Roger Sullivan
McGARVEY LAW
345 1st Avenue East
Kalispell, MT 59901
(406) 752-5566
rsullivan@mcgarveylaw.com

Philip L. Gregory*
GREGORY LAW GROUP
1250 Godetia Drive
Redwood City, CA 94062
(650) 278-2957
pgregory@gregorylawgroup.com

Julia A. Olson*
Andrea K. Rodgers*
Nathan Bellinger*
OUR CHILDREN'S TRUST
1216 Lincoln St.
Eugene, OR 97401
(415) 786-4825
julia@ourchildrenstrust.org
andrea@ourchildrenstrust.org
nate@ourchildrenstrust.org

Daniel C. Snyder*
Haley Nicholson*
PUBLIC JUSTICE
1620 L Street NW, Suite 630
Washington, DC 20036
(202) 797-8600
dsnyder@publicjustice.net
hnicholson@publicjustice.net

Attorneys for Plaintiffs
**Admitted pro hac vice*

UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MONTANA
BUTTE DIVISION

EVA LIGHTHISER; et al.
Plaintiffs,

v.

DONALD J. TRUMP, in his official capacity as President of the United States; et al.
Defendants.

Case No: CV-25-54-BU-DLC

DECLARATION OF MARK Z. JACOBSON, PhD, IN SUPPORT OF MOTION FOR PRELIMINARY INJUNCTION

I, Mark Z. Jacobson, hereby declare and if called upon would testify as follows:

1. I am a Professor of Civil and Environmental Engineering at Stanford University. I am offering this testimony in my personal capacity, and I have personal knowledge of the facts stated herein.

2. I am submitting this Declaration in support of Plaintiffs' Motion for Preliminary Injunction to prevent Defendants from implementing several sections of Executive Orders Nos. 14154, 14156, and 14261, which are designed to "unleash" fossil fuels and suppress the development and accessibility of climate change science, and the growth of renewable energy. I offer my expert opinion to show that the United States is not experiencing an "energy emergency," that no new fossil fuels are needed to meet this country's current and future energy needs, that unleashing fossil fuels would significantly increase the number of deaths associated with air pollution caused by fossil fuels, and that slowing the transition towards renewable energy at this pivotal time would be highly damaging to the health and economic wellbeing of the Youth Plaintiffs in this case.

Background & Qualifications

3. I have two Bachelor's Degrees with Distinction from Stanford University, one in Civil Engineering and the other in Economics. I earned a Master's Degree in Environmental Engineering from Stanford University. I earned a second

Master's Degree and then a Ph.D. (1994) in Atmospheric Sciences from UCLA. A true and correct copy of my curriculum vitae is attached as Exhibit A.

4. Since 1989, I have been researching the impacts of human emissions of gases (among them carbon dioxide and other greenhouse gases) and particles (including black and brown carbon) from fossil fuels on air pollution, human health, weather, and climate. Starting in 1999 and given the gravity of the health concerns associated with pollution from fossil fuels, I began examining in detail clean, renewable energy solutions to these problems. I have since developed roadmaps to transition the all-sector energy infrastructures of each of the 50 United States, including California, Oregon, Montana, Hawaii, and Florida, and 149 countries to 100% clean, renewable energy by 2050. In this declaration, I summarize how this research pertains to the United States and how it demonstrates that no further fossil fuel extraction, fossil-fuel infrastructure, or fossil-fuel combustion are necessary for the United States or the world.

5. I previously served as a testifying expert witness on similar topics addressed in this Declaration for the Youth Plaintiffs in *Rikki Held, et al. v. State of Montana et al.*, tried in June 12-20, 2023 before Judge Kathy Seeley, First Judicial District Court, Lewis and Clark County, in Cause No. CDV-2020-307.

6. After preparing an expert report in that litigation, as well as a rebuttal expert report, and testifying under oath at a deposition, I appeared in Court on June

16, 2023, to testify under oath on the following topics: research related to the feasibility of substituting fossil fuels for clean and renewable energy in all sectors by mid-century in Montana, where all energy sectors include electricity, transportation, heating/cooling, and industry. My expert report was not admitted as an exhibit into the trial record, but my testimony was recorded and is available at https://heldvmontana.ourchildrenstrust.org/. I was deemed qualified to testify as an expert on these topics.

7. The Court issued its Findings of Fact, Conclusions of Law, and Order on August 14, 2023, finding my expert opinions "informative and credible." ¶¶ 269-83 (citing MJ [Mark Jacobson] trial testimony and demonstratives). The paragraphs from the Court's opinion that reference my testimony are attached to this Declaration as Exhibit B.

8. The Court's 2023 Order was affirmed in full by the Montana Supreme Court. *Held v. State,* 2024 MT 312.

No New Fossil Fuels Are Needed to Meet United States' Energy Needs

9. The White House declaration of a "National Energy Emergency"[1] is a false claim. The United States is already meeting its energy needs and has the ability to meet its future energy needs entirely with clean, renewable energy.

[1] Donald J. Trump, *Declaring a National Energy Emergency* (Jan. 20, 2025), https://www.whitehouse.gov/presidential-actions/2025/01/declaring-a-national-energy-emergency/.

10. One way to show how the United States has adequate energy resources is that the United States is currently extracting more oil than any country ever in recorded history and is exporting more oil and liquified fossil gas than has any other country in history.[2] I show in Figure 1 the U.S. production of oil and fossil gas as far back as the U.S. Energy Information Agency (EIA) records extend.

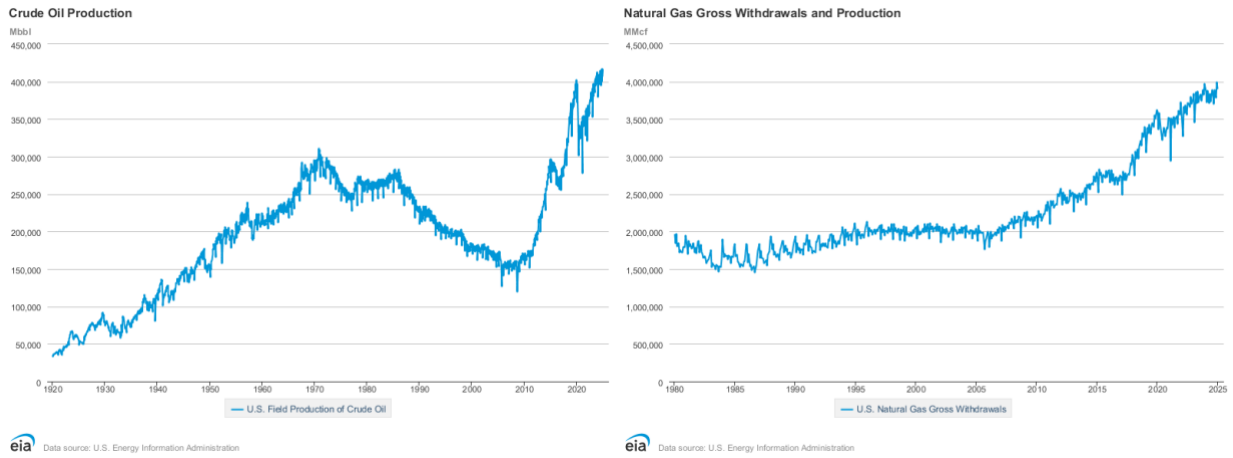


Figure 1. U.S. crude oil production in million barrels (Mbbl) since 1920 (left)[3] and fossil gas production in million cubic feet (MMcf) since 1980 (right)[4] according to the U.S. EIA.

11. I then show in Figure 2 U.S. imports and exports for oil as far back as U.S. EIA records extend.

---

[2] U.S. EIA, *United States Produces more Crude Oil than any Country, Ever* (Mar. 11, 2024), https://www.eia.gov/todayinenergy/detail.php?id=61545; U.S. EIA, *The United States Remained the World's Largest Liquefied Natural Gas Exporter in 2024* (Mar. 27, 2025), https://www.eia.gov/todayinenergy/detail.php?id=64844.
[3] U.S. EIA, https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_m.htm.
[4] U.S. EIA, https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_FGW_mmcf_m.htm.

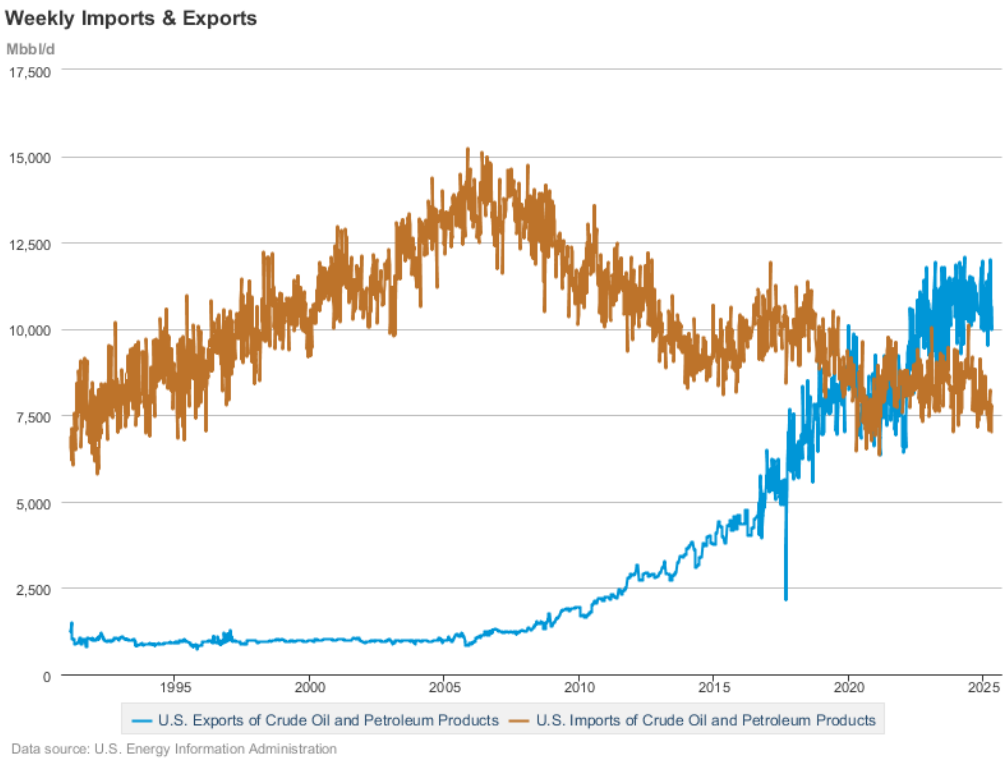


Figure 2. Weekly U.S. imports (brown) and exports (blue) of oil since 1991 in million barrels per day (Mbbl/day) according to the U.S. EIA.[5]

12. Figure 3 shows imports and exports of U.S. fossil gas for the entire EIA historic record. Oil imports have been below 350,000 million cubic feet (MMcf) since the early 2010s while exports are now close to 700,000 MMcf. Figure 2 similarly shows that oil exports have exceeded oil imports since around 2022. Clearly, the United States exports more oil and gas than it imports and has fossil fuels to spare. There is no need to expand fossil fuel extraction from the ground to meet U.S. energy needs, particularly when there are cleaner and cheaper options

[5] U.S. EIA, https://www.eia.gov/dnav/pet/pet_move_wkly_dc_NUS-Z00_mbblpd_w.htm.

available in the form of clean, renewable wind, solar, geothermal, and hydroelectric energy.

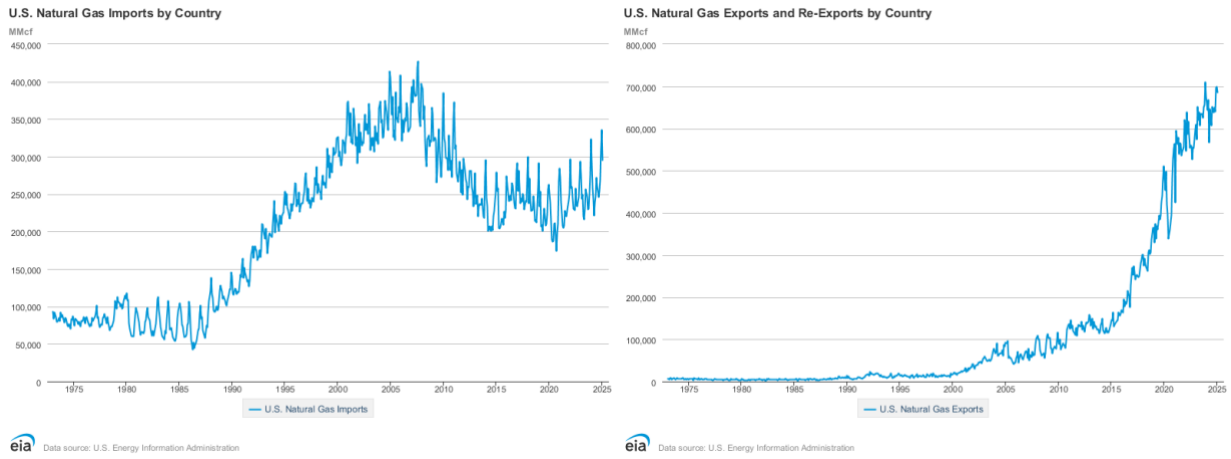


Figure 3. U.S. imports[6] (left) and exports[7] (right) of fossil gas in million cubic feet (MMcf) since 1973 according to the U.S. EIA. Note that in recent years, the U.S. has no appreciable re-exports.

13. Since January 2025, in accordance with the Executive Orders to "unleash fossil fuels," the Department of Energy has approved applications for projects that will export more than 9.5 billion cubic feet of liquified natural gas (LNG) per day.[8] Another illustration of the false factual nature of the Trump Administration's claimed "energy emergency" is that 80% of the capacity of active gas pipeline projects in the U.S. are designed to export gas overseas LNG facilities.[9]

[6] U.S. EIA, https://www.eia.gov/dnav/ng/ng_move_impc_s1_m.htm.
[7] U.S. EIA, https://www.eia.gov/dnav/ng/ng_move_expc_s1_m.htm.
[8] https://www.energy.gov/articles/energy-secretary-wright-testifies-house-appropriations-subcommittee-fy2026-budget-request
[9] https://ceea.us/wp-content/uploads/2025/06/Tidal-Wave-Report-Final-June-2-2025.pdf

14. Instead of an "energy emergency", the United States and the world are in a clear climate emergency.[10] There is an urgent and ever growing need to phase out fossil fuels and replace them with clean, renewable energy. Indeed, this is what much of the world is doing. In 2024, more than 90% of the new installed energy nameplate capacity worldwide was renewable (primarily solar and wind) and not fossil fuel based.[11] In the case of the United States, 93% of newly installed energy nameplate capacity in 2024 was solar, wind and battery storage, with Texas leading the way in both installed and planned solar and wind infrastructure.[12] In 2024, Texas installed nearly three times more solar capacity than Florida and more than 3.5 times more than California; one third of planned new solar capacity for 2025 is expected to be built in Texas. In 2024, Texas produced twice as much wind and solar electricity as California[13] and on March 2, 2025, renewables met 76% of Texas

[10] U.N. Environment Programme, Facts About the Climate Emergency, https://www.unep.org/facts-about-climate-emergency.
[11] Dan McCarthy, *Clean Energy Dominated Global Power Construction in 2024* (May 2, 2025), https://www.canarymedia.com/articles/clean-energy/renewables-global-power-construction-2024.
[12] Cleanview, The State of Clean Energy Deployment in 2025 (2025), https://storage.googleapis.com/2025_report/cleanview_january_2025_report_free_version.pdf.
[13] https://insideclimatenews.org/news/06032025/inside-clean-energy-texas-leads-renewable-generation/

demand with battery storage increasing 6.3 times since 2023.[14] Texas is thus a prime example of how renewable energy can be rapidly and cheaply deployed.

