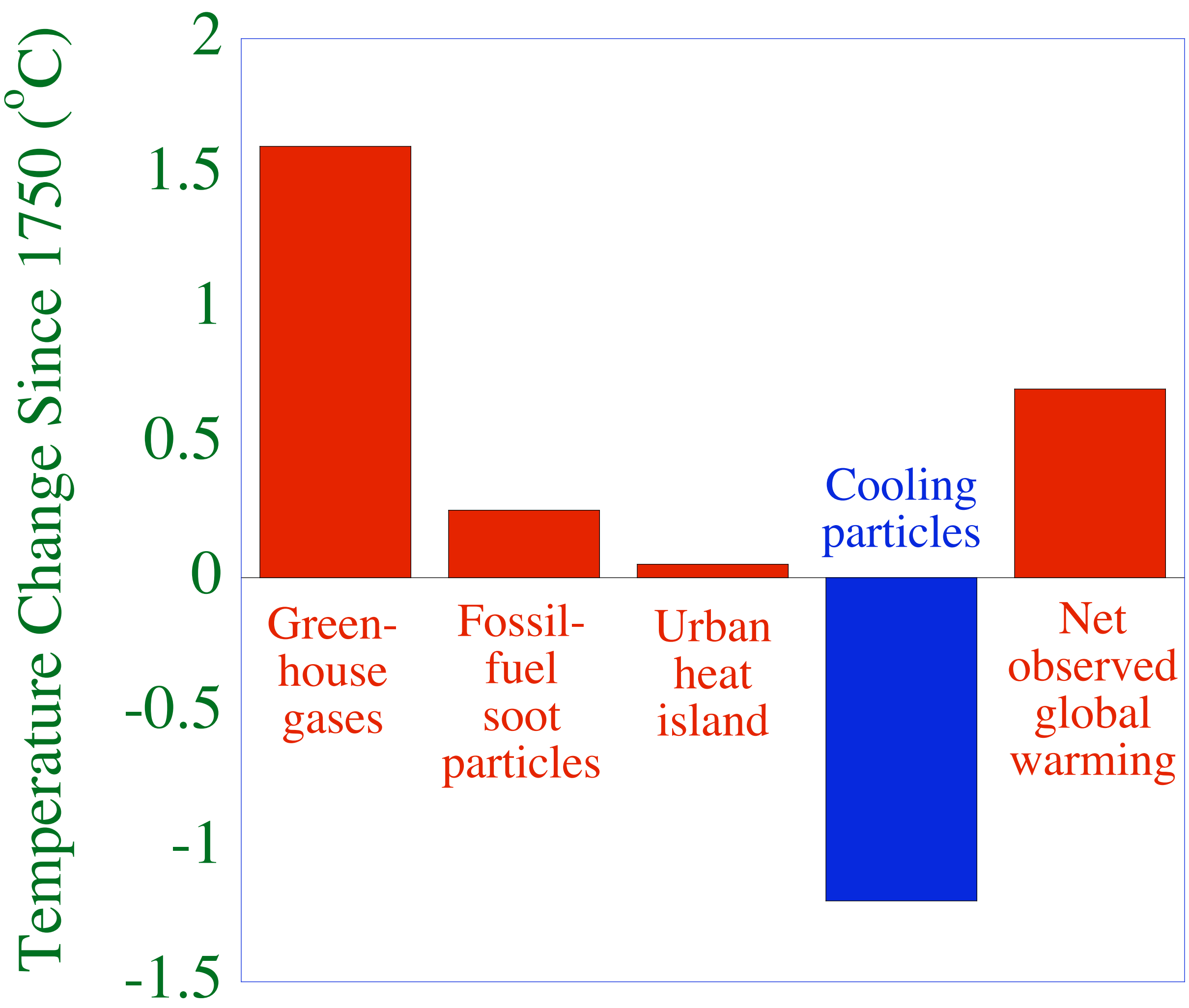
Causes of Global Warming



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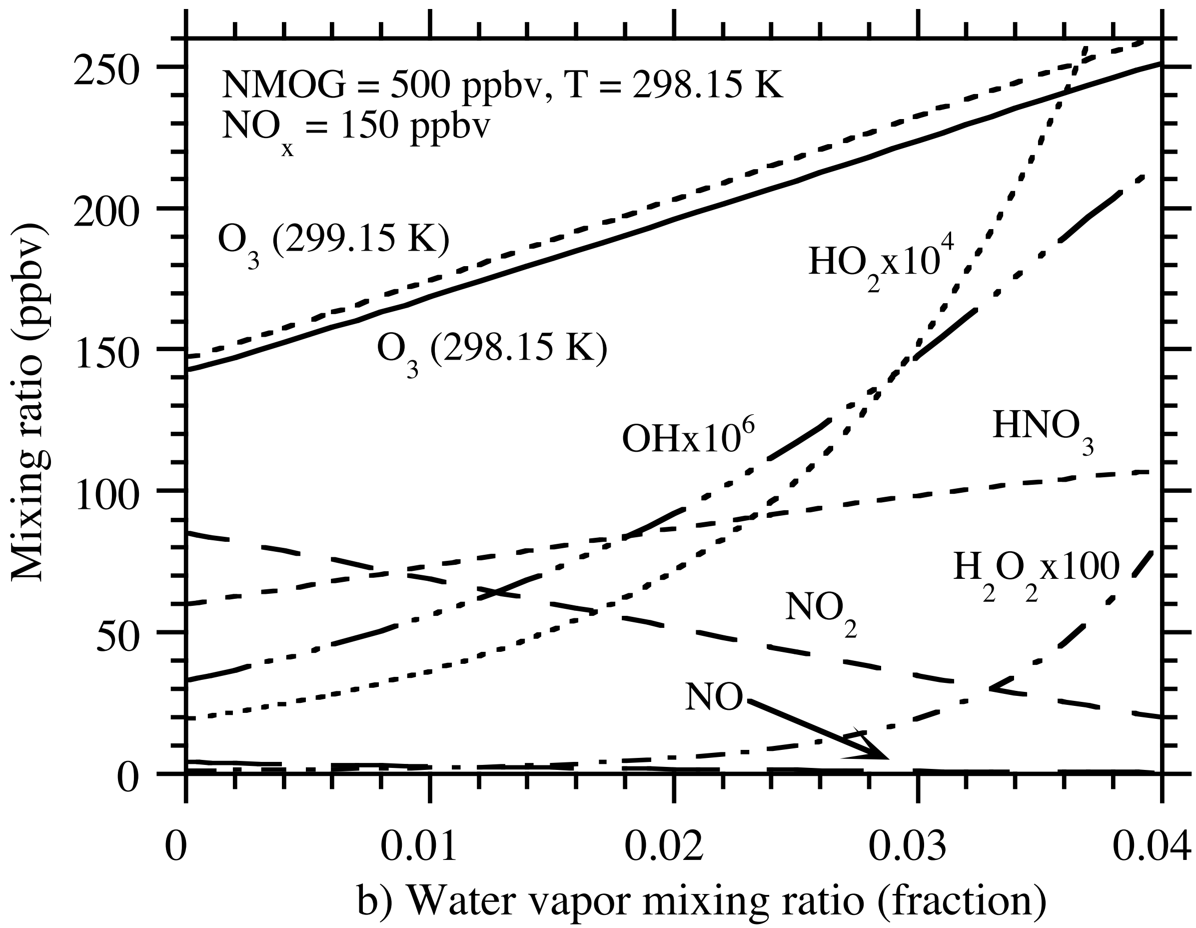
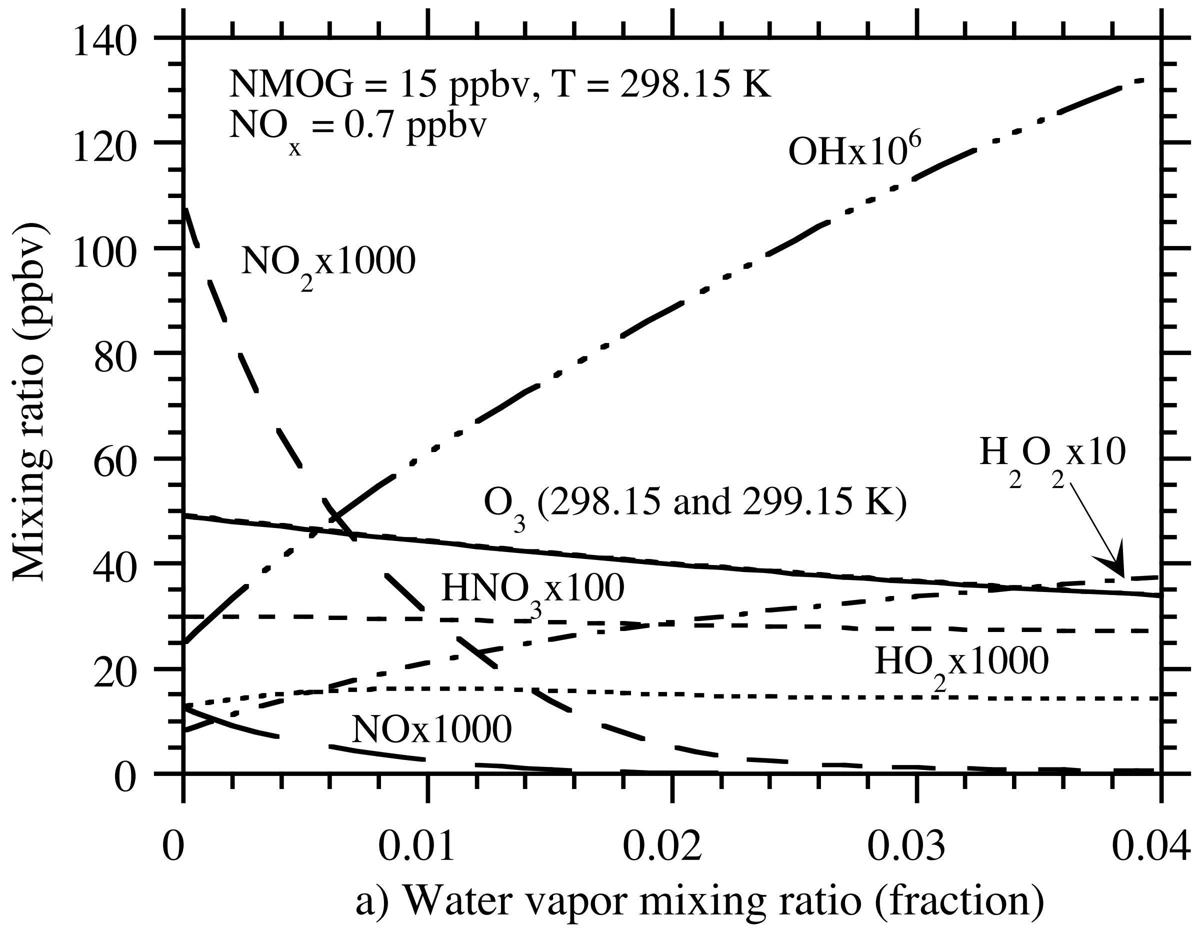
Causal Effect of CO_2 on Mortality

An increase in water vapor or an increase in temperature increases ozone in urban areas (high NO_x, high NMOG).