15. California, though, has installed more battery storage than any other state. On June 8, 2025, for example, batteries on California's main grid set a new record, discharging at a peak rate of 10.103 gigawatts (GW, or billion watts). This is almost seven times California's peak battery discharge rate in 2021.[15] What is more, during the first 159 days of 2025 (through June 8, 2025), wind, solar, geothermal, and hydro resources supplied more than 100% of all electricity demand on California's main grid for parts of 125 days (for an average of 4.8 hours per day and a maximum of 10.5 hours per day). In comparison, in 2023, there were only 35 days during the first 159 days where renewable supply exceeded demand for part of the day. This was accomplished in part by growing solar output 50% versus 2023, growing battery output, and decreasing fossil gas output by 42% versus 2023.[16]

16. From April 1, 2024 through March 31, 2025, there were 11 U.S. states that supplied 52-121% of their statewide electricity demand in the annual average

[14] https://www.canarymedia.com/articles/clean-energy/texas-broke-its-solar-wind-and-battery-records-in-one-spring-week
[15] https://www.gridstatus.io/records/caiso?record=Maximum%20Battery%20Discharging
[16] https://www.linkedin.com/posts/mark-jacobson-1b58b38_new-battery-record-on-the-california-iso-activity-7337898903796649984-IzHB/

with just wind, solar, geothermal, and hydro electric power.[17] These included South Dakota (121.3% of yearly-averaged demand supplied by clean, renewables), Montana (93.8%), Iowa (81.2%), Washington State (74.2%), Kansas (69.3%), Maine (67.5%), Wyoming (65.9%), New Mexico (63.2%), Oregon (62.4%), North Dakota (57.1%), and Oklahoma (52.4%). The electricity generation in seven of these states was dominated by wind; the rest were dominated by hydropower. Among the 11 states, 10 had electricity prices at least 2.1 cents per kilowatt-hour below the U.S. average (the only exception being Maine). This indicates that not only are many states now relying heavily on clean, renewable electricity, but their grids are staying stable at a cost of electricity that is lower than in states dominated by fossil fuels.

17. The United States no longer needs fossil fuels for its energy purposes and has not for some time. Given the longevity and expense of expanding fossil fuel extraction and infrastructure, the Executive Orders will lock in continuing fossil fuel use for decades to come, well past today, when it is already technologically and economically feasible for the United States to replace fossil fuels with clean, renewable sources.

[17] Mark Z. Jacobson, 60 Countries/Territories Whose Electricity Generation in 2023 was 50-100% Wind-Water-Solar (WWS) (Including 12 With 98.4-100% WWS Generation) and 11 U.S. States That Produced the Equivalent of 52.4-121.3% of the Electricity They Consumed With WWS From Q2-2024 to Q12025, https://web.stanford.edu/group/efmh/jacobson/WWSBook/Countries100Pct.pdf

18. I show in Figure 4 the levelized cost of different electricity-generation technologies.[18] Of the fossil fuels, gas peaking plants are the most expensive in 2024, followed by coal and then gas combined cycle plants. Onshore wind energy production has been cheaper than all fossil fuel energy sources since 2011 while solar photovoltaic energy has been cheaper than all fossil fuel energy sources since 2016. Thus, not only are there clean renewable alternatives to fossil fuels available today, but they are also cheaper, meaning that the continued use of fossil fuels costs Americans more than switching to clean, renewable alternatives.[19] Indeed, the White House executive order to "reinvigorate" coal[20] would actually shackle Americans with one of the most expensive energy sources, which is why much of the world is turning away from coal. A recent analysis shows that "coal plant owners spent $6.2 billion more in 2024 than they would have spent for the same amount of electricity generated by coal in 2021;" "95% of the nation's coal fleet was more expensive in

[18] Lazard, Levelized Cost of Energy, https://www.lazard.com/research-insights/levelized-cost-of-energyplus/.
[19] Mark Z. Jacobson et al., *No Blackouts or Cost Increases Due to 100 % Clean, Renewable Electricity Powering California for Parts of 98 Days*, 240 Renewable Energy 122262 (2025).
[20] Donald J. Trump, *Reinvigorating America's Beautiful Clean Coal Industry and Amending Executive Order 14241* (Apr. 8, 2025), https://www.whitehouse.gov/presidential-actions/2025/04/reinvigorating-americas-beautiful-clean-coal-industry-and-amending-executive-order-14241/.

2024 than it was in 2021;" and "76% of U.S. coal plants saw their costs rise faster than inflation between 2021 and 2024."[21]

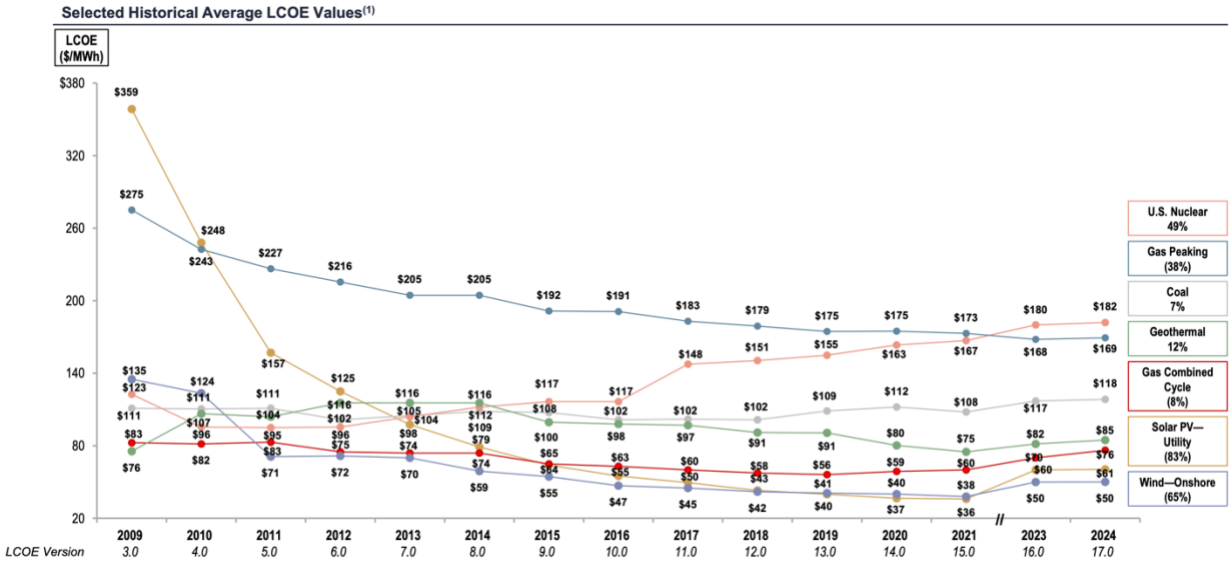


Figure 4. Levelized cost of different electricity-generation technologies as documented by Lazard.[22]

19. In 2022, I, along with my colleagues, published a study assessing the feasibility of transitioning each of the 50 states, including California, Oregon, Montana, Hawai'i, and Florida, to 100% clean, renewable energy across all energy sectors by 2050.[23] Clean, renewable energy emits zero health- and climate-affecting air contaminants and is derived from continuously replenishable sources. Energy

[21] https://energyinnovation.org/report/coal-power-28-percent-more-expensive-in-2024-than-in-2021/

[22] Lazard, Levelized Cost of Energy, https://www.lazard.com/research-insights/levelized-cost-of-energyplus/.

[23] Mark Z. Jacobson et al., *Zero Air Pollution and Zero Carbon from all Energy at Low Cost and Without Blackouts in Variable Weather Throughout the U.S. with 100% Wind-Water-Solar and Storage*, 184 Renewable Energy 430 (2022).

technologies that satisfy the clean, renewable criteria include onshore and offshore wind electricity, solar photovoltaic (PV) electricity on rooftops and in utility-scale plants, concentrated solar power (CSP) electricity, solar thermal heat, geothermal electricity and heat, hydroelectricity, tidal electricity, and wave electricity. Because wind and solar in particular are variable in nature, electricity storage is also needed. The main relevant electricity storage technologies for the United States included in the study, and in use today, are existing hydroelectric reservoirs, pumped hydroelectric storage, batteries, and hydrogen storage, where the hydrogen is produced from electricity and water and used in a fuel cell to regenerate electricity. The study examined all energy sectors, including the residential, commercial, industrial, and transportation sectors.[24]

20. Our findings demonstrate that it is technologically and economically feasible to transition all 50 states, statewide, for all energy purposes, to 100% clean, renewable energy by 2050, meeting all energy needs across all sectors while keeping the electricity grid stable 100% of the time. Additionally, meeting all of the United

[24] Mark Z. Jacobson et al., *Zero Air Pollution and Zero Carbon from all Energy at Low Cost and Without Blackouts in Variable Weather Throughout the U.S. with 100% Wind-Water-Solar and Storage*, 184 Renewable Energy 430 (2022); Mark Z. Jacobson, *Zero Air Pollution and Zero Carbon From All Energy Without Blackouts at Low Cost in the Whole United States* (2021), https://web.stanford.edu/group/efmh/jacobson/Articles/I/21-USStates-PDFs/21-WWS-USATotal.pdf.

States' energy needs with clean, renewable energy would require no new hydropower generation facilities.[25]

21. Because it is economically and technologically feasible to meet all energy needs statewide across all sectors in the United States with clean, renewable energy, expanding fossil fuel extraction and use are not needed to provide energy for Americans when less-expensive, healthier, and longer-lasting alternatives that do not cause harmful climate and localized air pollution are readily available and more affordable.

The Defendants Know that Replacing Fossil Fuels with Renewable Energy Sources are Viable

22. I have presented results of some of my earlier research on renewable energy pathways to the U.S. House of Representatives Committee on Energy and Commerce (November 19, 2015).[26] The federal government has thus been aware of the availability of renewable sources of energy and storage to replace fossil fuel energy at lower cost since at least 2015.

23. I also served as an expert witness in the climate change case against the government filed in 2015, *Juliana v. United States*. In that case, I prepared an expert

[25] https://web.stanford.edu/group/efmh/jacobson/Articles/I/21-USStates-PDFs/21-WWS-USATotal.pdf.
[26] https://web.stanford.edu/group/efmh/jacobson/Articles/I/15-11-19-HouseEEC-MZJTestimony.pdf.

report on renewable energy pathways in the U.S. and was deposed by lawyers at the Department of Justice.

Clean, Renewable Energy Avoids the Harms of Fossil Fuel Extraction, Production and Combustion While Providing Significant Benefits

24. Fossil fuels (coal, oil, and fossil gas) are limited resources and their extraction, transportation, and use causes climate and localized air pollution, resulting in serious harms to the health and safety of Americans, including the Plaintiffs in this case. In contrast, clean, renewable energy creates zero localized air and climate pollution, avoiding the significant health and climate harms that result from fossil fuels. Additionally, supplying energy needs through clean, renewable energy—replacing fossil fuels—provides significant benefits and cost saving for Americans.

25. Transitioning the United States to 100% clean, renewable energy by 2050 is estimated to create about 4.7 million more long-term, full-time jobs than lost and saves about 53,000 American lives in addition to reducing health problems for millions more, from air pollution every year. If this pathway is followed, then it is estimated to reduce all-purpose, end-use energy for electricity, transportation, buildings and industry in the United States by 56.7% and American's annual energy costs by 62.9%, from $2.51 trillion per year to $933 billion per year, a cost saving of about $1.58 trillion per year to the United States. It may reduce the United States' annual combined energy costs, health costs to Americans, and will cut climate costs

to the world, including the United States, by 86.3%, from $6.79 trillion per year to $933 billion per year, a social cost saving of about $5.87 trillion per year.[27]

26. By contrast, expanding fossil fuel use in the United States for decades and drastically increasing greenhouse gas emissions will cost about $3.58 trillion per year in climate damage costs.

27. In 2022 (last year of available data), the United States spent about $1.7 trillion on its existing energy needs.[28] I project, based on a business-as-usual, fossil-fuel pathway, that number will rise to about $2.513 trillion per year by 2050[29]. Replacing fossil fuels in the United States with 100% clean, renewable energy across all energy sectors would cost roughly $8.940 trillion upfront, but it would be paid back over time through energy sales. Given the $1.580 trillion per year energy-cost savings, obtained by reducing annual energy costs from around $2.51 trillion per year on a fossil-fuel pathway to about $0.933 trillion per year in 2050 with 100% clean renewable energy,[30] the payback time of the upfront capital cost from energy-cost savings alone is approximately 5.7 years. Accounting for the social cost savings of $5.87 trillion per year through avoided deaths and climate damages, gives a social-

[27] https://web.stanford.edu/group/efmh/jacobson/Articles/I/21-USStates-PDFs/21-WWS-USATotal.pdf
[28] https://www.eia.gov/todayinenergy/detail.php?id=62945
[29] https://web.stanford.edu/group/efmh/jacobson/Articles/I/21-USStates-PDFs/21-WWS-USATotal.pdf
[30] *Id.*

cost payback time of about 1.5 years.[31] In other words, investing in clean, renewable energy saves money and saves lives. Unleashing fossil fuels costs everyone more on energy bills, in lives lost, in illnesses, and in health costs, before even accounting for climate change damages.

28. The new land-area footprint required for 100% clean, renewable energy generation from new utility-scale solar and geothermal electricity generation in the United States is about 10,300 square miles or 0.29% of U.S. land. Onshore wind turbines require spacing between them, which necessitates another 19,600 square miles or 0.55% of U.S. land. However, unlike lands used for fossil fuel extraction and production, this land can be co-used for other purposes like farming, ranching, open space or solar panels. Even in the worst case, the U.S. land required for a 100% all-sector-renewable-energy transition is ~0.84% of U.S. land from this study. In comparison, the fossil-fuel industry occupies ~1.3% of U.S. land area.[32] The ethanol-fuel industry occupies another 1.24% of U.S. land to grow corn, where the resulting ethanol supplies only 4% of U.S. transportation fuel. Thus, a transition to 100% clean, renewable energy for all purposes should reduce energy-related land requirements from ~2.54% of U.S. land to less than 1% of U.S. land.

---

[31] *Id.*

[32] Mark Z. Jacobson, Land Area Occupied by the Fossil Fuel and Nuclear Industries in California and the U.S. (July 22, 2021), https://web.stanford.edu/group/efmh/jacobson/Articles/I/LandFossil.pdf.

29. Therefore, the footprint of 100% clean, renewable energy generation for the whole United States is just a fraction of the current land use for the use of fossil fuels. To drive this point home, a recent study documented that there are about 3.1 million abandoned and orphaned oil and gas wells in the United States. They found that 99% of these well sites are in settings conducive to wind power generation. If each of these sites were to be repurposed for wind generation, then the United States could install up to 13,551 gigawatts nameplate capacity of electricity from wind alone, compared with about 150 gigawatts installed today, far more than needed to power the U.S. for all energy purposes many times over. [33] For example, the United States' current electricity generation capacity from all technologies is about 1,190 gigawatts.[34]

30. I will also note just a few of the direct health harms that are avoided by substituting clean, renewable energy for fossil fuels. Globally, the ambient air pollution (ozone, fine particles, and other chemicals) from fossil fuels alone may kill about 5.1 million people each year.[35] To put that into perspective, about 16.5 million

---

[33] Jade Boutot & Mary Kang, *Renewable Energy Production Potential of Abandoned and Orphaned Oil and Gas Wells and Sites*, 20 Env't Rsch. Letters 054037 (2025).

[34] U.S. EIA, Electricity Explained, https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php (last updated July 16, 2024).

[35] Jos Lelieveld et al., *Air Pollution Deaths Attributable to Fossil Fuels: Observational and Modelling Study*, 383 BMJ e077784 (2023).

people died in World War I[36] from all causes over the course of 4.2 years.[37] Consequently, the background air pollution from fossil fuels kills 30% more people per year than died from each year of the war to end all wars.

31. In addition to death, pollution from fossil fuels cause preterm birth, impaired fetal growth, childhood asthma, decreased mental health, respiratory and cardiovascular disease, and cancer.[38] In the year 2016 alone, air pollution from the oil and gas industry in the United States caused an estimated 410,000 asthma exacerbations, 2,200 new cases of childhood asthma, and 7,500 deaths for a total health cost of $77 billion.[39] Fossil fuels also cause hundreds of thousands of preterm births in the United States.[40] Not surprisingly, living within 1 to 8 miles of an oil or gas well is associated with increased risk of childhood leukemia.[41] Low producing wells have also been found to emit deadly levels of hydrogen sulfide gas; of the 46

---

[36] https://www.history.com/articles/how-many-people-died-in-world-war-i.
[37] https://www.theworldwar.org/learn/about-wwi/armistice.
[38] Shaye Wolf et al., *Scientists' Warning on Fossil Fuels*, 5 Oxford Open Climate Change kgaf011 (2025).
[39] Jonathan J. Buonocore et al., *Air Pollution and Health Impacts of Oil & Gas Production in the United States*, 1 Env't Rsch. Health 021006 (2023).
[40] Shaye Wolf et al., *Scientists' Warning on Fossil Fuels*, 5 Oxford Open Climate Change kgaf011 (2025).
[41] Cassandra J. Clark et al., *Unconventional Oil and Gas Development Exposure and Risk of Childhood Acute Lymphoblastic Leukemia: A Case-Control Study in Pennsylvania, 2009-2017*, 130 Env't Health Perspectives 087001 (2022); Lisa M. McKenzie et al., *Exposures from Oil and Gas Development and Childhood Leukemia Risk in Colorado: A Population-Based Case-Control Study*, Cancer Epidemiology, Biomarkers Prevention 658 (2025).

wells analyzed near suburban residencies, 21 had hydrogen sulfide concentrations above the deadly concentration level of 100 parts per million and another nine were above the Occupational Safety and Health Administration upper limit of 20 parts per million.[42]

32. Looking at fracking or unconventional wells, which comprise an estimate of at least 79% of fossil gas and 65% of oil wells in the United States, the Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking and Associated Gas and Oil Infrastructure[43] found that fracking air pollution includes 61 classified hazardous pollutants such as the carcinogens benzene and formaldehyde. Other pollutants are fine particulates, deadly hydrogen sulfide gas, nitrogen oxides, chlorine and ozone, which cause respiratory, cardiovascular, and nervous system damage. These pollutants often exceed safe levels in communities near the wells. In fact, this report concluded that there is no evidence that fracking can be conducted in a manner that does not directly endanger human health.

---

[42] Amy Townsend-Small et al., *High Rates of Hydrogen Sulfide Emissions Measured from Marginal Oil Wells Near Austin and San Antonio, Texas*, 6 Env't Rsch. Communications 091007 (2024).

[43] Physicians for Social Responsibility et al., *Compendium of Scientific, Medical, and Media Findings Demonstrating Risks and Harms of Fracking and Associated Gas and Oil Infrastructure* (2023), https://psr.org/resources/fracking-compendium-9/

33. Turning to fossil fuel (gas and propane) stoves in American homes, these are associated with increased childhood asthma[44] and directly emit the carcinogen benzene into the kitchen[45]. In the United States, these fossil fuel stoves increase long term nitrogen dioxide pollution in homes to about 75% of World Health Organization guidelines, causing about 50,000 asthma cases in children.[46] Short term nitrogen dioxide exposure often exceeds even the less stringent U.S. Environmental Protection Agency safe levels.

34. By rapidly transitioning to clean renewable energy, we can eliminate all of the health harms, costs and suffering that fossil fuels cause.

35. As an example, I recently led and published a study where we compared the costs and impacts in 2050 in a world where all energy is produced with conventional fuels (oil, coal, gas, nuclear, bioenergy, and some renewables), but where carbon dioxide emissions from the use of fossil fuels and bioenergy fuels are directly captured, in order to reach a net of zero carbon-dioxide emissions, with a

---

[44] Talor Gruenwald et al., *Population Attributable Fraction of Gas Stoves and Childhood Asthma in the United States*, 20 Env't Rsch. Public Health 75 (2023).
[45] Yannai S. Kashtan et al., *Gas and Propane Combustion from Stoves Emits Benzene and Increase Indoor Air Pollution*, 57 Env't Science Technology (2023); Sebastian T. Rowland et al., *Downstream Natural Gas Composition Across U.S. and Canada: Implications for Indoor Methane Leaks and Hazardous Air Pollutant Exposures*, 19 Env't Rsch. Letters 064064 (2024).
[46] Yannai Kashtan et al., *Nitrogen Dioxide Exposure, Health Outcomes, and Associated Demographic Disparities Due to Gas and Propane Combustion by U.S. Stoves*, 10 Science Advances eadm8680 (2024).

case where 100% of global energy comes from clean, renewable sources (thus eliminating both carbon dioxide and air pollution emissions directly).[47] Because the extraction, transport, and combustion of fossil fuels still produces air pollution even when the emitted carbon dioxide is captured (note that today there are no economically viable methods available to capture carbon dioxide at this scale), annual deaths from fossil fuel pollution in 2050 in the carbon capture case are estimated to be 4.5 to 7.8 million people per year.[48] In the 100% clean, renewable energy world, these 4.5-7.8 million deaths per year are avoided entirely because the air pollution from fossil fuels is eliminated. If avoiding human deaths and protecting human life, including Plaintiffs', is the goal, the choice cannot be clearer.

Electric Vehicles Should Be Supported To Reduce Pollution and Energy Needs

36. Supporting battery electric vehicles (BEVs) is crucial to reducing pollution and energy consumption. At the most basic level, this is because BEVs are much more efficient in their use of energy than fossil-fuel powered vehicles with an internal combustion engine (ICE). BEVs use about 80% of the energy in their battery-stored electricity to move the vehicle, losing only 20% of the energy as heat

[47] Mark Z. Jacobson et al., *Energy, Health, and Climate Costs of Carbon-Capture and Direct-Air-Capture Versus 100%-Wind-Water-Solar Climate Policies in 149 Countries*, 59 Env't Science Technology 3034 (2025).

[48] The range in deaths reflects whether the energy to power carbon dioxide capture and storage comes clean, renewable energy (lower number of deaths) or from fossil fuels (higher number of deaths).

(Figure 5). In an ICE vehicle, only about 17-20% of the energy in the fuel goes toward vehicle movement, whereas more than 80% of the energy is lost as heat (Figure 5). Thus, it takes an ICE car 3.2 to 5.3 times more energy in gasoline than a BEV needs in electricity from the plug to travel the same distance.

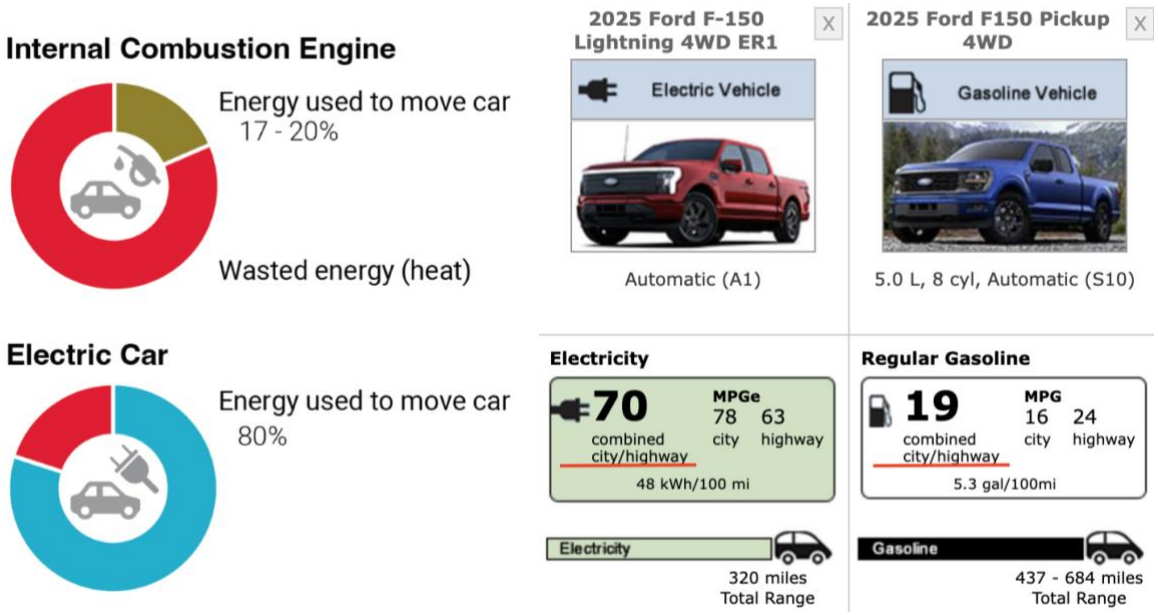


Figure 5. A comparison between an ICE and electric vehicle efficiency (left) and a fossil fuel and electric Ford F150 Pickup (right).[49] *The electric F150 is 3.7 times more efficient than its fossil fuel counterpart.*

37. I provide above a concrete example of the much higher BEV efficiency over a comparable ICE vehicle from the U.S. Department of Energy (Figure 5).[50] The Ford F150 is one the most popular pickup trucks in the United States and is offered as both electric and ICE models. The electric F150 goes 3.7 times the

[49] https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=48705&id=48896
[50] https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=48705&id=48896

distance on the same amount of energy in electricity as the fossil fuel ICE version goes on the same amount of energy in gasoline.

Defendants EOs Slow the Ability of Renewable Energy to Supplant Fossil Fuels

38. Not only do Defendants EOs that are being challenged in this case explicitly "eliminate the electric vehicle (EV) mandate," "terminat[e]" "state emissions waivers that function to limit sales of gasoline-powered automobiles," and "pause the disbursement of funds appropriated through the Inflation Reduction Act of 2022 (Public Law 117-169) or the Infrastructure Investment and Jobs Act (Public Law 117-58), including but not limited to funds for electric vehicle charging stations made available through the National Electric Vehicle infrastructure Formula Program and the Charging and Fueling Infrastructure Discretionary Grant Program," EO 14154, but the Defendants are implementing the EOs to stop renewable energy opportunities.

39. For example, I have reviewed the U.S. DOE's FY Congressional Justification Budget in Brief prepared in May 2025,[51] which "unleashes America's energy dominance through funding for nuclear energy and fossil energy." The Budget in Brief states that "[u]tilizing the Nation's energy resources of coal, natural gas, petroleum, and nuclear, stimulates the economy and builds a foundation for

[51] https://web.archive.org/web/20250603144257/https://www.energy.gov/sites/default/files/2025-05/doe-fy-2026-bib-v4.pdf

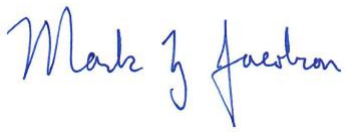
future growth and will allow us to unleash America's energy dominance." Although DOE purports to "take advantage of abundant domestic resources to promote competitiveness across industries," by providing "$595 million for the Office of Fossil Energy, restoring the office's central function of supporting the production of fossil energy, including coal, oil, gas, and critical minerals for the U.S.," the proposed budget drastically slashes the budget for energy efficiency and renewable energy programs by 74.3%, with renewable energy grid integration, wind energy, and solar energy getting zero dollars. At all costs, the Executive Orders prioritize fossil fuels over renewable sources of energy, even though the latter are cheaper, safer, and more abundant.

Conclusion

40. The United States is not in an "energy emergency" but is in a climate emergency that will only be worsened by the White House's Executive Orders that are being challenged in this case. Fossil fuels are not needed to meet energy needs in the United States or abroad and they can be replaced by clean, renewable energy alternatives, which are readily available and provide significant cost-saving and economic benefits to the United States and its citizens. The Defendants' Executive Orders would cause serious and unnecessary harm by significantly increasing localized air pollution, climate change impacts and energy costs, with serious consequences for young Americans, such as the Plaintiffs in this case, who will

suffer the most adverse consequences from actions taken to lock-in the use of fossil fuels.

In accordance with 28 U.S.C. § 1746, I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct. Executed on June 10, 2025 at Stanford, California.



Mark Z. Jacobson

EXHIBIT A

Mark Z. Jacobson Curriculum Vitae June 9, 2025

Department of Civil & Environmental Engineering
Stanford University, Stanford, CA 94305-4020, USA

Academic Degrees

Stanford University, Stanford, CA; Civil Engineering B.S., with distinction, 1988
Stanford University, Stanford, CA; Economics B.A., with distinction, 1988
Stanford University, Stanford, CA; Environmental Engineering M.S., 1988
UCLA, Los Angeles, CA; Atmospheric Sciences M.S., 1991
UCLA, Los Angeles, CA; Atmospheric Sciences Ph.D., 1994

Professional Appointments

Stanford University Civil & Environmental Engineering Professor, 2007-present
Stanford University Civil & Environmental Engineering Associate Professor, 2001-2007
Stanford University Civil & Environmental Engineering Assistant Professor, 1994-2001
Stanford University Atmosphere/Energy Program Director/co-founder, 2004-present

Teaching, Mentoring, and Research

Mark Z. Jacobson's career has focused on better understanding air pollution and climate problems and developing clean, renewable energy solutions to them. Toward that end, he has developed and applied three-dimensional (3-D) atmosphere-biosphere-ocean computer models and solvers to simulate and understand air pollution, weather, climate, and renewable energy resources. He has also developed a computer model to simulate grid stability in the presence of 100% renewable energy and roadmaps to transition countries, states, and cities to 100% clean, renewable energy for all energy purposes.

Jacobson has been a professor at Stanford University since 1994. His research and teaching cross two fields: Atmospheric Sciences and Energy. In his 31 years at Stanford, Jacobson has developed five courses that he has taught among 85 academic quarters to 4,000 undergraduate and graduate students. He also developed two online courses (XEIET 100 and 200) reached by thousands of distance learners. In 2004, Jacobson founded and has ever since directed the Atmosphere/Energy Program at Stanford, which has graduated about 600 MS, BS, and PhD students. Jacobson himself has advised 25 Ph.D. students, hundreds of M.S. students, and dozens of undergraduate students. For four of Jacobson's five courses, he has written textbooks to guide student learning. His first book was *Fundamentals of Atmospheric Modeling* (1999) (second edition in 2005) used in two courses: Numerical Weather Prediction and Air Pollution Modeling. For a third more general course, Air Pollution and Global Warming, he wrote *Atmospheric Pollution: History, Science, and Regulation* (2002) (second edition in 2012). In 2020, he wrote *100% Clean, Renewable Energy and Storage for Everything* for a course of the same name. Since then, he has written two more energy-related layman's books, *No Miracles Needed* (2023) and *Still No Miracles Needed* (2025). Thus, he has written seven books/editions, all geared toward educating students and/or the public.

Jacobson has published 187 peer-reviewed journal articles (47,683 citations as of 6/9/25 from Google Scholar) and given ~750 invited talks. Based on the impact of his research through citations, in 2022, he was ranked the most impactful scientist in the world in the field of Meteorology & Atmospheric Sciences among those first publishing past 1985 (Ioannidis, J.P.A., Elsevier Data Repository, V5, Nov. 3, 2022, doi: 10.17632/btchxktzyw.5). In Energy, he was ranked #6 among those first publishing past 1980. His work in both fields is summarized next.

Atmospheric Sciences

Jacobson started computer modeling in 1990. He developed over 85% of the computer code for the world's first 3-D urban air pollution model coupled, with feedback, to meteorology. He then developed the first coupled 3-D global air pollution-weather-climate model and first unified nested global-through-urban air pollution-weather-climate model, GATOR-GCMOM. Zhang (2008) calls Jacobson's unified model "*the first fully-coupled online model in the history that accounts for all major feedbacks among major atmospheric processes based on first principles*." Many features in GATOR-GCMOM are now mainstream in other models worldwide. For his models, he coded the world's fastest (at the time) ordinary differential equation solver in a 3-D model for a given level of accuracy (SMVGEAR). He also

developed solvers for aerosol particle and cloud particle coagulation, condensation/evaporation, freezing, dissolution, chemical equilibrium, breakup, and lightning; air-sea exchange; ocean chemistry; greenhouse gas radiation absorption; and land-surface processes. Thousands of researchers have used his computer codes.

In 2000 and 2001, Jacobson applied his model to discover that black carbon, the main component of soot air pollution particles, may be the second-leading cause of global warming in terms of radiative forcing, after carbon dioxide. Several subsequent studies, including the highly-cited review by Bond et al. (2013), confirmed his finding. Jacobson's finding about black carbon's climate effects resulted in his invitation to testify to the U.S. House of Representatives in 2007 and formed the original scientific basis for several proposed laws and policies. These included U.S. Senate Report 110-489 (Black Carbon Research Bill of 2008), U.S. House Bill 7250 (Arctic Climate Preservation Act of 2008), U.S. House Bill 1760 (Black Carbon Emissions Reduction Act of 2009), U.S. Senate Bill 849 (2009 Bill for the U.S. EPA to research black carbon), U.S. Senate Bill 3973 (Diesel Emission Reduction Act of 2010), European Parliament Resolution B7-0474/2011 (Resolution calling for black carbon controls on climate grounds), the 2012 multi-country Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants, California Senate Bill 1383 (2016 Bill to reduce black carbon), and California's 2002 rule to not allow diesel vehicles to have higher particle emissions than gasoline vehicles.

For his black carbon discovery and modeling, Jacobson received the 2005 American Meteorological Society Henry G. Houghton Award, given for his "*significant contributions to modeling aerosol chemistry and to understanding the role of soot and other carbon particles on climate*" and a 2013 American Geophysical Union Ascent Award for "*his dominating role in the development of models to identify the role of black carbon in climate change*."

Jacobson's 2008 and 2010 findings that carbon dioxide domes over cities have enhanced air pollution mortality through its feedback to particles and ozone resulted in another invitation for him to testify in the U.S. House of Representatives in 2008 and to testify twice in U.S. Environmental Protection Agency (EPA) hearings. In the first EPA hearing he was called as the State of California's only expert witness to testify on how carbon dioxide can damage health locally by increasing temperatures and water vapor. This testimony served as a direct scientific basis for the EPA's 2009 approval of the first regulation in U.S. history of carbon dioxide (the California waiver). The U.S. Supreme Court refused to hear a challenge by several states to the waiver in December, 2024.