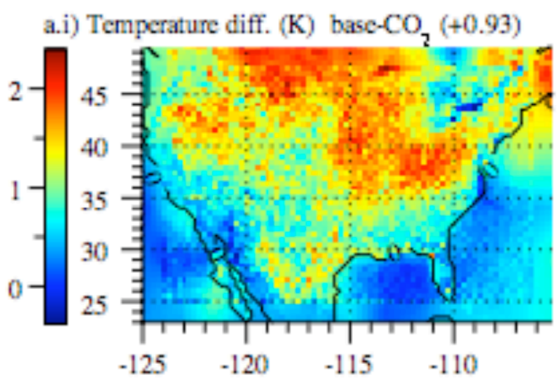
Causal Effect of CO_2 on Mortality

An increase in water vapor decreases ozone and an increase in temperature causes little ozone change in rural areas (low NO_x; low NMOG).

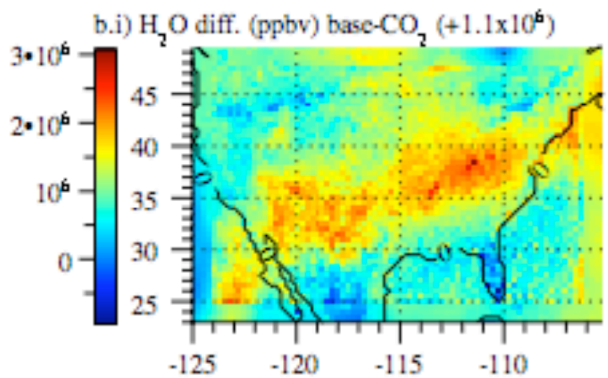


Causal Effect of CO_2 on Mortality

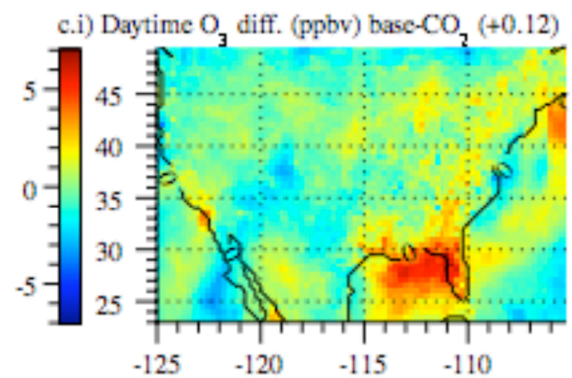
Global-regional nested simulations demonstrate that CO_2 alone increases temperature, water vapor, ozone, and PM



Δ Temperature



Δ Water vapor



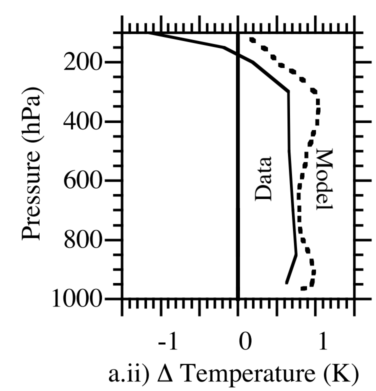
Δ Ozone

U.S. Δ ozone deaths/yr per 1 K +500 (190-575)

U.S. Δ PM2.5 death/yr per 1 K +640 (160-1280)

U.S. Δ Total deaths/yr per 1K +1140 (350-1855)

World Δ Total deaths/yr per 1K +24,000 (7200-37,000)



Potential Effects of E85 vs. Gas: Emission Differences From Data

	Percent change
Oxides of nitrogen	-30 (-59 to +33)
Carbon monoxide	+5 (-33 to +320)
Total organic gas	+22 (+38 to +95)
Methane	+43 (+43 to +340)
Formaldehyde	+60 (+7 to +240)
Acetaldehyde	+2000 (+1250 to +4340)
1,3-butadiene	-10 (0 to -13)
Benzene	-79 (-62 to -85)
PM number	0 (+100)
PM mass	0 (+31)

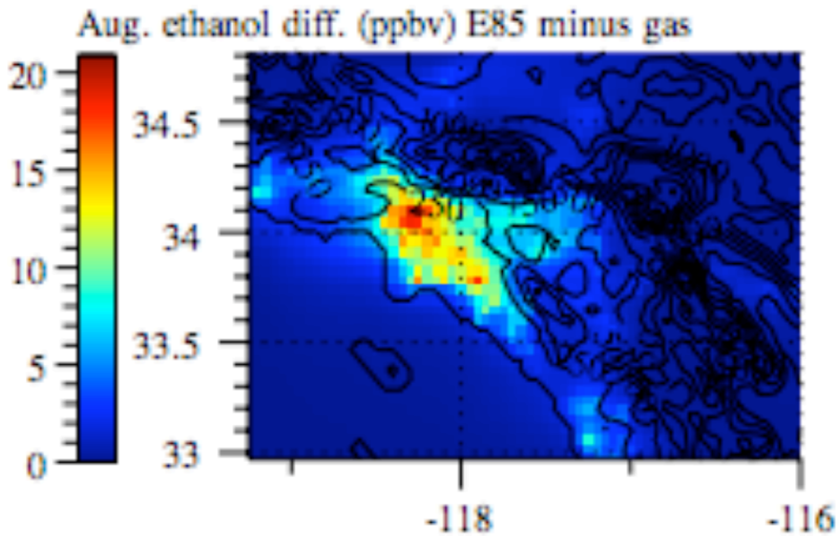
Comparison of Emission Assumptions With Recent CARB and Other Data

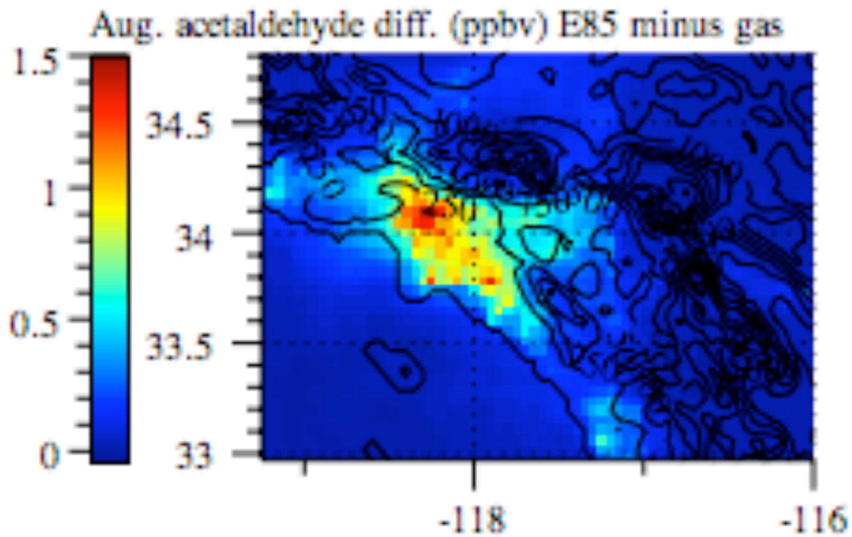
Percent change E85 minus gas

	Cert data (2006)	Jacobson (2007)
NMOG	+45%	+19.6%
NO_x	-29.7%	-30%

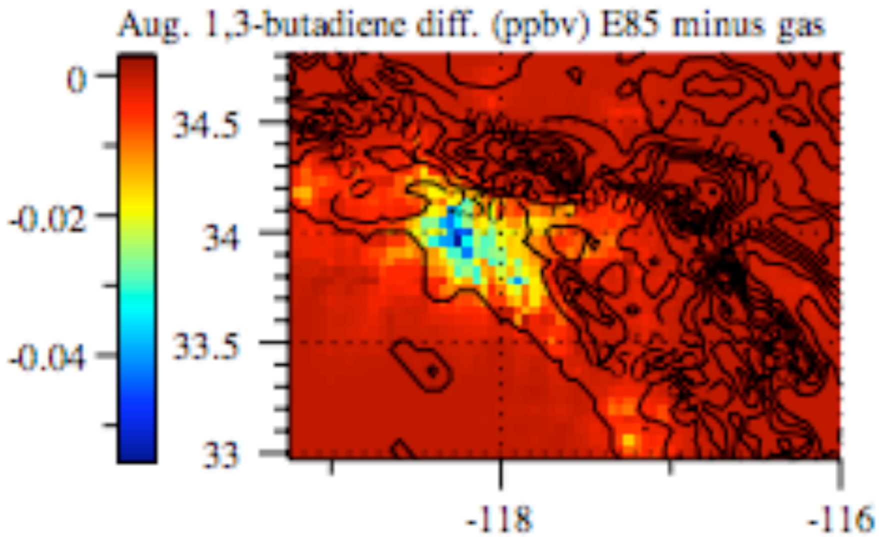
	Whitney (2007)	Jacobson (2007)
Benzene	-64%	-79%
1,3-butadiene	-66%	-10%
Acetaldehyde	+4500%	+2000%
Formaldehyde	+200%	+60%

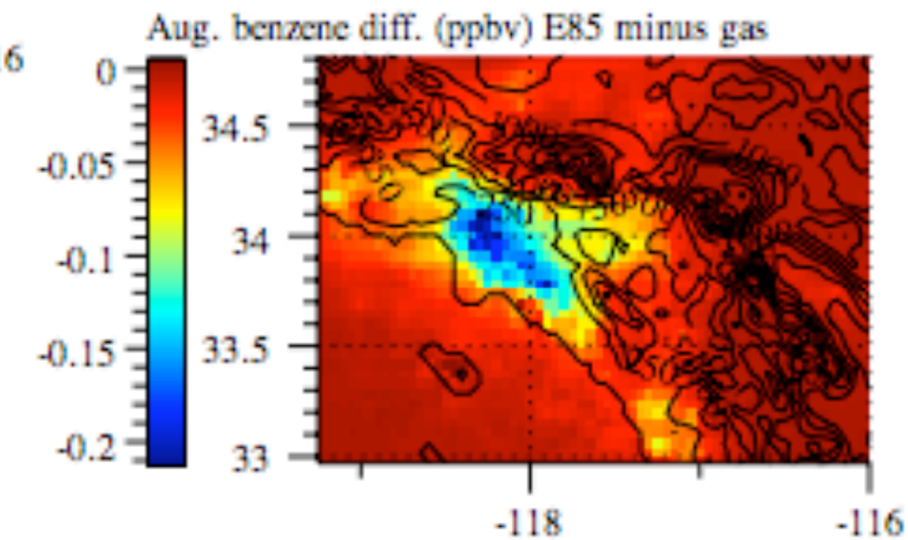
Effect in 2020 of E85 vs. Gasoline on Ethanol and Acetaldehyde



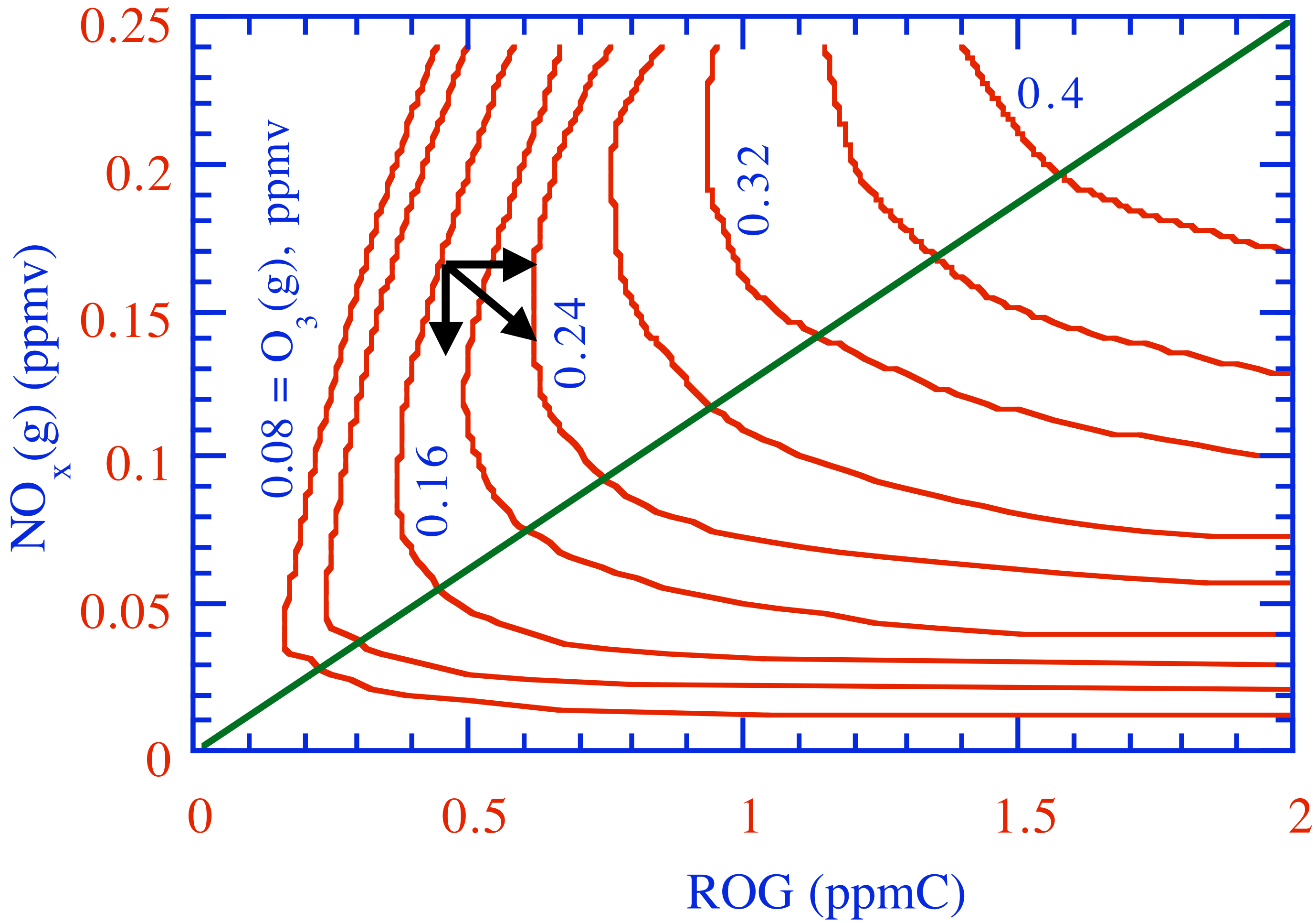


Effect in 2020 of E85 vs. Gasoline on 1,3-Butadiene and Benzene

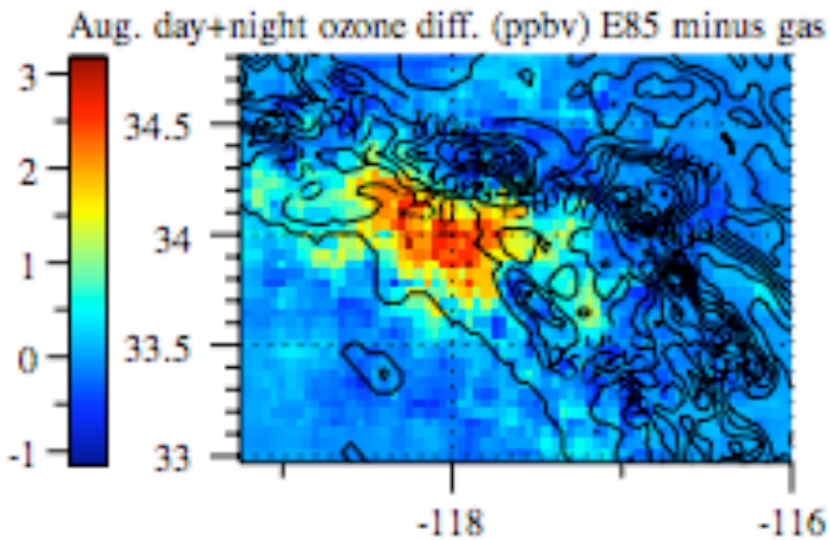


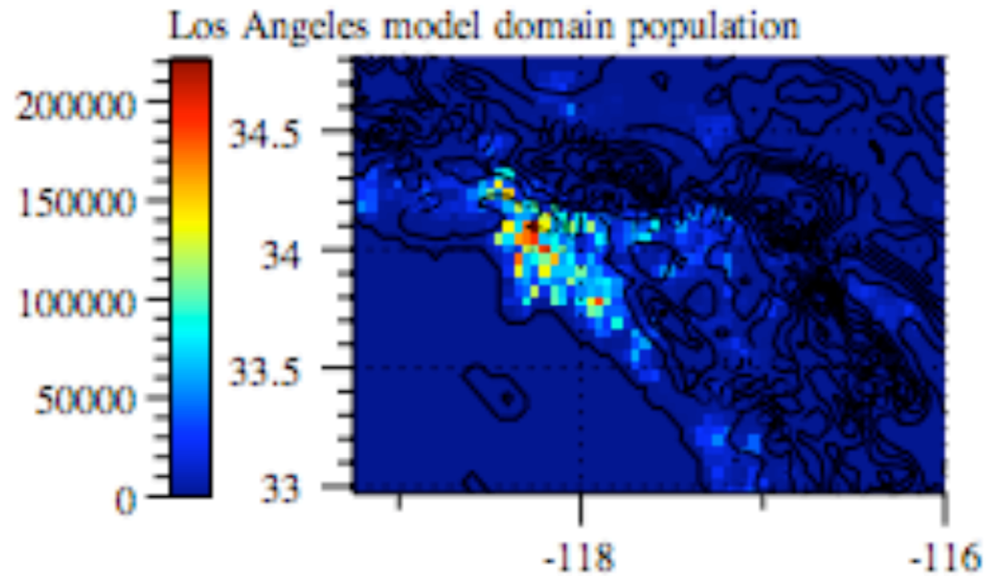


Ozone isopleth



Effect in 2020 of E85 vs. Gasoline on Ozone and Health





Δ Pop-weighted $O_3 \geq 35$ ppbv E85 minus gas: +1.33 ppbv

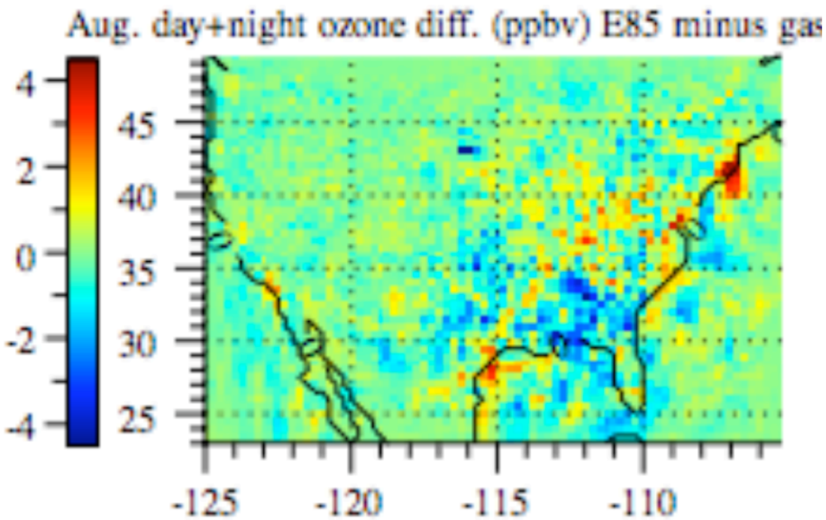
Δ O_3 deaths/yr: +120 (+9%) (47-140)