Energy

With respect to energy, in 2001 Jacobson published a paper in *Science* examining the ability of the U.S. to convert a large fraction of its energy to wind. In 2005, his group developed the first world wind map based on data alone. His students and he subsequently published on the impacts of hydrogen fuel cell vehicles on air quality and climate, on reducing the variability of wind energy by interconnecting wind farms; on integrating solar, wind, geothermal, and hydroelectric power into the grid; on integrating offshore wind and wave power; on comparing ethanol with gasoline; and on mapping U.S. offshore wind resources.

In 2008, he carried out a review of proposed energy technologies to address air pollution, global warming, and energy security, concluding that wind-water-solar (WWS) technologies resulted in the greatest benefits. In 2009, he coauthored a plan, featured on the cover of *Scientific American*, to determine if powering the world for all purposes with WWS was possible. In 2010, he was invited to participate in a TED debate. From 2010-2012, he served on the Energy Efficiency and Renewables advisory committee to the U.S. Secretary of Energy. In 2011, he co-founded The Solutions Project non-profit, which combined science, business, culture, and community, to educate people of all ages about science-based 100% clean, renewable energy roadmaps for 100% of the people.

In 2013, 2014, and 2016, he and his students and colleagues developed roadmaps to transition New York, California, and Washington State, respectively, to 100% WWS. Jacobson's New York energy roadmap resulted in an invitation for him to appear on the Late Show with David Letterman on October 9, 2013. Jacobson was then asked by the New York governor's office to provide more information about a possible transition of New York to 100% WWS. In 2016, the governor proposed and passed a 50% renewable law (the New York Clean Energy Standard). Also in 2016, and in 2018, the New York Senate proposed New York Senate Bills S5527 and S5908A, respectively, for the state to go to 100% renewable electricity. The texts of both bills state, "*This bill builds upon the Jacobson wind, water and solar (WWS) study*." In 2019, New York State implemented Jacobson's goal for the electricity sector by passing a law to go

to 100% renewable electricity. Similarly, on October 27, 2014, after the publication of Jacobson's California WWS roadmap, the California governor's office invited Jacobson to meet with the governor's policy advisors to discuss the roadmap. In January, 2015, the governor proposed and, shortly after, obtained passage of a law (SB 350) for California to move to 50% renewable electricity. In 2018, this law was updated for the state to go to 100% renewable electricity (SB 100).

In 2015, Jacobson and his group published WWS plans for all 50 states and a continental-U.S.-wide grid study assuming 100% WWS. The grid paper earned Jacobson and his coauthors a 2016 Cozzarelli Prize from the *Proceedings of the National Academy of Sciences*, given for "*outstanding scientific excellence and originality*." The plans and grid study were updated for the 50 U.S. states and individual U.S. regions in 2022. The publication of these roadmaps, together with their dissemination by the Solutions Project and dozens of other nonprofits, resulted in the widespread awareness of Jacobson's plans and the growth of the 100% renewable energy movement. Jacobson's science-based plans resulted in all three Democratic presidential candidates for the 2016 election making 100% renewable energy part of their platforms. Senator Sanders included Jacobson's roadmaps on his web site and, after the election, wrote an op-ed with Jacobson in the Guardian calling for a transition to 100% renewables.

People inspired by Jacobson's plans encouraged 19 U.S. states (CA, CT, HI, IL, ME, MI, MN, NC, NE, NJ, NM, NV, NY, OR, RI, VA, VT, WA, WI), the District of Columbia, and Puerto Rico to pass laws or Executive Orders requiring up to 100% clean, renewable electricity. Eight U.S. federal laws or resolutions were also proposed calling the U.S. to move to 100% renewable electricity or all energy. These included House Resolution 540 (2015), House Bill 3314 (2017), House Bill 3671 (2017), House Bill 330 (2019); Senate Resolution 632 (2019), Senate Bill 987 (2019), House Resolution 109 (2019), and Senate Resolution 59 (2019). All were inspired by Jacobson's plans. For example, the first, House Resolution 540, states: "*Whereas a Stanford University study concludes that the United States energy supply could be based entirely on renewable energy by the year 2050 using current technologies*."

House Resolution 109 and Senate Resolution 59 are the proposed U.S. *Green New Deal*. As stated by Dr. Marshall Shepherd, "*Professor Mark Jacobson at Stanford University has been a longtime leader in climate science and renewable energy transition. Many of the assumptions in the Green New Deal seem to be anchored in his scholarship*." The main goals of the Green New Deal, to transition the U.S. to 100% renewable energy by 2030, came from Jacobson and Delucchi's 2009 *Scientific American* paper.

In 2009 and 2011, Jacobson developed plans to transition the world to 100% WWS. In 2017-2018, he developed more detailed plans and grid studies for 139 countries. These were updated for 143 countries in 2019, 145 countries in 2022, and 149 countries in 2024. Jacobson has also published 100% WWS plans for 53 towns and cities (2018) and 74 metropolitan areas (2020). The Sierra Club used these and his state plans to encourage cities to adopt 100% renewable laws. Ultimately 200 U.S. cities and counties enacted policies to transition to 100% renewable electricity. Also, 442 international companies have committed to 100% renewables in their global operations.

In 2023, Jacobson served as an expert witness on behalf of 16 youth plaintiffs in the first climate case in U.S. history, *Held v. Montana*, to discuss Montana's ability to transition to WWS. The plaintiffs prevailed, and the Montana Supreme Court upheld the ruling on December 18, 2024. In 2024, Jacobson served as an expert witness on behalf of 13 youth plaintiffs in *Navahine v. State of Hawai'i*, which was the world's first climate case to reach a settlement, in this case requiring the state effectively to electrify most land, sea, and inter-island air transportation.

For his research and leadership in Energy, Jacobson received the 2013 Global Green Policy Design Award for the "*design of analysis and policy framework to envision a future powered by renewable energy*." In 2016, he received a Cozzarelli Prize. In 2018, he received the Judi Friedman Lifetime Achievement Award "For a distinguished career dedicated to finding solutions to large-scale air pollution and climate problems." In 2019 and 2022, he was selected as "one of the world's 100 most influential people in climate policy" by *Apolitical*. In 2022, he was recognized as "World Visionary CleanTech Influencer of the Year" by the *CleanTech Business Club*. In 2023, he was named by *Worth Magazine* as one of the top 100 people globally "who have made an impact on the world this year" among "innovators across various industries, including art, entertainment, business, and philanthropy. In 2025, he was named one of 10 "clean energy leaders to know and follow" worldwide by *Climate Insider*.

Peer-Reviewed Journal Articles and Books

Peer-Reviewed Papers Since 1990 (187 Total)

2025

1. Jacobson, M.Z., D. Fu, D.J. Sambor, and A. Mühlbauer, Energy, health, and climate costs of carbon-capture and direct-air-capture versus 100%-wind-water-solar climate policies in 149 countries, *Environmental Science & Technology, 59,* 3034-3045 doi:10.1021/acs.est.4c10686, 2025. https://web.stanford.edu/group/efmh/jacobson/Articles/I/149Country/149-Countries.pdf

2. Jacobson, M.Z., D.J. Sambor, Y.F. Fan, A. Mühlbauer, and M.A. Delucchi, No blackouts or cost increases due to 100% clean, renewable electricity powering California for parts of 98 days, *Renewable Energy, 240*, 122262, doi:10.1016/j.renene.2024.122262, 2025. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/25-CaliforniaWWS.pdf

2024

3. Jacobson, M.Z., D.J. Sambor, Y.F. Fan, and A. Mühlbauer, Effects of firebricks for industrial process heat on the cost of matching all-sector energy demand with 100% wind-water-solar supply in 149 countries, *PNAS Nexus*, *3*, pgae274, doi:10.1093/pnasnexus/pgae274, 2024. https://academic.oup.com/pnasnexus/advance-article/doi/10.1093/pnasnexus/pgae274/7710221
4. Jacobson, M.Z., Batteries or hydrogen or both for grid electricity storage upon full electrification of 145 countries with wind-water solar? *iScience*, *27*, 108988, doi:10.1016/j.isci.2024.108988, 2024. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/24-GridH2.pdf
5. Mayer, A.C.R., J. Mayer, M. Wyser, F. Legerer, J. Czerwinski, T.W. Lutz, T.V. Johnson, and M.Z. Jacobson, Particulate filters for combustion engines to mitigate global warming. Estimating the effects of a highly efficient but underutilized tool, *Emission Control Science and Technology*, *10*, 10-21, doi:10.1007/s40825-023-00236-x, 2024. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/24-Mayer-Filters.pdf
6. Von Krauland, A.K., P. Enevoldsen, and M.Z. Jacobson, India onshore wind energy atlas accounting for altitude, land use restrictions, and co-located solar, *Cell Reports Sustainability*, 1, 100083, doi:10.1016/j,crsus.2024.100083, 2024. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/24-IndiaWind.pdf

2023

7. Jacobson, M.Z., Should transportation be transitioned to ethanol with carbon capture and pipelines or electricity? A case study, *Environmental Science and Technology*, 57, 16,843-16,850, doi:10.1021/acs.est.3c05054, 2023. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/23-E85vBEVs.pdf
8. Jacobson, M.Z., A.-K. von Krauland, K. Song, and A.N. Krull, Impacts of green hydrogen for steel, ammonia, and long-distance transport on the cost of meeting electricity, heat, cold, and hydrogen demand in 145 countries running on 100% wind-water-solar, *Smart Energy*, *11*, 100106, doi:10.1016/j.segy.2023.100106, 2023. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/23-NonEnergyH2.pdf
9. Sambor, D.J., H. Penn, and M.Z. Jacobson, Energy optimization of a food-energy-water microgrid living laboratory in Yukon, Canada, *Energy Nexus Journal*, 10, 100200, doi.org/10.1016/j.nexus.2023.100200, 2023. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/23-YukonMicrogrid.pdf
10. Von Krauland, A.K., Q. Long, P. Enevoldsen, and M.Z. Jacobson, United States offshore wind energy atlas: availability, potential, and economic insights based on wind speeds at different altitudes and thresholds and policy-informed exclusions, *Energy Conversion and Management*, 20, 100410, doi:10.1016/j.ecmx.2023.100410, 2023. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/23-USOffshoreAtlas.pdf

2022

11. Jacobson, M.Z., A.-K. von Krauland, S.J. Coughlin, E. Dukas, A.J.H. Nelson, F.C. Palmer, and K.R. Rasmussen, Low-cost solutions to global warming, air pollution, and energy insecurity for 145 countries, *Energy and Environmental Sciences*, *15*, 3343-3359, doi:10.1039/d2ee00722c, 2022. https://web.stanford.edu/group/efmh/jacobson/Articles/I/145Country/22-145Countries.pdf

12. Jacobson, M.Z., A.-K. von Krauland, S.J. Coughlin, F.C. Palmer, and M.M. Smith, Zero air pollution and zero carbon from all energy at low cost and without blackouts in variable weather throughout the U.S. with 100% wind-water-solar and storage, *Renewable Energy*, *184*, 430-444, doi:10.1016/j.renene.2021.11.067, 2022. https://web.stanford.edu/group/efmh/jacobson/Articles/I/21-USStates-PDFs/21-USStatesPaper.pdf
13. Breyer, C., S. Khalili, D. Bogdanov, M. Ram, A.S. Oyewo, A. Aghahosseini[1], A. Gulagi[1], A.A. Solomon, D. Keiner, G. Lopez, P.A. Østergaard, H. Lund, B.V. Mathiesen, M.Z. Jacobson, M. Victoria, S. Teske, T. Pregger, V. Fthenakis, M. Raugei, H. Holttinen, U. Bardi, A. Hoekstra, and B.K. Sovacool, On the history and future of 100% renewable energy systems research, *IEEE Access*, 10, 78,176-78,218, doi: 10.1109/ACCESS.2022.3193402, 2022. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/22-100PctRE-History.pdf
14. Katalenich, S.M., and M.Z. Jacobson, Toward battery electric and hydrogen fuel cell military vehicles for land, air, and sea, *Energy*, 254, 124355, doi:10.1016/j.energy.2022.124355, 2022. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/22-BEH2Vehicles.pdf
15. Sambor, D.J., S.C.M. Bishop, A. Dotson, S. Aggarwal, and M.Z. Jacobson, Optimizing demand response of a modular water reuse system in a remote Arctic microgrid, *J. Cleaner Production*, 346, 131110, doi.org/10.1016/j.jclepro.2022.131110, 2022. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/22-WaterReuseArctic.pdf

2021

16. Jacobson, M.Z., The cost of grid stability with 100% clean, renewable energy for all purposes when countries are isolated versus interconnected, *Renewable Energy*, 179, 1065-1075, doi:10.1016/j.renene.2021.07.115, 2021. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/21-CountriesVRegions.pdf
17. Jacobson, M.Z., On the correlation between building heat demand and wind energy supply and how it helps to avoid blackouts, *Smart Energy, 1,* 100009*,* doi:10.1016/j.segy.2021.100009, 2021. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/21-Wind-Heat.pdf
18. Enevoldsen, P., and M.Z. Jacobson, Data investigation of installed and output power densities of onshore and offshore wind turbines worldwide, *Energy for Sustainable Development*, 60, 40-51, 2021. https://web.stanford.edu/group/efmh/jacobson/Articles/I/WindSpacing.pdf
19. Howarth, R.W., and M.Z. Jacobson, How green is blue hydrogen? *Energy Science and Engineering*, 9, 1676-1687, https://doi.org/10.1002/ese3.956, 2021. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/21-GreenVsBlueH2.pdf
20. Katalenich, S.M., and M.Z. Jacobson, Renewable energy and energy storage to offset diesel generators at expeditionary contingency bases, *Journal of Defense Modeling and Simulation,* 1-15, doi:10.1177/15485129211051377, 2021. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/21-REforFOBs.pdf
21. von Krauland, A.-K., F.-H. Permien, P. Enevoldsen, and M.Z. Jacobson, Onshore wind energy atlas for the United States accounting for land use restrictions and wind speed thresholds, *Smart Energy*, 3, 100046, doi:10.1016/j.segy.2021.100046, 2021. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/21-USWindAtlas.pdf

2020

22. Jacobson, M.Z., A.-K. von Krauland, Z.F.M. Burton, S.J. Coughlin, C. Jaeggli, D. Nelli, A.J.H. Nelson, Y. Shu, M. Smith, C. Tan, C.D. Wood, and K.D. Wood, Transitioning all energy in 74 metropolitan areas, including 30 megacities, to 100% clean and renewable wind, water, and sunlight, *Energies*, 13, 4934, doi:10.3390/en13184934, 2020. https://web.stanford.edu/group/efmh/jacobson/Articles/I/Megacities.pdf
23. Sambor, D.J., M. Wilber, E. Whitney, and M.Z. Jacobson, Development of a tool for optimizing solar and battery storage for container farming in a remote Arctic microgrid, *Energies*, 13, 5143, doi:10.3390/en13195143, 2020. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/20-ArcticMicrogrid.pdf
24. Wu, Xiawei, W. Hu, Q. Huang, C. Chen, M.Z. Jacobson, and Z. Chen, Optimizing the layout of onshore wind farms to minimize noise, *Applied Energy*, 267, 114896, doi:10.1016/j.apenergy.2020.114896, 2020. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/20-Wu-AppliedEnergy
25. Xu, X., W. Hu , D. Cao, Q Huang, W. Liu, M. Z. Jacobson, and Z. Chen, Optimal operational strategy for an offgrid hybrid hydrogen/electricity refueling station powered by solar photovoltaics, *J. Power Sources*, 451, 227810, doi:10.1016/j.jpowsour.2020.227810, 2020. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/20-Xu-JPowSour.pdf

26. Zhan, S., P. Hou, P. Enevoldsen, G. Yang, J. Zhu, J. Eichman, and M.Z. Jacobson, Co-optimized trading of hybrid wind power plant with retired EV batteries in energy and reserve markets under uncertainties, *Elec. Power and Energy Systems*, *117*, 105631, doi:10.1016/j.ijepes.2019.105631, 2020. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/19-Hou-JEPES.pdf

2019

27. Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, S.J. Coughlin, C. Hay, I.P. Manogaran, Y. Shu, and A.-K. von Krauland, Impacts of Green New Deal energy plans on grid stability, costs, jobs, health, and climate in 143 countries, *One Earth,* 1, 449-463, doi:10.1016/j.oneear.2019.12.003, 2019. https://web.stanford.edu/group/efmh/jacobson/Articles/I/143WWSCountries.pdf
28. Jacobson, M.Z., S.V. Nghiem, A. Sorichetta, Short-term impacts of the mega-urbanizations of New Delhi and Los Angeles between 2000 and 2009, *J. Geophys Res*., *124*, 35-56, doi:10.1029/2018JD029310, 2019, https://web.stanford.edu/group/efmh/jacobson/Articles/Others/19-NewDelhiLA.pdf
29. Jacobson, M.Z., The health and climate impacts of carbon capture and direct air capture, *Energy and Environmental Sciences*, *12*, 3567-3574, doi:10.1039/C9EE02709B, 2019. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/19-CCS-DAC.pdf
30. Jacobson, M.Z., Short-term impacts of the Aliso Canyon natural gas blowout on weather, climate, air quality, and health in California and Los Angeles, *Environmental Science & Technology*, *53*, 6081-6093, doi:10.1021/acs.est.9b01495, 2019. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/19-Aliso.pdf
31. Enevoldsen, P., F.-H. Permien, I. Bakhtaoui, A.-K. von Krauland, M.Z. Jacobson, G. Xydis, B.K. Sovacool, S.V. Valentine, D. Luecht, and G. Oxley, How much wind power potential does Europe have? Examining European wind power potential with an enhanced socio-technical Atlas, *Energy Policy*, *132*, 1092-1100, doi:10.1016/j.enpol.2019.06.064, 2019. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/19-EuropeWind.pdf

2018

32. Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, and B.V, Mathiesen, Matching demand with supply at low cost among 139 countries within 20 world regions with 100% intermittent wind, water, and sunlight (WWS) for all purposes, *Renewable Energy*, 123, 236-248, 2018. https://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/WorldGridIntegration.pdf
33. Jacobson, M.Z., M.A. Cameron, E.M. Hennessy, I. Petkov, C.B. Meyer, T.K. Gambhir, A.T. Maki, K. Pfleeger, H. Clonts, A.L. McEvoy, M.L. Miccioli, A.-K. von Krauland, R.W. Fang, and M.A. Delucchi, 100% clean and renewable wind, water, and sunlight (WWS) all-sector energy roadmaps for 53 towns and cities in North America, *Sustainable Cities and Society*, *42*, 22-37, doi:10.1016/j.scs.2018.06.031, 2018. https://web.stanford.edu/group/efmh/jacobson/Articles/I/TownsCities.pdf
34. Jacobson, M.Z., V. Jadhav, World estimates of PV optimal tilt angles and ratios of sunlight incident upon tilted and tracked PV panels relative to horizontal panels, *Solar Energy*, 169, 55-66, 2018. https://web.stanford.edu/group/efmh/jacobson/Articles/I/TiltAngles.pdf
35. Cebulla, F., and M.Z. Jacobson, Alternative renewable energy scenarios for New York, *Journal of Cleaner Production*, *205*, 884-894, 2018. https://web.stanford.edu/group/efmh/jacobson/Articles/I/NYNuclearVsRenewables.pdf

2017

36. Jacobson, M.Z., M.A. Delucchi, Z.A.F. Bauer, S.C. Goodman, W.E. Chapman, M.A. Cameron, Alphabetical: C. Bozonnat, L. Chobadi, H.A. Clonts, P. Enevoldsen, J.R. Erwin, S.N. Fobi, O.K. Goldstrom, E.M. Hennessy, J. Liu, J. Lo, C.B. Meyer, S.B. Morris, K.R. Moy, P.L. O'Neill, I. Petkov, S. Redfern, R. Schucker, M.A. Sontag, J. Wang, E. Weiner, A.S. Yachanin, 100% clean and renewable wind, water, and sunlight (WWS) all-sector energy roadmaps for 139 countries of the world, *Joule, 1*, 108-121, doi:10.1016/j.joule.2017.07.005, 2017. https://web.stanford.edu/group/efmh/jacobson/Articles/I/CountriesWWS.pdf
37. Cameron, M.A., M.Z. Jacobson, S. R. H. Barrett, H. Bian, C.-C. Chen, S. D. Eastham, A. Gettelman, A. Khodayari, Q. Liang, H. B. Selkirk, N. Unger, D. J. Wuebbles, and X. Yue, An inter-comparative study of the effects of aircraft emissions on surface air quality, *J. Geophys. Res. Atmos., 122*, 8325-8344, doi:10.1002/2016JD025594, 2017. https://web.stanford.edu/group/efmh/jacobson/Articles/VIII/17CameronJGR.pdf
38. Hou, P., P. Enevoldsen, J. Eichman, W. Hu, M.Z. Jacobson, and Z. Chen, Optimizing investments in coupled offshore wind-electrolytic hydrogen storage systems in Denmark, *J. Power Sources, 359*, 186-197,

doi:10.1016/j.jpowsour.2017.05.048, 2017. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/17-Hou-JPowSources.pdf

2016

39. Jacobson, M.Z., M.A. Delucchi, G. Bazouin, M.J. Dvorak, R. Arghandeh, Z. A.F. Bauer, A. Cotte, G.M.T.H. de Moor, E.G. Goldner, C. Heier, R.T. Holmes, S.A. Hughes, L. Jin, M. Kapadia, C. Menon, S.A. Mullendore, E.M. Paris, G.A. Provost, A.R. Romano, C. Srivastava, T.A. Vencill, N.S. Whitney, and T.W. Yeskoo, A 100% wind, water, sunlight (WWS) all-sector energy plan for Washington State, *Renewable Energy*, *86*, 75-88 2016. https://web.stanford.edu/group/efmh/jacobson/Articles/I/WashStateWWS.pdf
40. Brasseur, G.P., M. Gupta, B.E. Anderson, S. Balasubramanian, S. Barrett, D. Duda, G. Fleming, P.M. Forster, J. Fluglestvedt, A. Gettelman, R.N. Halthore, S.D. Jacob, M.Z. Jacobson, A. Khodayari, K.-N. Liou, M.T. Lund, R.C. Miake-Lye, P. Minnis, S. Olsen, J.E. Penner, R. Prinn, U. Schumann, H.B. Selkirk, A. Sokolov, N. Unger, P. Wolfe, H.-W. Wong, D.W. Wuebbles, B. Yi, P. Yang, C. Zhou, Impact of aviation on climate: FAA's Aviation Climate Change Research Initiative, *Bulletin of the American Meteorological Society*, 561-583, doi:10.1175/BAMS-D-13-00089.1, April 2016. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/ACCRI-BAMS-15.pdf
41. Frew, B.A., S. Becker, M.J. Dvorak, G.B. Andresen, and M.Z. Jacobson, Flexibility mechanisms and pathways to a highly renewable U.S. electricity future, *Energy*, *101*, 65-78, 2016. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/16-Frew-Energy.pdf
42. Frew, B.A., and M.Z. Jacobson, Temporal and spatial tradeoffs in power system modeling with assumptions about storage: An application of the POWER model, *Energy*, 117, 198-213, 2016. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/16-Frew-Energy-B.pdf

2015

43. Jacobson, M.Z., M.A. Delucchi, G. Bazouin, Z.A.F. Bauer, C.C. Heavey, E. Fisher, S. B. Morris, D.J.Y. Piekutowski, T.A. Vencill, T.W. Yeskoo, 100% clean and renewable wind, water, sunlight (WWS) all-sector energy roadmaps for the 50 United States, *Energy and Environmental Sciences*, *8*, 2093-2117, doi:10.1039/C5EE01283J, 2015. https://web.stanford.edu/group/efmh/jacobson/Articles/I/USStatesWWS.pdf
44. Jacobson, M.Z., M.A. Delucchi, M.A. Cameron, and B.A. Frew, A low-cost solution to the grid reliability problem with 100% penetration of intermittent wind, water, and solar for all purposes, *Proc. Nat. Acad. Sci*., *112* (*49*), 15,060-15,065 doi: 10.1073/pnas.1510028112, 2015. https://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/CONUSGridIntegration.pdf
45. Jacobson, M.Z., S.V. Nghiem, A. Sorichetta, and N. Whitney, *Ring of impact* from the mega-urbanization of Beijing between 2000 and 2009, *J. Geophys. Res*., *120*, 5740-5756, doi:10.1002/2014JD023008, 2015. https://web.stanford.edu/group/efmh/jacobson/Articles/IV/15-Beijing-Paper-JGR.pdf
46. Becker, S., B.A. Frew, G.B. Andresen, M.Z. Jacobson, S. Schramm, and M. Greiner, Renewable build-up pathways for the U.S.: Generation costs are not system costs, *Energy*, *81*, 437-445, 2015. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/BeckerEnergy15.pdf
47. Boehm, A.B., M.Z. Jacobson, M.J. O'Donnell, M. Sutula, W. Wakefield, and S.B. Weisberg, Ocean acidification science needs for resource managers and users of the North American Pacific coast, *Oceanography*, 28, 170-181, doi:/10.5670/oceanog.2015.40 2015. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/BoehmOceanography15.pdf
48. Morrison, G.M., S. Yeh, A.R. Eggert, C. Yang, J.H. Nelson, Alphabetic: J.B. Greenblatt, R. Isaac, M.Z. Jacobson, J Johnston, D.M. Kammen, A. Mileva, J. Moore, D. Roland-Holst, M. Wei, J.P. Weyant, J.H. Williams, R. Williams, C.B. Zapata, Comparison of low-carbon pathways for California, *Climatic Change*, *131*, 540-557, doi:10.1007/s10584-015-1403-5, 2015. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/15-04-ClimaticChangeLowCarb.pdf

2014

49. Jacobson, M.Z., M.A. Delucchi, A.R. Ingraffea, R.W. Howarth, G. Bazouin, B. Bridgeland, K. Burkhart, M. Chang, N. Chowdhury, R. Cook, G. Escher, M. Galka, L. Han, C. Heavey, A. Hernandez, D.F. Jacobson, D.S. Jacobson, B. Miranda, G. Novotny, M. Pellat, P. Quach, A. Romano, D. Stewart, L. Vogel, S. Wang, H. Wang, L. Willman, T. Yeskoo, A roadmap for repowering California for all purposes with wind, water, and sunlight, *Energy, 73,* 875-889, doi:10.1016/j.energy.2014.06.099, 2014. https://web.stanford.edu/group/efmh/jacobson/Articles/I/CaliforniaWWS.pdf

50. Jacobson, M.Z., Effects of biomass burning on climate, accounting for heat and moisture fluxes, black and brown carbon, and cloud absorption effects, *J. Geophys. Res*., *119*, 8980-9002, doi:10.1002/2014JD021861, 2014. https://web.stanford.edu/group/efmh/jacobson/Articles/VIII/bioburn/14BburnJGR.pdf
51. Jacobson, M.Z., C.L. Archer, and W. Kempton, Taming hurricanes with arrays of offshore wind turbines, *Nature Climate Change*, *4*, 195-200, doi: 10.1038/NCLIMATE2120, 2014. https://web.stanford.edu/group/efmh/jacobson/Articles/I/WindHurricane/HurricTurbPaperNatCC.pdf
52. Becker, S., B.A. Frew, G.B. Andresen, T. Zeyer, S. Schramm, M Greiner, and M.Z. Jacobson, Features of a fully renewable U.S. electricity-system: Optimized mixes of wind and solar PV and transmission grid extensions, *Energy*, *72*, 443-458, doi:10.1016/j.energy.2014.05.067, 2014. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/BeckerEnergy14.pdf
53. Stoutenburg, E.D., N. Jenkins, and M.Z. Jacobson, Variability and uncertainty of wind power in the California electric power system, *Wind Energy*, *17*, 1411-1424, doi:10.1002/we.1640, 2014. https://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/EStoutWindEn13.pdf

2013

54. Jacobson, M.Z., R.W. Howarth, M.A. Delucchi, S.R. Scobies, J.M. Barth, M.J. Dvorak, M. Klevze, H. Katkhuda, B. Miranda, N.A. Chowdhury, R. Jones, L. Plano, and A.R. Ingraffea, Examining the feasibility of converting New York State's all-purpose energy infrastructure to one using wind, water, and sunlight, *Energy Policy*, 57, 585-601, 2013. https://web.stanford.edu/group/efmh/jacobson/Articles/I/NewYorkWWSEnPolicy.pdf
55. Jacobson, M.Z., J.T. Wilkerson, A.D. Naiman, and S.K. Lele, The effects of aircraft on climate and pollution. Part II: 20-year impacts of exhaust from all commercial aircraft worldwide treated individually at the subgrid scale, *Faraday Discussions*, *165,* 369-382*,* doi:10.1039/C3FD00034F, 2013. https://web.stanford.edu/group/efmh/jacobson/Articles/VIII/ContrailPaperPt2.pdf
56. Archer, C.L., and M.Z. Jacobson, Geographical and seasonal variability of the global "practical" wind resources, *Applied Geography, 45*, 119-130, 2013. https://web.stanford.edu/group/efmh/winds/Applied_Geography_practical_wind_2013.pdf
57. Bond, T.C., S.J. Doherty, D.W. Fahey, P.M. Forster, T. Berntsen, O. Boucher, B.J. DeAngelo, M.G. Flanner, S. Ghan, B. Karcher, D. Koch, S. Kinne, Y. Kondo, P.K. Quinn, M.C. Sarofim, M.G. Schultz, M. Schulz, C. Venkataraman, H. Zhang, S. Zhang, N. Bellouin, S.K. Guttikunda, P.K. Hopke, M.Z. Jacobson, J.W. Kaiser, Z. Klimont, U. Lohmann, J.P. Schwarz, D. Shindell, T. Storelvmo, S.G. Warren and C.S. Zender, Bounding the role of black carbon in the climate system: A scientific assessment, *J. Geophys. Res*., *118*, 5380-5552, doi: 10.1002/jgrd.50171, 2013. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/bondJGR2013.pdf
58. Cameron, M.A., M.Z. Jacobson, A.D. Naiman, and S.K. Lele, Effects of plume-scale versus grid-scale treatment of aircraft exhaust photochemistry, *Geophys. Res. Lett., 40*, 5815-5820, 2013. https://web.stanford.edu/group/efmh/jacobson/Articles/VIII/13CameronGRL.pdf
59. Olsen, S.C., G.P. Brasseur, D.J. Wuebbles, S.R.H. Barrett, H. Dang, S.D. Eastham, M.Z. Jacobson, A. Khodayari, H. Selkirk, A. Sokolov, N. Unger, Comparison of model estimates of the effects of aviation emissions on atmospheric ozone and methane, *Geophys. Res. Lett*., *40*, 6004-6009, 2013. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/13OlsenGRL.pdf
60. Zamora, I.R., and M.Z. Jacobson, Measuring and modeling the hygroscopic growth of two humic substances in mixed aerosol particles of atmospheric relevance, *Atmos. Chem. Phys., 13*, 8973-8989, doi:10.5194/acp-13-8973-2013, 2013. https://acp.copernicus.org/articles/13/8973/2013/

2012

61. Jacobson, M.Z., and C.L. Archer, Saturation wind power potential and its implications for wind energy, *Proc. Nat. Acad. Sci*., *109*, 15,679-15,684, doi:10.1073/pnas.1208993109, 2012. https://web.stanford.edu/group/efmh/jacobson/Articles/I/SatWindPot2012.pdf
62. Jacobson, M.Z., J.T. Wilkerson, S. Balasubramanian, W.W. Cooper, Jr., and N. Mohleji, The effects of rerouting aircraft around the Arctic Circle on Arctic and global climate, *Climatic Change*, 115, 709-724, doi:10.1007/s10584-012-0462-0, 2012. https://web.stanford.edu/group/efmh/jacobson/Articles/VIII/PolarReroutingClimChang12.pdf
63. Jacobson, M.Z., Investigating cloud absorption effects: Global absorption properties of black carbon, tar balls, and soil dust in clouds and aerosols, *J. Geophys. Res*., *117*, D06205, doi:10.1029/2011JD017218, 2012. https://web.stanford.edu/group/efmh/jacobson/Articles/VII/CloudAbsorpJGR12.pdf