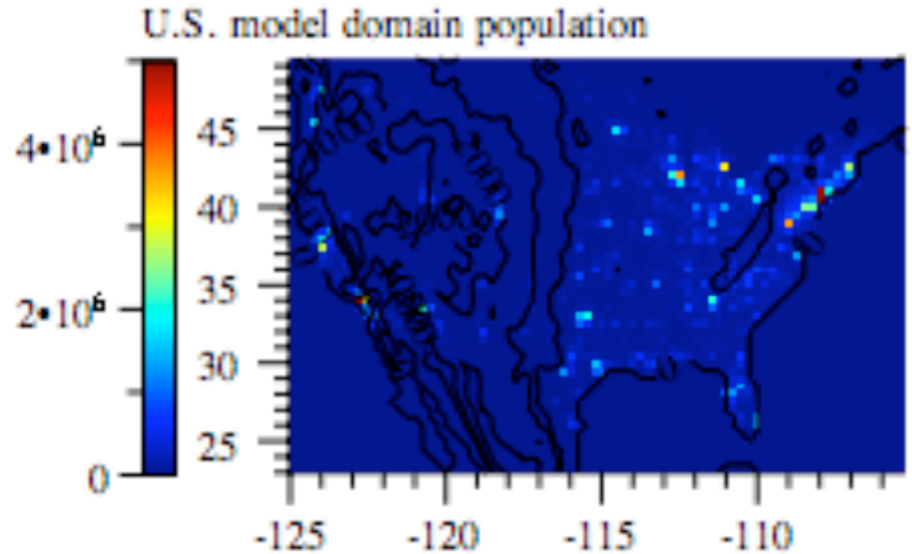
Δ O_3 hospitalizations/yr respiratory illness: +650

Δ O_3 -emergency-room visits/yr for asthma: +770

Δ Cancer/yr : -3.5 to +0.3

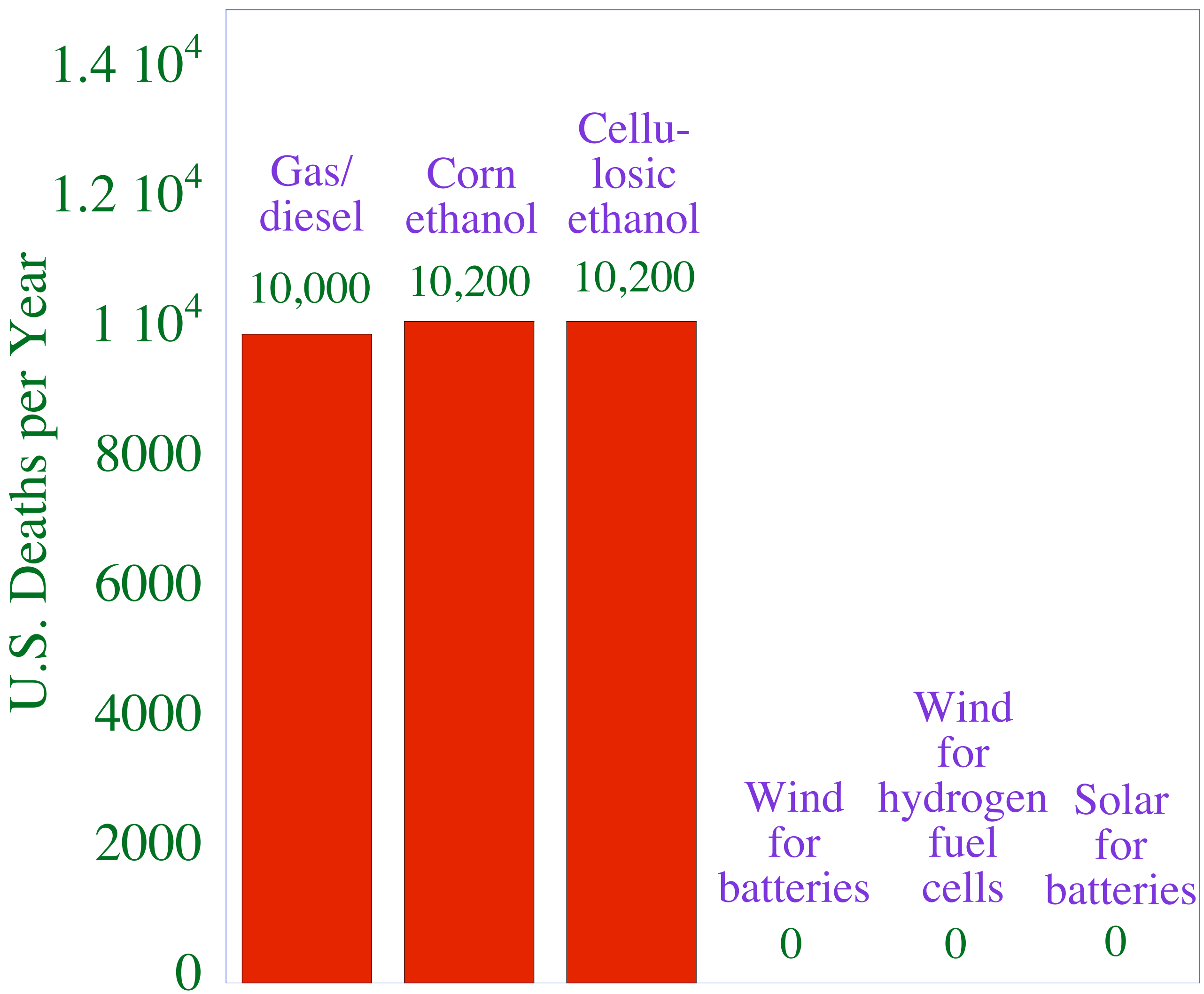
2020 U.S. Effects of E85 vs. Gasoline

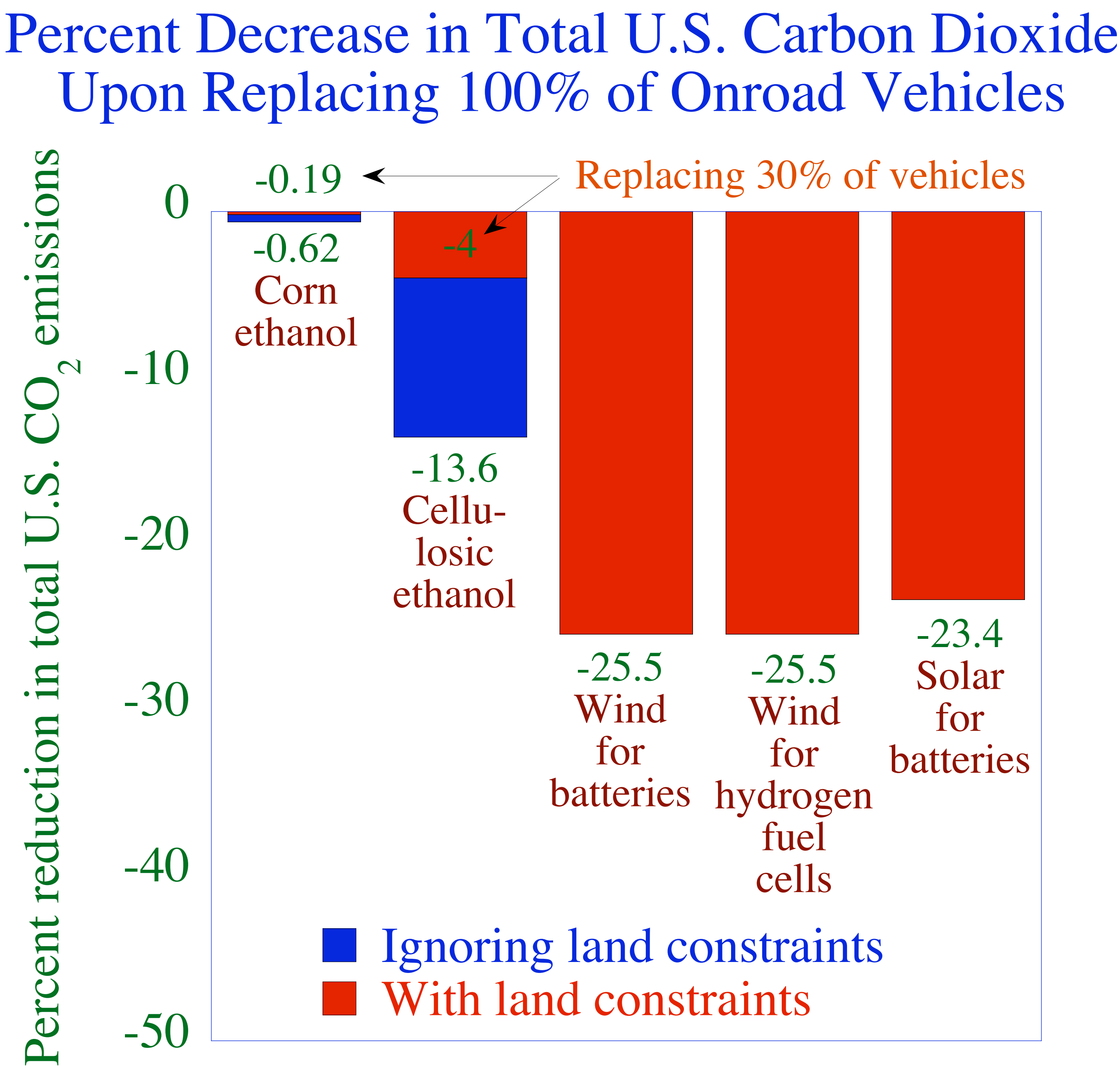




Δ Pop-weighted ozone ≥ 35 ppbv E85 minus gas:	+0.28 ppbv
Δ Ozone deaths/yr:	+185 (72-213)
Δ Ozone hospitalizations/yr respiratory illness:	+990
Δ Ozone-emergency-room visits/yr for asthma:	+1200
Δ Cancer/yr	+3 to -29

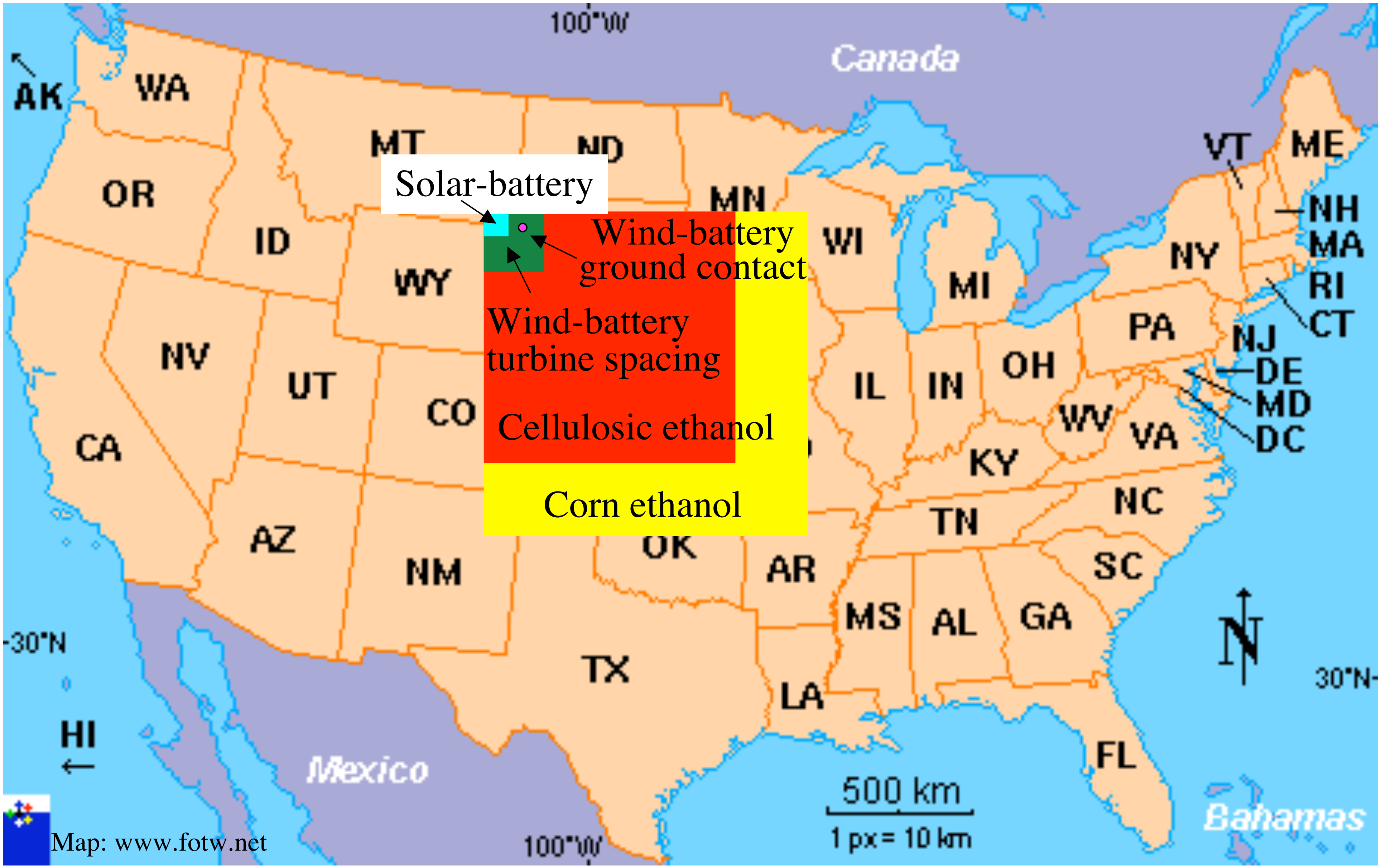
Future U.S. Deaths Per Year From Onroad Vehicle Emissions



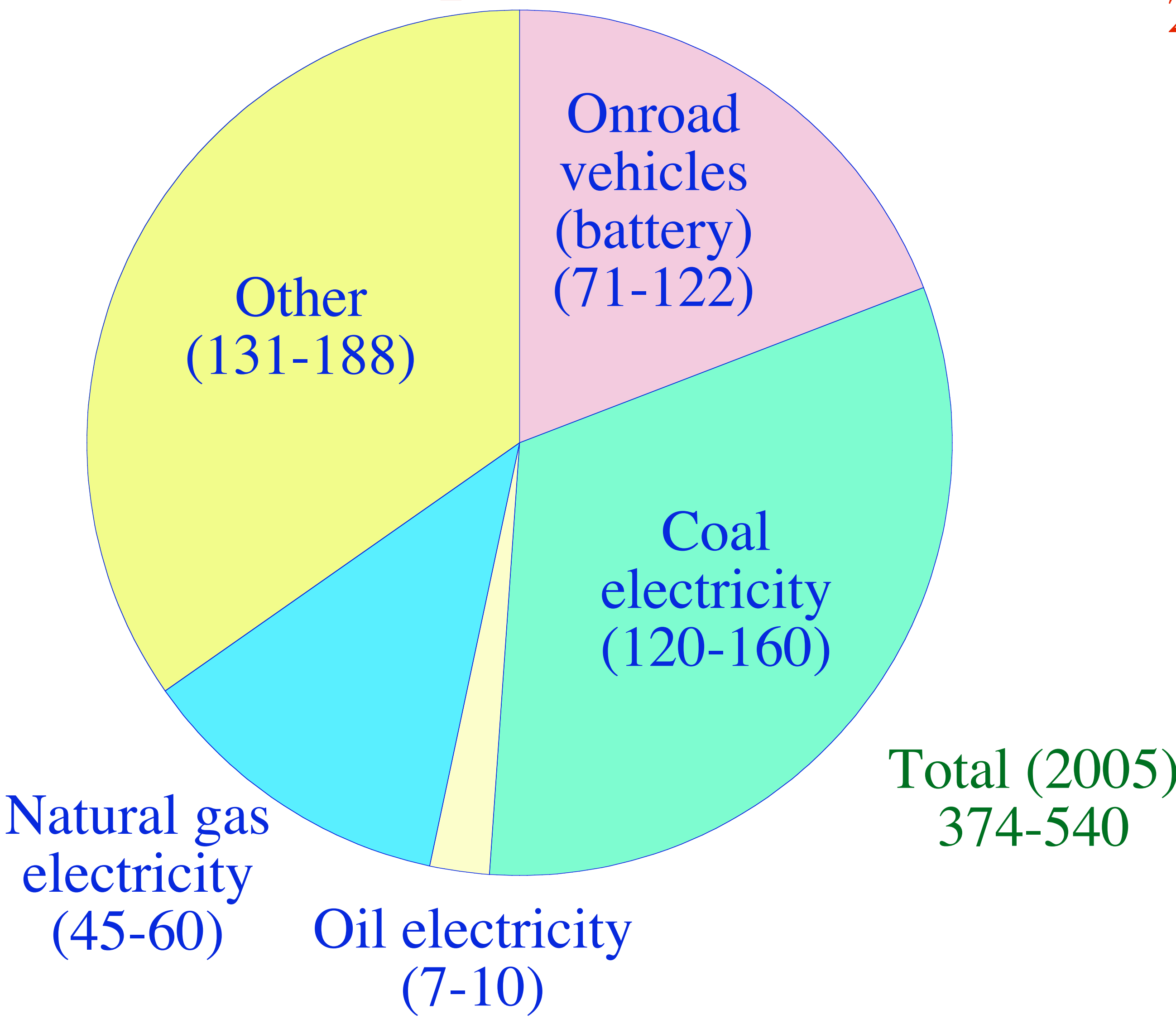


Percent Decrease in Total U.S. Carbon Dioxide
Upon Replacing 100% of Onroad Vehicles
Percent reduction in total U.S. CO_2 emissions
0
-10
-20
-30
-40
-50
-0.19
Replacing 30% of vehicles
-4
-0.62
Corn ethanol
-13.6
Cellu-losic ethanol
-25.5
Wind for batteries
-25.5
Wind for hydrogen fuel cells
-23.4
Solar for batteries
Ignoring land constraints
With land constraints