64. Jacobson, M.Z., and J.E. Ten Hoeve, Effects of urban surfaces and white roofs on global and regional climate, *J. Climate*, *25*, 1028-1044, doi:10.1175/JCLI-D-11-00032.1, 2012. https://web.stanford.edu/group/efmh/jacobson/Articles/IV/HeatIsWhitRoofJClim12.pdf
65. Bahadur, R., L.M. Russell, M.Z. Jacobson, K.A. Prather, A. Nenes, P.J. Adams, and J.H. Seinfeld, Importance of composition and hygroscopicity of BC particles to the effect of BC mitigation on cloud properties: application to California conditions, *J. Geophys. Res*., *117*, D09204, doi:10.1029/2011JD017265, 2012. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2012JGRBahadur.pdf
66. Corcoran, B.A., N. Jenkins, and M.Z. Jacobson, Effects of aggregating electric load in the United States, *Energy Policy*, 46, 399-416, doi:10.1016/j.enpol.2012.03.079, 2012. https://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/CorcoranEnPol12.pdf
67. Dvorak, M.J., B.A. Corcoran, J.E. Ten Hoeve, N.G. McIntyre, and M.Z. Jacobson, U.S. East Coast offshore wind energy resources and their relationship to peak-time electricity demand, *Wind Energy*, 16, 977-997, doi:10.1002/we.1524, 2012. https://web.stanford.edu/group/efmh/jacobson/Articles/I/Offshore/12DvorakEastCoastWindEn.pdf
68. Dvorak, M.J., E.D. Stoutenburg, C.L. Archer, W. Kempton, and M.Z. Jacobson, Where is the ideal location for a U.S. East Coast offshore grid, *Geophys. Res. Lett*., *39*, L06804, doi:10.1029/2011GL050659, 2012. https://web.stanford.edu/group/efmh/jacobson/Articles/I/Offshore/DvorakGRL12.pdf
69. Ginnebaugh, D.L., and M.Z. Jacobson, Coupling of highly explicit gas and aqueous chemistry mechanisms for use in 3-D, *Atmos. Environ*., *62*, 408-415 2012. https://web.stanford.edu/group/efmh/jacobson/Articles/I/GinnebaughAE2012.pdf
70. Ginnebaugh, D.L., and M.Z. Jacobson, Examining the impacts of ethanol (E85) versus gasoline photochemical production of smog in a fog using near-explicit gas- and aqueous-chemistry mechanisms, *Environmental Research Letters*, 7, 045901, doi:10.1088/1748-9326/7/4/045901, 2012. https://web.stanford.edu/group/efmh/jacobson/Articles/I/Ginnebaugh2010.pdf
71. Hart, E.K., E.D. Stoutenburg, and M.Z. Jacobson, The potential of intermittent renewables to meet electric power demand: A review of current analytical techniques, *Proceedings of the IEEE*, *100*, 322-334, doi:10.1109/JPROC.2011.2144951, 2012. https://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/HartIEEE2012.pdf
72. Hart, E.K., and M.Z. Jacobson, The carbon abatement potential of high penetration intermittent renewables, *Energy and Environmental Science*, *5*, 6592-6601, doi:10.1039/C2EE03490E, 2012. https://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/HartEES12Online.pdf
73. Ten Hoeve, J.E., M.Z. Jacobson, and L. Remer, Comparing results from a physical model with satellite and in situ observations to determine whether biomass burning aerosols over the Amazon brighten or burn off clouds, *J. Geophys. Res*., *117*, D08203, doi:10.1029/2011JD016856, 2012. https://web.stanford.edu/group/efmh/jacobson/Articles/VII/ModMeasAmazonCldJGR12.pdf
74. Ten Hoeve, J.E., L.A. Remer, A.L. Correia, and M.Z. Jacobson, Recent shift from forest to savanna burning in the Amazon basin observed from satellite, *Environmental Research Letters*, *7,* 024020, doi:10.1088/1748-9326/7/2/024020, 2012. https://web.stanford.edu/group/efmh/jacobson/Articles/VIII/bioburn/TenHoeveERL12.pdf
75. Ten Hoeve, J.E., and M.Z. Jacobson, Worldwide health effects of the Fukushima Daiichi nuclear accident, *Energy and Environmental Sciences*, *5*, 8743-8757, doi:10.1039/c2ee22019a, 2012. https://web.stanford.edu/group/efmh/jacobson/TenHoeveEES12.pdf

2011

76. Jacobson, M.Z., J.T. Wilkerson, A.D. Naiman, and S.K. Lele, The effects of aircraft on climate and pollution. Part I: Numerical methods for treating the subgrid evolution of discrete size- and composition-resolved contrails from all commercial flights worldwide, *J. Comp. Phys*., 230, 5115-5132, doi:10.1016/j.jcp.2011.03.031, 2011. https://web.stanford.edu/group/efmh/jacobson/Articles/VIII/JCompPhysPt1.pdf
77. Jacobson, M.Z., and M.A. Delucchi, Providing all global energy with wind, water, and solar power, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials, *Energy Policy*, 39, 1154-1169, doi:10.1016/j.enpol.2010.11.040, 2011. https://web.stanford.edu/group/efmh/jacobson/Articles/I/susenergy2030.html
78. Jacobson, M.Z., Numerical Solution to Drop Coalescence/Breakup With a Volume-Conserving, Positive-Definite, and Unconditionally-Stable Scheme, *J. Atmos. Sci*., *68*, 334-346, doi:10.1175/2010JAS3605.1, 2011. https://web.stanford.edu/group/efmh/jacobson/Articles/IX/JASBreakupMZJ2010.pdf

79. Creamean, J.M., A.P. Ault, J.E. Ten Hoeve, M.Z. Jacobson, G.C. Roberts, and K.A. Prather, Measurements of aerosol chemistry during new particle formation events at a remote rural mountain site, *Environ. Sci. Technol.*, *45*, 8208-8216, doi:10.1021/es103692f, 2011. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/CreameanEST.pdf
80. Delucchi, M.Z., and M.Z. Jacobson, Providing all global energy with wind, water, and solar power, Part II: Reliability, System and Transmission Costs, and Policies, *Energy Policy*, 39, 1170-1190, doi:10.1016/j.enpol.2010.11.045, 2011. https://web.stanford.edu/group/efmh/jacobson/Articles/I/DJEnPolicyPt2.pdf
81. Hart, E.K., and M.Z. Jacobson, A Monte Carlo approach to generator portfolio planning and carbon emissions assessments of systems with large penetrations of variable renewables, *Renewable Energy*, *36*, 2278-2286, doi:10.1016/j.renene.2011.01.015, 2011. https://web.stanford.edu/group/efmh/jacobson/Articles/I/CombiningRenew/HartJacRenEnMar11.pdf
82. Ketefian, G.S., and M.Z. Jacobson, A mass, energy, vorticity, and potential enstrophy conserving lateral boundary scheme for the shallow water equations using piecewise linear boundary approximations, *J. Comp. Phys*., *230*, 2751-2793, doi:10.1016/j.jcp2010.11.008, 2011. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/Ketefian_Jacobson_2011.pdf
83. Liang, J., and M.Z. Jacobson, CVPS: An operator solving complex chemical and vertical processes simultaneously with sparse-matrix techniques, *Atmos. Environ*., *45*, 6820-6827, doi:10.1016/j.atmosenv.2010.12.035, 2011. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/OpSparsMat2011.pdf
84. Naiman, A.D., S.K. Lele, and M.Z. Jacobson, Large eddy simulations of contrail development: Sensitivity to initial and ambient conditions over first twenty minutes, *J. Geophys. Res*., *116*, D21208, doi:10.1029/2011JD015806, 2011. https://web.stanford.edu/group/efmh/jacobson/Articles/VIII/NaimanJGR2011JD015806.pdf
85. Stoutenburg, E.K., and M.Z. Jacobson, Reducing offshore transmission requirements by combining offshore wind and wave farms, *IEEE Journal of Oceanic Engineering*, *36*, 552-561, doi:10.1109/JOE.2011.2167198, 2011. https://web.stanford.edu/group/efmh/jacobson/Articles/I/Wind&wave/StoutenburgIEEE11.pdf
86. Ten Hoeve, J.E, L.A. Remer, and M.Z. Jacobson, Microphysical and radiative effects of aerosols on warm clouds during the Amazon biomass burning season as observed by MODIS: impacts of water vapor and land cover, *Atmos. Chem. Phys. 11*, 3021-3036, 2011. https://acp.copernicus.org/articles/11/3021/2011/acp-11-3021-2011.html
87. Whitt, D.B., J.T. Wilkerson, M.Z. Jacobson, A.D. Naiman, and S.K. Lele, Vertical mixing of commercial aviation emissions from cruise altitude to the surface, *Journal of Geophysical Research*, *116*, D14109, doi:1029/2010JD015532, 2011. https://web.stanford.edu/group/efmh/jacobson/Articles/VIII/Whitt2010JD015532.pdf
88. Zamora, I.R., A. Tabazadeh, D.M. Golden, and M.Z. Jacobson, Hygroscopic growth of common organic aerosol solutes, including humic substances, as derived from water activity measurements, *J. Geophys. Res*., *116,* D23207, doi:10.1029/2011JD016067, 2011. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/ZamoraJGR11.pdf

2010

89. Jacobson, M.Z., and D.L. Ginnebaugh, Global-through-urban nested three-dimensional simulation of air pollution with a 13,600-reaction photochemical mechanism, *J. Geophys. Res*., *115*, D14304, doi:10.1029/2009JD013289, 2010. https://web.stanford.edu/group/efmh/jacobson/Articles/V/MCMJacGinnJGR10.pdf
90. Jacobson, M.Z., Short-term effects of controlling fossil-fuel soot, biofuel soot and gases, and methane on climate, Arctic ice, and air pollution health, *J. Geophys. Res., 115*, D14209, doi:10.1029/2009JD013795, 2010. https://web.stanford.edu/group/efmh/jacobson/Articles/VIII/BCClimRespJGR0710.pdf
91. Jacobson, M.Z., The enhancement of local air pollution by urban CO_2 domes, *Environ. Sci. Technol., 44*, 2497-2502, doi:10.1021/es903018m, 2010. https://web.stanford.edu/group/efmh/jacobson/Articles/V/es903018m.pdf
92. Dvorak, M., C.L. Archer, and M.Z. Jacobson, California offshore wind energy potential, *Renewable Energy*, 35, 1244-1254, doi:10.1016/j.renene.2009.11.022, 2010. https://web.stanford.edu/group/efmh/jacobson/Articles/I/Offshore/DvorakRenewEn2010.pdf
93. Ginnebaugh, D.L., J. Liang, and M.Z. Jacobson, Examining the temperature dependence of ethanol (E85) versus gasoline emissions on air pollution with a largely-explicit chemical mechanism**,** *Atmos. Environ., 44,* 1192-1199, doi:10.1016/j.atmosenv.2009.12.024, 2010. https://web.stanford.edu/group/efmh/jacobson/Articles/I/GinnebaughERL2012.pdf

94. Naiman, A.D., S.K. Lele, J.T. Wilkerson, and M.Z. Jacobson, Parameterization of subgrid plume dilution for use in large-scale atmospheric simulations, *Atmos. Chem. Phys*., 10, 2551-2560, 2010. https://acp.copernicus.org/articles/10/2551/2010/acp-10-2551-2010.html
95. Stoutenburg, E.D., N. Jenkins, and M.Z. Jacobson, Power output variations of co-located offshore wind turbines and wave energy converters in California, *Renewable Energy*, *35*, 2781-2791, doi:10.1016/j.renene.2010.04.033, 2010. https://web.stanford.edu/group/efmh/jacobson/Articles/I/Wind&wave/WindWaveStoutenburgRenEn2010.pdf
96. Wilkerson, J.T., M.Z. Jacobson, A. Malwitz, S. Balasubramanian, R. Wayson, G. Fleming, A.D. Naiman, and S.K. Lele, Analysis of emission data from global commercial aviation: 2004 and 2006, *Atmos. Chem. Phys., 10*, 6391-6408, 2010. https://acp.copernicus.org/articles/10/6391/2010/acp-10-6391-2010.html
97. Zhang, Y., P. Liu, X.-H. Liu, B. Pun, C. Seigneur, M.Z. Jacobson, W. Wang, Fine scale modeling of wintertime aerosol mass, number, and size distributions in Central California, *J. Geophys. Res*., *115*, D15207, doi:10.1029/2009JD012950, 2010. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2009JD012950.pdf
98. Zhang, Y., P. Liu, X.-H. Liu, M.Z. Jacobson, P.H. McMurry, F. Yu, S. Yu, and K.L. Schere, A comparative study of homogeneous nucleation parameterizations: 2. Three-dimensional model application and evaluation, *J. Geophys. Res*., *115*, D20213, doi:10.1029/2010JD014151, 2010. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2010JD014151.pdf
99. Zhang, Y., P.H. McMurry, F. Yu, and M.Z. Jacobson, A comparative study of nucleation parameterizations: 1. Examination and evaluation of the formulations, *J. Geophys. Res*., *115*, D20212, doi:10.1029/2010JD014150, 2010. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2010JD014150.pdf

2009

100. Jacobson, M.Z., and M.A. Delucchi, A path to sustainable energy by 2030, *Scientific American*, November 2009. https://web.stanford.edu/group/efmh/jacobson/Articles/I/sad1109Jaco5p.indd.pdf
101. Jacobson, M.Z., Effects of biofuels vs. other new vehicle technologies on air pollution, global warming, land use, and water, *Int. J. Biotechnology*, 11, 14-59, 2009. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/BiofuelFinPapMZJIntJBiotechnol08.pdf
102. Jacobson, M.Z., and D.G. Streets, The influence of future anthropogenic emissions on climate, natural emissions, and air quality, *J. Geophys. Res*., 114, D08118, doi:10.1029/2008JD011476, 2009. https://web.stanford.edu/group/efmh/jacobson/Articles/VII/2009JGRJacStreets.pdf
103. Jacobson, M.Z., Review of solutions to global warming, air pollution, and energy security, *Energy & Environmental Science*, 2, 148-173, doi:10.1039/b809990c, 2009. https://web.stanford.edu/group/efmh/jacobson/Articles/I/ReviewSolGW09.pdf
104. Ketefian, G.S., and M.Z. Jacobson, A mass, energy, vorticity, and potential enstrophy conserving lateral fluid-land boundary scheme for the shallow water equations, *J. Comp. Phys*., *228*, 1-32, doi:10.1016/j.jcp.2008.08.009, 2009. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/Ketefian_Jacobson_2009.pdf
105. Sta. Maria, M.R.V., and M.Z. Jacobson, Investigating the effect of large wind farms on energy in the atmosphere, *Energies*, 2, 816-836, doi:10.3390/en20400816, 2009. https://web.stanford.edu/group/efmh/jacobson/Articles/I/mdpi-1996-1073.2.4.816.pdf
106. Zhang, Y., K. Vijayaraghavan, X. Wen, H.E. Snell, and M.Z. Jacobson, Probing into regional ozone and particulate matter pollution in the United States: Part I. A 1-year CMAQ simulation and evaluation using surface and satellite data, *J. Geophys. Res*., 114, D22304, doi:10.1029/2009JD011898, 2009. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2009JD011898.pdf
107. Zhang, Y., X. Wen, K. Wang, K. Vijayaraghavan, and M.Z. Jacobson, Probing into regional O_3 and particulate matter pollution in the United States: 2. An examination of formation mechanisms through a process analysis technique and sensitivity study, *J. Geophys. Res*., 114, D22305, doi:1029/2009JD011900, 2009. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2009JD011900.pdf

2008

108. Jacobson, M.Z, On the causal link between carbon dioxide and air pollution mortality, *Geophysical Research Letters*, *35*, L03809, doi:10.1029/2007GL031101, 2008. https://web.stanford.edu/group/efmh/jacobson/Articles/V/2007GL031101.pdf
109. Jacobson, M.Z., Effects of wind-powered hydrogen fuel cell vehicles on stratospheric ozone and global climate, *Geophys. Res. Lett*., 35, L19803, doi:10.1029/2008GL035102, 2008. https://web.stanford.edu/group/efmh/jacobson/Articles/I/2008GL035102.pdf

110. Jacobson, M.Z., The short-term effects of agriculture on air pollution and climate in California, *J. Geophys. Res.*, 113, D23101, doi:10.1029/2008JD010689, 2008. https://web.stanford.edu/group/efmh/jacobson/Articles/IV/2008JD010689Ag.pdf
111. Edgerton, S.A, M.C. MacCracken, M.Z. Jacobson, A. Ayala, C.E. Whitman, and M.C. Trexler, Critical review discussion: Prospects for future climate change and the reasons for early action, *Journal of the Air & Waste Management Association, 58*, 1386-1400, 2008. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/10.3155-1047-3289.58.11.1386.pdf
112. Hu, X.-M, Y. Zhang, M.Z. Jacobson, and C.K. Chan, Coupling and evaluating gas/particle mass transfer treatments for aerosol simulation and forecast, *J. Geophys. Res*., 113, D11208, doi:10.1029/2007JD009588, 2008. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2007JD009588.pdf
113. Jiang, Q., J.D. Doyle, T. Haack, M.J. Dvorak, *C.L. Archer*, and M.Z. Jacobson, Exploring wind energy potential off the California coast, *Geophys. Res. Lett*., 35, L20819, doi:10.1029/2008GL034674, 2008. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2008GL034674.pdf