Area to Power 100% of U.S. Onroad Vehicles



Thousands of 5 MW Wind Turbines Needed to Displace 100% U.S. CO_2



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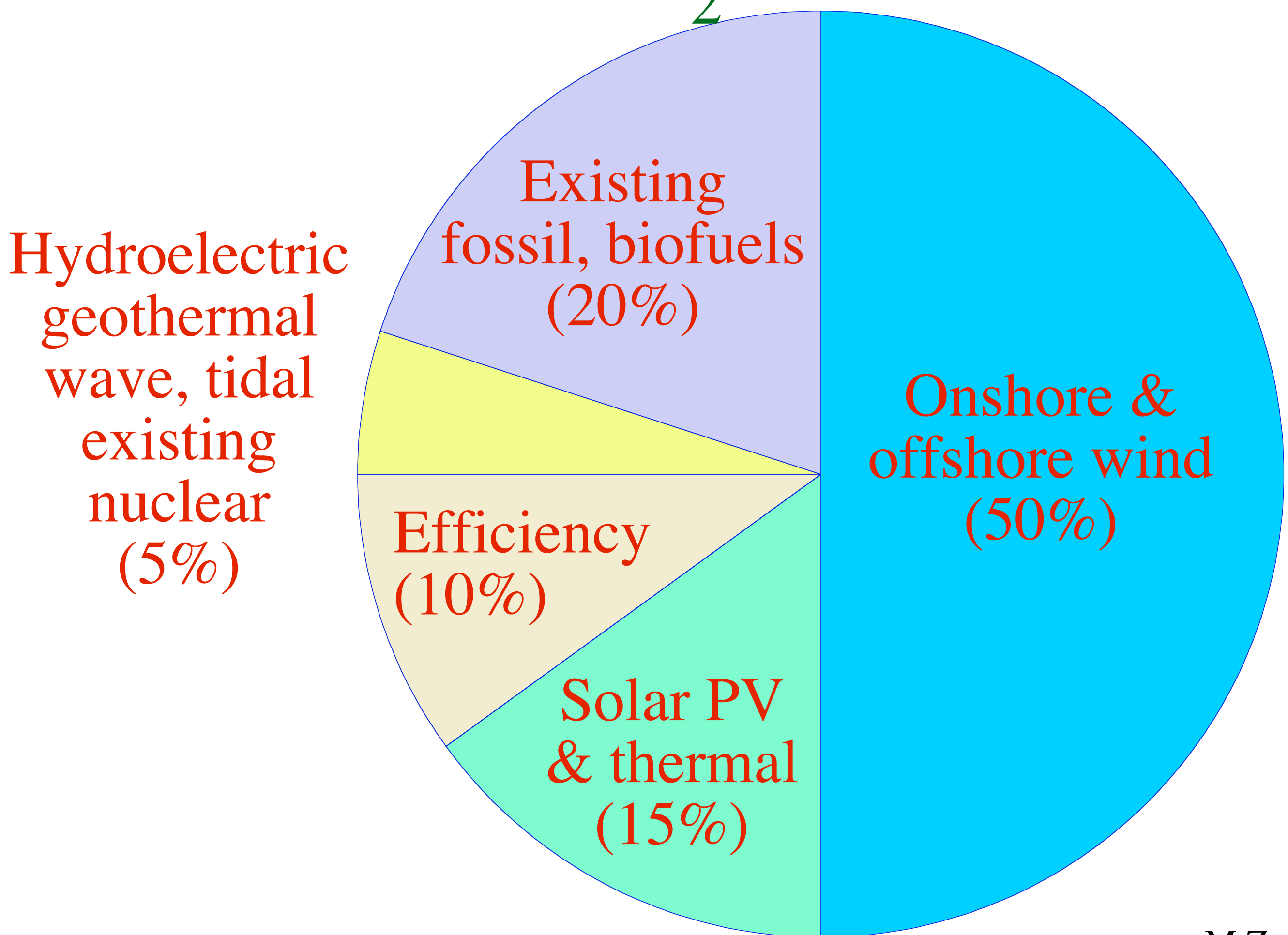
Path to Satisfy All U.S. Energy Needs and Reduce CO_2 and BC by 80%



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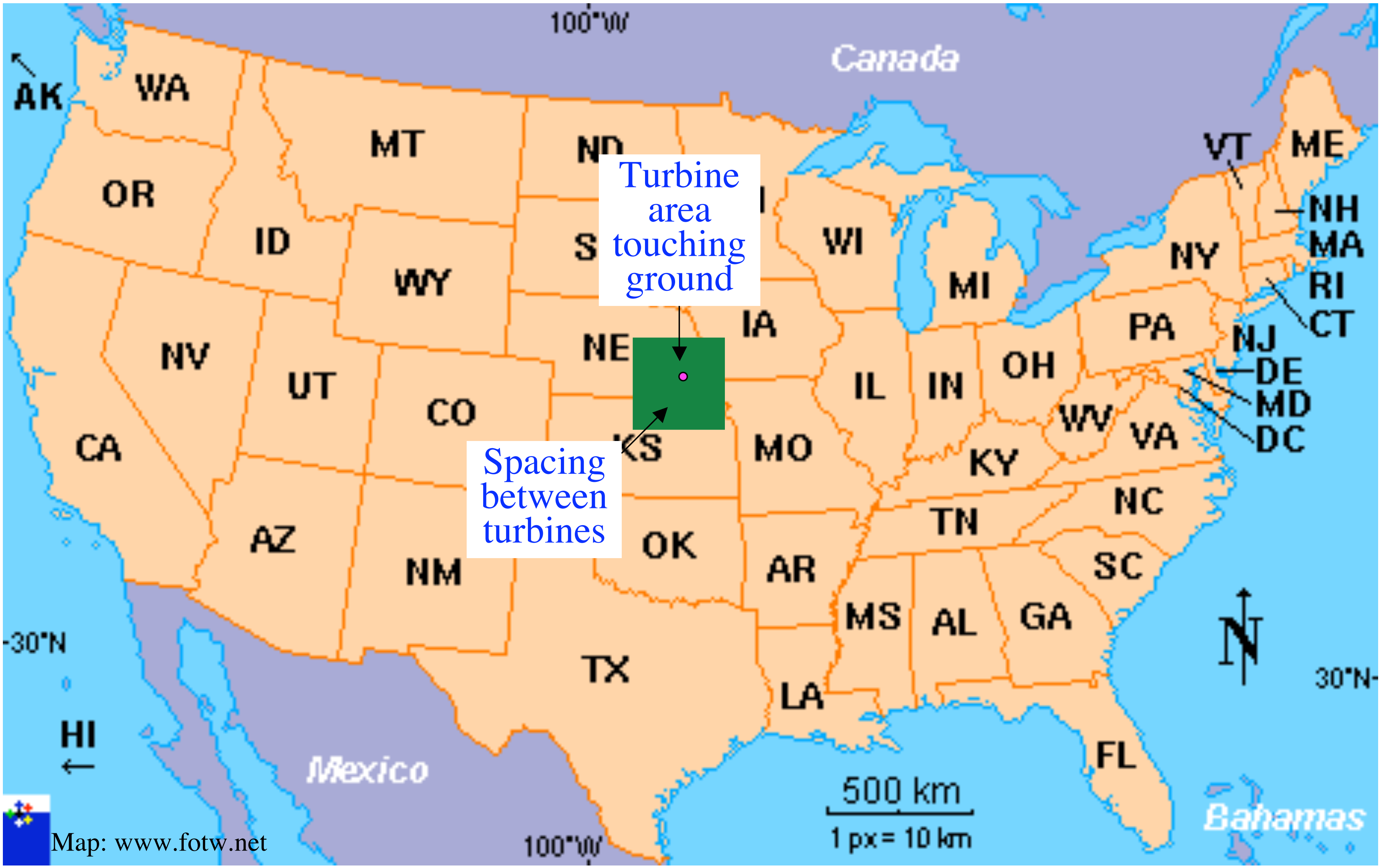
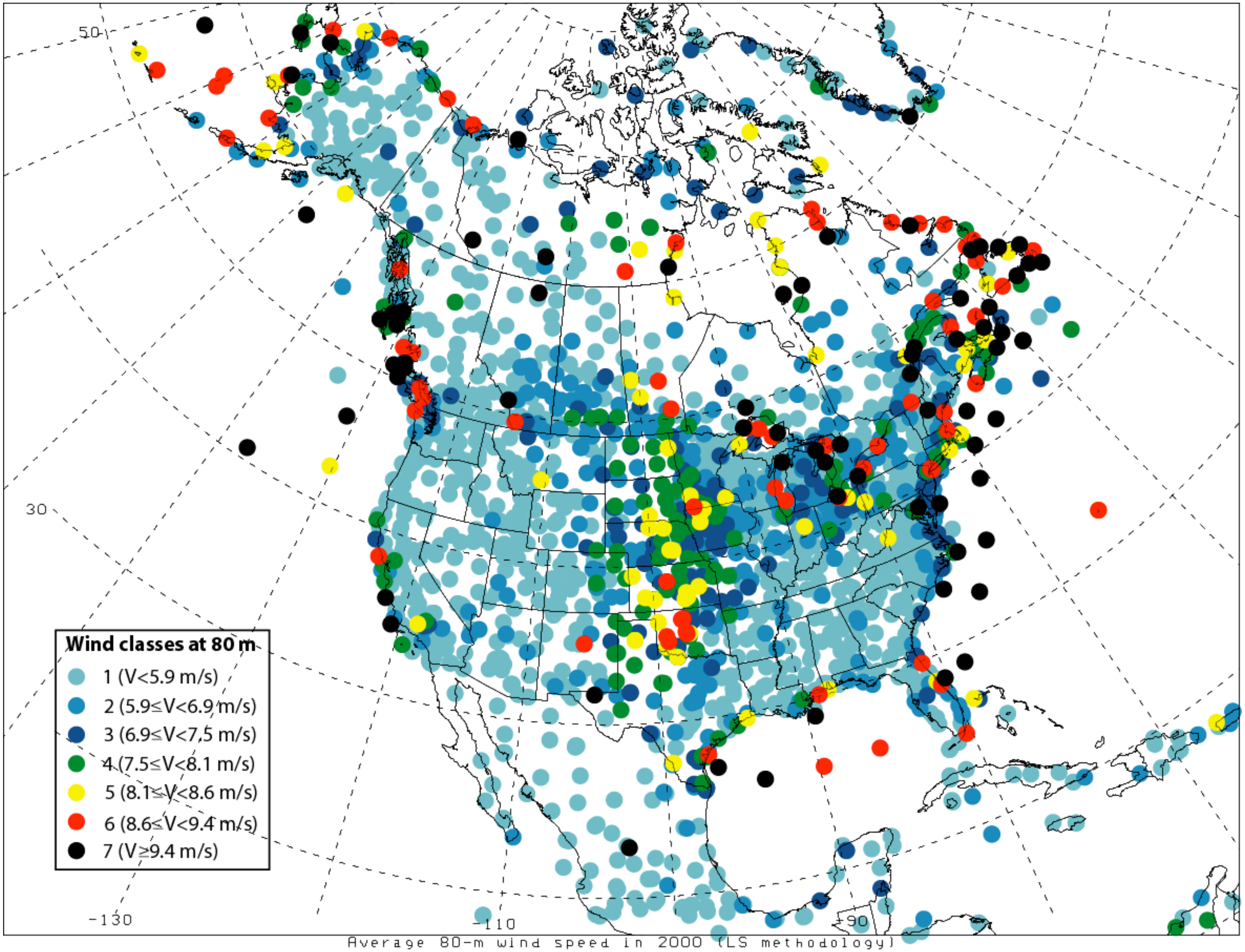
Land Area For 50% of US Energy From Wind



Alternatively, Water Area For 50% of US Energy From Wind

Mean 80-m Wind Speed in North America

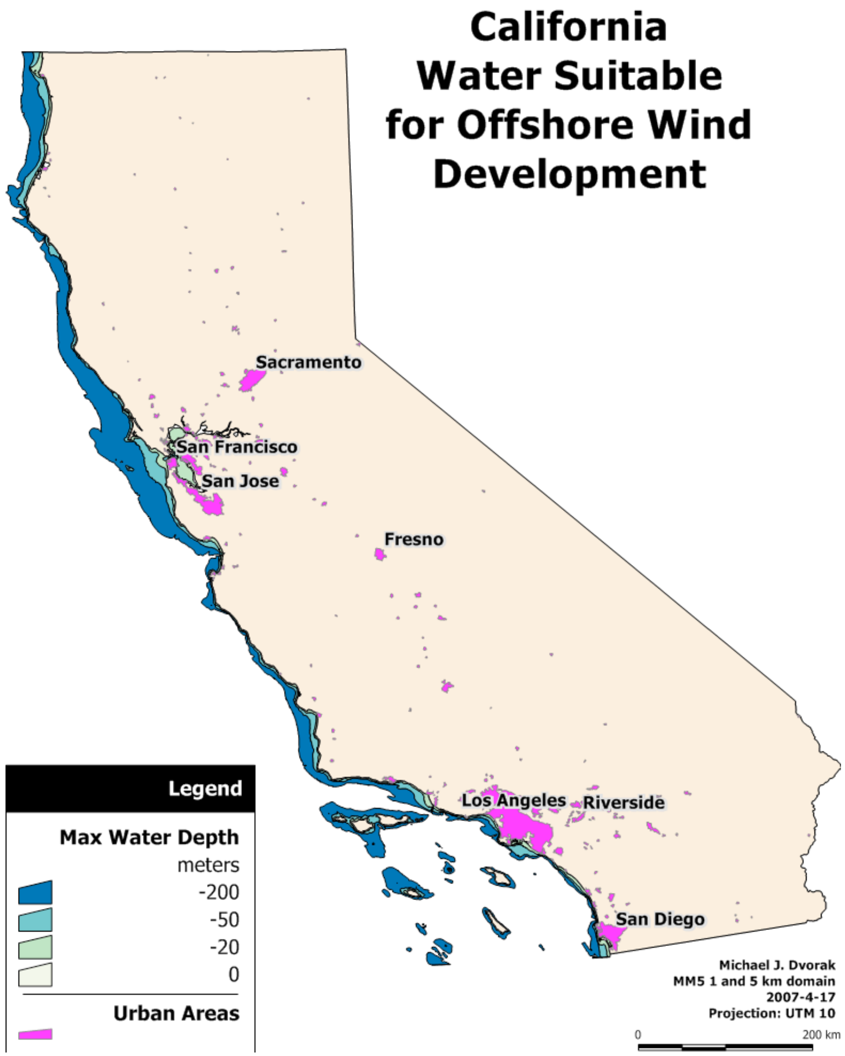
Archer and Jacobson (2005) www.stanford.edu/group/efmh/winds/

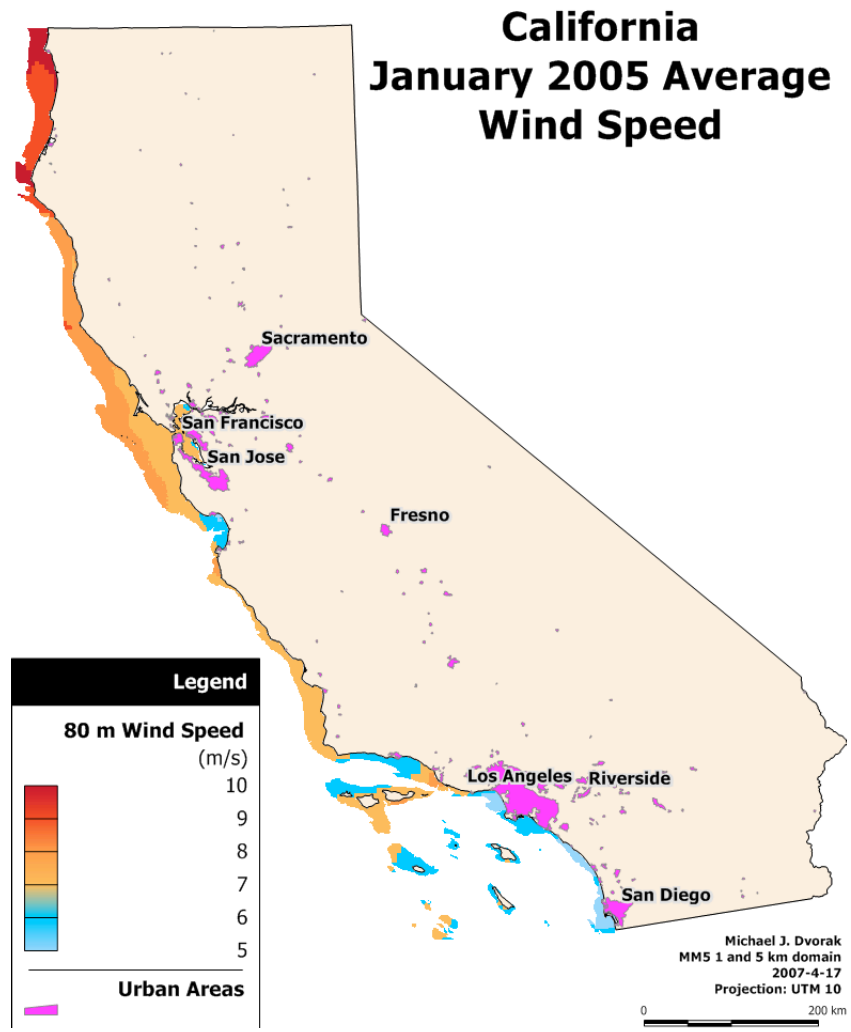


Percent of Land+Near Shore Stations With Annual Wind Speeds > 6.9 m/s at 80 m

Europe	14.2
North America	19.0
United States over land	15.0
United States over land+near shore	17.0
South America	9.7
Oceania	21.2
Africa	4.6
Asia	2.7
Antarctica	60
Global over land	13

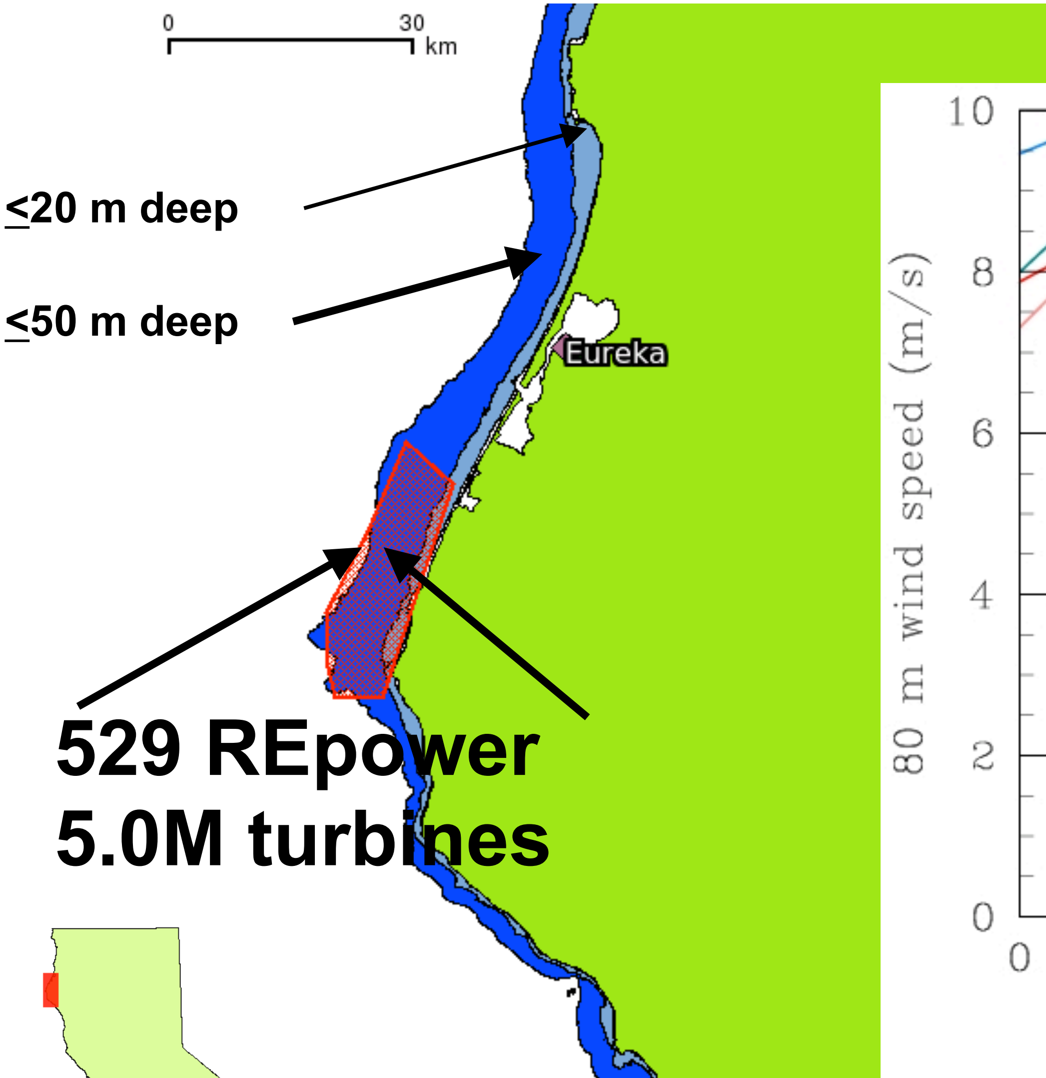
Archer and Jacobson (2005)