2007

114. Jacobson, M.Z., Effects of ethanol (E85) versus gasoline vehicles on cancer and mortality in the United States, *Environ. Sci. Technol*., *41* (11), 4150-4157, doi:10.1021/es062085v, 2007. https://web.stanford.edu/group/efmh/jacobson/Articles/I/es062085v.pdf
115. Jacobson, M.Z., Y.J. Kaufmann, Y. Rudich, Examining feedbacks of aerosols to urban climate with a model that treats 3-D clouds with aerosol inclusions, *J. Geophys. Res*., 112, D24205, doi:10.1029/2007JD008922, 2007. https://web.stanford.edu/group/efmh/jacobson/Articles/III/2007JD008922.pdf
116. Archer, C.L., and M.Z. Jacobson, Supplying baseload power and reducing transmission requirements by interconnecting wind farms, *J. Applied Meteorol. and Climatology*, 46, 1701-1717, doi:10.1175/2007JAMC1538.1, 2007. https://web.stanford.edu/group/efmh/winds/aj07_jamc.pdf
117. Chen, Y., S. Mills, J. Street, D. Golan, A. Post, M.Z. Jacobson, A. Paytan, Estimates of atmospheric dry deposition and associated input of nutrients to Gulf of Aqaba seawater, *J. Geophys. Res*., *112*, D04309, doi:10.1029/2006JD007858, 2007. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2006JD007858.pdf
118. Kempton, W., C.L. Archer, A. Dhanju, R.W. Garvine, and M.Z. Jacobson, Large CO_2 reductions via offshore wind power matched to inherent storage in energy end-uses, *Geophys. Res. Lett*., 34, L02817, doi:10.1029/2006GL028016, 2007. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2006GL028016.pdf

2006

119. Jacobson, M.Z., Effects of externally-through-internally-mixed soot inclusions within clouds and precipitation on global climate, *J. Phys. Chem*., *110*, 6860-6873, 2006. https://web.stanford.edu/group/efmh/jacobson/Articles/VII/CloudSootJPChem.pdf
120. Jacobson, M.Z., and Y.J. Kaufmann, Wind reduction by aerosol particles, *Geophys. Res. Lett*., *33*, L24814, doi:10.1029/2006GL027838, 2006. https://web.stanford.edu/group/efmh/jacobson/Articles/III/2006GL027838%201.pdf

2005

121. Jacobson, M.Z., A solution to the problem of nonequilibrium acid/base gas-particle transfer at long time step, *Aerosol Sci. Technol, 39*, 92-103, 2005. https://web.stanford.edu/group/efmh/jacobson/Articles/IX/ASTNoneq.pdf
122. Jacobson, M.Z., A refined method of parameterizing absorption coefficients among multiple gases simultaneously from line-by-line data, *J. Atmos. Sci., 62*, 506-517, 2005. https://web.stanford.edu/group/efmh/jacobson/Articles/IX/JASJacobson05.pdf
123. Jacobson, M.Z., Studying ocean acidification with conservative, stable numerical schemes for nonequilibrium air-ocean exchange and ocean equilibrium chemistry, *J. Geophys. Res., 110,* D07302, doi:10.1029/2004JD005220, 2005. https://web.stanford.edu/group/efmh/jacobson/Articles/IX/2004JD005220.pdf
124. Jacobson, M.Z., *W.G. Colella*, and D.M. Golden, Cleaning the air and improving health with hydrogen fuel cell vehicles, *Science*, *308*, 1901-1905, 2005. https://web.stanford.edu/group/efmh/jacobson/Articles/I/SciencePubHyd.pdf

125. Jacobson, M.Z., D.B. Kittelson, and W.F. Watts, Enhanced coagulation due to evaporation and its effect on nanoparticle evolution, *Environmental Science and Technology*, 39, 9486-9492, 2005. https://web.stanford.edu/group/efmh/jacobson/Articles/II/es0500299.pdf
126. Archer, C.L. M.Z. Jacobson, and F.L. Ludwig, The Santa Cruz eddy. Part I: Observations and statistics, *Mon. Wea. Rev., 133*, 767-782, 2005. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/SCEPart1.pdf
127. Archer, C.L. and M.Z. Jacobson, The Santa Cruz eddy. Part II: Mechanisms of formation, *Mon. Wea. Rev*., 133, 2387-2405, 2005. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/SCEPart2.pdf
128. Archer, C.L. and M.Z. Jacobson, Evaluation of global wind power, *J. Geophys. Res*., 110, D12110, doi:10.1029/2004JD005462, 2005. https://web.stanford.edu/group/efmh/winds/2004jd005462.pdf
129. Colella, W.G., M.Z. Jacobson, and D.M. Golden, Switching to a U.S. hydrogen fuel cell vehicle fleet: The resultant change in emissions, energy use, and global warming gases, *J. Power Sources*, *150*, 150-181, 2005. https://web.stanford.edu/group/efmh/jacobson/Articles/I/JPowerSources2005.pdf
130. Stuart, A.L., and M.Z. Jacobson, A numerical model of the partitioning of trace chemical solutes during drop freezing, *J. Atmos. Chem*., *53*, 13-42, doi:10.1007/s10874-006-0948-0, 2005. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/NumModel2006.pdf

2004

131. Jacobson, M. Z., J. H. Seinfeld, G. R. Carmichael, and D.G. Streets, The effect on photochemical smog of converting the U.S. fleet of gasoline vehicles to modern diesel vehicles, *Geophys. Res. Lett., 31,* L02116, doi:10.1029/2003GL018448, 2004. https://web.stanford.edu/group/efmh/jacobson/Articles/I/DiesNOxTextnew.pdf
132. Jacobson, M.Z., and J.H. Seinfeld, Evolution of nanoparticle size and mixing state near the point of emission, *Atmos. Environ., 38*, 1839-1850, 2004. https://web.stanford.edu/group/efmh/jacobson/Articles/II/HiResAer.pdf
133. Jacobson, M. Z., The short-term cooling but long-term global warming due to biomass burning, *J. Clim., 17* (15), 2909-2926, 2004. https://web.stanford.edu/group/efmh/jacobson/Articles/VIII/bioburn/BburnJClim.pdf
134. Jacobson, M.Z., The climate response of fossil-fuel and biofuel soot, accounting for soot's feedback to snow and sea ice albedo and emissivity, *J. Geophys. Res., 109*, D21201, doi:10.1029/2004JD004945, 2004. https://web.stanford.edu/group/efmh/jacobson/Articles/VIII/SootAlb.pdf
135. Stuart, A. L., and M. Z. Jacobson, Chemical retention during dry-growth riming: A model. *J. Geophys. Res, 109*, D07305, doi:10.1029/2003JD004197, 2004. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2003JD004197
136. Zhang, Y., B. Pun, K. Vijayaraghavan, S.-Y. Wu, C. Seigneur, S. Pandis, M. Jacobson, A. Nenes, and J. H. Seinfeld, Development and application of the model of aerosol dynamics, reaction, ionization, and dissolution (MADRID), *J. Geophys. Res., 109* (D1), D01202, doi:10.1029/2003JD003501, 2004. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2003JD003501.pdf

2003

137. Jacobson, M. Z., Development of mixed-phase clouds from multiple aerosol size distributions and the effect of the clouds on aerosol removal, *J. Geophys. Res., 108* (D8), 4245, doi:10.1029/2002JD002691, 2003. https://web.stanford.edu/group/efmh/jacobson/Articles/IX/cloudaer/CloudAerPap.pdf
138. Archer, C.L. and M. Z. Jacobson, Spatial and temporal distributions of U.S. winds and wind power at 80 m derived from measurements, *J. Geophys. Res., 108* (D9) 4289, doi:10.1029/2002JD002076, 2003. https://web.stanford.edu/group/efmh/winds/2002JD002076.pdf
139. Barth, M. C., S. Sillman, R. Hudman, M. Z. Jacobson, C.-H. Kim, A. Monod, and J. Liang, Summary of the cloud chemistry modeling intercomparison: Photochemical box model simulation, *J. Geophys. Res., 108* (D7) 4214, doi: 10.1029/2002JD002673, 2003. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2002JD002673.pdf
140. Freedman, F., and M. Z. Jacobson, Modification of the standard ε-equation for the stable ABL through enforced consistency with Monin-Obukhov similarity theory, *Bound.-Lay. Meteorol., 106*, 383-410, 2003. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/mzj_blm_final.pdf
141. Fridlind, A. M., and M. Z. Jacobson, Point and column aerosol radiative closure during ACE 1: Effects of particle shape and size, *J. Geophys. Res., 108* (D3) 4094, doi:10.1029/2001JD001553, 2003. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2003_Fridlind_Jacobson.pdf
142. Kreidenweis, S. M., C. Walcek, G. Feingold, W. Gong, M. Z. Jacobson, C.-H. Kim, X. Liu, J. E. Penner, A. Nenes and J. H. Seinfeld, Modification of aerosol mass and size distribution due to aqueous-phase SO_2 oxidation

in clouds: Comparisons of several models, *J. Geophys. Res*., *108* (D7) 4213, doi:10.1029/2002JD002697, 2003. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2002JD002697.pdf

143. Ma, Jianzhong, J. Tang, S.-M. Li, and M. Z. Jacobson, Size distributions of ionic aerosols measured at Waliguan Observatory: Implication for nitrate gas-to-particle transfer processes in the free troposphere, *J. Geophys. Res*., *108*, (D17) 4541, doi:10.1029/2002JD003356, 2003. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2002JD003356.pdf
144. Stuart, A. L., and M. Z. Jacobson, A timescale investigation of volatile chemical retention during hydrometeor freezing: Nonrime freezing and dry growth riming without spreading, *J. Geophys. Res*., *108* (D6), 4178, doi:10.1029/2001JD001408, 2003. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2001JD001408.pdf

2002

145. Jacobson, M. Z., Analysis of aerosol interactions with numerical techniques for solving coagulation, nucleation, condensation, dissolution, and reversible chemistry among multiple size distributions, *J. Geophys. Res., 107* (D19), 4366, doi:10.1029/ 2001JD002044, 2002. https://web.stanford.edu/group/efmh/jacobson/Articles/IX/multdist/multdist.pdf
146. Jacobson, M. Z., Control of fossil-fuel particulate black carbon plus organic matter, possibly the most effective method of slowing global warming*, J. Geophys. Res., 107* (D19), 4410, doi:10.1029/ 2001JD001376, 2002. https://web.stanford.edu/group/efmh/jacobson/Articles/VIII/fossil/fossil.pdf
147. Carmichael, G. R., D. Streets, G. Calori, H. Ueda, M. Amann, M. Z. Jacobson and J. E. Hansen, Changing trends in sulfur emissions in Asia: Implications for acid deposition, air pollution, and climate, *Environmental Sci. Technol., 36*, 4707-4713, 2002. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/es011509c.pdf
148. Freedman, F. R., and M. Z. Jacobson, Transport-dissipation analytical solutions to the E-ε turbulence model and their role in predictions of the neutral ABL, *Bound.-Lay. Meteorol., 102*, 117-138, 2002. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/mzj_blm_final.pdf
149. Moya, M., S. N. Pandis, and M. Z. Jacobson, Is the size distribution of urban aerosols determined by thermodynamic equilibrium? An application to Southern California, *Atmos. Environ*., *36*, 2349-2365, 2002. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/SizeDistAer2001.pdf

2001

150. Jacobson, M.Z., Global direct radiative forcing due to multicomponent anthropogenic and natural aerosols, *J. Geophys. Res., 106*, 1551-1568, 2001. https://web.stanford.edu/group/efmh/jacobson/Articles/VI/GlobForc01.pdf
151. Jacobson, M. Z., Strong radiative heating due to the mixing state of black carbon in atmospheric aerosols, *Nature, 409*, 695-697, 2001. https://web.stanford.edu/group/efmh/jacobson/Articles/VI/nature.pdf
152. Jacobson, M. Z., GATOR-GCMM: A global through urban scale air pollution and weather forecast model. 1. Model design and treatment of subgrid soil, vegetation, roads, rooftops, water, sea ice, and snow, *J. Geophys. Res., 106*, 5385-5401, 2001. https://web.stanford.edu/group/efmh/jacobson/Articles/IX/GATORGCMM101.pdf
153. Jacobson, M. Z., GATOR-GCMM: 2. A study of day- and nighttime ozone layers aloft, ozone in national parks, and weather during the SARMAP field campaign, *J. Geophys. Res., 106*, 5403-5420, 2001. https://web.stanford.edu/group/efmh/jacobson/Articles/V/GATORGCMM201.pdf
154. Jacobson, M. Z., and G. M. Masters, Exploiting wind versus coal, *Science, 293*, 1438-1438, 2001. https://web.stanford.edu/group/efmh/jacobson/Articles/I/energy.pdf
155. Streets, D. G., K. Jiang, X. Hu, J. E. Sinton, X.-Q. Zhang, D. Xu, M. Z. Jacobson, and J. E. Hansen, Recent reductions in China's greenhouse gas emissions, *Science, 294*, 1835-1836, 2001. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/Science-2001-Streets-1835-7.pdf

2000

156. Jacobson, M. Z., A physically-based treatment of elemental carbon optics: Implications for global direct forcing of aerosols, *Geophys. Res. Lett., 27*, 217-220, 2000. https://web.stanford.edu/group/efmh/jacobson/Articles/VI/GlobDirForc.pdf
157. Fridlind, A. M., and M. Z. Jacobson, A study of gas-aerosol equilibrium and aerosol pH in the remote marine boundary layer during the First Aerosol Characterization Experiment (ACE 1), *J. Geophys. Res., 105*, 17,325-17,340, 2000. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2000_Fridlind_Jacobson.pdf
158. Fridlind, A. M., M. Z. Jacobson, V. -M. Kerminen, R. E. Hillamo, V. Ricard, and J.-L Jaffrezo, Analysis of gas-aerosol partitioning in the Arctic: Comparison of size-resolved equilibrium model results with field data, *J.*

Geophys. Res., 105, 19,891-19,904, 2000. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/2000_Fridlind_etal.pdf

159. Liang, J., and M. Z. Jacobson, Comparison of a 4000-reaction chemical mechanism with the Carbon Bond IV and an adjusted Carbon Bond IV-EX mechanism using SMVGEAR II, *Atmos. Environ., 34*, 3015-3026, 2000. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/CompReac2000.pdf
160. Liang, J., and M. Z. Jacobson, Effects of subgrid segregation on ozone production efficiency a chemical model, *Atmos. Environ*., *34*, 2975-2982, 2000. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/EffSubGrid2000.pdf
161. Zhang, Y., C. Seigneur, J. H. Seinfeld, M. Jacobson, S. L. Clegg, and F. Binkowski, A comparative review of inorganic aerosol thermodynamic equilibrium modules: Similarities, differences, and their likely causes, *Atmos. Environ., 34*, 117-137, 2000. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/CompRevAer2000.pdf

1999

162. Jacobson, M. Z., Isolating nitrated and aromatic aerosols and nitrated aromatic gases as sources of ultraviolet light absorption, *J. Geophys. Res., 104*, 3527-3542, 1999. https://web.stanford.edu/group/efmh/jacobson/Articles/III/NitArom99.pdf
163. Jacobson, M. Z., Effects of soil moisture on temperatures, winds, and pollutant concentrations in Los Angeles, *J. Appl. Meteorol., 38*, 607-616, 1999. https://web.stanford.edu/group/efmh/jacobson/Articles/IV/SoilMoist99.pdf
164. Jacobson, M. Z., Studying The effects of calcium and magnesium on size-distributed nitrate and ammonium with EQUISOLV II, *Atmos. Environ., 33*, 3635-3649, 1999. https://web.stanford.edu/group/efmh/jacobson/Articles/IX/EquisolvII.pdf
165. Liang, J., and M. Z. Jacobson, A study of sulfur dioxide oxidation pathways over a range of liquid water contents, pHs, and temperatures, *J. Geophys. Res*., *104*, 13,749-13,769, 1999. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/1999JD900097.pdf
166. Zhang, Y., C. Seigneur, J. H. Seinfeld, M. Z. Jacobson, and F. Binkowski, Simulation of aerosol dynamics: A comparative review of algorithms used in air quality models, *Aerosol Sci. Technol., 31*, 487-514, 1999. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/3972920.pdf

1998

167. Jacobson, M. Z., Improvement of SMVGEAR II on vector and scalar machines through absolute error tolerance control. *Atmos. Environ., 32*, 791–796, 1998. https://web.stanford.edu/group/efmh/jacobson/Articles/IX/TechNote.SMVGEAR.pdf
168. Jacobson, M. Z., Studying the effects of aerosols on vertical photolysis rate coefficient and temperature profiles over an urban airshed, *J. Geophys. Res*., *103*, 10,593-10,604, 1998. https://web.stanford.edu/group/efmh/jacobson/Articles/III/VertPhotJGR98.pdf
169. Tabazadeh, A., M. Z. Jacobson, H. B. Singh, O. B. Toon, J. S. Lin, B. Chatfield, A. N. Thakur, R. W. Talbot, and J. E. Dibb Nitric acid scavenging by mineral and biomass burning aerosols, *Geophys. Res. Lett., 25*, 4185-4188, 1998. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/1998GL900062.pdf

1997

170. Jacobson, M. Z., Development and application of a new air pollution modeling system. Part II: Aerosol module structure and design, *Atmos. Environ*., *31A*, 131–144, 1997. https://web.stanford.edu/group/efmh/jacobson/Articles/III/DevAppModII.pdf
171. Jacobson, M. Z., Development and application of a new air pollution modeling system. Part III: Aerosol-phase simulations, *Atmos. Environ*., *31A*, 587–608, 1997. https://web.stanford.edu/group/efmh/jacobson/Articles/III/AerSimAE97.pdf
172. Jacobson, M. Z., Numerical techniques to solve condensational and dissolutional growth equations when growth is coupled to reversible reactions, *Aerosol Sci. Technol*., *27*, 491–498, 1997. https://web.stanford.edu/group/efmh/jacobson/Articles/IX/NumTech.pdf
173. Lu, R., R. P. Turco, and M. Z. Jacobson, An integrated air pollution modeling system for urban and regional scales. Part I: Structure and performance, *J. Geophys. Res*., *102*, 6063 – 6080, 1997. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/96JD03501.pdf

174. Lu, R., R. P. Turco, and M. Z. Jacobson, An integrated air pollution modeling system for urban and regional scales. Part II: Simulations for SCAQS 1987, *J. Geophys. Res*., *102*, 6081 – 6098, 1997. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/96JD03502.pdf

1996

175. Jacobson, M. Z., R. Lu, R. P. Turco, and O. B. Toon, Development and application of a new air pollution modeling system. Part I: Gas-phase simulations, *Atmos. Environ*., *30B*, 1939–1963, 1996. https://web.stanford.edu/group/efmh/jacobson/Articles/V/DevApAirPol1.pdf
176. Jacobson, M. Z., A. Tabazadeh, and R. P. Turco, Simulating equilibrium within aerosols and non-equilibrium between gases and aerosols, *J. Geophys. Res., 101*, 9079–9091, 1996. https://web.stanford.edu/group/efmh/jacobson/Articles/IX/EquilibPap96.pdf
177. Elliott, S., M. Shen, C. Y. J. Kao, R. P. Turco, and M. Z. Jacobson, A streamlined family photochemistry module reproduces major nonlinearities in the global tropospheric ozone system, *Computers Chem., 20*, 235–259, 1996. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/96-Elliott-ComputChem.pdf
178. Elliott , S., C.-Y. J. Kao, F. Gifford, S. Barr, M. Shen, R. P. Turco, and M. Z. Jacobson, Free tropospheric ozone production after deep convection of dispersing tropical urban plumes, *Atmos. Environ., 30A*, 4263 – 4274, 1996. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/OzProd1996.pdf

1995

179. Jacobson, M. Z., and R. P. Turco, Simulating condensational growth, evaporation, and coagulation of aerosols using a combined moving and stationary size grid, *Aerosol Sci. and Technol., 22*, 73–92, 1995. https://web.stanford.edu/group/efmh/jacobson/Articles/IX/SimConGrid.pdf
180. Jacobson, M. Z., Computation of global photochemistry with SMVGEAR II. *Atmos. Environ., 29A*, 2541-2546, 1995. https://web.stanford.edu/group/efmh/jacobson/Articles/IX/TechNCompGlobSMVGEARII.pdf

1994

181. Jacobson, M. Z., and R. P. Turco, SMVGEAR: A sparse-matrix, vectorized Gear code for atmospheric models, *Atmos. Environ., 28A*, 273-284, 1994. https://web.stanford.edu/group/efmh/jacobson/Articles/IX/SMVGEARgearcode.pdf
182. Jacobson, M. Z., R. P. Turco, E. J. Jensen, and O. B. Toon, Modeling coagulation among particles of different composition and size, *Atmos. Environ., 28A*, 1327–1338, 1994. https://web.stanford.edu/group/efmh/jacobson/Articles/VII/ModCoag.pdf
183. Drdla, K., A. Tabazadeh, R. P. Turco, M. Z. Jacobson, J. E. Dye, C. Twohy, and D. Baumgardner, Analysis of the physical state of one Arctic polar stratospheric cloud based on observations*, Geophys. Res. Lett., 21*, 2475 – 2478, 1994. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/94GL02405.pdf
184. Tabazadeh, A., R. P. Turco, and M. Z. Jacobson, A model for studying the composition and chemical effects of stratospheric aerosols, *J. Geophys. Res., 99*, 12,897 - 12,914, 1994. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/94JD00820.pdf
185. Tabazadeh, A., R. P. Turco, K. Drdla, and M. Z. Jacobson, A study of Type I polar stratospheric cloud formation, *Geophys. Res. Let., 21*, 1619-1622, 1994. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/94GL01368.pdf

1993

186. Elliott, S., R. P. Turco, and M. Z. Jacobson, Tests on combined projection / forward differencing integration for stiff photochemical family systems at long time step, *Computers Chem., 17*, 91–102, 1993. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/TestComp1993.pdf

1990

187. Delitsky, M. L., R. P. Turco, and M. Z. Jacobson, Nitrogen ion clusters in Triton's atmosphere, *Geophys. Res. Lett., 17*, 1725-1728, 1990. https://web.stanford.edu/group/efmh/jacobson/Articles/Others/GL017i010p01725.pdf

Books (7)

Jacobson, M.Z., *Fundamentals of Atmospheric Modeling,* Cambridge University Press, New York, 656 pp., 1999; reprint, 2000. https://web.stanford.edu/group/efmh/jacobson/FAMbook/FAMbook.html

Jacobson, M. Z., *Atmospheric Pollution: History, Science, and Regulation*, Cambridge University Press, New York, 399 pp., 2002. https://web.stanford.edu/group/efmh/jacobson/POLbook/POLbook.html

Jacobson, M.Z., *Fundamentals of Atmospheric Modeling, Second Edition*, Cambridge University Press, New York, 813 pp., 2005. https://web.stanford.edu/group/efmh/jacobson/FAMbook2dEd/index.html

Jacobson, M. Z., *Air Pollution and Global Warming: History, Science, and Solutions*, Cambridge University Press, New York, 375 pp., 2012. https://web.stanford.edu/group/efmh/jacobson/POLbook2/index.html

Jacobson, M.Z., *100% Clean, Renewable Energy and Storage for Everything*, Cambridge University Press, New York, 427 pp., 2020. https://web.stanford.edu/group/efmh/jacobson/WWSBook/WWSBook.html

Jacobson, M.Z., *No Miracles Needed: How Today's Technology can Save our Climate and Clean our Air*, Cambridge University Press, New York, 437 pp., 2023. https://web.stanford.edu/group/efmh/jacobson/WWSNoMN/NoMiracles.html

Jacobson, M.Z., *Still No Miracles Needed: How Today's Technology can Save our Climate and Clean our Air*, Cambridge University Press, New York, in press, 2025. https://web.stanford.edu/group/efmh/jacobson/WWSStillNMN/StillNMN.html

EXHIBIT B

MONTANA FIRST JUDICIAL DISTRICT COURT
LEWIS AND CLARK COUNTY

RIKKI HELD, et al., Plaintiff, v. STATE OF MONTANA, et al., Defendant.	Cause No. CDV-2020-307 **FINDINGS OF FACT, CONCLUSIONS OF LAW, AND ORDER**

PROCEDURAL HISTORY

On March 13, 2020, sixteen Montana youth (collectively Plaintiffs or Youth Plaintiffs) filed a Complaint for Declaratory and Injunctive Relief (Doc. 1) against the State of Montana, the Governor, Montana Department of Environmental Quality, Montana Department of Natural Resources and Conservation, Montana Department of Transportation, and Montana Public Service Commission (collectively Defendants or State). Plaintiffs' Complaint challenged the constitutionality of the State's fossil fuel-based state energy system, which they allege causes and contributes to climate change in violation

268. The State's actions exacerbate anthropogenic climate change and cause further harms to Montana's environment and its citizens, especially its youth. [AH 845:14-846:2; P150].

VIII. THE MEPA LIMITATION PREVENTS FULL REVIEW OF THE TECHNOLOGICALLY AND ECONOMICALLY AVAILABLE ALTERNATIVES TO FOSSIL FUEL ENERGY IN MONTANA.

269. Dr. Mark Jacobson obtained a M.S. in Environmental Engineering, from Stanford University. Dr. Jacobson also obtained both a M.S. and later a Ph.D. in Atmospheric Sciences from UCLA. In 1994, Dr. Jacobson became an Assistant Professor in the Department of Civil & Environmental Engineering at Stanford. Since 2007, he has been a full professor in that Department. Dr. Jacobson was a co-founder and is Director of Stanford's Atmosphere/Energy Program, as well as a Senior Fellow at Stanford's Precourt Institute for Energy, and Stanford's Woods Institute for the Environment. Since 2008, Dr. Jacobson has been Director and Co-founder of The Solutions Project, an organization that utilizes the combined efforts of individuals in the fields of science, business, and culture to accelerate the transition to 100% renewable energy use in the United States. Starting in 1999, Dr. Jacobson began examining clean, renewable energy solutions. In 2015, this research culminated in the development of roadmaps to transition the all-sector energy infrastructures of each of the fifty United States to 100% clean, renewable energy by 2050, which Dr. Jacobson updated in 2022. Dr. Jacobson has published six textbooks of two editions each and over 175 peer-reviewed journal articles. Dr. Jacobson's career has focused on understanding air pollution and global warming problems and developing large-scale clean, renewable energy solutions to those problems. In

this case, Dr Jacobson summarized his research related to Montana and the feasibility of transitioning Montana swiftly from fossil fuels to clean and renewable energy in all sectors by mid-century, where all energy sectors include electricity, transportation, heating/cooling, and industry. Dr. Jacobson is a well-qualified expert, and his testimony was informative and credible.

270. The MEPA Limitation causes the State to ignore renewable energy alternatives to fossil fuels. [MJ 1030:7-1032:24, 1035:9-23, 1069:18-1071:8, 1066:6-17, 1067:10-20; MJ-15, MJ-62, MJ-63; AH 823:15-825:3; P312].

271. Non-fossil fuel-based energy systems across all sectors, including electricity, transportation, heating/cooling, and industry, are currently economically feasible and technologically available to employ in Montana. Experts have already prepared a roadmap for the transition of Montana's all-purpose energy systems (for electricity, transportation, heating/cooling, and industry) to a 100% renewable portfolio by 2050, which, in addition to direct climate benefits, will create jobs, reduce air pollution, and save lives and costs associated with air pollution. [MJ 1030:7-1032:24, 1035:9-23, 1069:18-1071:8, 1066:6-17, 1067:10-20; P312; MJ-15, MJ-62, MJ-63].

272. It is technically and economically feasible for Montana to replace 80% of existing fossil fuel energy by 2030 and 100% by no later than 2050, but as early as 2035. [MJ 1072:4-23, 1100:9-1101:4; P312; MJ-62, MJ-63]. A number of countries around the world with populations far larger than Montana's relied on >95% wind, water, and sunlight (WWS) to power their electricity sectors in 2021. [MJ-44].

273. To replace fossil fuel energy, Montana would need to electrify all energy sectors with existing or near-existing appliances and

machines, and then generate the electricity for all sectors with 100% WWS, namely onshore wind, utility-scale photovoltaics (PV), rooftop PV, geothermal power, and hydroelectric power. [MJ 1043:9-1045:8, 1045:15-1047:10; P312; MJ-12, MJ-15, MJ-18, MJ-19, MJ-20, MJ-29].

274. All-purpose Montana energy in 2050 can be met, for example, in one scenario, with 4.5 gigawatts (GW) of onshore wind, 3 GW of rooftop PV, 2.9 GW of utility-scale PV, 0.17 GW of geothermal electricity, and 2.7 GW of hydropower (which already exists). [MJ 1057:2-1058:15; MJ-29].

275. Converting from fossil fuel energy to renewable energy would eliminate another $21 billion in climate costs in 2050 to Montana and the world. Most noticeable to those in Montana, converting to wind, water, and solar energy would reduce annual total energy costs for Montanans from $9.1 to $2.8 billion per year, or by $6.3 billion per year (69.6% savings). [MJ-39]. The total energy, health, plus climate cost savings, therefore, will be a combined $29 billion per year (decreasing from $32 to $2.8 billion per year), or by 91%. [MJ 1061:20-1063:24; MJ-15, MJ-39, MJ-40, MJ-41, MJ-42].

276. Wind, water, and solar are the cheapest and most efficient form of energy. Cost per unit of energy in a 100% WWS system in Montana would be about 15% lower than a business-as-usual case by 2050, even when including increased costs for energy storage. New wind and solar are the lowest cost new forms of electric power in the United States, on the order of about half the cost of natural gas and even cheaper compared to coal. [MJ 1045:9-1047:10, 1062:8-1063:24; MJ-20].

/////

/////

277. According to a 2018 Montana DEQ report, Understanding Energy in Montana, Montana has significant solar energy potential, comparable to many other U.S. cities. [MJ 1086:21-1087:4; P9; MJ-50].

278. The new footprint over land required to implement a 100% renewable energy system in Montana would be only about 0.06% of Montana's land. Utility scale solar would occupy 0.01% of Montana's land (fourteen square miles), while new wind turbines, including the land around those turbines, which could be used for agriculture, open space, or more solar panels, would occupy about 0.05% (seventy-one square miles) of Montana's land. In comparison, Montana's oil and gas wells and associated infrastructure already occupy about 304 square miles of land (0.21% of Montana land area). [MJ 1079:25-1082:3; MJ-46].

279. There is an abundant supply of renewable energy and four ways to store renewable energy: heat storage (in water), cold storage (as ice), electricity storage (pumped hydropower, batteries, hydrogen fuel cells), and hydrogen as a form of storage (for use in long distance transportation and steel production). [MJ 1057:2-15, 1058:5-15, 1072:24-1073:7, 1076:9-1077:22, 1079:22-1082:8; MJ-15, MJ-19, MJ-45, MJ-62].

280. Montana's energy needs in 2050 under a 100% WWS roadmap would decline significantly (over fifty percent) as compared to a business-as-usual energy system due to a mix of gains in energy efficiency in vehicles and appliances, and through eliminating the significant amounts of energy required to extract, transport, and refine fossil fuels. [MJ 1045:9-1047:10; MJ-15, MJ-19, MJ-20, MJ-21, MJ-22, MJ-23, MJ-24, MJ-25, MJ-26, MJ-27, MJ-28, MJ-55].

281. Transitioning to WWS will keep Montana's lights on while saving money, lives, and cleaning up the air and the environment, and ultimately using less of Montana's land resources. [MJ 1061:4-1062:12, 1066:6-17, 1066:18-1067:20, 1079:22-1082:8; MJ-15, MJ-20-MJ-30, MJ-39, MJ-41, MJ-42, MJ-46, MJ-56, MJ-57, MJ-58, MJ-62].

282. The current barriers to implementing renewable energy systems are not technical or economic, but social and political. Such barriers primarily result from government policies that slow down and inhibit the transition to renewables, and laws that allow utilization of fossil fuel development and preclude a faster transition to a clean, renewable energy system. [MJ 1042:15-1043:2, 1059:9-1061:3, 1100:9-1101:4, 1103:11-1104:24; MJ-15, MJ-19, MJ-20, MJ-33, MJ-35, MJ-36, MJ-38, MJ-62, MJ-63].

283. Montana has abundant renewable energy resources that can provide enough energy to power Montana's energy needs for all purposes in 2050. [MJ 1058:2-15; MJ-15, MJ-19, MJ-29, MJ-30, MJ-46, MJ-47, MJ-48, MJ-50, MJ-61, MJ-62].

IX. THE 1972 MONTANA CONSTITUTION.

284. Mae Nan Ellingson was a delegate to the 1972 Montana Constitutional Convention. Ms. Ellingson's testimony was informative and provided useful context, including on the compilation of the records of the Constitutional Convention proceedings on which Montana courts regularly rely. Ms. Ellingson was elected to the Constitutional Convention as a delegate from Missoula County.

/////

/////