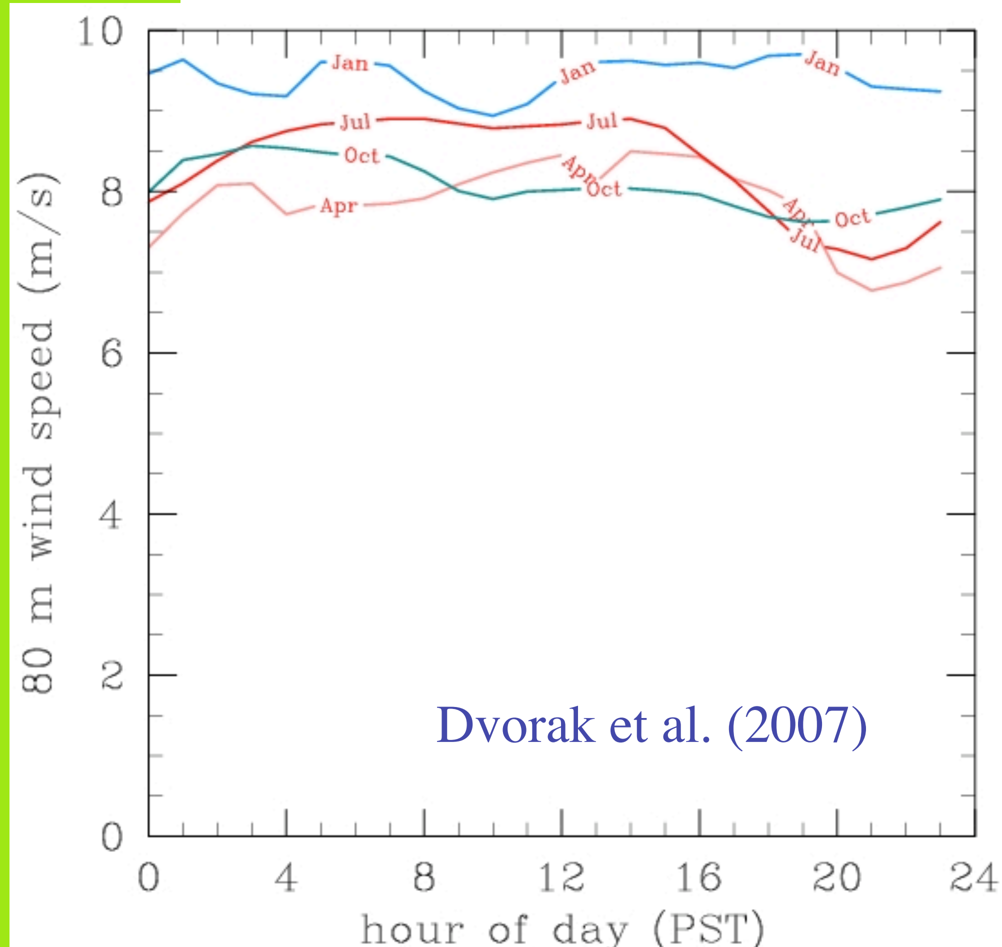


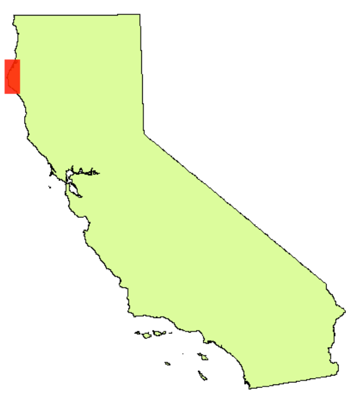


Dvorak et al. (2006)

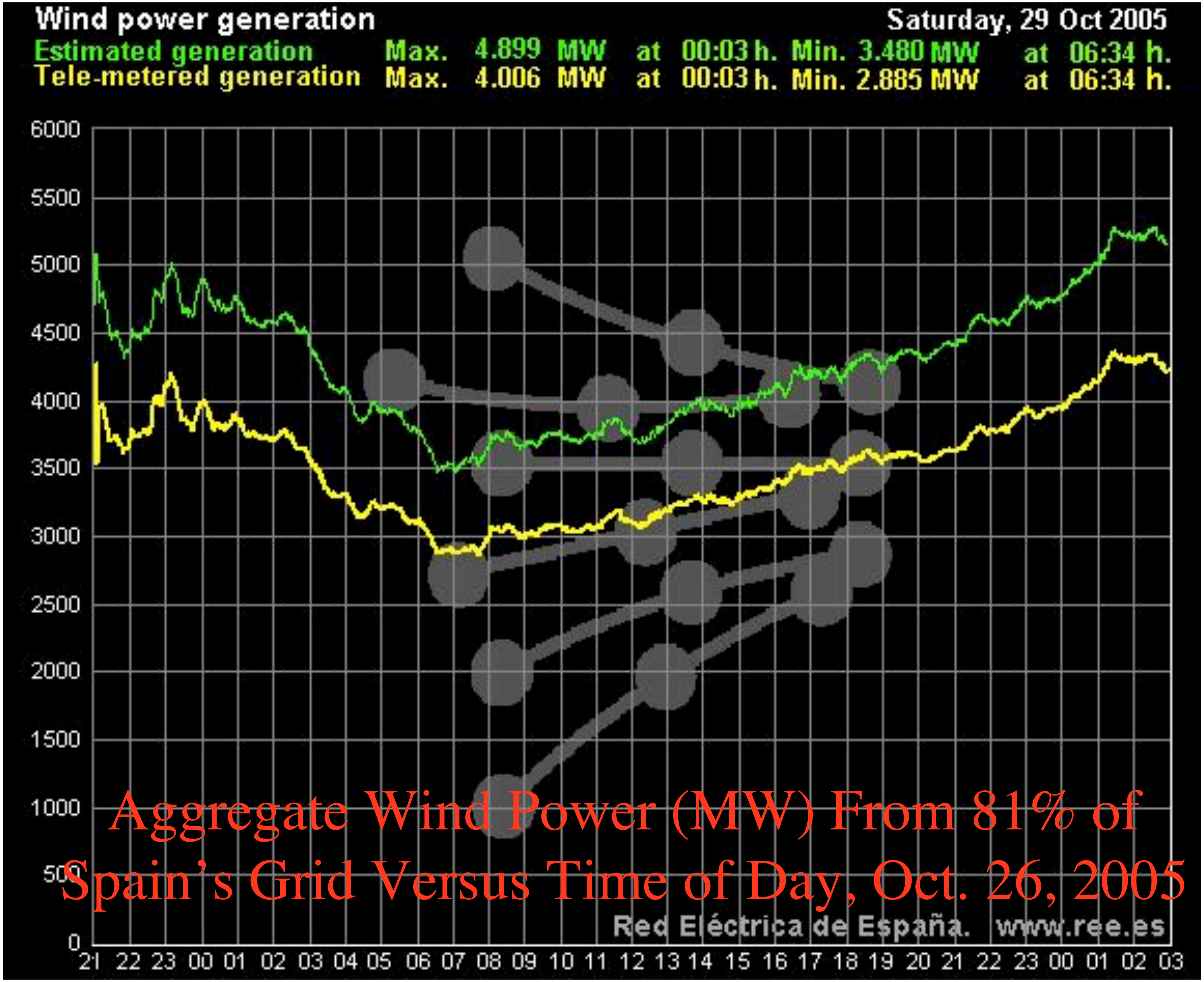
Eureka Wind Park Example (Preliminary)







2645 MW capacity (529 5 MW turbines), capacity factor of 42%
Yields 5.9 TWh/yr (8.2% of California's carbon electricity)
Requires about 28 km (18 mi) or 2.1% of California's 840 mi coast.



Aggregate Wind Power (MW) From 81% of Spain's Grid Versus Time of Day, Oct. 26, 2005

Birds and Wind

U.S. bird deaths from current wind turbines 10,000-40,000/yr (!)
U.S. bird deaths from communication towers: 50 million/yr (!)
Worldwide bird deaths from avian flu: 200 million/yr (%)

Est. bird deaths with 2,500,000 turbines worldwide: 2.5-10 million/yr

Outdoor human deaths reduced by these turbines: 800,000/yr (*)

The effect of wind turbines on birds will be small relative to the benefit of reducing fossil-biofuels on human and animal illness.

(!) Bird Conservancy (April 2006); (%) San Jose Mercury News (April 2006)
(*) World Health Organization (2002)

Summary

Global warming will hasten as aerosol pollution decreases.

CO_2 increases air pollution mortality due to its effect on temperature, water vapor, and atmospheric stability, which increase ozone and particulate matter in urban areas.

80% reductions in current emissions are needed to stabilize CO_2. Corn ethanol cannot practically reduce CO_2 in the U.S. by more than 0.07-0.2%; cellulosic ethanol cannot reduce CO_2 by more than 1.3-4%, based on current understanding.

Wind-battery electric vehicles can reduce U.S. CO_2 by 25.5%; solar-battery electric vehicles can reduce it by 23.4% Wind turbines require 30 times less land than corn ethanol and 20 time less land than cellulosic ethanol for the same power.

Sufficient wind and solar are available worldwide to supply all electric and nonelectric energy needs simultaneously several times over.

Summary

Converting all U.S. gasoline vehicles to ethanol (E85) vehicles will not improve air quality. At 100% penetration, it may enhance air pollution mortality from 0 to 200/yr deaths above the 10,000/yr due to gasoline in 2020. At 10-30% penetration, deaths may still be 0 to 20-60/yr above 10,000/yr.

The long lifetime of unburned ethanol may result in a global source of acetaldehyde and ozone.

Each ethanol or gasoline vehicle developed from now on will enhance air pollution and climate problems significantly compared with each renewable-powered battery-electric or hydrogen fuel cell vehicle produced.